State of Mississippi
Mississippi Department of Environmental Quality
Office of Pollution Control

SMALL MUNICIPAL SEPARATE STORM SEWER SYSTEM (MS4) GENERAL PERMIT

THIS CERTIFIES THAT

MS4s ISSUED A CERTIFICATE OF PERMIT COVERAGE UNDER THIS PERMIT ARE GRANTED PERMISSION TO DISCHARGE STORM WATER FROM SMALL MUNICIPAL SEPARATE SEWER SYSTEMS INTO STATE WATERS

in accordance with effluent limitations, inspection requirements and other conditions set forth in herein. This permit is issued in accordance with the provisions of the Mississippi Water Pollution Control Law (Section 49-17-1 et seq., Mississippi Code of 1972), and the regulations and standards adopted and promulgated thereunder, and under authority granted pursuant to Section 402(b) of the Federal Water Pollution Control Act.

Mississippi Environmental Quality Permit Board

Authorized Signature

Mississippi Department of Environmental Quality

Issued: MAR 1 8 2016
Expires: FEB 2 8 2021

Permit No. MSRMS4

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ACT1 (MS4) Introduction:

Narrative Requirements:

Subject to regulation and compliance with the conditions set forth, this Small Municipal Separate Storm Sewer System (MS4) General Permit (this permit) authorizes stormwater discharges and allowable non-stormwater discharges outlined in ACT2, (5) of this permit. This permit replaces the previous Small Municipal Separate Storm Sewer System (MS4) General Permit that expired on December 31, 2013.

ACT2 (MS4) Permit Applicability and Coverage:

Narrative Requirements:

PERMIT AREA:

The permit covers the State of Mississippi.

ELIGIBILITY:

COVERED AREAS AND DISCHARGES:

(1) The permitting of selected storm sewer systems is required as a result of the U.S. Environmental Protection Agency's Phase II Stormwater Rule. This permit authorizes discharges of stormwater from small Municipal Separate Storm Sewer Systems (MS4s), as defined in 40 CFR 122.26(b)(16).

MS4s are authorized to discharge under the terms and conditions of this general permit that:
- Operate a small MS4 within the State of Mississippi, and
- Are located fully or partially within an urbanized area as determined by the latest census by the Bureau of Census and pursuant to 40 CFR 122.32, or
- Are designated by the Mississippi Commission on Environmental Quality (Commission) pursuant to 40 CFR 122.32(a)(2), 122.32(b), or 123.35(b)(3) or (4).

(2) For the Mississippi Department of Transportation (MDOT), at a minimum, permit coverage must be obtained for the entire counties (including cities within) of: DeSoto, Forrest, Hancock, Harrison, Hinds, Jackson, Lamar, Madison and Rankin and any other county containing an urbanized area as determined by the latest census conducted by the U.S. Census Bureau.

(3) The discharges of stormwater commingled with discharges authorized by and in compliance with separate NPDES permits are authorized under this permit.

(4) An MS4 is eligible for coverage under this permit for discharges of pollutants of concern to water bodies for which there is a total maximum daily load (TMDL) established or approved by EPA if measures and controls are incorporated that are consistent with the assumptions and requirements of such TMDL. To be eligible for coverage under this permit, the facilities within the MS4 must incorporate in their respective SWPPPs and/or effluent limitations and any conditions applicable to any discharge(s) necessary for consistency with the assumptions and requirements of the TMDL. If, after coverage issuance, a specific waste load allocation (WLA) is established that would apply to a facility's discharge, the facility must implement steps necessary to meet that allocation. The MS4 should ensure that the SWMP identifies sufficient BMPs to numerically show through pollutant reduction estimates that the reductions called for by the TMDL will be achieved. See ACT4, (5) for a current list of receiving waters with approved/established TMDLs.

ACT2 (MS4) Permit Applicability and Coverage:

Narrative Requirements:

(5) This permit authorizes the following non-stormwater discharges provided: (1) they do not cause or contribute to a violation of water quality standards, (2) the Executive Director of the Mississippi Department of Environmental Quality (MDEQ) has determined these sources entering the MS4 are not a substantial cause or contributor of pollutants entering the MS4 that may violate applicable state or federal laws, regulations, or criteria, (3) the regulated entity has determined these sources entering the MS4 are not a substantial contributor of pollutants entering the MS4 that may violate applicable state or federal laws, regulations, or criteria, and (4) the regulated entity is implementing the Storm Water Management Program (SWMP) as set forth in ACT5 of this permit:

-Water line flushing
-Landscape irrigation
-Diverted stream flows
-Rising ground waters
-Uncontaminated ground water infiltration (infiltration is defined as water other than wastewater that enters a storm sewer system, including sewer service connections and foundation drains, from the ground through such means as defective pipes, pipe joints, connections, or manholes. Infiltration does not include, and is distinguished from, inflow.)
-Uncontaminated pumped ground water
-Discharges from potable water sources
-Foundation drains
-Air conditioning condensate and coil wash water with no additives
-Irrigation water
-Springs
-Water from crawl space pumps
-Footing drains
-Lawn watering runoff
-Water from individual residential car washing
-Flows from riparian habitats and wetlands
-Dechlorinated swimming pool discharges
-Street wash water
-Discharges or flows from firefighting activities
-Fire hydrant flushings
-External building wash downs which do not use detergents

ACT2 (MS4) Permit Applicability and Coverage:

Narrative Requirements:

THIS PERMIT DOES NOT AUTHORIZE:

(1) Stormwater discharges that are mixed with non-stormwater unless such non-stormwater discharges are in compliance with a separate NPDES permit.

(2) Stormwater discharges that are mixed with non-stormwater discharges and that are determined to be a substantial contributor of pollutants to waters of the United States.

(3) Stormwater discharges associated with industrial activity as defined in 40 CFR 122.26(b)(14)(i) - (ix) and (xi).

(4) Stormwater discharges associated with construction activity as defined in 40 CFR 122.26(b)(14)(x) or 40 CFR 122.26(b)(15).

(5) Discharges or discharge-related activities that are likely to jeopardize the continued existence of any species that is listed as endangered or threatened under the Endangered Species Act (ESA) or result in the adverse modification or destruction of habitat that is designated as critical under the ESA. Coverage under this permit is available only if the regulated entity's stormwater discharges, allowable non-stormwater discharges, and discharge-related activities are not likely to jeopardize the continued existence of any species that is listed as endangered or threatened ("listed") under the ESA or result in the adverse modification or destruction of habitat that is designated as critical under the ESA ("critical habitat"). Submission of a signed Notice of Intent (NOI) will be deemed to constitute the regulated entity's certification of eligibility.

(6) Implementation of a Stormwater Management Program (SWMP) which directly and adversely affect properties listed or eligible for listing in the National Register of Historic Places, unless the regulated entity is in compliance with requirements of the National Historic Preservation Act and has coordinated any necessary activities to avoid or minimize such direct and adverse impacts with the appropriate State Historic Preservation Officer. Submission of a signed NOI will be deemed to constitute the regulated entity's certification of eligibility.

(7) Stormwater discharges, which result in violation of State Water Quality Standards. If a discharge authorized under this permit is later determined to cause or have the reasonable potential to cause or contribute to the violation of an applicable water quality standard, MDEQ will notify the regulated entity of such water quality violation(s) in writing and will provide the public information used by MDEQ to make this determination. The regulated entity must take all necessary actions required by their SWMP to ensure future discharges do not cause or contribute to the violation of a water quality standard and document these actions in the SWMP. If such violations remain or re-occur, then additional measures such as the addition of BMPs or the requirement to obtain an individual permit may be required by the Permit Board. Compliance with this requirement does not preclude any enforcement activity as provided by the Clean Water Act for the underlying violation. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT3 (MS4) Obtaining Coverage:

Submittal/Action Requirements:

OBTAINING AUTHORIZATION:

(1) The regulated entity must submit a MS4 Notice of Intent (MS4 NOI) and a Stormwater Management Program (SWMP) in accordance with the requirements of ACT4 of this permit. MS4 NOI packages submitted in 3-ring binders will not be accepted due to limited file space.

(2) Upon review of the MS4 NOI and attachments, the staff may require additional information, deny coverage, or require an alternate permit. Staff decisions may be brought before the Mississippi Environmental Quality Permit Board (Permit Board) for review and reconsideration at a regularly scheduled meeting.

(3) A regulated entity is authorized to discharge stormwater from its MS4 under the terms and conditions of this permit, only upon receipt of written notification of approval of coverage by the Permit Board. Discharge of stormwater by a regulated entity without written notification of coverage or issuance of an individual NPDES Stormwater Permit by the Permit Board is a violation of State law.

(4) In the event that a regulated entity submits an MS4 NOI that substantially complies with the requirements of the general permit, including development of the Stormwater Management Program, the discharges occurring between the submission of the MS4 NOI and the issuance of notification of coverage shall be considered in compliance with this permit.

REQUIRING AN INDIVIDUAL PERMIT OR ALTERNATIVE GENERAL PERMIT:

(1) The Permit Board may require the regulated entity to apply for and obtain an individual NPDES permit instead of coverage under this permit. Any interested person may petition the Permit Board to take action under this paragraph in accordance with Section 49-17-29 of the Mississippi Code. The Permit Board may require the regulated entity to apply for an individual NPDES permit only after they have been notified in writing. This notice shall include reasons for this decision, an application form and a filing deadline. The Permit Board may grant additional time upon request. If the regulated entity fails to submit a requested application, then coverage under this permit is automatically terminated at the end of the day specified for application submittal.

(2) The regulated entity may request to be excluded from permit coverage by applying for an individual permit. The regulated entity shall submit an individual application in accordance with 40 CFR 122.33 (2)(i - iii).

(3) Coverage under this permit is automatically terminated on the issuance or coverage date of the respective alternate individual NPDES permit. When an alternate individual NPDES permit is denied, coverage under this permit continues unless terminated on the date of such denial by the Permit Board. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT3 (continued):

Submittal/Action Requirements:

HOW TO REQUEST SUBSEQUENT RE-COVERAGE UNDER A REISSUED PERMIT:

The submittal of the fourth Annual Report (due no later than January 28, 2019) shall be deemed to be a notification of the MS4's intent to be covered by the subsequently issued MS4 General Permit, provided the Annual Report is signed by a principal executive officer or ranking elected official according to ACT10: SIGNATORY REQUIREMENTS of this permit.

Upon reissuance of the general permit, MDEQ will send recoverage packages to each MS4 with instructions on how to continue coverage under the reissued permit. If reissuance of this permit does not occur before its expiration date and the coverage recipient has submitted a timely and complete final Annual Report, continued coverage under this permit will be allowed until the effective date of the reissued general permit coverage.

ACT4 (MS4) Small Municipal Separate Storm Sewer System Notice of Intent (MS4 NOI):

Submittal/Action Requirements:

MS4 NOI Submittal:

A regulated entity desiring coverage for stormwater discharges under this general permit shall submit a MS4 NOI form for initial coverage and a request for recoverage for subsequent coverage. For regulated entities that have been designated by the Commission pursuant to 40 CFR 122.32(a)(2), the regulated entity is required to submit an MS4 NOI and Storm Water Management Plan (SWMP) within 180 days of permit issuance. For regulated entities covered by a previous Small Municipal Separate Storm Sewer System (MS4) General Permit, re-coverage must be made in accordance with the requirements of the reissued permit.

CONTENTS OF THE MUNICIPAL SEPARATE STORM SEWER SYSTEM (MS4) NOTICE OF INTENT (NOI):

The MS4 NOI shall be signed in accordance with ACT10: SIGNATORY REQUIREMENTS of this permit and shall include the following information:

(1) The name of the regulated entity, mailing address, and telephone number specifying the contact person.

(2) An indication of whether the regulated entity is a Federal, State, County, Municipal, or other public entity.

(3) The urbanized area where your MS4 is located; the name of your organization, and county/counties where your MS4 is located.

(4) The name of the major (named on a USGS Quad Map) receiving water(s).

(5) A current list of receiving waters with approved/established TMDLs and the current State of Mississippi 303(d) list of impaired waters are available at https://www.deq.state.ms.us/MDEQ.nsf/page/TWB_Total_Maximum_Daily_Load_Section?OpenDocument and http://www.deq.state.ms.us/MDEQ.nsf/0/E9EDFB5201D8E99586257D500048F8D6/$file/MS_2014_Section_303d_List_Adopted.pdf?OpenElement, respectively.

(6) If relying on another governmental entity regulated under the stormwater regulations (40 CFR 122.26 & 122.32) to satisfy one or more of the regulated entity's permit obligations, the identity of that entity or entities and the element(s) they will be implementing must be submitted. If the entity that the permitted MS4 operator is relying on to carry out the requirements of the minimum control measure fails to meet the permit requirements, it is the regulated entity's responsibility to correct these failures to assure compliance.

(7) As an attachment to the MS4 NOI, a Stormwater Management Program (SWMP) must be submitted that includes the minimum requirements as outlined in ACT5 of this permit. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT4 (continued):

Submittal/Action Requirements:

JOINT MUNICIPAL SEPARATE STORM SEWER SYSTEM NOTICE OF INTENT (MS4 NOI)

A regulated entity may, pursuant to the Mississippi Stormwater Management District Act, Miss. Code Ann. Section 51-39-1 et. Seq., or under other applicable authority, partner with another regulated entity to develop and/or implement a SWMP. However, each regulated entity remains responsible for the implementation of the SWMP in their MS4. Each regulated entity must complete the joint MS4 NOI form. The SWMP must clearly describe which regulated entity will be implementing each control measure.

Narrative Requirements:

WHERE TO OBTAIN THE MS4 NOI AND/OR RE-COVERAGE FORMS:

MS4 NOI forms are contained in the MS4 Forms Package or may be obtained from the MDEQ at the address shown below or by calling 601/961-5171. MS4 NOI forms, as well as the general permit, may also be found on the MDEQ web site at http://www.deq.state.ms.us/MDEQ.nsf/page/epd_epdgeneral?OpenDocument

WHERE TO SUBMIT THE MUNICIPAL SEPARATE STORM SEWER SYSTEM NOTICE OF INTENT (MS4 NOI) AND/OR RE-COVERAGE FORM:

MDEQ encourages electronic submittals due to limited file space. Please submit the MS4 Forms Package, SWMP, and Annual Reports to: MS4@deq.state.ms.us

Alternatively, hard copies can be submitted to:

Chief, Environmental Permits Division
MS Dept. of Environmental Quality,
Office of Pollution Control P.O. Box 2261
Jackson, Mississippi 39225.

FAILURE TO NOTIFY:

Failure to submit a MS4 NOI in accordance with State and Federal Law and Regulations, or as required by this general permit and discharges of stormwater from regulated MS4s to waters of the State without coverage under this permit or an individual NPDES permit are violations of State law.

ACT5 (MS4) Stormwater Management Program (SWMP) Development and Content:

Submittal/Action Requirements:

SWMP DEVELOPMENT AND SUBMITTAL:

The regulated entity must develop, implement, and enforce a Stormwater Management Program (SWMP) designed to reduce the discharge of pollutants from its Municipal Separate Storm Sewer System (MS4) to the maximum extent practicable (MEP) (see Definitions) to protect water quality and to satisfy applicable water quality requirements of the Clean Water Act. The application of the MEP standard is an iterative process that continually adapts to current conditions and BMP effectiveness in order to improve water quality. Successive iterations of the mix of BMPs and measurable goals shall be driven by the objective of assuring maintenance of water quality standards. Given the unique hydrologic and geologic features for each MS4, pollutant reduction strategies may differ. Each regulated entity will determine appropriate BMPs to satisfy each of the six minimum control measures through an evaluative process. Please reference the Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas for detailed information on BMP practice description, planning consideration, design criteria and construction, common problems, and maintenance.

If water quality impairment associated with discharges from the MS4 is not mitigated to the desired standard, the regulated entity will need to expand or better tailor its BMPs within the scope of the six minimum control measures in an ongoing, iterative or annual interval.

The MS4 must determine whether stormwater discharges from any part of the MS4 contribute pollutants of concern to an impaired waterbody. For those impaired waters, the MS4 must determine whether or not a TMDL has been established and approved. If an MS4 discharges into a water body with an approved or established TMDL, then the SWMP must include BMPs specifically targeted to achieve the wasteload allocations prescribed by the TMDL. The SWMP shall identify sufficient BMPs to numerically show, through pollution reduction estimates, that load reductions called for in the TMDL will be achieved. The SWMP must include a schedule for installation of such BMPs. A monitoring component to assess the effectiveness of the BMPs in achieving the wasteload allocations must also be included in the SWMP. Monitoring can entail a number of activities including, but not limited to: outfall monitoring, in-stream monitoring, or modeling. Upon initial issuance of the coverage and each submittal of an annual report, the MS4 must implement stormwater pollutant reductions consistent with assumptions and requirements of any applicable wasteload allocation(s) in established or approved TMDLs.

MS4s are required to develop a SWMP on a location-by-location basis in order to optimize reductions in stormwater pollutants. This evaluative process will consider factors including, but not limited to: conditions of receiving waters, beneficial uses of receiving waters, MS4 size, climate, hydrology, geology, ability to finance the program, capacity to perform operation and maintenance, specific local concerns (existing and historical), etc.

The SWMP is not required to address discharges into the regulated MS4 that occur outside the jurisdiction (or boundary) of the regulated entity. The SWMP should include management practices, control techniques and system design, engineering methods, and such other provisions necessary for the control of pollutants to satisfy the applicable water quality requirements of the Clean Water Act.

ACT5 (continued):

Submittal/Action Requirements:

A regulated entity's SWMP must include the following six (6) minimum control measures:

(1) Public Education and Outreach on Stormwater Impacts
(2) Public Involvement/Participation
(3) Illicit Discharge Detection and Elimination (IDDE)
(4) Construction Site Stormwater Runoff Control
(5) Post-Construction Stormwater Management in New Development and Redevelopment
(6) Pollution Prevention/Good Housekeeping for Municipal Operations

The SWMP, at a minimum, must be implemented for the entire urbanized area, or if designated separately by the MDEQ Executive Director, the entire designated area. The plan must identify:

(1) Best Management Practices (BMPs) that the regulated entity or partner regulated entity will implement for each of the stormwater minimum control measures.

(2) Measurable goals for each of the BMPs including, as appropriate, the years in which the regulated entity will undertake required actions, including interim milestones and the frequency of the action.

(3) Responsible persons for implementing or coordinating the BMPs for the SWMP.

(4) In addition to the requirements listed above, the regulated entity must:

- Provide a rationale for how and why the regulated entity selected each of the BMPs and measurable goals for the SWMP

- Develop and fully implement the regulated entity's program within five (5) years from coverage issuance

- Implement BMPs and set measurable goals that are targeted to addressing existing water quality problems and preventing new water quality problems.

ACT5 (continued):

Submittal/Action Requirements:

SIX MINIMUM CONTROL MEASURES:

(1) PUBLIC EDUCATION AND OUTREACH ON STORMWATER IMPACTS:

The regulated entity shall develop a program for educating the public on issues impacting stormwater.

The program shall, at a minimum, include the following components:

(A) Develop, implement, update/revise (as necessary), and enforce a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of stormwater discharges on water bodies and the steps that the public can take to reduce pollutants in stormwater runoff.

(B) Define appropriate BMPs for this minimum control measure and measurable goals for each BMP. [11 Mississippi Admin Code PT. 6, CH. 1]

(C) Document the decision process for the development of a stormwater public education and outreach program. The regulated entity's rationale statement must address overall public education program, individual BMPs, measurable goals, and including responsible persons for this program. The rationale statement must include the following information, at a minimum:

(i) The regulated entity's plan to inform individuals and households about the steps they can take to reduce stormwater pollution such as proper septic system maintenance, proper use and disposal of landscape and garden chemicals including fertilizers and pesticides, protection and restoration of riparian vegetation and proper disposal of household hazardous waste.

(ii) The regulated entity's plan to inform individuals and groups on how to become involved in the stormwater program (with activities such as storm drain stenciling/marking, adopt-a-stream, and-litter clean-up projects, etc.).

(iii) The target audiences that are likely to have significant stormwater impacts (including commercial, industrial and institutional entities) and why those target audiences were selected.

(iv) The target pollutant sources the public education program is designed to address.

(v) The regulated entity's outreach strategy, including the mechanisms (e.g., printed brochures, newspapers, media, workshops, surveys accompanying water/sewer bills, etc.) it will use to reach target audiences and how many people the regulated entity expects by the outreach strategy over the permit term.

ACT5 (continued):

Submittal/Action Requirements:

(vi) The process to evaluate the success of this minimum measure, including how the measurable goals for each of the BMPs were selected.

(vii) Responsibility for overall management and implementation of the stormwater public education and outreach program and, if different, who is responsible for each of the BMPs identified for this program. [11 Mississippi Admin Code PT. 6, CH. 1]

(2) PUBLIC INVOLVEMENT/PARTICIPATION:

The regulated entity shall develop, implement, update/revise (as necessary), and enforce a program for public involvement and participation that contains the following elements:

(A) At a minimum, notify the public of opportunities to provide input to the process of implementing a SWMP by complying with local public notice requirements.

(B) Define appropriate BMPs for this minimum control measure and measurable goals for each BMP. [11 Mississippi Admin Code PT. 6, CH. 1]

(C) Document the decision process for the development of a stormwater public involvement/participation program. The regulated entity's rationale statement must address both the overall public involvement/participation program and the individual BMPs, measurable goals, and responsible persons for this program. The rationale statement must include the following information, at a minimum:

(i) A plan for public involvement in the development and implementation of this program.

(ii) Plans to maintain public involvement in the development and submittal of the MS4 NOI and SWMP.

(iii) The target audiences for the public involvement program, including a description of the types of ethnic and economic groups engaged. The regulated entity is encouraged to actively involve all potentially affected stakeholder groups, including commercial and industrial businesses, trade associations, environmental groups, homeowners associations, and educational organizations, among other interested parties. [11 Mississippi Admin Code PT. 6, CH. 1]

(iv) The types of public involvement events and activities included within the program. Where appropriate, consider the following types of public involvement events and activities:

(a) Citizen representatives on a stormwater management panel
(b) Public hearings
(c) Working with citizen volunteers willing to educate others about the program
(d) Volunteer monitoring or stream/beach clean-up activities

ACT5 (continued):

Submittal/Action Requirements:

(v) The process to evaluate the success of this minimum measure, including how the measurable goals for each of the BMPs were selected.

(vi) Responsibility for the overall management and implementation of the stormwater public involvement/participation program and, if different, who is responsible for each of the BMPs identified for this program. [11 Mississippi Admin Code PT. 6, CH. 1]

(3) ILLICIT DISCHARGE DETECTION AND ELIMINATION (IDDE):

The regulated entity shall develop, implement, update, revise and enforce a program to detect and eliminate illicit discharges, which contains the following components:

(A) Develop, implement and enforce an IDDE program to detect and eliminate illicit discharges (as defined in 40CFR 122.26(b)(2)) into the regulated entity's small MS4.

(B) Develop a storm sewer system map, showing the location of all outfalls along with the names and location of all waters of the United States that receive discharges from those outfalls (see Definition). Mapping is useful to provide a foundation for outfall screening procedures, including scheduling and prioritizing where field work will take place. In addition, records of outfall screening and field work in an electronic format is useful for compatibility with GIS (geographic information system) and strongly recommended by MDEQ.

(C) To the extent allowable under State or local law, effectively prohibit, through ordinance, or other regulatory mechanism, non-stormwater discharges into the regulated entity's storm sewer system and implement appropriate enforcement procedures and actions. For compliance review with the SWMP, existing or draft ordinances addressing illicit discharges shall be submitted to MDEQ. Draft ordinances shall be submitted to MDEQ for review 30 days before proposed adoption.

(D) Inform public employees, businesses, and the general public of hazards associated with illegal discharges and improper disposal of waste.

(E) Address the non-stormwater discharges or flows identified in ACT2, (5) of this permit only if the regulated entity or MDEQ identify them as significant contributors of pollutants to the regulated entity's small MS4. The regulated entity may also develop a list of other similar occasional incidental non-stormwater discharges (e.g. non-commercial or charity car washes, etc.) that will not be addressed as illicit discharges. These non-stormwater discharges must not be expected (based on available information) to be significant sources of pollutants to the MS4. If a list of incidental non-stormwater discharges is developed the regulated entity must:

(i) Document in your plan any local controls or conditions placed on the discharges.

ACT5 (continued):

Submittal/Action Requirements:

(ii) Include a provision prohibiting any individual non-stormwater discharge that is determined to be contributing significant amounts of pollutants to the MS4.

(F) Define appropriate BMPs for this minimum control measure and measurable goals for each BMP Please refer to the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas for guidance in selecting appropriate BMPs.

(G) Document the decision process for the development of a stormwater illicit discharge detection and elimination (IDDE) program. The regulated entity's rationale statement must address the overall IDDE program and the individual BMPs, measurable goals, and responsible persons for the program. The rationale must include the following information, at a minimum:

(i) The plan to detect and address illicit discharges to the regulated entity's system, including discharges from illegal dumping and spills. This plan must include a dry weather field screening (see Definitions) for non-stormwater flows.
The purpose of developing a dry weather field screening plan is to distinguish illicit discharges from normal rainfall runoff in conveyance systems in the MS4. MDEQ recommends the following tasks for developing a dry weather screening plan:

(1) Define dry weather that is specific to the MS4. To define dry weather for the MS4, the following factors are recommended for consideration:
(a) A generally accepted definition for dry weather is after a period of 72 hours with less than 0.10 inches of rain.
(b) Dry weather may be based on a waiting period 48-72 after rainfall events that produce runoff.
(c) Determine where in your MS4 is experiencing dry weather using local weather/precipitation reports.
(d) Consider other variables such as soil type, water table level, and drainage lag times.

(2) Define a screening method:
(a) Visual screening, at minimum, is generally a good initial practice to identify illicit discharges. If a flow is observed, make note of color, odor, floatables, suds, deposits, stains, etc. at the outfall.
(b) Consider testing water quality at flowing outfalls for parameters such as temperature, pH, ammonia, bacteria, dissolved oxygen, turbidity, conductivity, etc. Choose parameters that are meaningful for the purpose of detecting and eliminating illicit discharges of concern for each area.

(3) Determine criteria for evaluating illicit discharges. Consider the following factors when prioritizing the detection and elimination of target pollutants within the MS4:
(a) Is there a history of citizen complaints about illicit discharges in a certain area?
(b) Do the complaints pertaining to the problem area identify any specific pollutant(s)?
(c) Are any of these impairments caused by pollutants that your IDDE program has the capability to measure during dry screening?
(d) Do these pollutants appear on an established total maximum daily load (TMDL) for neighboring waters of the state? Can you set a measurable goal of reducing pollutant loads documented in the TMDL study through the elimination of illicit discharges?

ACT5 (continued):

Submittal/Action Requirements:

(4) Select a method for tracking outfall information. MDEQ recommends the following:
- (a) Assign each outfall a unique identifier
- (b) Consider a method for recording outfall screening information which will be used consistently over time.
- (c) The method should optimally keep track of the identifier, screening information for the outfall, the outfall's history (e.g., previous illicit
- (d) Discharges detected, if or how they were eliminated, etc.)
- (e) Keep electronic records (e.g., spreadsheets, databases) for compatibility with GIS for convenient tracking purposes.

(5) Define measurable goals for Dry Weather Screening. The achievement of measurable goals should lead to the reductions in the amounts of pollutants entering the stormwater conveyance system.
- (a) Define measurable goals by setting a schedule of percentages of outfalls to be screened on a prescribed timetable.
- (b) Interpret screening results in order to identify suspected illicit discharges and determine appropriate follow-up actions.
- (c) Create an annual goal to eliminate a percentage of identified illicit discharges.

(ii) This plan must also address on-site sewage disposal systems that flow into the regulated entity's storm drainage system. MDEQ requires the plan to include:

(a) Procedures for locating priority areas which include areas with higher likelihood of illicit connections (e.g., areas with older sanitary sewer lines) MDEQ employs a Complaint Tracking System (CTS) to log and track reported complaints. Information on the status of inspections/investigations, reports, and the enforcement actions pertaining to complaints is available upon request. Records available through the system can be useful in identifying problem areas and targeting pollutants.

(b) If feasible, a plan to consult with entities within the MS4 to share information on water quality (e.g., coordinating with the Wastewater Treatment Facility to coordinate water quality testing and sharing of results).

(c) If available, use testing data to identify the pollutant(s) to aid in locating the source of the illicit discharge. Having a certified test result may be necessary to enforce the local illicit discharge ordinance.

(iii) The regulated entity's plans to inform public employees, businesses, and the general public of hazards associated with illegal discharges and improper disposal of waste. Include in the regulated entity's description how this plan will coordinate with the regulated entity's public education minimum measure and the regulated entity's pollution prevention/good housekeeping minimum measure programs. Illicit discharge education actions may include storm drain marking, a program to promote, publicize, and facilitate public reporting of illicit connections or discharges, and distribution of outreach materials

(iv) The process to evaluate the success of this minimum measure, including how the measurable goals for each of the BMPs were selected.

(v) Responsibility for overall management and implementation of the IDDE program and, if different, who is responsible for each of the BMPs identified for this program.

ACT5 (continued):

Submittal/Action Requirements:

(4) CONSTRUCTION SITE STORMWATER RUNOFF CONTROL:

The regulated entity shall develop, implement, update/revise (as necessary), and enforce a program to control stormwater runoff from construction sites, which contains the following elements.

(A) Develop, implement, update/revise (as necessary), and enforce a program to reduce pollutants in any stormwater runoff to the small MS4 from construction activities that result in a land disturbance of greater than or equal to one (1) acre. Reduction of stormwater discharges from construction activity disturbing less than one (1) acre must be included in your program if that construction activity is part of a larger common plan of development (See Definitions) or sale that would disturb one (1) acre or more. The program must include the development and implementation of, at a minimum:

(i) An ordinance or other regulatory mechanism to require erosion and sediment controls, as well as sanctions to ensure compliance, to the extent allowable under State or local law. Modified or new (draft) ordinances addressing construction site stormwater runoff shall be submitted to MDEQ for review 30 days before proposed adoption.

(ii) Requirements for construction site operators to provide the regulated entity a copy of their Stormwater Pollution Prevention Plan and proof of issuance of applicable MDEQ approvals/permits prior to the issuance of local construction approvals/permits. Examples of MDEQ approvals/permits include:

(a) Small Construction General Permit coverage for land disturbances one (1) acre to less than five (5) acres (less than one acre if part of a larger common plan of development or sale)
(b) Large Construction General Permit coverage for land disturbances five (5) acres and greater (or less if part of a larger common plan of development or sale)
(c) Registration Form for Residential Lot Coverage and Large Construction General Permit coverage number for residential lots in subdivision covered under a Large Construction General Permit

(iii) Requirements for construction site operators to provide the regulated entity a copy of the proper permits or approvals from the Army Corps of Engineers if waters of the United States are being filled, rerouted or dammed. [11 Mississippi Admin Code PT. 6, CH. 1]

(iv) Requirements for construction site operators to implement appropriate erosion and sediment control best management practice (please refer to Volume 1 of the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas)., including verification that operators have received training in proper installation of said controls (See ACT9, Training Personnel).

(v) Requirements for construction site operators to control waste such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste at the construction site that may cause adverse impacts to water quality.

ACT5 (continued):

Submittal/Action Requirements:

(vi) Procedures for site plan review which incorporate consideration of potential water quality impacts.

(vii) Procedures for receipt and consideration of information submitted by the public.

(viii) Procedures for site inspection and enforcement of control measures.

(ix) Procedures to ensure implementation of required post-construction controls (see next page).

(B) Define appropriate BMPs for this minimum control measure and measurable goals for each BMP. Select BMPs which are most appropriate to achieve measureable goals to reduce and control runoff from active and post-construction sites. MDEQ strongly recommends adopting ordinances to promote and encourage the implementation of non-structural BMPs, including Low Impact Development (LID) and Green Infrastructure (GI). This includes site-design and infiltration techniques such as green roofs, pervious pavement, eliminating curbs and gutters, grassed swales, rain gardens, rain harvesting, low-impact and cluster developments, and disconnection of impervious areas from riparian zones. For guidance in selecting an appropriate BMP, please refer to Volume 2 of the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas. MDEQ recommends examining Low Impact Development (LID) options that include Green Infrastructure BMPs such as: green parking (Vol. 2, Ch. 4, pg. 43), green roofs (Vol. 2, Ch. 4, pg. 47), narrower residential streets (Vol. 2, Ch. 4, pg. 55), riparian/forested buffers (Vol. 2, Ch. 4, pg. 58).

(C) Document the decision process for the development of a construction site stormwater control program. The regulated entity's rationale statement must address the overall construction site stormwater control program, the individual BMPs, measurable goals, and responsible persons for this program. The rationale statement must include the following information, at a minimum:

(i) The procedures for site plan review, including the review of pre-construction site plans, which incorporate consideration of potential water quality impacts and consistency with local sediment and erosion control requirements. For guidance in preparing an Erosion and Sediment Control Plan, please refer to Volume 1 of the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(ii) The procedures for receipt and consideration of information submitted by the public. Consider coordinating this requirement with the regulated entity's public education program. [11 Mississippi Admin Code PT. 6, CH. 1]

(iii) The procedures for site inspection and enforcement of control measures, including how the regulated entity will prioritize sites for inspection based on the nature of the construction activity, topography, soil characteristics, and receiving water quality. Some examples of sanctions to ensure compliance include non-monetary penalties, fines, bonding requirements and/or permit denials for non-compliance.

(iv) The procedures to provide appropriate educational training measures for construction site operators (See ACT9: Training Personnel).

ACT5 (continued):

Submittal/Action Requirements:

(v) The process to evaluate the success of this minimum measure, including how the measurable goals for each of the BMPs were selected. For guidance in selecting an appropriate BMP, please refer to Volume 2 of the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(vi) Responsibility for overall management and implementation of the construction site stormwater control program and, if different, who is responsible for each of the BMPs identified for this program. For guidance in Stormwater Management, please refer to Volume 2 of the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(5) POST-CONSTRUCTION STORMWATER MANAGEMENT IN NEW DEVELOPMENT AND REDEVELOPMENT:

The regulated entity shall develop, implement, update/revise (as necessary), and enforce a program to address post-construction stormwater management in new development and redevelopment, including the following elements:

(A) Develop, implement, and enforce a program to address stormwater runoff from publicly-owned and privately-owned new development and redevelopment projects that disturb greater than or equal to one (1) acre, including projects less than one (1) acre that are part of a larger common plan of development or sale, that discharge into the regulated entity's small MS4. The program must ensure that controls are in place that would prevent or minimize water quality impacts.

(B) Develop and implement strategies that include a combination of structural and non-structural best management practices (BMPs), appropriate for the regulated entity. For aid in selecting combinations of appropriate structural and non-structural BMPs that best suit the MS4, refer to the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas (see Appendix).

(C) Within one year of obtaining permit coverage, the permitee shall review local codes and ordinances. Newly-designated and currently permitted MS4s shall update codes and ordinances, if necessary, within 4 years of coverage under this permit. Currently permitted MS4s shall continue to implement their existing permanent Stormwater Management Programs until the codes and ordinances review and update are completed. The permitee should consider making revisions to policies, codes and ordinances that will achieve the greatest improved protection of receiving waters. Use of an ordinance or other regulatory mechanism to address post construction runoff from publicly-owned and privately-owned new development and redevelopment projects to the extent allowable under State or local law. Existing ordinances and new (draft) ordinances addressing post-construction stormwater management shall be submitted to MDEQ for compliance review with the SWMP. In addition, the regulated entity must develop a regulatory mechanism (e.g. a post-construction ordinance) to allow inspections of post-construction BMPs for private development and redevelopment projects within the MS4. New (draft) ordinances shall be submitted to MDEQ for review 30 days before proposed adoption. The ordinance or regulatory mechanism shall not limit the post-construction minimum measure to a single type of best management practice. MDEQ recommends that post-construction stormwater control and treatment systems be implemented through a treatment train approach (see Definitions) which would incorporate more than one BMP.

ACT5 (continued):

Submittal/Action Requirements:

(D) The MS4 must implement and enforce permanent stormwater controls that are comprised of runoff reduction and pollutant removal. The permittee must require that stormwater discharges from new development and redevelopment sites be managed such that post-development hydrology does not exceed the pre-development hydrology at the site, in accordance with the performance standards contained in this section. Pre-development infiltrative capacity of soils at the site must be taken into account in selection of runoff reduction management measures. Runoff reduction is the preferred control practice as it can achieve both volume control and pollutant removal.

(E) Develop site design standards for all new and redevelopment projects and require, in combination or alone, management measures that are designed, built and maintained to infiltrate, evapotranspire, harvest and/or use, at a minimum the first inch of every rainfall event preceded by 72 hours of no measurable precipitation. For all new and redevelopment on the private property, the MS4 may opt to have controls installed on that private property, in the public right-of-way, or a combination of both. Post-construction BMPs would include, but are not limited to: grassed swales (Vol. 1, Ch. 4, pg. 162) for runoff conveyance, filter strips (Vol. 1, Ch. 4, pg. 261) and bioretention systems for filtration of sediment (Vol 2 Ch. 1, pg. 14), runoff control using dry/wet retention/detention basins, and buffer zones for stream protection (Vol. 1, Ch. 4 pg. 25). Please refer to the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas for more information.

(i) Limitations to the application of runoff reduction requirements include, but are not limited to:
- (a) Where a potential for introducing pollutants into the groundwater exists, unless pre-treatment is provided;
- (b) Pre-existing soil contamination is present in areas subject to contact with infiltrated runoff; and
- (c) Sinkholes or other karst features.

(F) Ensure adequate long term operation and maintenance of BMPs. For maintenance considerations, please refer to the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas. The MS4 shall require a maintenance agreement and provide verification of maintenance provisions for post-construction management practices. These agreements shall allow the MS4, or its designee, to conduct inspections of the management practices and also account for transfer of responsibility in leases and/or deed transfers. Verification shall include one or more of the following as applicable:

(i) The developer's signed statement accepting responsibility for maintenance until the maintenance responsibility is legally transferred to another party; and/or

(ii) Written conditions in the sales or lease agreement that require the recipient to assume responsibility for maintenance; and/or

(iii) Written conditions in project conditions, covenants and restrictions for residential properties assigning maintenance responsibilities to a home owners' association, or other appropriate group, for maintenance of structural and treatment control management practices; and/or

ACT5 (continued):

Submittal/Action Requirements:

(iv) Any other legally enforceable agreement that assigns permanent responsibility for maintenance of structural or treatment control management practices.

(G) Define appropriate BMPs for this minimum control measure and measurable goals for each BMP. For guidance in selecting appropriate BMPs, please refer to the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(H) Document the decision process for the development of a post-construction stormwater management program. The regulated entity's rationale statement must address the overall post-construction Stormwater management program, the individual BMPs, measurable goals, and responsible persons for this program. The rationale statement must include the following information, at a minimum:

(i) The regulated entity's program to address stormwater runoff from new development and redevelopment projects. Include in this description any specific priority areas for this program. Please refer to the Planning section of Volume 2, Chapter 4 of the Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas for guidance on planning. MDEQ recommends considering the following factors during the planning phase: designating conservation easements (Vol 2, Ch. 4, pg. 3) and development districts (Vol 2, Ch. 4, pg. 7), infrastructure planning (Vol. 2, Ch.4, pg. 12), open space design (Vol. 2, Ch.4, pg. 12), protection of natural features(Vol. 2, Ch.4, pg. 18), street design and patterns (Vol. 2, Ch.4, pg. 27), and urban forestry (Vol. 2, Ch.4, pg. 32).

(ii) How the regulated entity's program will be specifically tailored for the regulated entity, minimize water quality impacts, and attempt to maintain pre-development runoff conditions.

(iii) Any non-structural BMPs in the program, including, as appropriate:

(a) Policies and ordinances that provide requirements and standards to: direct growth to identified areas, protect sensitive areas such as wetlands and riparian areas, maintain and/or increase open space (including a dedicated funding source for open space acquisition), provide buffers along sensitive water bodies, minimize impervious surfaces, minimize disturbance of soils and vegetation, and encourage infill development in higher density urban areas and areas with existing storm sewer infrastructure.

(b) Education programs for developers and the public about project designs that minimize water quality impacts.

(c) Measures such as minimization of the percentage of impervious area after development, and minimization of directly connected impervious areas. Please refer to the Planning and Site Design section of Volume 2, Chapter 4, of the Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas. MDEQ recommends examining Low Impact Development (LID) options that include Green Infrastructure BMPs such as: green parking (Vol. 2, Ch. 4, pg. 43), green roofs (Vol. 2, Ch. 4, pg. 47), narrower residential streets (Vol. 2, Ch. 4, pg. 55), riparian/forested buffers (Vol. 2, Ch. 4, pg. 58). [11 Mississippi Admin Code PT. 6, CH. 1]

ACT5 (continued):

Submittal/Action Requirements:

(iv) Any structural BMPs in the program, including, as appropriate:

(a) Stormwater retention/detention practices (Vol. 2, Ch. 4, pg. 127), such as constructed wetlands (Vol. 2, Ch. 4, pg. 127), dry detention ponds (Vol. 2, Ch. 4, pg. 144), in-line storage (Vol. 2, Ch. 4, pg. 150), and extended detention outlet structures. For detailed information on retention/detention BMP practice description, planning consideration, design criteria and construction, common problems, and maintenance, please refer to Volume 2, Chapter 4, of the Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(b) Filtration practices (Vol. 2, Ch. 4, pg. 96) such as grassed swales (Vol. 2, Ch. 4, pg. 96), bioretention (Vol. 2, Ch. 4, pg. 96), catch basin inserts(Vol. 2, Ch. 4, pg. 112), sand/organic filters (Vol. 2, Ch. 4, pg. 115) and vegetative filter strips (Vol. 2, Ch. 4, pg. 123). For detailed information on filtration BMP practice description, planning consideration, design criteria and construction, common problems, and maintenance, please refer to Volume 2, Chapter 4, of the Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(c) Infiltration practices such as grassed swales (Vol. 2, Ch. 4, pg. 63), infiltration basins(Vol. 2, Ch. 4, pg. 72), infiltration trenches (Vol. 2, Ch. 4, pg. 78), permeable interlocking concrete pavement(Vol. 2, Ch. 4, pg. 83), pervious asphalt pavement(Vol. 2, Ch. 4, pg. 87) and pervious concrete(Vol. 2, Ch. 4, pg. 91). For detailed information on infiltration BMP practice description, planning consideration, design criteria and construction, common problems, and maintenance, please refer to Volume 2, Chapter 4 of the Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas.

(v) Ensure the appropriate implementation of the structural BMPs by considering some or all of the following:

(a) Pre-construction review of BMP design
(b) Inspections during construction to verify BMPs are built and properly designed
(c) Post-construction inspection and maintenance of BMPs
(d) Penalty provisions for non-compliance

(vi) How the regulated entity will evaluate the success of this minimum measure, including how the measurable goals for each of the BMPs were selected.

(vii) Responsibility for overall management and implementation of the regulated entity's post-construction Stormwater management program and, if different, who is responsible for each of the BMPs identified for this program.

ACT5 (continued):

Submittal/Action Requirements:

(6) POLLUTION PREVENTION/GOOD HOUSEKEEPING FOR MUNICIPAL OPERATIONS
The regulated entity shall develop a pollution prevention/good housekeeping program with the following components.

(A) Develop and implement an operation and maintenance program that includes a training component and has the ultimate goal of preventing or reducing pollutant runoff from the regulated entity's operations.

(B) Using training materials that are available from EPA, the State, or other organizations, the regulated entity's program must include employee training to prevent and reduce stormwater pollution from activities such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, and stormwater system maintenance. See ACT9 for personnel training requirements.

(C) Define appropriate BMPs for this minimum control measure and measurable goals for each BMP. [11 Mississippi Admin Code PT. 6, CH. 1]

(D) Document the decision process for the development of a pollution prevention/good housekeeping program for municipal operations. The regulated entity's rationale statement must address the overall pollution prevention/good housekeeping program, the individual BMPs, measurable goals, and responsible persons for this program. The rationale statement must include the following information, at a minimum:

(i) The regulated entity's program must specifically list the municipal operations that are impacted by this operation and maintenance program. The regulated entity must also include a list of industrial facilities that the regulated entity owns or operates which are covered by General Stormwater Permits or have individual NPDES Stormwater Permits. Include the facility's coverage number and/or permit number.

(ii) Any employee training program the regulated entity will use to prevent and reduce stormwater pollution from activities such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, and stormwater system maintenance. Describe any existing, available materials the regulated entity plans to use. Describe how this training program will be coordinated with the outreach programs developed for the public information minimum measure and the illicit discharge minimum measure. ACT9 of this permit requires the regulated entity to document all training records for personnel. See ACT9: Personnel Training Requirements for more information on training program development and documentation requirements.

ACT5 (continued):

Submittal/Action Requirements:

(iii) The regulated entity's program description must specifically address the following areas:

(a) Maintenance activities, maintenance schedules, and long-term inspection procedures for controls to reduce floatables (including froth, oil and floating solids) and other pollutants to the MS4.

(b) Controls for reducing or eliminating the discharge of pollutants from streets, roads, highways, municipal parking lots, maintenance and storage yards, waste transfer stations, fleet or maintenance shops with outdoor storage areas, salt/sand storage locations and waste transfer stations.

(c) Procedures for the proper disposal of waste removed from the MS4 and regulated entity's operations, including dredge spoil, accumulated sediments, floatables, and other debris.

(d) Procedures to ensure that new flood management projects are assessed for impacts on water quality and existing projects are assessed for incorporation of additional water quality protection devices or practices.

(iv) The process to evaluate the success of this minimum measure, including how the measurable goals for each of the BMPs were selected.

(v) Responsibility for overall management and implementation of the pollution prevention/good housekeeping program and, if different, who is responsible for each of the BMPs identified for this program.

ACT6 (MS4) Storm Water Management Program (SWMP) Implementation Requirements:

Submittal/Action Requirements:

REVIEWING AND UPDATING STORM WATER MANAGEMENT PROGRAMS:

(1) Storm Water Management Program Review: The regulated entity must conduct an annual review of their Storm Water Management Program in conjunction with preparation of the annual report required under ACT7 of this permit. The annual review is required in order to evaluate the SWMP's effectiveness over the five-year period permit cycle. The Storm Water Management Program is best implemented iteratively; annual reviews are intended to assist in tailoring the storm water management program to be most effective for regulated entities that are eligible for coverage under this permit.

(2) Storm Water Management Program Update: The regulated entity may change their Storm Water Management Program during the life of the permit in accordance with the following procedures:

(A) Changes adding (but not subtracting or replacing) components, control measures, or requirements to the Storm Water Management Program may be made at any time upon written notification to MDEQ. These changes must be documented in the annual report.

(B) Changes subtracting or replacing ineffective or impracticable components, control measures, or requirements, specifically identified in the Storm Water Management Program, with alternate components, controls, or requirements may be requested at any time. Unless denied by the Permit Board, changes proposed in accordance with the criteria below shall be deemed approved and may be implemented 60 days from submittal of the request. If request is denied, the Permit Board, or MDEQ acting on behalf of the Permit Board, will respond in writing. The regulated entity's modification requests must include the following:

(i) An analysis of why the components, control measures, goals, or requirements are ineffective or impracticable (including cost analyses)

(ii) Expectations on the effectiveness of replacement components, control measures, goals, or requirements.

(iii) An analysis of why the replacement components, control measures, goals, or requirements are expected to achieve the goals of the components, controls, or requirements to be replaced.

(C) Change requests or notifications must be signed in accordance with the signatory requirements of ACT10: SIGNATORY REQUIREMENTS of this permit. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT6 (continued):

Submittal/Action Requirements:

(3) Storm Water Management Program Updates Required by MDEQ:

(A) The Permit Board shall require Storm Water Management Program updates as part of the re-coverage process for subsequently issued MS4 General Permits. These updates may include, but not be limited to, best management practices, measurable goals, policies, procedures, programs, ordinances, strategies, etc.

(B) The Permit Board may require changes to the Storm Water Management Program as needed to:

(i) Meet the conditions of this permit.

(ii) Address impacts on receiving water quality caused, or contributed to, by discharges from the MS4.

(iii) Include additional control measures or monitoring requirements when a Total Maximum Daily Load (TMDL) has been specified for a receiving waterbody, when a Watershed Management Plan has been adopted for a watershed or if a coverage recipient's SWMP proves to be inadequate in reducing pollutants in storm water runoff. This will include requiring additional and sufficient BMPs in the SWMP to numerically show through pollution reduction estimates that the load reductions called for by the TMDL are being met.

(iv) Include more stringent requirements necessary to comply with new federal statutory or regulatory requirements.

(v) Include such other conditions necessary to comply with the requirements of the Clean Water Act.

(C) Changes requested by the Permit Board must be made in writing, set forth the time schedule for the regulated entity to develop the changes, and offer the regulated entity the opportunity to propose alternative program changes to meet the objective of the requested modification. All changes required by the Permit Board will be made in accordance with 40 CFR 124.5, 40 CFR 122.62, or as appropriate 40 CFR 122.63.

(4) Transfer of Operational Authority, or Responsibility for Storm Water Management Program Implementation: The regulated entity must implement the Storm Water Management Program on all new areas added to the regulated entity's portion of the municipal separate storm sewer system (or for which the regulated entity becomes responsible for implementation of storm water quality controls) as expeditiously as practicable, but not later than one year from addition of the new areas. Implementation may be accomplished in a phased manner to allow additional time for controls that cannot be implemented immediately. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT6 (continued):

Submittal/Action Requirements:

(A) Within 90 days of a transfer of operational authority, or responsibility for storm water management program implementation, the regulated entity must have a plan for implementing the regulated entity's Storm Water Management Program on all affected areas. The plan may include schedules for implementation. Information on all new annexed areas and any resulting updates required to the Storm Water Management Program must be included in the annual report.

Only those portions of the Storm Water Management Programs specifically required as permit conditions shall be subject to the modification requirements of 40 CFR 124.5. Addition of components, controls, or requirements by the regulated entity(s) and replacement of an ineffective or infeasible BMP implementing a required component of the Storm Water Management Program with an alternate BMP expected to achieve the goals of the original BMP shall be considered minor changes to the Storm Water Management Program and not modifications to the permit. [11 Mississippi Admin Code PT. 6, CH. 1]

SHARING MINIMUM MEASURE RESPONSIBILITY:

(1) Implementation of one or more of the minimum measures may be shared with another entity, or the other entity may fully take over the measure. A regulated entity may rely on another entity only if:

(A) The other entity, in fact, implements the control measure.

(B) The particular control measure, or component of that measure, is at least as stringent as the corresponding permit requirement.

(C) The other entity agrees to implement the control measure on the regulated entity's behalf and accepts this obligation in writing. This obligation must be maintained as part of the description of the regulated entity's storm water management program. If the other entity fails to implement the control measure on the regulated entity's behalf, then the regulated entity remains liable for any discharges due to that failure to implement.

(2) In the case of the construction minimum measure, MDEQ may agree to assume responsibility, if petitioned by the regulated entity, for the portion of the minimum measure that addresses construction activities five (5) acres and greater (residential subdivisions are specifically excluded). If MDEQ agrees to assume responsibility, the regulated entity is not required to include that portion of the minimum control measure in the SWMP, nor required to address large construction in the annual report. The MS4 General Permit Forms Package contains a petition form for this purpose.

(3) Programs that meet or exceed the provisions of this minimum measure and the provisions of Mississippi's construction general permit requirements may, at the request of the regulated entity and at the discretion of MDEQ, be designated as a qualifying local program. Construction sites that meet the requirements of the qualifying local program may be deemed to also satisfy Mississippi's construction general permit requirements. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT7 (MS4) Monitoring, Reporting, and Recordkeeping Requirements:

Submittal/Action Requirements:

FAILURE TO IMPLEMENT STORM WATER MANAGEMENT PROGRAM (SWMP):

Any permit noncompliance constitutes a violation of the Mississippi Water Pollution Control Law and is grounds for enforcement action against the MS4. In addition, failure by the MS4 to initiate appropriate enforcement actions as defined in the SWMP may be the basis for State determination that the MS4 has failed to take timely enforcement action. In instances where the State determines that the MS4 has not initiated timely and appropriate enforcement action, the State may proceed with any or all enforcement options against the discharger and MS4 under the Clean Water Act.

MONITORING:

The coverage recipient must evaluate program compliance, the appropriateness of their identified best management practices, and progress towards achieving their identified measurable goals. Inspections will be required as part of the monitoring program. Although water quality sampling and analysis is not required by this permit, MDEQ strongly encourages the adoption of water quality sampling and analysis to determine the effectiveness of reducing pollutants in storm water runoff.

ANNUAL REPORTS:

The coverage recipient must prepare and submit to MDEQ an annual report. The objective of the annual report is to summarize the progress made in implementing the conditions of the permit and elements of the SWMP. The submittal of the fourth Annual Report shall be deemed to be a notification of the MS4's intent to be covered by the subsequently issued MS4 General Permit. The annual report shall be in the approved MDEQ format. A template of the approved MDEQ annual report format may be obtained from MDEQ at the address shown below or by calling 601-961-5171. The annual report template, general permit and forms package may also be found on the MDEQ web site at www.deq.state.ms.us. Annual reports in 3-ring binders will not be accepted due to limited filing space. These annual reports must include, at a minimum:

(1) The status of compliance with permit conditions, an assessment of the appropriateness of the coverage recipient's identified BMPs and progress towards achieving the coverage recipient's identified measurable goals for each of the minimum control measures.

(2) Results of information collected and analyzed, including monitoring data, if any, during the reporting period.

(3) A summary of the storm water activities planned during the next reporting cycle.

(4) Proposed changes to the storm water management program, including changes to any BMPs or any identified measurable goals that apply to the program elements.

ACT7 (continued):

Submittal/Action Requirements:

(5) Changes in any identified measurable goals that apply to the program elements.

(6) Notice that you are relying on another government entity to satisfy some of your permit obligations (if applicable). [11 Mississippi Admin Code PT. 6, CH. 1]

(7) The number of small construction projects receiving approval from the MS4. Small construction projects are land disturbance activities of equal to or greater than one (1) acre and less than five (5) acres or are part of a larger common plan of development or sale with a planned disturbance of equal to or greater than one (1) acre and less than five (5) acres. Small construction activity does not include routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, and original purpose of the facility (i.e. an existing ditch, channel, or other similar storm water conveyance, as well as routine grading of existing dirt roads, asphalt overlays of existing roads, and similar maintenance activities).

(8) The number of large construction projects receiving approval from the MS4. Large construction projects are land disturbance activities of equal to or greater than five (5) acres or are part of a larger common plan of development or sale with a planned disturbance of equal to or greater than five (5) acres. Large construction activity does not include routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, and original purpose of a ditch, channel, or other similar storm water conveyance. Large construction activity does not include the routine grading of existing dirt roads, asphalt overlays of existing roads, and similar maintenance activities.

(9) The number and type of inspections conducted and enforcement actions taken.

(10) The number of illicit discharges detected and the number of illicit discharges eliminated.

(11) The number, type (i.e., detention basin, manufactured system, etc.) and location of post-construction management practices installed at new development and redevelopment projects. Both publicly-owned and privately-owned projects apply. [11 Mississippi Admin Code PT. 6, CH. 1]

(12) Documentation that all control measures being planned or implemented that may address Wasteload Allocation (WLA) provisions of a TMDL, if it is found that a MS4 must implement specific WLA provisions of a TMDL. Also, include a schedule of implementation for all planned controls.

(13) Certification that the MS4 NOI and SWMP are up to date. The annual report shall be certified according to ACT10: SIGNATORY REQUIREMENTS and ACT10: DULY AUTHORIZED REPRESENTATIVES of this permit. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT7 (continued):

Submittal/Action Requirements:

WHERE TO SEND REPORTS:

The annual reports required in ACT7 of this permit are to be submitted annually postmarked no later than the 28th day of January. The first submission may be for less than a 12-month period. Failure to submit a complete annual report and/or meet goals established by the SWMP, as required by this ACT, is a violation of this permit and subject to enforcement action.

Please address electronic submittals to MS4@deq.state.ms.us

Alternatively, hard copies of Annual Reports can be submitted to MDEQ at the following address:

Chief, Environmental Compliance and Enforcement Division
Office of Pollution Control
Dept. of Environmental Quality
P.O. Box 2261
Jackson, Mississippi 39225

RECORDS RETENTION:

All records, reports and information resulting from activities required by this permit shall be retained for a period of at least three years from the date of the coverage recipient's MS4 NOI, inspection or report. The coverage recipient must make records required by this permit, including the regulated entity's SWMP, available to the public at reasonable times during regular business hours. (The regulated entity may assess a reasonable charge for copying. The coverage recipient may require a member of the public to provide advance notice, not to exceed two working days).

NONCOMPLIANCE REPORTING:

(1) Anticipated Noncompliance. The regulated entity shall give at least 10 days advance notice, if possible, before any planned noncompliance with permit requirements.

(2) Unanticipated Noncompliance. The regulated entity shall notify the MDEQ orally within 24 hours from the time he or she becomes aware of unanticipated noncompliance. A written notice shall be provided to the MDEQ within 5 working days of the time he or she becomes aware of the circumstances. The written report shall describe the cause, the exact dates and times, steps taken or planned to reduce, eliminate, or prevent reoccurrence of the noncompliance and, if the noncompliance has not ceased, the anticipated time for correction. [11 Mississippi Admin Code PT. 6, CH. 1]

ACT8 (MS4) Storm Water Quality Requirements:

Limitation Requirements:

Storm water shall be free from:

(1) Debris, oil, scum, and other floating materials other than in trace amounts

(2) Eroded soils and other materials that will settle to form objectionable deposits in receiving waters

(3) Suspended solids, turbidity and color at levels inconsistent with the receiving waters

(4) Substances in concentrations that would cause violation of State Water Quality Criteria in the receiving waters. [11 Mississippi Admin Code PT. 6, CH. 2]

ACT9 (MS4) Personnel Training Requirements:

Submittal/Action Requirements:

TRAINING DOCUMENTATION:

Personnel training conducted to meet the requirements of this ACT shall be documented. Training records shall include employee's name, worker identification number, date of training, contents of training, and the employee's signature acknowledging that training was received. All training records shall be maintained for at least three (3) years from the date of training.

TRAINING PROGRAM REQUIREMENTS:

The coverage recipient shall develop and implement a program for initial and periodic refresher training of personnel that are responsible for implementing and/or complying with the requirements of this permit. Initial training for all personnel that are responsible for implementing and/or complying with the requirements of this permit shall be performed within twelve (12) months of issuance of coverage or recoverage under this permit. Newly hired employees responsible for implementing and/or complying with the requirements of this permit shall receive initial training prior to performing such responsibilities.

Training shall at a minimum address, but not be limited to, the following elements:

(1) SWMP goals and plan components identified in ACTs 5 through 9 of this permit, including:

(A) Housekeeping and pollution prevention requirements,

(B) Spill prevention and response procedures,

(C) Installation, maintenance and inspection of erosion and sediment controls Best Management Practices (BMPs).

(2) Recordkeeping, reporting and record retention requirements (includes understanding the records filing system and being able to produce the required permit documentation during an MDEQ on-site inspection).

ACT10 (MS4) Standard Requirements Applicable to All Water Permits:

Narrative Requirements:

DUTY TO COMPLY:
Any permit noncompliance constitutes a violation of the Mississippi Water Pollution Control Law and is grounds for enforcement action or coverage termination and requiring reapplication in accordance with ACT3 (2) of this permit. [11 Mississippi Admin Code PT. 6, CH. 1]

CONTINUATION OF AN EXPIRED GENERAL PERMIT:
All general permits and coverages issued by the Permit Board shall remain in full force and effect until the Permit Board makes a final determination regarding any reissuance, modification, or revocation of the permits and coverages.

DUTY TO MITIGATE:
The regulated entity shall take all reasonable steps to minimize or prevent any discharge in violation of this permit that is likely to adversely affect human health or the environment.

DUTY TO PROVIDE INFORMATION:

The regulated entity shall furnish to the MDEQ, within a reasonable time, any information which the MDEQ may request to determine compliance with this permit. [11 Mississippi Admin Code PT. 6, CH. 1]

SIGNATORY REQUIREMENTS:

All Notice of Intent forms, reports, certifications, or information submitted to the permitting authority, or that this permit requires be maintained by you shall be signed and certified as follows:

(1) The MS4 NOI(s) and SWMP(s) submitted to the MDEQ shall be signed by a principal executive officer or ranking elected official. For purposes of this section, a principal executive officer of a Federal agency includes (1) the chief executive officer of the agency, or (2) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency (e.g., Regional Administrators of EPA).
Electronic submittals are highly encouraged and can be sent to: MS4@deq.state.ms.us

ACT10 (continued):

<u>Narrative Requirements:</u>

DULY AUTHORIZED REPRESENTATIVE:

A person is a duly authorized to sign submissions to the MDEQ only if:

(1) The authorization is made in writing by a person described in SIGNATORY REQUIREMENTS above, and submitted to MDEQ.

(2) The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated activity, such as manager, operator, superintendent or one having overall environmental responsibility (a duly authorized representative may be a named individual or any individual occupying a named position).

CHANGES TO AUTHORIZATION:

If an authorization is no longer accurate because a different individual or position has permit responsibility, a new authorization satisfying the above requirements must be submitted to the MDEQ prior to or together with any reports, information or applications signed by the representative.

CERTIFICATION:

Any person signing documents under this section shall make the following certification:

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

OIL AND HAZARDOUS SUBSTANCE LIABILITY:

Nothing in this permit shall relieve the regulated entity from responsibilities, liabilities, or penalties under Section 311 of the Clean Water Act (CWA).

PROPERTY RIGHTS:

The issuance of this permit does not convey any property rights of any sort, nor any exclusive privileges, nor does it authorize any injury to private property nor any invasion of personal rights, nor any infringement of Federal, State or local laws or regulations.

ACT10 (continued):

Narrative Requirements:

SEVERABILITY

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit shall not be affected thereby.

PROPER OPERATION AND MAINTENANCE:

The regulated entity shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the regulated entity to achieve compliance with the conditions of this permit including the storm water pollution prevention plan. Proper operation and maintenance includes adequate laboratory controls with appropriate quality assurance procedures and requires the operation of backup or auxiliary facilities when necessary to achieve compliance with permit conditions.

BYPASS PROHIBITION:

Bypass (see 40 CFR 122.41(m)) is prohibited and enforcement action may be taken against a regulated entity for a bypass, unless: (1) The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage; (2) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This conditions is not satisfied if the regulated entity should, in the exercise of reasonable engineering judgment, have installed adequate backup equipment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and (3) The regulated entity submitted notices per ACT7: NONCOMPLIANCE REPORTING of this permit.

UPSET CONDITIONS:

An upset (see 40 CFR 122.41(n)) constitutes an affirmative defense to an action brought for noncompliance with technology-based permit limitations if a regulated entity shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence, that: (1) An upset occurred and the regulated entity can identify the specific cause(s) of the upset, (2) The permitted facility was at the time being properly operated, (3) The regulated entity submitted notices per ACT7: NONCOMPLIANCE REPORTING of this permit. The regulated entity took remedial measures as required under ACT10, DUTY TO MITIGATE of this permit. In any enforcement proceeding, the regulated entity has the burden of proof that an upset occurred. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review.

ACT10 (continued):

Narrative Requirements:

INSPECTION AND ENTRY:

The regulated entity shall allow MDEQ or an authorized representative, upon the presentation of credentials and other documents as may be required by law, to

(1) Enter upon the regulated entity's premises where a regulated activity is located or conducted or where records must be kept under the conditions of this permit;

(2) Have access to and copy at reasonable times any records that must be kept under the conditions of this permit; and

(3) Inspect at reasonable times any facilities or equipment.

PERMIT ACTIONS:

This permit may be modified, revoked and reissued, or terminated for cause. A request by the regulated entity for permit or coverage modification, revocation and reissuance, or termination, or a certification of planned changes or anticipated noncompliance does not stay any permit condition.

SCIENTIFIC, TECHNICAL AND LEGAL ENVIRONMENTAL ASSISTANCE:

Where a discharge authorized under this permit is determined to cause or have the reasonable potential to cause or contribute to the violation of an applicable water quality standard or other requirement of a regulation promulgated by the Commission or any of the minimum control measures set forth in its SWMP and required by this permit (referred to herein as "Environmental Requirement"), MDEQ shall, in writing, notify the regulated entity of the actual or potential violation of the Environmental Requirement. After receiving such notification from MDEQ, the regulated entity may request MDEQ assistance in determining the source of the pollutant discharge to the MS4, which is causing the MS4 to violate or have the potential to violate the Environmental Requirement. Such requests are proper where MDEQ's scientific, technical, or other environmental knowledge may assist the regulated entity in isolating and addressing sources of actual or potential violation of the Environmental Requirement which are not readily discoverable by the regulated entity after completing the procedures required by the regulated entity's SWMP. When a regulated entity requests MDEQ assistance, MDEQ will provide to the regulated entity available public information relevant to MDEQ's notification.

The Commission shall retain jurisdiction and responsibility to enforce compliance with all applicable Commission regulations and the permit. The regulated entity shall retain jurisdiction and responsibility to enforce compliance with its SWMP, local laws, regulations, and ordinances. MDEQ, as appropriate and able, will provide technical assistance to the regulated entity as it pursues judicial or administrative enforcement procedures. However, the implementation of the SWMP remains the responsibility of the regulated entity.

ACT10 (continued):

Narrative Requirements:

REOPENER CLAUSE:

If there is evidence indicating potential or realized impacts on water quality due to storm water discharge covered by this permit, the regulated entity may be required to obtain an individual permit or an alternative general permit in accordance with ACT3, (2) of this permit or the permit may be modified to include different limitations and/or requirements.

PERMIT MODIFICATION:

Permit modification or revocation will be conducted according to 40 CFR 122.62, 122.63, 122.64 and 124.5

ACT11 (Definitions):

All definitions contained in Section 502 of the Act and 40 CFR 122 shall apply to this permit and are incorporated herein by reference. For convenience, simplified explanations of some regulatory/statutory definitions have been provided, but in the event of a conflict, the definition found in the Statute or Regulation takes precedence.

BEST MANAGEMENT PRACTICES (BMPs) means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of the State. BMPs also include treatment requirements, operating procedures, and practices to control runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

CODES OF FEDERAL REGULATIONS (CFR) are documents containing all finalized regulations. The contents of 40 CFR are all related to the environmental aspects.

COMMISSION means the Mississippi Commission on Environmental Quality.

CONTROL MEASURE as used in this permit refers to any Best Management Practice or other method used to prevent or reduce the discharge of pollutants to waters of the State.

CLEAN WATER ACT (CWA) means the Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Pub.L. 92-500, as amended Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483 and Pub. L. 97-117, 33 U.S.C. 1251 et.seq.

DISCHARGE-RELATED ACTIVITIES include: activities which cause, contribute to, or result in storm water point source pollutant discharges; and measures to control storm water discharges, including the siting, construction and operation of best management practices (BMPs) to control, reduce or prevent storm water pollution.

DRY WEATHER FIELD SCREENING means screening outfalls during dry weather to find illicit discharges. Most rainfall events (wet weather) carry pollutants to stormwater conveyances, but it is difficult to track and eliminate specific pollutant sources during wet weather without intensive monitoring and investigation. The best opportunity to find an illicit discharge is during dry weather, when rainfall runoff is not running through the conveyance system(s) within the MS4. During dry weather, any flow in the conveyance system is potentially an illicit discharge because it is something other than rainfall runoff.

ILLICIT CONNECTION means any man-made conveyance connecting an illicit discharge directly to a municipal separate storm sewer.

ILLICIT DISCHARGE means any discharge to a municipal separate storm sewer that is not composed entirely of storm water except discharges pursuant to a NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and those non-storm water discharges identified in ACT2, (5) of this permit.

ACT11 (Definitions):

LARGER COMMON PLAN OF DEVELOPMENT OR SALE means a contiguous area where multiple separate and distinct construction activities are occurring under one plan. The plan in a common plan of development or sale is broadly defined as any announcement or piece of documentation (including a sign, public notice or hearing, sales pitch, advertisement, drawing, permit application, zoning request, computer design, etc.) or physical demarcation (including boundary signs, lot stakes, surveyor markings, etc.) indicating that construction activities may occur on a specific plot.

MAJOR RECEIVING WATER(s) are those waters of the State that are named on an United States Geological Quadrangle Map.

MAXIMUM EXTENT PRACTICABLE "MEP" is the statutory standard that establishes the level of pollutant reductions that operators of regulated MS4s must achieve. The CWA requires that NPDES permits for discharges from MS4s "shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods." Compliance with the conditions of the general permit and the series of steps associated with identification and implementation of the minimum control measures will satisfy the MEP standard. EPA has intentionally not provided a precise definition of MEP to allow maximum flexibility in MS4 permitting.

MEASURABLE GOALS are a municipality's storm water program goals, which are intended to gauge permit compliance and program effectiveness.

MUNICIPALITY refers to a city, town, county, district, association, or other public body created by or under State law and having jurisdiction over disposal of sewage, industrial wastes, or other wastes.

MS4 is an acronym for "Municipal Separate Storm Sewer System" and is used to refer to either a Large, Medium (e.g. "the Jackson MS4"), or Small Municipal Separate Storm Sewer System. The term is used to refer to either the system operated by a single entity or a group of systems within an area that are operated by multiple entities (e.g., the Jackson MS4 includes MS4s operated by the city of Jackson, the Mississippi Department of Transportation (MDOT) - state and interstate highways, their right-of-ways and thoroughfares [including highways, streets, roads, bridges, maintenance facilities, service areas, and rest areas] within the jurisdictional boundary of MDOT, the University Medical Center and others).

MUNICIPAL SEPARATE STORM SEWER means a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains): (i) Owned or operated by a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the CWA that discharges to waters of the United States; (ii) Designed or used for collecting or conveying storm water; (iii) Which is not a combined sewer; and (iv) Which is not part of a Publicly Owned Treatment Works (POTW).

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) refers to Section 402 of the federal Clean Water Act.

NOI is an acronym for "Notice of Intent" to be covered by this permit and is the mechanism used to "register" for coverage under a general permit.

OUTFALL, as used within this general permit, is defined by 40 CFR 122.26

ACT11 (Definitions):

PERMIT BOARD means the Mississippi Environmental Quality Permit Board established pursuant to Miss. Code Ann. Section 49-17-28.

PHASE II is the second stage of the State and Federal storm water permit regulations.

REGULATED ENTITY , as used within this general permit, is a small MS4 within the State of Mississippi and located fully or partially within an urbanized area as determined by the latest Decennial Census pursuant to 40 CFR 122.32, or designated by MDEQ pursuant to 40 CFR 123.35.

SMALL MUNICIPAL SEPARATE STORM SEWER SYSTEM refers to all separate storm sewers that are owned or operated by the United States, a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the CWA that discharges to waters of the United States, but is not defined as "large" or "medium" municipal separate storm sewer system (those municipalities with a population of 100,00 or more) . This term includes systems similar to separate storm sewer systems in municipalities, such as systems at military bases, large hospital or prison complexes, and highways and other thoroughfares. The term does not include separate storm sewers in very discrete areas, such as individual buildings.

STORM WATER means rainfall runoff, snowmelt runoff, and surface runoff.

STORM WATER MANAGEMENT PROGRAM (SWMP) refers to a comprehensive program to manage the quality of storm water discharged from the municipal separate storm sewer system.

TOTAL MAXIMUM DAILY LOAD (TMDL) means the calculated maximum permissible pollutant loading to a waterbody at which water quality standards can be maintained. The sum of wasteload allocations (WLAs) and load allocations (LAs) for any given pollutant.

TREATMENT TRAIN APPROACH is the use of multiple BMPs in series to effectively manage stormwater runoff in addition to controlling sediment and erosion. For instance, the use grassed swales for water conveyance to a retention/detention basin is an example of a treatment train approach. In this example, a grass swale is not only useful for water conveyance, but provides treatment via vegetative filtration and infiltration as the stormwater flows through the channel and the retention/detention basin provides a means for runoff control.

URBANIZED AREA (UA) is a land area comprising one or more places {core and fringe} with urban limits defined by a population density of 1,000 people per square mile and its contiguous census tracks of 500 people per square mile - that together have a residential population of at least 50,000.

APPENDIX

Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas
(Volumes 1 & 2)

MISSISSIPPI

Handbook for

Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas

Volume 1
Erosion and Sediment Control Practices

MDEQ

Mississippi Department
of Environmental Quality
Published 2011

Volume 1 Erosion and Sediment Control Manual

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Acknowledgments

The Erosion and Sediment Control and Stormwater Runoff Management Manuals were made possible via a US Environmental Protection Agency grant and are products of a partnership project among the Mississippi Department of Environmental Quality, the Mississippi Department of Transportation and the US Department of Agriculture (USDA)–Natural Resources Conservation Service.

Volume 1 – Erosion and Sediment Control Manual was created by adapting the *Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* (2009) with Mississippi-specific information where appropriate. The State of Alabama graciously provided their *Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas* for Mississippi to use as a template. Therefore, a special thanks is warranted to the following agencies who worked on Alabama's Handbook: Alabama Soil and Water Conservation Committee, Alabama Chapter of the Soil and Water Conservation Society, Alabama Association of Conservation Districts, Alabama Department of Environmental Management, Alabama Department of Transportation, Associated General Contractors of Alabama, Home Builders Association of Alabama, and the USDA–Natural Resources Conservation Service.

Volume 2 – Stormwater Runoff Management Manual was created by adapting North Carolina's *Stormwater Best Management Practices Manual* (2007) with Mississippi-specific information where appropriate. Special thanks go to the North Carolina Division of Water Quality, the North Carolina Department of Environment and Natural Resources, and North Carolina State University for their work in developing the *Stormwater Best Management Practices Manual*.

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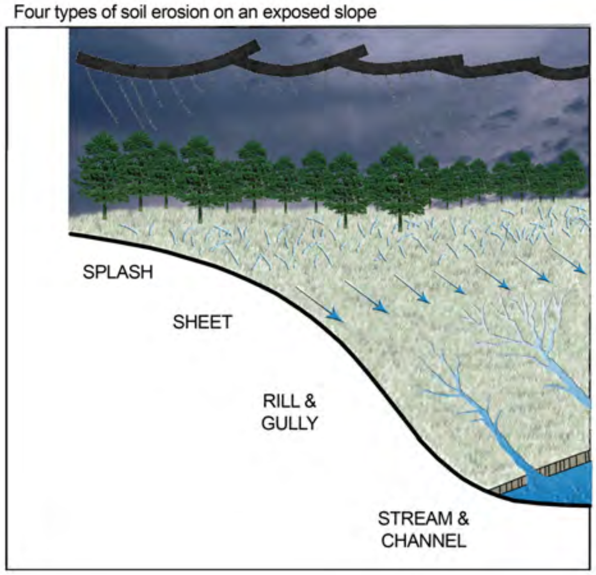
Chapter 1
Introduction to Erosion and Sediment Processes

This chapter is intended to be an introduction to the processes referred to as erosion, sedimentation and stormwater management. If in-depth information is needed on these subjects, other references should be used.

Erosion and Sedimentation Processes

Erosion

Four types of soil erosion on an exposed slope



Erosion is the process by which the land surface is worn away by the action of water, wind, ice or gravity. Water-related erosion is the primary problem in the developing areas of Mississippi and is the primary type of erosion that this handbook addresses.

The slow sedimentation and deposition of products from millions of years of geological erosion of upland sources has created the Mississippi we know today. With the exception of shorelines and stream channels where erosion may be rapid and catastrophic, geologic erosion occurs at very slow rates. This natural erosion process, which has taken place over millions of years, has probably occurred at rates comparable to erosion on our current forests.

In contrast to geologic erosion, the erosion accelerated by the disturbances of humans, through agriculture and non-agricultural uses of the land, has caused several inches of erosion over the last 100 to 150 years, a comparatively short period. Thus, “accelerated erosion" can be very significant and can potentially create related adverse impacts. Accelerated erosion occurs in developed or developing areas where developing sites are either poorly planned or the plans that appear adequate are not installed and maintained properly.

To understand erosion caused by water, it is helpful to think of the erosive action of water as the effects of the energy developed by rain as it falls or as the energy derived from water's motion as it flows across the land surface. Both falling rain and flowing water, typically referred to as stormwater, perform work in detaching and moving soil particles, but their actions are different. The force of falling rain is applied vertically. The force of flowing water is applied mostly horizontally.

The energy of raindrops falling on bare soil detaches soil particles. Water flowing over exposed soil picks up detached soil particles. As the velocity of flowing water increases, additional soil particles are detached and transported. Flowing water concentrates because of surface irregularities. If not prevented, these flows will create small channels, or rills, and eventually larger channels, or gullies of varying widths and depths. If the volume and velocity of storm runoff leaving a disturbed site increases because of the activities on the site, it is likely to cause additional erosion of streambanks and within floodplains beyond the rate of geologic erosion.

Although not as prominent in the Southeast as erosion caused by water, wind erosion can cause on-site health and safety problems and is a source of fugitive dust.

Sedimentation and Turbidity

Sedimentation is the process that describes soil particles settling out of suspension as the velocity of water decreases. The larger and heavier particles, gravel and sand, settle out more rapidly than silt and clay particles. Silt and clay particles are easily transported and settle out very slowly. It is difficult, and perhaps impossible in some instances, to totally eliminate the transport of clay and silt particles, even with the most effective erosion control programs.

Turbidity occurs in conjunction with sedimentation. Turbidity—a cloudy, muddy condition in the water—occurs when eroded soil is suspended in the water (i.e. before it settles out). Turbid water can stress or kill fish by clogging their gills and making it difficult for them to identify food sources.

Factors Influencing Erosion

The erosion process is influenced primarily by climate, topography, soils, and vegetative cover. The following description of the factors is an overview adequate for this handbook; however, it is recognized that this is a very complex subject and many details are not included here.

Climate

Climate includes rainfall, temperature and wind. The frequency, intensity and duration of rainfall are the principal aspects of rainfall influencing the volume of runoff, erosion, and sediment (potential) from a given area. As the volume and intensity of rainfall increase, the ability of water to detach and transport soil particles increases. When storms are frequent, intense, and of long duration, the potential for erosion of bare soils is high. Temperature has a major influence on soil erosion. Frozen soils are relatively erosion resistant. However, bare soils with high moisture content are subject to uplift or “spew” by freezing action and are usually easily eroded upon thawing. Wind contributes to the drying of soil and increases the need for irrigation for new plantings and for applying wind erosion control practices during periods of bare soils.

Topography

Topography includes the shape and slope characteristics of an area or watershed and influences the amount and duration of runoff. The greater the slope length and slope gradient, the greater the potential for runoff, erosion and sediment delivery.

Soils

Soil characteristics include texture, structure, organic matter content and permeability. In addition, in many situations, compaction is significant. These characteristics greatly determine the erodibility of soil.

Soils containing high percentages of sand and silt are the most susceptible to detachment because they lack inherent cohesive characteristics. However, the high infiltration rates of sands either prevent or delay runoff except where overland flow is concentrated. Clearly, well-graded and well-drained sands are usually the least erodible soils in the context of sheet and rill erosion.

Clay and organic matter act as a binder to soil particles, thus reducing erodibility. As the clay and organic matter content of soils increase, the erodibility decreases. However, while clays have a tendency to resist erosion, they are easily transported by water once detached.

Soils high in organic matter resist raindrop impact, and the organic matter also increases the binding characteristics of the soil.

Sandy and silty soils on slopes are highly susceptible to gully erosion where flows concentrate because they lack inherent cohesiveness.

Small clay particles, referred to as colloids, resist the action of gravity and remain in suspension for long periods of time. Colloids are potentially a major contributor to turbidity where they exist.

Vegetative Cover

Vegetative cover is an extremely important factor in reducing erosion at a site. It will:

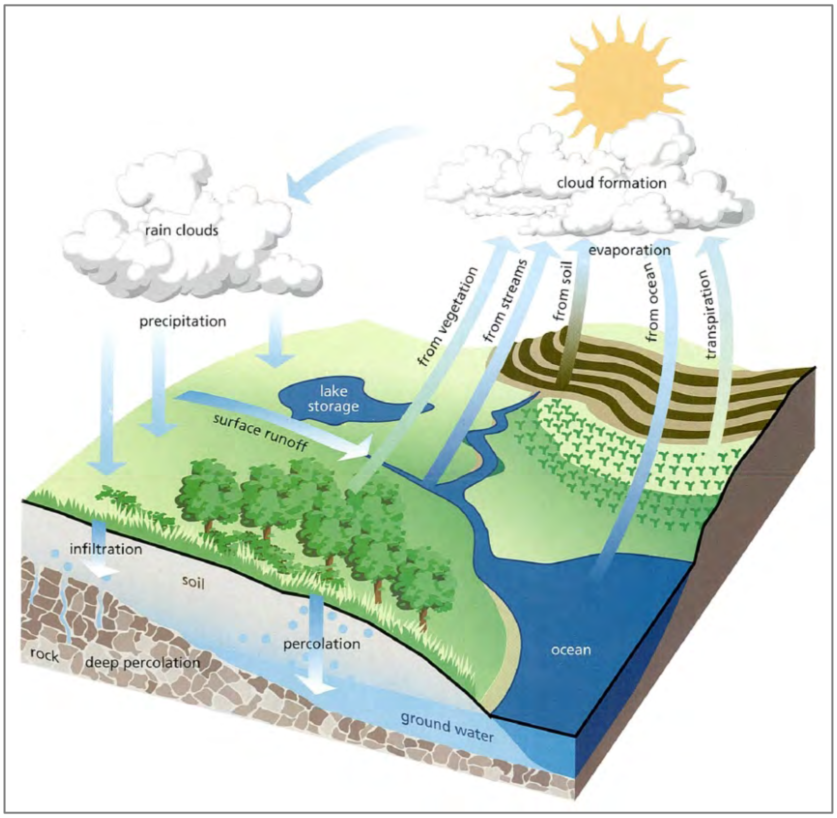
a. Absorb energy of raindrops.
b. Bind soil particles.
c. Slow velocity of runoff water.
d. Increase the ability of a soil to absorb water.
e. Remove subsurface water between rainfall events through the process of evapotranspiration.
f. Reduce off-site fugitive dust.

By limiting the amount of vegetation disturbed and the exposure of soils to erosive elements, soil erosion can be greatly reduced.

Stormwater

Water flowing over the land during and immediately following a rainstorm is called stormwater runoff. The runoff passing a particular point is equal to the total amount of rainfall upstream of that point less the amounts of infiltration, transpiration, evaporation, surface storage and other losses. The amount of these losses is a function of climate, soils, geology, topography, vegetative cover and, most importantly, land use.

In an undeveloped area, stormwater runoff is managed by nature through the hydrologic cycle. The cycle begins with rainfall. Rain either stands where it falls and evaporates or is absorbed into the ground near the surface, to feed trees and vegetation, ultimately to be returned to the atmosphere by transpiration; or it percolates deeply into the ground replenishing the groundwater supply. The remainder of the rainfall collects into rivulets. This collected runoff increases in quantity as it moves down the watershed, through drainageways, streams, reservoirs and to its ultimate destination, the river and then the sea. Evaporation from the sea surface begins the cycle again.



The Hydrological Cycle
(Source: NRCS "Stream Corridor Restoration: Principles, Processes, and Practices")

This simple explanation of the hydrologic cycle belies its complexity. Nature's inability to accommodate severe rainfalls without significant damage, even in undeveloped areas, is very apparent. Nature's stormwater management systems are not static but are constantly changing. Streams meander, banks erode, vegetation changes with the seasons, lakes fill in with sediment and eventually disappear. The stripping of ground and tree cover by fire can change an entire system, forcing new natural accommodations throughout the system.

The volume of stormwater runoff is governed primarily by infiltration characteristics and is related to the land use, soil type, topography and vegetative cover. Thus, runoff is directly related to the percentage of the area covered by roofs, streets and other impervious surfaces. Water intercepted by vegetation and evaporated or transpired is lost from runoff. A small portion of the water that infiltrates into the soil and groundwater is delivered to the stream as delayed flow and does not contribute directly to peak stormwater runoff. Impervious surfaces normally contribute almost all of the total rain immediately to stormwater runoff.

There are four distinct yet interrelated effects of land use changes on the hydrology of an area:

1) Changes in peak flow characteristics; 2) changes in total runoff; 3) changes in water quality; and 4) changes in the hydrologic amenities (Leopold, 1968). The hydrologic amenities are what might be called the appearance or the impression that the river, and its channel and valleys, leaves with the observer.

Of all land use changes affecting the hydrology of an area, urbanization is the most impactful. As an area becomes urbanized, the peak rate of runoff and volume of runoff increase. These effects are caused by: 1) a reduction in the opportunity for infiltration, evaporation, transpiration and depression storage; 2) an increase in the amount of imperviousness; and 3) modification of the surface drainage patterns, including the associated development of stormwater management facilities.

Summary of Hazards Associated with Land Development

Land development clearly increases potential erosion and sediment hazards on-site by removing cover, developing cuts and fills that are more susceptible to erosion than the previously undisturbed soils and changing water conveyance routes. More subtle changes related to erosion and sediment include soil compaction (both planned and unplanned), longer slopes, and more and faster stormwater runoff.

Land development, in most instances, has the following potential effects off-site both during and following the development phase and reflect the impacts of changed use of the land on stormwater:

- Increased volumes of storm runoff.
- Higher peak flows of storm runoff if not modified by planned measures.
- Increased loads of sediment and other pollutants associated with the site unless prevented or minimized by planned measures.

The potential off-site effects include increased flooding, accelerated erosion of stream systems, increased sediment deposition in both streams and floodplains, and adverse impacts to the biological communities associated with the streams and floodplains.

Each progression toward more intensive land use tends to disrupt the ongoing natural processes that protect and preserve water quantity and water quality. Therefore, to ensure future protection of water resources, it is imperative that land uses be managed in a responsible way.

As we reflect on the processes and the potential impact, we should recognize the importance of sound site planning, timely and proper installation of the measures planned, and the need for long-term maintenance of measures that sustain site stabilization. If the best available technology is used for planning, design, installation and maintenance of erosion and sediment control and stormwater management, the impacts of land development will be minimized. Other chapters of this handbook present relevant planning considerations, design criteria, and installation and maintenance information.

To address the hazards associated with land disturbance, The National Pollutant Discharge Elimination System (NPDES) Stormwater Program regulates stormwater discharges from construction activities. (Two other sources are also regulated, MS4s and industrial activities.) Most stormwater discharges are considered point sources, and operators of these sources may be required to receive an NPDES permit before they can discharge. This permitting mechanism is designed to prevent stormwater runoff from washing harmful pollutants into local surface waters such as streams, rivers, lakes or coastal waters.

Most states are authorized to implement the NPDES Stormwater Program and administer their own stormwater permitting programs. Mississippi is such a delegated state (see **Appendix B**). EPA remains the permitting authority in a few states, in territories, and on most tribal lands. For these areas, EPA provides oversight and issues stormwater permits.

Chapter 2
General Planning Concepts for Erosion Control, Sediment Control and Stormwater Management

This chapter provides important concepts and other selected information that is important for qualified design professionals to know about various aspects of erosion control, sediment control, and stormwater management. It is believed that the contents will, as a minimum, cause qualified design professionals to recognize when other professionals may need to be involved. A qualified design professional should recognize that planning involves several disciplines and that each discipline has a body of in-depth knowledge that is important and needed on complex sites. Although often discussed separately, erosion control, sediment control, and stormwater management are interrelated and, when planning occurs, the thought process must conceive a system of practices and measures that consider all three together.

The basic details of planning, including step-by-step procedures, are located in Chapter 3.

Potential Erosion and Sediment Problems Associated with Land Development

The principal effect land development activities have on the erosion process consists of exposing disturbed soils to raindrops and to storm runoff. Shaping of land for construction or development purposes alters the soil cover in many ways, often detrimentally affecting physical properties of the soil, onsite drainage and storm runoff patterns and, eventually, off-site stream and stream-flow characteristics. Adverse effects of erosion and sedimentation include impacts on soil, water quantity, water quality, and the aquatic ecosystem. Potential hazards associated with development include the following items:

1. An increase in developed areas exposed to storm runoff and soil erosion.

2. Increased volumes of storm runoff, accelerated soil erosion and sediment yield and higher peak flows caused by:

    a. Removal of existing protective vegetative cover.

    b. Exposure of underlying soil or geologic formations potentially more erodible than original soil surface.

    c. Reduced capacity of exposed soils to absorb rainfall due to compaction caused by heavy equipment.

    d. Enlarged drainage areas caused by grading operations, diversions and street construction.

    e. Prolonged exposure of unprotected disturbed areas due to scheduling problems and/or delayed construction.

f. Shortened times of concentration of surface runoff caused by altering slope steepness, slope length, and surface roughness and through installation of “improved” storm-drainage facilities.

g. Increased impervious surfaces associated with the construction of streets, buildings, sidewalks, paved driveways, and parking lots.

3. Creation of exposures facing south and west that may hinder plant growth due to adverse temperature and moisture conditions.

4. Exposure of subsurface materials that are rocky, acidic, droughty, or otherwise unfavorable to the establishment of vegetation.

Erosion and Sediment Control

A wide array of practices and measures are used for erosion and sediment control. Most of the practices and measures have application over the entire State.

There are numerous simple concepts that can provide an effective framework for minimizing erosion on a construction site and reducing delivery of sediment off of the site.

- Minimize the area disturbed by leaving existing vegetation that does not have to be removed.
- Minimize the period of bare ground by shortening construction periods and staging a project when possible.
- Sequence installation in a manner that supports shortened construction periods and permits the use of temporary and permanent seeding when the practices can be most effective.
- Use sediment control and turbidity measures that minimize sediment and turbid water from leaving the disturbed site.
- Plan appropriate erosion control for all kinds of erosion that may occur depending upon specific site conditions. Give special attention to cut and fill slopes. Give special attention to sites that are transected by streams or are in close proximity to streams or reservoirs.
- Install erosion-control plantings at every opportunity.
- Prevent sediment from leaving a construction site at entrance/exits during muddy periods.

- Maintain practices to ensure their effectiveness. This includes regular and timely inspections.

Potential Stormwater Problems Associated with Land Development

All forms of land use affect water quality. In an undeveloped area, many ongoing physical, chemical and biological processes interact to recycle most of the materials found in the stormwater runoff. As human land use intensifies, these processes are disrupted. Human activities add materials to the land surface (pesticides, fertilizers, animal wastes, oil, grease, heavy metals, etc.). These materials are then washed off by the rainfall and runoff, thereby increasing the pollutant load carried to receiving waters by stormwater runoff.

Of primary importance to water quality is the “first flush”. This term describes the washing action that stormwater has on accumulated pollutants in the watershed. In the early stages of a runoff rain-event, the land surfaces, especially impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This flushing creates a shock loading of pollutants. Extensive studies in Florida have determined that the first flush equates to the first 1″ of runoff which carries 90% of the pollution load from a storm (USGS, 1984). More recently, research has identified that the first ½″ of runoff provides the first flush in some instances, while other research has determined that runoff in excess of 1″, including cut/fill areas associated with construction, may be more realistic. It is proper to say at this time that the amount of runoff that creates the “first flush” depends on several factors, including the activity, site conditions and pollutants. Treatment of the first flush, whatever the runoff amount, will help ensure that the water-quality impacts of stormwater are minimized.

Finally, the value of the hydrologic environment as an amenity is primarily affected by three factors: stability of the stream channel, accumulation of trash, and disruption of the stream community. A channel which is gradually enlarged because of increased floods caused by urbanization tends to have unstable and unvegetated banks, scoured or muddy channel beds, and unusual accumulations of sediment and debris. Together with the accumulation of trash in the channel and floodplain (beverage cans, lumber scraps, lawn clippings, concrete, wire, etc.), these all tend to severely decrease the visual attractiveness of a stream. Ultimately, these factors disrupt the natural balance in the streams’ biota resulting from the addition of nutrients, organics, and sediment. These disruptions increase algal growth and turbidity, lower the oxygen content of the water, and thereby change the biological character of the stream.

In summary, each progression toward more intensive land use tends to disrupt the ongoing natural processes that protect and preserve water quality. Therefore, to ensure future protection of water resources, it is imperative that land uses be managed in a responsible way.

What is Stormwater Management?

Historically, urbanization has resulted in the development of stormwater-management systems to reduce flooding. These systems were developed because of their convenience and the protection they provided to property. Often, stormwater-management systems were designed for safety and convenience without recognition of other important considerations. Therefore, no matter how large the rainfall or its duration, the stormwater system was expected to remove the runoff as quickly as possible, and to restore maximum convenience in the shortest possible time. In other words, until recently, stormwater management was concerned with only the quantitative effects of runoff.

Today, however, stormwater management is far more comprehensive. An effective program involves the implementation of actions to control water in its hydrologic cycle with the objectives of providing (1) flood control; (2) nonpoint source pollution control; and (3) off-site erosion control. Stormwater management applies to rural and urban areas alike; however, the techniques presented in this manual are most relevant to urban or urbanizing situations.

To accomplish the three objectives of stormwater management, it is necessary to ensure that the volume, rate, timing and pollutant load of runoff after development are similar to those that occurred prior to development. The approach suggested in this manual is to minimize the adverse impacts of stormwater through a coordinated system of source controls. Source controls emphasize the prevention and reduction of nonpoint pollution and excess stormwater flow before it ever reaches a collection system or receiving waters. Typical control strategies and management criteria to accomplish the objectives of stormwater management are discussed below.

Flood Control

Flood control has historically been the most common goal of local, stormwater-management programs. The property damage, safety hazards, and inconvenience that can result from increased stream flooding in urbanizing watersheds usually get wide public attention and urgent demands for government action. Two levels of drainage systems must be considered in developing a management strategy for flood control: the primary drainage system and the major drainage system.

The <u>primary drainage system</u> consists of the street gutters and ditches, storm sewers, culverts, and open channels that are designed to prevent inconvenience and minor property damages from relatively frequent storm events. Of course, the most effective strategy for flood control at this level is to plan and design the primary drainage system adequately in advance, keeping in mind the future development potential of the drainage area. Unfortunately, many existing drainage systems were designed on a piecemeal, “as needed” basis with little regard for future upstream development. The capacity of such systems often becomes severely inadequate as upstream development progresses, resulting in frequent minor flooding and property damages.

One strategy for dealing with this problem is to replace or modify elements of the primary drainage system to provide the required capacity. This option is often expensive and does not control the source of the problem. However, this may be the only feasible method of correcting existing problems. To prevent future problems, an alternative strategy may be employed. Persons wishing to undertake new development may be required to control runoff from their sites in a manner that will not adversely affect the downstream drainage system. This control is usually accomplished through stormwater detention criteria.

Typical detention criteria will specify that stormwater runoff from a new development must be controlled so that the post-development peak runoff rate does not exceed the pre-development peak rate for some specific frequency design-storm or range of design-storm events. In many localities, a 10-year design storm is specified to preserve the effectiveness of downstream drainage structures that were originally designed to pass a 10-year pre-development storm. Other localities require that larger storms (i.e., 50- to 100-year events) must be detained and released at a controlled rate to reduce the downstream effects of major storms.

It should be kept in mind that, as attempts are made to control larger storm events, requiring slower release rates will also require larger storage volumes in detention systems.

The major drainage system comes into play when the capacity of the primary drainage system is exceeded.

This major system consists of the floodplains and surface-flow routes that water will follow during major storms. The most effective strategy for dealing with flooding at this level is to ensure that stormwater has a route to follow which will not cause major property damage or loss of life. To implement this strategy, floodplain ordinances, zoning regulations, or other land-use controls should be used to restrict floodplain development. In areas where development has already encroached on the floodplain, land owners should be encouraged to purchase flood insurance.

Nonpoint Source Pollution Control

Pollutants that are washed from the land surface and carried into the streams, rivers, and lakes with stormwater runoff have only recently been recognized as major contributors to water-quality degradation in urban and urbanizing watersheds. The goal of controlling this problem is therefore relatively new. Nonpoint-source pollution control is likely to receive highest priority in watersheds that feed public water supplies or recreation reservoirs; however, this goal should be addressed in all local stormwater management programs.

In urban areas, most of the stormwater detention practices that are used to control runoff quantity may also be adapted for use as best management practices for nonpoint-source pollution control. The design criteria of these practices for this purpose, however, are often different. The primary design strategy for pollution removal is to maximize the detention time of captured runoff. Although there have not been many monitoring studies to produce definitive design criteria, it is believed that basin-drawdown times between 30 and 40 hours will result in significant pollutant removal. The required storage volume of detention facilities can be tied to a first-flush capture (i.e., the initial 0.1″ to 1″ of runoff).

Off-Site Erosion Control

Off-site erosion control, as a management goal, must be addressed in all local stormwater-management programs. The strategies for dealing with this problem are similar to those for flood control. The major difference is in the frequency of the storm that must be controlled.

Studies have shown that most natural stream channels are formed with a bank-full capacity to pass runoff from a storm with a 1.5- to 2-year recurrence interval. As upstream development occurs, the volume and velocity of flow from these relatively frequent storms increases. Even smaller storms with less than 1-year recurrence intervals begin to cause streams to flow full or flood.

Stream channels are often subject to a 3- to 5-fold increase in the frequency of bank-full flows in a typical urbanizing watershed. This increase in flooding frequency places a stress on the channel to adjust its shape and alignment to accommodate the increased flow. Unfortunately, this adjustment takes place in a very short time period (in geologic terms). and the transition is usually not a smooth one. Meandering stream channels which were once parabolic in shape and covered with vegetation typically become straight, wide, rectangular channels with barren, vertical banks. This process of channel erosion often causes significant property damage, and the resulting sediment which is generated is transported downstream, further contributing to channel degradation.

An old strategy for dealing with this problem is to increase the carrying capacity and stability of affected streams through channel modifications (i.e. straightening, widening, lining with non-erodible material, etc.). Modifications to natural, continuous flowing streams, however, can be the subject of intense local controversy and require special permits such as a 404 permit issued by the U.S. Army Corps of Engineers. Recent innovations based on natural, stream-hydrology concepts are rapidly gaining favor and should be considered because of their beneficial effects on the aquatic environment.

Wherever modifications to natural flowing streams are being considered, extreme care must be taken to weigh the benefits of such modifications against the cost and the concerns of the local citizens. Where channel modifications are necessary, an attempt must be made to incorporate measures that will minimize adverse impacts to fish, wildlife, and the aesthetic quality of the stream.

On-site stormwater-detention criteria for new development projects can also be an effective strategy for preventing future increases in channel erosion. However, such criteria should be tied to more frequent storm events than typical flood-control criteria. Maintaining the pre-development peak-runoff rate from a 10-year storm, for example, will probably not effectively reduce downstream erosion since the majority of storm events will pass right through the detention system unimpeded.

For example, the minimum state or local stormwater-management criteria could be tied to a 2-year storm event. Receiving channels would then be capable of passing a 2-year storm without flooding or erosion after development of the site, or stormwater would be detained on the site so that the pre-development peak-flow rate from a 2-year storm is not exceeded after development. While flows from larger, less frequent storm events may cause erosion problems downstream, it is believed that, because such events will occur less often, streams will have more time to recover and restabilize themselves.

Local stormwater-detention criteria can be made more restrictive by requiring that storms larger than a 2-year event be detained. However, the allowable release rate should be tied to the actual carrying capacity of the receiving stream or the 2-year pre-development peak-runoff rate.

Multiple-Purpose Criteria

Stormwater management criteria for flood control, erosion control, and pollution control are not necessarily mutually exclusive. In many cases, stormwater can be managed to accomplish all three goals simultaneously. For example, a stormwater-detention basin can be designed as a multipurpose structure by incorporating different release rates at different stages (storage elevations).

The first stage is designed to capture an initial volume of runoff (i.e., the first flush) and release it very slowly through a subsurface drainage system. The second stage begins with an orifice cut in the riser pipe which has the capacity to pass stormwater runoff at a 2-year pre-development rate when water elevation reaches the top of the riser. The purpose of this stage would be to control downstream channel erosion from frequent storms. The top of the riser pipe could serve as the outlet for the third stage and may be designed to pass a l0-year storm at a pre-development rate for moderate flood protection downstream. The emergency spillway should be designed to pass at least the l00-year storm. While such a multi-purpose design may not be feasible for all detention systems, there are often innovative approaches which can be taken to satisfy two or more local stormwater-management goals.

Flexibility

Flexibility is extremely important in stormwater-management programs. Each development project has a unique set of conditions and circumstances and a different potential for affecting the downstream drainage system.

Criteria which may be perfectly applicable to one project may be totally unsuitable for another. For example, requiring stormwater detention for flood control may be highly applicable to projects constructed in the upper reaches of a watershed, but may be unnecessary or even undesirable for new projects constructed near the outlet of the watershed.

A qualified design professional should be given an opportunity to design a drainage system which contributes to the achievement of established, local stormwater-management goals in the most cost-effective manner. To accomplish this, each project must be considered on an individual basis.

Principles of Stormwater Management

It is much more efficient and cost effective to prevent problems than to attempt to correct problems after the fact. Sound land-use planning decisions based on the site planning principles are essential as the first, and perhaps the most important, step in managing stormwater-related problems. All new development plans (e.g., subdivisions, shopping centers, industrial parks, office centers, etc.) and redevelopment plans should include a comprehensive stormwater-management system.

Every piece of land is part of a larger watershed. A stormwater-management system for each development project should be based on, and should support, a plan for the entire drainage basin.

Optimum design of the stormwater-management system should mimic (and use) the features and functions of the natural drainage system, which is largely capital, energy and maintenance-cost free. Every site contains natural features that contribute to the management of stormwater under existing pre-development conditions. Depending upon the site, existing features such as natural drainageways, depressions, wetlands, floodplains, highly permeable soils, and vegetation provide natural infiltration, help control the velocity of runoff, extend the time of concentration, filter sediments and other pollutants, and recycle nutrients. Each development plan should carefully map and identify the existing natural systems. “Natural” engineering techniques should be used to preserve and enhance the natural features and processes of a site and to maximize the economic and environmental benefits. Engineering design can and should be used to improve the effectiveness of natural systems, rather than negate, replace or ignore them.

The volume, rate, timing and pollutant load of stormwater after development should closely approximate the conditions that occurred before development. To accomplish these objectives, two overall concepts must be considered: (1) the perviousness of the site should be maintained to the greatest extent possible, and (2) the rate of runoff should be slowed. Preference should be given to stormwater-management systems that use measures that maintain vegetative and pervious land cover and include on-site storage mechanisms. These systems will promote infiltration and slowing of the runoff.

On-site storage of stormwater should be maximized. Provision for storage can reduce peak runoff rates; aid in groundwater recharge; provide settling of pollutants; lower the probability of downstream flooding, stream erosion and sedimentation; and provide water for other beneficial uses. Stormwater runoff should never be discharged directly into surface or ground waters. Runoff should be routed over a longer distance, through grassed waterways, wetlands, vegetated buffers, and other works designed to increase overland flow. These systems provide time for increased infiltration and evaporation, allow suspended solids to settle, and remove pollutants before they are introduced to waters of the State.

Stormwater-management systems, especially those emphasizing vegetative practices, should be planned, constructed, and stabilized in advance of the facilities that will discharge into them. This principle is frequently ignored, thereby causing unnecessary off-site impacts, extra maintenance, re-working of grades, re-vegetation of slopes and grassed waterways, and extra expense to the developer. The stormwater-management system, including erosion and sedimentation controls, should be constructed and stabilized at the start of site disturbance and construction activities.

The stormwater-management system must be designed beginning with the outlet or point of outflow from the project. The downstream conveyance system should be evaluated to ensure that it contains sufficient capacity to accept the design discharge without adverse downstream impacts such as flooding, streambank erosion, and sedimentation. It may be necessary to stabilize the downstream conveyance system, especially near the stormwater system outlet. A common problem is a restricted outlet which causes stormwater to back up and exceed the storage capacity of the collection and treatment system, resulting in temporary upstream flooding. This may lead to hydraulic failure of the stormwater-management system causing re-suspension of the pollutants and/or expensive repairs to damaged structures or property. In such circumstances, it is advisable to use more than one outlet or to increase the on-site storage volume.

Stormwater is a component of the total water resources that should not be casually discarded, but used to replenish those resources. Stormwater represents a potential resource out of place, with its location determining whether it is a liability or an asset. Given the water quantity and quality problems and challenges facing Mississippi, it is imperative that stormwater be considered an asset. Treated stormwater has great potential for providing beneficial uses such as irrigation (farm, lawn, parks, golf courses, etc.), recreational lakes, groundwater recharge, industrial cooling and process water, and other non-potable domestic uses.

Whenever practical, multiple-use, temporary-storage basins should be an integral component of the stormwater-management system. All too often, storage facilities planned as part of the system are conventional, unimaginative ponds which are aesthetically unpleasing. Recreational areas (e.g., ball fields, tennis courts, volleyball courts, etc.), greenbelt areas, neighborhood parks, and even parking facilities provide excellent settings for the temporary storage of stormwater. Such areas are not usually in use during periods of precipitation, and the ponding of stormwater for short durations does not seriously impede their primary functions. Storage areas should be designed with sinuous shorelines. Shorelines that are sinuous rather than straight increase the length of the shoreline. The increased shoreline also provides more space for the growth of shoreline vegetation, thus providing for greater pollutant filtering and for increased and diversified aquatic habitat.

Vegetated buffer strips should be retained in their natural state or created along the banks of all water bodies. Vegetated buffers prevent erosion, trap sediment, filter runoff, provide public access, enhance the site amenities, and function as a floodplain during periods of high water. They also provide a pervious strip along a shoreline which can accept sheet flow from developed areas and help minimize the adverse impacts of untreated stormwater.

The stormwater-management system must receive regular maintenance. Failure to provide proper maintenance reduces the pollutant removal efficiency of the system and reduces the system’s hydraulic capacity. Lack of maintenance, especially to vegetative systems that may require revegetating, can increase the pollutant load of stormwater discharges. The key to effective maintenance is the clear assignment of responsibilities to an established agency (local government) or organization (homeowners association) and a regular schedule of inspections to determine maintenance needs. In addition, stormwater-system designers should find ways to make their systems as simple, natural, and maintenance free as possible.

Vegetation for Erosion and Sediment Control

Introduction

A dense and healthy vegetative cover protects the soil surface from raindrop impact, a major force in erosion and sedimentation. Also, vegetation shields the soil surface from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity.

The shielding effect of a plant canopy is augmented by roots and rhizomes that hold the soil, improve its physical condition, and increase the rate of infiltration, further decreasing runoff. Plants also reduce the moisture content of the soil through transpiration, thus increasing its capacity to absorb water.

Suitable vegetative cover offers excellent erosion protection and sediment control. Vegetative cover is essential to the design and stabilization of many structural, erosion-control practices. Vegetative cover is relatively inexpensive to achieve and maintain. Also, it is often the only practical, long-term solution to stabilization and erosion control on many disturbed sites.

Timely vegetative establishment or retention reduces the cost of vegetation, minimizes maintenance and repairs, and makes structural, erosion-control measures more effective and less costly to maintain. Landscaping is also less costly where soils have not been eroded. Natural areas (those left undisturbed) can provide low-maintenance landscaping, shade, and screening. Large trees increase property values if they are properly protected during construction.

Besides preventing erosion, healthy vegetative cover provides a stable land surface that absorbs rainfall, cuts down on heat reflectance and dust, and complements architecture. Property values can be increased dramatically by small investments in erosion control.

Plant selection should be considered early in the process of preparing the erosion and sediment-control plan. A diversity of species can be grown in Mississippi due to the variation in both soils and climate. However, for practical, economical stabilization and long-term protection of disturbed sites, plant selection should be made with care. Many plants that will grow in Mississippi are inappropriate for soil stabilization because they do not protect the soil effectively, or they cannot be established quickly. Some plants may be very effective for soil stabilization, but are not aesthetically acceptable on some sites. In all cases, native vegetation should be the first plants considered when selecting plant materials for stabilization. Plant selection is discussed and suggestions are made in the ***Surface Stabilization*** sections of Chapter 4 entitled *Permanent Seeding*, *Temporary Seeding,* and *Shrub, Vine and Groundcover Planting*. Also, a Vegetation Schedule used by the Mississippi Department of Transportation is provided as **Appendix G**.

Stabilization of most disturbed sites requires grasses and/or legumes that grow close together to provide a thick, close-growing cover. This is true even where part of or the entire site is planted to trees or shrubs. In landscape plantings, disturbed areas between trees and shrubs must also be protected either by mulching or by permanent grass, legumes, or mixtures.

Trees are excellent for long-term soil and water protection, but they will not stabilize concentrated flow areas.

Site Planning For Tree Protection

Select and clearly identify trees to be saved before beginning construction. No tree should be destroyed or altered until the construction plans are final. Floodplains and wetlands should be left in their natural condition. Locate roadways so they cause the least damage to valuable trees. Follow contours where feasible to minimize cuts and fills. Minimize trenching by locating several utilities in the same trench. Excavations for basements and utilities should be kept away from the dripline of trees.

Storage areas for construction materials and worker-parking areas should be noted on the site plan, and located where they will not cause soil compacting over roots.

When retaining existing trees in parking areas, leave enough ground ungraded around the tree to allow for its survival. Tree protection measures should be extended from the trunk to the edge of the dripline to protect the root systems from compaction. Tree wells may be needed to protect the roots from too much soil cover, ultimate compaction, and lack of aeration. Specific tree preservation practices are discussed in Chapter 4, *Preservation of Vegetation*.

Locate erosion and sediment-control measures within the limits of clearing and not in wooded areas to prevent deposition of sediment within the dripline of trees being preserved. Sediment basins should be constructed in the natural depressions, if possible, rather than in locations where extensive grading and tree removal will be required.

Selecting Trees to Be Retained or Planted

Trees may be exposed to insufficient sunlight and water; high winds; heat radiation from highways and parking lots; pollutants from cars and industries; root amputation because of sewer, water, gas and electric lines; pruning or "topping" because of power lines; and covering of roots by pavement and compaction. These items make the selection and management of trees extremely important.

The proper development of a forested-urban site requires a plan for tree retention or tree planting before construction begins. An overall requirement for selecting trees is that those trees selected should be appropriate for the proposed use of the development. The selection of tree species depends on the desired function of the tree, whether it be just erosion control or other functions such as shade, privacy screening, noise screening, appearance, enhancement of wildlife habitat, or a combination of these. The following characteristics of a tree should be considered when choosing a tree to retain or plant.

Hardiness

Select trees that are recommended for the area. See practice entitled *Tree Planting on Disturbed Areas*.

Mature Height and Spread

The eventual height of a tree must be considered in relation to location on the site to avoid future problems with buildings and utility lines. See practice entitled *Tree Planting on Disturbed Areas*.

Growth Rate

Some trees attain mature height at an early age; others take many years. Fast-growing trees may be brittle and possibly short-lived, while slow-growing trees are usually less brittle and live longer.

Root System

Avoid trees that have fibrous roots which may cause damage to water lines, septic tanks, or sidewalks and driveways.

Cleanliness

Maintenance problems can be avoided by not selecting trees that drop seedpods, cones, flowers, or twigs, in large amounts.

Moisture and Fertility Requirements

If suitable soils with adequate fertility are not available, trees tolerant of poor growing conditions should be planted.

Ornamental Effects

If a tree is unusually attractive in appearance, some other shortcomings may be overlooked, but make sure the tree is suited to the site.

Evergreen vs. Deciduous

Evergreens retain their leaves or needles throughout the year and are useful for privacy screens and noise barriers. Most deciduous trees drop their leaves in the fall and are preferable as shade trees. Some deciduous trees do not drop their leaves until spring.

Pest Resistance

Insects and disease problems exist among many trees. Each pest is related to the tree species itself, its vigor, and the site on which it is planted. Where control techniques are available, the tree owner's commitment and ability to apply them to a pest problem will determine whether the tree should be planted.

Life Expectancy and Present Age

Tree species with expected long-life spans should be favored. Long-lived species that are old may succumb to the stresses of construction, so younger trees of desirable species are preferred since they are more resilient and will last longer.

Health and Disease Susceptibility

Unhealthy trees and those with damaged areas on the tree should be considered for removal.

Structure

Check for structural defects that indicate weakness or reduce the aesthetic value of a tree: trees growing from old stumps, large trees with overhanging limbs that endanger property, trees with brittle wood, misshapen trunks or crowns, and small crowns at the top of tall trunks. Trees with strong tap- or fibrous-root systems are preferred to trees with weak rooting habits.

Aesthetics

Trees that are attractive and pleasing to the eye are desirable. Trees that have beauty during several seasons of the year are desirable and add value to the site.

Comfort

Trees provide cooling during the summer and buffer the cold winds of winter. Summer temperatures may be 10 degrees cooler under hardwoods than under conifers. Most deciduous trees drop their leaves in winter, allowing the sun to warm buildings and soil. Evergreens are more effective wind buffers.

Wildlife

Preference may be given to trees that provide food and cover for wildlife.

Relationship to Other Trees

Trees growing alone generally are more valuable than trees growing in groups, but trees in groups are more effective in preventing erosion and reducing stormwater runoff.

Suitability for the Site

Consider the height and spread of trees and how they may interfere with proposed structures and overhead utilities. Roots may interfere with walls, walks, driveways, patios, parking lots, waterlines, and septic systems.

Desirable trees should be identified and located on a map as part of the planning process.

Damage to Trees from Construction

Construction activities expose existing trees to a variety of stresses, resulting in injury ranging from superficial wounds to death. Understanding the types of damages that may occur to trees is important in planning for protection.

Surface Impacts

Tree trunks are often damaged during construction activities. Trees scarred by construction equipment are more susceptible to damage by insects and disease. Excessive pruning of trees to prevent contact with utility lines or buildings may destroy the visual appeal of the tree, may provide a source of entry for disease-causing fungi, or may kill the tree.

Wind damage is a greater potential problem than scarring, especially when some of the trees have been removed from a group of trees causing the survivors to be exposed to greater wind velocities. Also, trees develop root anchorage where it is needed the most. Isolated trees develop anchorage rather equally all around, with stronger root development on the side of the prevailing wind. The more a tree has been protected from the wind, the less anchorage it usually has. The result of thinning of trees may be that some of the remaining trees are blown over by strong winds (windthrow). An additional factor related to thinning is that thinning in favor of a single tall tree increases the hazard of lightning strike.

Root Zone Impacts

Disturbing the relationship between soil and tree roots can damage or kill a tree. The roots of an existing tree are established in an area where a specific environment of soil, water, oxygen, and nutrients is present. The mass of the root system must be the correct size to balance the intake of water from the soil with the transpiration of water from the leaves.

Raising the grade as little as 6″ can retard the normal exchange of air and gases. Roots may suffocate due to lack of oxygen or be damaged by toxic gases and chemicals released by soil bacteria. Raising the grade may also elevate the water table and change the potential of the soil to function as a growing medium suitable for the trees that were growing there before the filling occurred.

Lowering the grade is usually not as damaging as elevating the grade. Shallow cuts of 6″ to 8″ will remove most of the topsoil and some feeder roots and expose some to drying and freezing. Deep cuts may sever a large portion of the root system, depriving the tree of water and increasing the chance of windthrow. Lowering the grade may also lower the water table.

Trenching or excavating through a tree's root system eliminates part of the root system and can be very detrimental. Trees that lose as much as 40 percent of their root system usually die within 2 to 5 years. Tunneling may be a better alternative with species that do not have tap roots.

Soil compaction caused by heavy equipment, materials storage, and paving within the dripline of trees restricts air and water from roots by reducing pore space of the soil and by reducing infiltration.

Site Considerations for Non-woody Vegetation

Species selection, establishment methods, and maintenance procedures should be based on site characteristics, including soils, slope, aspect, climate, and expected management.

Soils

Many soil characteristics influence the selection of plants and their establishment requirements. These include: including acidity, moisture retention, drainage, texture, organic matter, fertility, and slope influence the selection of plants and their establishment requirements. For example, Bahia grass and centipede are suited to droughty soils since they are more drought tolerant than most other grasses. **Appendix A** contains tables that provide a number of interpretations related to the soils that exist in Mississippi. One characteristic that will not be found in tables is the occurrence of compaction created incidentally as a result of equipment traffic, especially when the soil is wet or moist. Compaction can have an adverse impact on plant establishment and maintenance and should be addressed before establishment of vegetative cover

Slope

The steeper the slope, the more essential is a vigorous vegetative cover. Good establishment practices, including seedbed preparation, liming, fertilizing, proper planting, mulching, and anchoring of mulch are critical. The degree of slope may limit the equipment that can be used in seedbed preparation, planting, and maintenance.

Woody plants, shrubs, vines, and trees generally provide better long-term erosion control on steep slopes. They may be more costly and slower to establish, but can provide substantial savings in maintenance. Also, they can be more desirable in the overall landscape plan.

Aspect

Aspect affects soil temperature and available moisture. South- and west-facing slopes tend to be warmer and drier, and often require special treatment. Warm-season species tend to do better on south- and west-facing slopes in Mississippi because they are usually more drought and heat tolerant.

Climate

The regional climate must be considered in selecting well-adapted plant species. Species adaptation and seeding dates in Mississippi are based on three broad geographical areas: North, Central, and South. Climatic differences determine the appropriate plant selections based on such factors as cold-hardiness, heat tolerance, and tolerance to a cool-growing season.

Management Requirements

When selecting plant species for erosion control and stabilization, the post-construction land use and the expected level of maintenance must be considered. In every case, future site management is an important factor in plant selection.

Select plant species that are wear resistant and have rapid wear recovery for sites that receive heavy use, such as a sports field. A wear-resistant plant that also recovers rapidly from foot traffic is Bermuda grass. Bermuda grass also has a fast establishment rate and is adapted to all geographical areas in Mississippi.

Where a neat appearance is desired, use plants that respond to frequent mowing and other types of intensive maintenance. Likely choices for quality turf in north Mississippi are Bermuda grass or fescue, while in central or south Mississippi, Bermuda grass, centipede, or zoysia are good choices.

At sites where low maintenance is desired, low fertility requirements and vegetation persistence are particularly important. *Sericea lespedeza* and tall fescue are good choices in north Mississippi, while Bahia grass and centipede do well in central and south Mississippi.

Seasonal Considerations for Non-Woody Vegetation

Newly constructed slopes and other barren areas should be seeded or sodded as soon as possible after grading. Grading operations should be planned around optimal seeding dates for the particular region, where feasible. The most effective times for planting perennial grasses and legumes generally extend from March through May and from late August through October. Outside these dates, the probability of failure is higher. If the time of year is not suitable for seeding permanent cover (perennial species), a temporary cover should be planted or the area may be stabilized with crimped or tackified mulch. Temporary seedings of annual species (small grains, ryegrass, millets, etc.) often succeed at times of the year that are unsuitable for seeding permanent (perennial) species. Planting dates may differ for temporary species, depending on the geographical area of Mississippi.

Growing seasons must be considered when selecting species. Grasses and legumes are usually classified as warm-season or cool-season in reference to their season of growth. Cool-season species produce most of their growth during the fall and spring and are relatively inactive or dormant during the hot summer months. Therefore, fall is the most dependable time to plant them. Warm-season plants grow most actively during the summer, and go dormant after the first frost in the fall. Spring and early summer are the preferred planting times for warm-season species.

Selecting Shrubs, Vines and Groundcovers to be Retained or Planted

As with trees, several plant characteristics and environmental requirements should be considered when selecting shrubs, vines and groundcovers. Closer adherences to plant requirements yield a greater chance of achieving a successful landscape.

Hardiness

Plants have varying capacities to tolerate cold or heat. Cold tolerance is of most concern. The state of Mississippi spans four plant hardiness zones: Zone 7a (located generally in the northeast corner of the state), Zone 7b (located in the northwest corner of the state spanning the north-central portions of the state), Zone 8a (located along the western portion of the state and throughout the south-central areas), and Zone 8b (located in the six southernmost counties). The zones are determined by the range of average annual minimum temperatures. The average range of minimum temperatures for Zone 7a is 0 to 5 degrees Fahrenheit; Zone 7b is 5 to 10 degrees Fahrenheit; Zone 8a is 10 to15 degrees Fahrenheit; and for Zone 8b, 15 to 20 degrees Fahrenheit (See Figure-1: Geographical Areas for Species Adaptation).

Landscape plants that are not capable of tolerating temperatures below 10 degrees should not be expected to escape injury during an average winter in Zones 7a and 7b. However, they should be adequately adapted to Zones 8a and 8b.

Plant hardiness can be greatly influenced by nearby bodies of water since water buffers change in temperature. Other structures or other plants can moderate extreme temperatures and shelter landscape plants, enabling marginal species to better tolerate winter conditions.

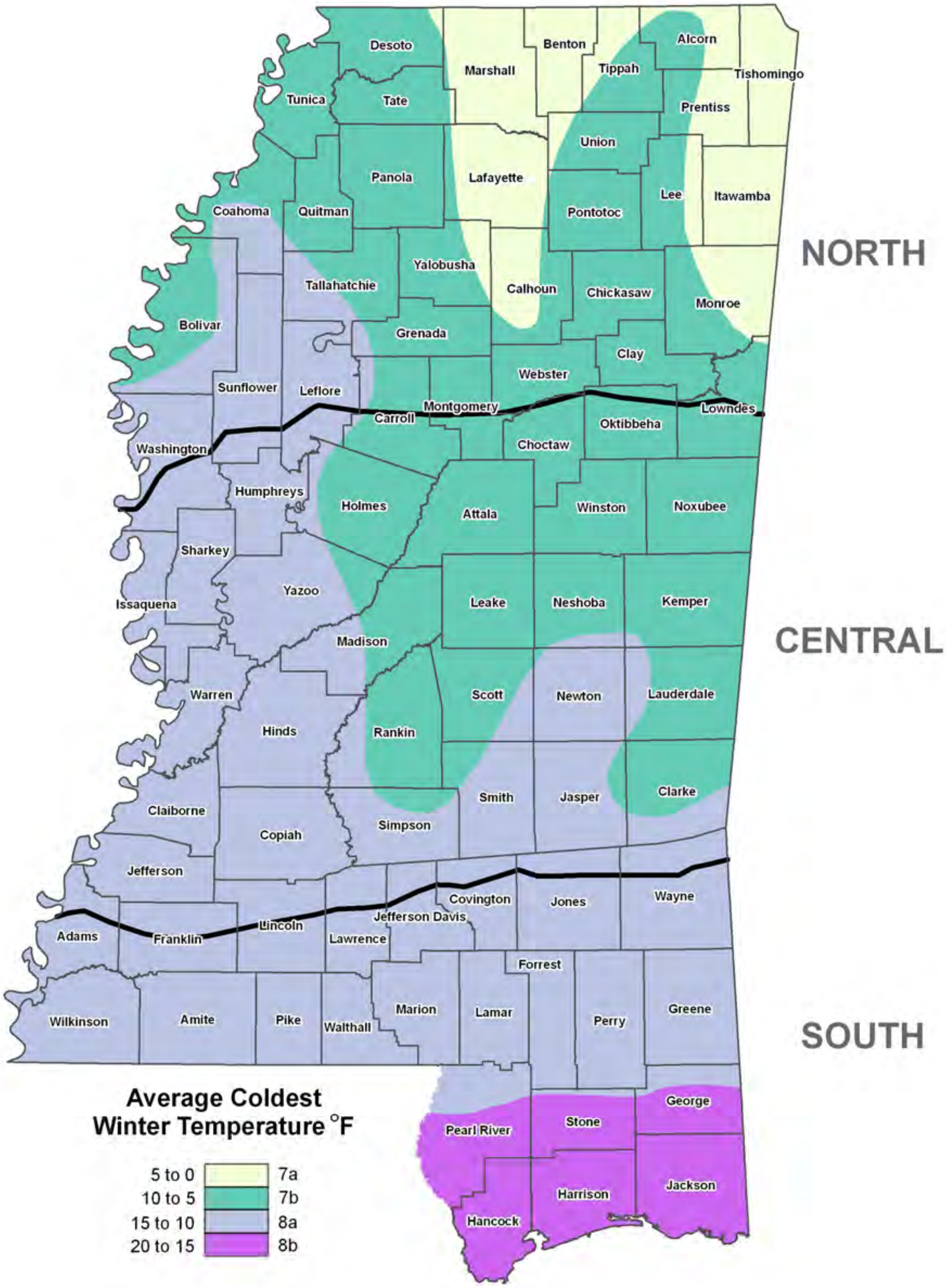


Figure -1 Geographical Areas for Species Adaptation

Summer Heat Tolerance

A plant's capacity to survive the stress of high temperature is also a concern. Heat interacts with other environmental factors, especially soil moisture conditions and sunlight, to influence the range of adaptability of a plant. Usually associated with high temperatures is rapid depletion of soil moisture, especially in late summer. Direct sunlight increases the severity of heat effects on plants. Since Mississippi has periods of high temperatures and short winters, spruce, hemlock, and yew are generally poor performers. Other conifers such as deodar cedars and cryptomeria are not hardy farther north into Zone 7a, but offer good substitutes for hemlocks and spruces in Mississippi.

Moisture Requirements and Soil Drainage

Landscape plants vary widely in the amount of moisture they need to thrive. If a drought-tolerant plant receives a lot of rain, it can be more susceptible to invasion by normally weak pathogens, especially where the soil drains slowly. On the other hand, plants that require large amounts of water for best performance are easily drought stressed when water is withheld or if planted in very well-drained soils. Such conditions may actually attract insect pests to stressed plants.

Plants that normally require a lot of water can be irrigated so that the ornamental attributes of the plant are maintained. However, this is a misuse of water resources that can be avoided if consideration is given to appropriate plant selection.

Soil pH

Soil pH can have a profound influence on the performance of landscape plants. However, most landscape plants perform adequately within a soil pH range of 5.5 to 6.2. Plants listed in Tables SVG 1-5 should grow satisfactorily within this pH range.

Plant Pest Susceptibility

It is unwise to use pest-susceptible plants in areas where those particular pests thrive. For example, most species of euonymus are attacked by euonymus scale, and Red Tip is highly susceptible to leaf spot. Other landscape options for plant materials might be selected that do not have the same susceptibilities. Plants listed in Tables SVG 1-5 have few major pest problems.

Nutritional Requirements

Newly set plants often require little additional fertilizer because of the presence of residual fertilizer in the root ball. At this stage, supplying water is far more important than adding fertilizer. Also, most well-established shrubs require less fertilizer to maintain an attractive plant than is usually required by poorly established shrubs.

Light Requirement

Plants that require full sun (at least 8 hours of direct sunlight per day) are weakened in low light situations. Plants that need some shade can become damaged and unattractive in full sun.

Rate of Growth and Mature Size

For rapid cover, faster growing plants are desired. However, mature size and other plant characteristics should be considered. For example, where a screen is needed, a slower growing evergreen shrub may be desired over a fast-growing deciduous plant. Take all plant characteristics into account when selecting plants for a site. If money is available, both needs can be met by planting fast-growing, short-lived plants to provide a quick screen and, at the same time, planting slower growing plants and allowing them to mature. When the fast-growing plants become overgrown, they can be removed to allow the more desirable plants to take their place.

Treating Sites to Establish Grass, Legumes, Shrubs, Vines and Groundcover

Topsoiling

The surface layer of an undisturbed soil is often enriched in organic matter and has physical, chemical, and biological properties that make it a desirable planting and growth medium. These qualities are particularly beneficial to plant establishment. Consequently, where practical, topsoil should be stripped prior to construction and stockpiled for use in the final vegetation of the site. Stockpiling topsoil may eliminate costly amendments and repair measures later. Topsoil may not be required for the establishment of less demanding, lower maintenance plants, but it is essential on sites having shallow soils or soils with other severe limitations. It is essential for establishing fine turf and ornamentals.

The need for topsoil should be evaluated, taking into account the amount and quantity of available topsoil and weighing this against the difficulty of preparing a good seedbed on the existing subsoil. Where a limited amount of topsoil is available, it should be reserved for use on the most critical areas.

Soil Amendments

Lime is almost always required on disturbed sites in Mississippi to decrease soil acidity. Lime raises the pH, reduces exchangeable aluminum, supplies calcium and magnesium for vigorous plant growth, and dispenses heavy clays that impede root penetration. A soil test should be used to determine the need for liming materials.

Plant nutrients, such as phosphorus and potassium, will usually be required even on the best soils. Plant-nutrient application rates for a particular species of vegetative cover should be applied according to a soil-test report.

Soil amendments should be applied uniformly and well mixed with the top 6″ of soil during seedbed preparation.

Site Preparation

The soil on a disturbed site must be modified to provide an optimum environment for germination and growth. Addition of topsoil, soil amendments, and tillage are used to prepare a good seedbed. At planting, the soil must be loose enough for water infiltration and root penetration, but firm enough to retain moisture for seedling growth. Tillage generally involves disking, harrowing, chiseling, or some similar method of land preparation. Tillage should be done on the contour, where feasible, to reduce runoff and erosion. Lime and fertilizer should be incorporated during the tillage.

Planting Methods

Seeding is by far the fastest and most economical method that can be used with most species. However, some grasses, such as hybrid Bermuda grass do not produce seed and must be planted vegetatively. Seedbed preparation, liming, and fertilization are essentially the same regardless of the method chosen.

Uniform seed distribution is essential. This is best obtained using a cyclone seeder, conventional grain drill, cultipacker seeder, or hydraulic seeder. The grain drill and cultipacker seeder are pulled by a tractor and require a fairly clean, smooth seedbed.

Seeding rates recommended in this manual have taken into account the “insurance” effect of extra seed. Rates exceeding those given are not recommended because over dense stands are more subject to drought, competitive interference, and are unnecessarily costly.

Because uniform distribution is difficult to achieve with hand broadcasting, it should be considered only as a last resort. When hand broadcasting of seed is necessary, uneven distribution may be minimized by applying half the seed in one direction and the other half at right angles to the first. Small seed should be mixed with sand for better distraction.

A sod seeder (drill seeder or no-till planter) can plant seed into an existing cover or mulch or be used to restore or repair a weak stand. It can be used on moderately uneven, rough surfaces. It is designed to penetrate the sod, open narrow slits, and deposit seed with a minimum of surface disturbance.

Hydroseeding may be the most effective seeding method on steep slopes where equipment cannot work safely. A rough surface is particularly important when preparing slopes for hydroseeding. In contrast to other seeding methods, a rugged or rough seedbed gives the best results.

Sprigging refers to planting stem fragments consisting of runners (stolons) or lateral, below-ground stems (rhizomes), which are sold by the bushel. Sprigs can be hand-planted or planted in furrows using a transplanter. This method works well with Bermuda grass. Sprigs can be covered with soil by light disking, or cultipacking. Common and forage-type hybrid Bermuda grass will cover over much more quickly than the lawn-type Bermuda grass.

Plugging differs from sprigging only in the use of plugs cut from established sod, in place of sprigs. It requires more planting stock, but usually produces a complete cover more quickly than sprigging. It is usually used to introduce a superior grass into an old lawn.

In sodding, the soil surface is completely covered by laying cut sections of turf. It is limited primarily to lawns, steep slopes, and sod waterways in Mississippi. Turf-type Bermuda, centipede, and zoysia are usually the types of turf used for sodding. Plantings must be wetted down immediately after planting, and kept well watered for a week or two thereafter.

Sodding, though quite expensive, is warranted where immediate establishment is required, as in stabilizing drainage ways and steep slopes, or in the establishment of high-quality turf. If properly done, it is the most dependable method and the most flexible in seasonal requirements. Sodding can be done almost any time of the year in Mississippi.

Inoculation of Legumes

Legumes have bacteria called rhizobia, which invade the root hairs and form gall-like "nodules." The host plant supplies carbohydrates to the bacteria, that supply the plant with nitrogen compounds fixed from the atmosphere. A healthy stand of legumes, therefore, does not require nitrogen fertilizer. *Rhizobium s*pecies are host specific in that a given species will inoculate some legumes but not others. Therefore, successful establishment of legumes requires the presence of specific strains of nodule forming, nitrogen-fixing bacteria on their roots. In areas where a legume has been growing, sufficient bacteria may be present in the soil to inoculate seeded plants, but in other areas the natural *Rhizobium* population may be too low.

In acidic subsoil material, if the specific *Rhizobium* is not already present, it must be supplied by mixing it with the seed at planting. Cultures for inoculating various legume seed are usually available through seed dealers.

Among the legumes listed for use in this manual, crownvetch is the only one generally requiring inoculation. Lespedeza nodule bacteria are widely distributed in the soils of Mississippi unless the site has had all surface soil removed.

Irrigation

Irrigation, though not usually required, can extend planting dates into the summer and ensure seedling establishment. Damage can be caused by both under and over irrigating. If the amount of water applied penetrates only the first few inches of soil, plants may develop shallow root systems that are prone to desiccation during droughts. If supplementary water is used to get seedlings up, it must be continued until plants become completely established.

Mulching

Mulch is essential to the successful establishment of vegetation of most disturbed sites, especially on difficult sites such as southern exposures, channels, and excessively dry soils. The steeper the slope and the poorer the soil, the more valuable mulch becomes. Mulch protects the site from erosion until the vegetation is established. In addition, mulch aids seed germination and seedling growth by reducing evaporation, preventing soil crusting, and insulating the soil against rapid temperature changes.

Mulch may also protect surfaces that cannot be seeded. Mulch prevents erosion in the same manner as vegetation, by protecting the surface from raindrop impact and by reducing the velocity of overland flow.

Small grain straw (wheat, oats, barley, or rye) is the most widely used and one of the best mulch materials. However, other materials, including manufactured mulches, also work well. Mulching materials covered in this manual have their respective advantages and appropriate applications, and a material should not be selected on the basis of cost alone. The effectiveness of straw mulch can be increased by crimping or tacking.

Maintenance

Satisfactory stabilization and erosion control requires a complete vegetative cover. Even small breaches in vegetative cover can expand rapidly and, if not repaired, can result in excessive soil loss from an otherwise stable site. A single heavy rain will enlarge rills and bare spots and, the longer repairs are delayed, the more costly they become. Prompt action will keep soil loss, sediment damage, and repair costs down. New plantings should be inspected frequently and maintenance performed as needed. If rills and eroded areas develop, they must be repaired, seeded, and mulched as soon as possible.

Maintenance requirements extend beyond the seeding phase. Damage to vegetation from disease, insects, traffic, etc., can occur at any time. Pest control (weed or insect) may be needed at any time. Weak or damaged spots must be fertilized, seeded, and mulched as promptly as possible.

Vegetation established on disturbed soils often requires additional fertilization. Frequency and amount of fertilizer to apply can best be determined through periodic soil testing. A fertilization program is required for the maintenance of turf and sod that is mowed frequently. Maintenance requirements should always be considered when selecting plant species for vegetation.

Chapter 3
Erosion and Sediment Control Plan Preparation

What is a Plan for Erosion and Sediment Control and Stormwater Management?

A plan for erosion and sediment control and stormwater management is the document which provides the practices and measures to prevent or reduce erosion on construction sites and minimize the impacts of sediment, turbidity, and hydrologic changes off-site. It is the part of a Stormwater Pollution Prevention Plan (SWPPP) (defined in glossary) or Construction Best Management Practices Plan (CBMPP) that ensures that erosion and sediment control is appropriate for the development activities and planned use of the site. Plan components are described in detail later in this chapter.

Designs of practices are usually prepared after a plan is adopted and, therefore, designs are not considered a part of the plan. Design of practices may also require the plan to be modified based on design requirements. Practice design criteria and guidelines for installation are discussed in Chapter 4 and provide a basis for developing sound specifications.

Who is Responsible for the Plan?

The owner or operator of the land planned for development or needing treatment from a previous disturbance has the responsibility for plan preparation and adequacy. Although the owner or operator may designate a qualified design professional to prepare and implement the plan, the owner or operator retains the ultimate responsibility.

Under the State of Mississippi's General Permit for Large Construction Sites (greater than five acres), "owner or operator" is defined as "the party that has operational control over construction plans and specifications, including the ability to make modifications to those plans and specifications" or "the party has day to day operational control of those activities at a project that are necessary to ensure compliance with a stormwater pollution prevention plan for the site or other permit conditions (i.e., they are authorized to direct workers at a site to carry out activities required by the SWPPP or comply with other permit conditions)."

If it becomes obvious during construction that additional practices or measures are needed or that the planned system is not appropriate, the shortcoming should be brought to the attention of the project manager for action by an appropriate design professional and concurrence by the owner, operator, or their designee. In this scenario, additional planning must continue to ensure that the plan is up-to-date and adequate.

What Is an "Adequate" Plan?

An adequate plan contains sufficient information to describe the system intended to control erosion on the construction site, minimize related off-site sediment delivery and turbidity, and address potential problems associated with hydrologic changes off-site. If regulations exist, more details may be required to satisfy the approving authority that the potential problems of erosion and sediment will be adequately addressed.

The length and complexity of the plan should be commensurate with the size and complexity of the project, severity of site conditions, and the potential for off-site damage. Obviously, a plan for constructing a house on a single subdivision lot will not need to be as complex as a plan for a shopping center development. Plans for projects undertaken on relatively flat terrain will generally be less complicated than plans for projects constructed with steep slopes with higher erosion and sediment-delivery potential. The greatest level of planning and detail should be evident on plans for projects that are adjacent to flowing streams, wetlands, dense population centers, high-value properties, coastal resources, and other critical habitats where damage may be particularly costly or detrimental to the environment.

The Step-by-Step Procedures for Plan Development outlined later in this chapter are recommended for the development of all plans. **Appendix B** of this manual provides a copy of the State of Mississippi Large Construction general permit, which provides requirements for site plans of developments greater than 5 acres. A sample Erosion and Sediment Control Plan is provided in **Appendix D**.

The checklist following the procedures can be used by qualified design professionals as a checklist for plan content and format.

General Considerations for Preparing Plans

Qualified design professionals should have a sound understanding of state and local laws and regulations related to erosion and sediment control and stormwater management. In addition, they must be competent in the principles of erosion and sediment control and stormwater management.

Developers and qualified design professionals can minimize erosion, off-site sediment delivery, turbidity issues, and other construction problems by selecting areas appropriate for the intended use because tracts of land vary in suitability for development. Knowing the soil type, topography, natural-landscape values, drainage patterns, receiving-stream characteristics and classification, flooding potential, areas of contaminated soil, and other pertinent data are useful in identifying both beneficial features and potential problems and challenges of a site.

A plan should contain enough information to ensure that the party responsible for development of a site can install the measures in the correct sequence at the appropriate season of the year. Sufficient information should be included to provide for maintaining the practices and measures during construction and after installation has been completed. A schedule of regular inspections and repair of erosion and sediment control BMP’s should be set forth to ensure that maintenance receives appropriate attention and is accomplished.

Will the development of the site result in increased peak rates of runoff? Will this result in flooding or channel degradation downstream? If so, considerations should be given to stormwater-control structures on the site. Local ordinances related to stormwater management must be considered and met.

As previously stated, the length and complexity of a plan should be commensurate with the size and complexity of the project, severity of site conditions, and the potential for off-site impacts. A plan may contain a description of the potential erosion and sediment-related problems. If a site is in the coastal zone, in a watershed with a formally designated impacted stream, or has contaminated soil or hazardous waste on the site, additional attention will be required during plan development (see Areas of Special Concern below).

For regulated sites in Mississippi, the plan must satisfy the Mississippi Department of Environmental Quality's (MDEQ) requirement that the potential problems related to erosion, sediment, stormwater, and wastewater will be adequately addressed.

New or innovative conservation measures or modifications to standard measures in this manual may be used if the proposed measure is reviewed by a qualified design professional and determined to be as effective as the practice for which it is being substituted.

Where applicable, the plan for a site should be included in the general-construction contract. To facilitate reviews and its use on the site, the plan should be prepared and assembled so that it may be reviewed as a separate document.

Areas of Special Concern

Contaminated Sites

For sites that are contaminated with hazardous substances (based on background levels), care should be taken to ensure that the contamination is appropriately managed. When soil potentially containing hazardous substances (based on background levels) is excavated at a site, it should be stored in covered roll-off containers or some other conveyance until an adequate waste determination, as required by both State and federal law, has been conducted. Soil that is contaminated above either the U.S. Environmental Protection Agency's or the MDEQ's established toxic concentrations or contaminated with listed hazardous wastes must be manifested and disposed at an approved hazardous waste treatment, storage, disposal (TSD) facility. Also, equipment used in the excavation process must be adequately decontaminated. All investigation-derived waste materials produced as a result of the decontamination procedures must be disposed in accordance with applicable State and federal requirements.

Solid waste that has been disposed of illegally (unpermitted solid waste dumps or burial sites) may be encountered during construction activities, and a variety of solid wastes can be generated during construction activities. Persons should contact the MDEQ's Office of Pollution Control if there are questions on how to proceed if illegal solid-waste dumps or buried solid wastes are encountered, or regarding proper management of solid wastes generated during construction. Brownfield sites (see Glossary for definition) may have issues that call for unique approaches for remediation and or construction. The MDEQ's Groundwater Assessment and Remediation Division provides oversight of assessment and remediation activities concerning these types of sites through its Brownfield Redevelopment and Voluntary Cleanup Program.

Cultural Resources

Cultural resources that may be altered, disturbed or destroyed by project implementation should be reported. Cultural resources consist of prehistoric and historic archaeological sites and historic structures (bridges, objects, buildings, etc., 50 years or older). If a cultural resource is known to exist or is discovered during project implementation, the Mississippi Department of Archives and History should be contacted immediately for further guidance. The Mississippi Department of Archives and History also maintains a listing of Historic Districts and Historic Structures and is responsible for maintaining a Statewide Archaeological Inventory, a database that contains the locations and significance of previously recorded archaeological sites. A project will be allowed to proceed as planned under normal circumstances, after a cultural resource has been recorded and protected if required.

Stream Alterations

Streams, both perennial and intermittent, are considered “waters” of the United States and are regulated as “wetlands” under the Clean Water Act, Section 404, by the U.S. Army Corps of Engineers. Relocating streams or other modifications must be approved by the Corps of Engineers. In-depth guidance for obtaining approval for alterations of streams is beyond the scope of this manual. Detailed information should be obtained from the U.S. Army Corps of Engineers serving the area.

Stream alterations also require a 401 Clean Water Certification from the U.S. Army Corps of Engineers. Alterations also require approval by the MDEQ under applicable rules of the department.

Associated with streams are the nearby adjacent areas, and local regulations involving buffer zones may prohibit or otherwise restrict disturbances and construction in these areas. Streams and nearby adjacent areas should be avoided whenever possible. If disturbance of these areas is absolutely necessary, the applicable stream protection methods are discussed in-depth in the *Stream Protection* section of Chapter 4. However, as stated, these methods should be used only where absolutely necessary.

Wetlands

Construction plans must respect the wetlands regulations of the Clean Water Act, Section 404, and all applicable MDEQ and Mississippi Department of Marine Resources rules. While the details of the regulations are beyond the scope of this manual, it must be noted that wetlands cannot be altered by dredging and filling except in small increments approved by the U.S. Army Corps of Engineers and, in addition, construction plans shall be prepared to prevent negatively impacting wetlands off-site.

Threatened and Endangered Species

Threatened and endangered species habitats that may be altered, disturbed, or destroyed should be reported. If a threatened and endangered species is found within the proposed work area, the U.S. Fish and Wildlife Service should be consulted before work proceeds.

Components of a Plan

This subtopic describes the typical components that should be included in a plan. Local or state regulations may require additional items or more detailed information than listed. There are typically two components of a plan: a Site-Plan Map showing locations of the planned practices and a Written Narrative. Supporting materials are essential to develop the plan and they should be a part of the associated file material available with the plan. In addition, other components such as a site-location map are needed or required to satisfy regulatory requirements.

Site-Plan Map (Sometimes Referred to as Treatment Map)

This map may include a site-development drawing and a site-erosion and sediment-control drawing depicting types and, to the extent possible, locations of planned conservation practices. Map scales and drawings should be appropriate for clear interpretation. Site planners are urged to use the standard coding system for conservation practices contained at the end of this chapter. Use of the coding system will result in increased uniformity of plans and better readability for plan reviewers, job superintendents, and inspectors statewide. The State of Mississippi's Large Construction General Permit provides specific requirements concerning site maps and can be found in **Appendix C**.

Written Narrative

Where needed, additional information that is not included on the site-plan map should be included in a plan narrative that is written in a clear, concise manner. Typical items to include are the planned measures. Other items that may be needed include (a) a construction schedule that provides information both on sequence and time of year for installing the various practices and measures; (b) information on maintaining the practices and measures during construction and after installation have been completed, and (c) a schedule for regular inspections and repair of erosion and sediment-control and stormwater measures during construction. In some instances, existing conditions at the site and adjacent areas and rationale for those decisions involved in choosing erosion and sediment-control measures may be included to help clarify the plan.

Adequate information provided by the narrative is important for the plan reviewer, the construction superintendent, and the inspector. These details help ensure that erosion- and sediment-control and stormwater measures are understood and properly installed.

Supporting Materials (Referred to Later in Chapter as "Supporting Data")

These items include inventory information collected and used during the planning process (contour maps, soils maps, charts, or other materials, as applicable, used in evaluating the site and formulating the plan). Supporting materials are important to all those involved in plan formulation and plan reviews and should be available to those with a specific need for them.

Step-By-Step Procedures for Plan Development

The context of the procedures presented in this subtopic is that a professional skilled in erosion and sediment control and stormwater management will assist another professional who is developing the overall site plan.

Step 1–Data Collection

Data collection includes inventorying the existing site conditions to gather information that will help in developing the most effective erosion- and sediment-control plan. The information should be shown on a map and explained in well-organized notes. This information eventually becomes a part of *Supporting Data* and is used to analyze and evaluate the site and practice options.

Topography

A large-scale topographic map of the site should be prepared. The suggested contour interval is usually 1 to 2 feet, depending upon the slope of the terrain. The interval may be increased on steep slopes.

Drainage Patterns

All existing drainage swales and patterns on the site should be located and clearly marked on the topographic map.

Soils

Major soil type(s) on the site should be determined and shown on the topographic map if the information is available. Soils information for previously undisturbed sites can be obtained from a soil survey if one has been published for the county by the Natural Resources Conservation Service. Commercial soils evaluations and borings are available from consultants for many sites. For ease of interpretation, soils information should be plotted directly onto the map or an overlay of the same scale.

Groundcover

The existing vegetation on the site should be determined. Such features as trees and other woody vegetation, grassy areas, and unique vegetation should be shown on the map or described in the notes describing the site. In addition, existing bare- or exposed-soil areas should be indicated. This information may be important in determining clearing limits and establishing stages of construction.

Adjacent Areas

Areas adjacent to the site should be inventoried, and important features that may be impacted by the proposed plan should be marked on the topographic map or identified in the notes. Applicable features include streams, springs, roads, wells, houses, other buildings, utilities, and other land areas.

Floodplain Boundaries

The existence of floodplains should be determined. Sources of information include soil surveys available from the Natural Resources Conservation Service, topographic maps, and floodplain maps that are available from many municipalities, as well as from the Federal Emergency Management Agency (www.fema.gov).

Receiving Waters

The use-classification and special designation of streams and lakes that receive stormwater from the proposed site should be determined.

Wetlands

Wetlands and other areas that are possibly wetlands should be identified. Wetlands may be quite apparent, or some areas may be questionable. Maps developed as part of the National Wetlands Inventory, U.S. Geological Survey (USGS) topographic maps, and soil surveys showing the location of hydric soils should be collected to evaluate an area for wetlands.

Contaminated Sites

Trash, abandoned appliances, potential-contaminated soil and hazardous waste, or any other material that should not be on the site should be identified. Brownfields fit into this category.

Cultural Resources

If federal funds (grants or other directed federal funds) or federal property is involved, a cultural resources review or survey is required before any ground–disturbing activities may begin (Section 106, National Historic Preservation Act). On public and private lands, the Mississippi Department of Archives and History is the primary state agency responsible for archaeological-resources protection. In addition to cultural-resource regulations, there are laws protecting cemeteries and human remains (marked and un-marked); permits are required to excavate graves.

Threatened and Endangered Species

Threatened and endangered species that may exist in the area and their associated habitat should be considered. Lists containing both the species and their habitat characteristics are available from the local office of the Natural Resources Conservation Service.

Step 2–Data Analysis

When all of the data in Step 1 are considered, a picture of a site's potentials and limitations should emerge. The qualified design professional should be able to determine those areas that have potentially critical erosion hazards and the potential for construction disturbances to cause adverse off-site impacts. Described below are some important points to consider in site analysis.

Topography

Topographic considerations are slope steepness and slope length; that is, the longer and steeper the slope, the greater the erosion potential from surface runoff. Slope modifications with large cuts and fills may exacerbate the potential for erosion.

Drainage Patterns

Swales, depressions, and natural watercourses should be evaluated to plan where water will concentrate and what measures will be needed to maintain a stable condition for concentrated flow. Where it is possible, natural drainageways should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage system. Man-made ditches and waterways become part of the erosion and turbidity problem if they are not properly stabilized. Potential for flooding and possible sites for stormwater-detention ponds and sediment basins should be determined.

Soils

Soil properties such as depth-to-bedrock, depth-to-seasonal water table, permeability, shrink-swell potential, and texture should exert a strong influence on development decisions. Also, the flood hazard related to the soils can be determined based on the relationship between soils and flooding. A list of common Mississippi soils along with interpretations for developmental uses is included in Appendix A.

Groundcover

Groundcover is the most important factor in terms of preventing erosion. Any existing vegetation that can be saved will help prevent erosion. Trees and other vegetation protect the soil and beautify the site after construction. It is important to recognize vegetation that can be retained during, and possibly after, construction to assist in stabilizing the site.

Adjacent Areas

Generally, the analysis of adjacent properties should focus on areas downslope or downstream from the construction project. Because of construction-related erosion, the potential for sediment deposition on adjacent properties should be analyzed so that appropriate erosion- and sediment-control measures can be planned.

Floodplains

Floodplains are generally restrictive in nature, and uses planned within them must be consistent with local regulations. The location of facilities within floodplains should usually be avoided to prevent restriction of flood flows and potential changes in flood stages downstream.

Receiving Waters

Watercourses that will receive direct runoff from the site should be of major concern; these streams should be analyzed to determine their use classification and whether they have a sensitive-water designation. The potential impact from sediment and turbidity pollution on these watercourses should be considered, as well as the potential for downstream-channel erosion due to increased velocity of stormwater runoff from the site.

Wetlands

Wetlands or the absence of wetlands should be determined by a qualified professional. Wetland boundaries should be clearly marked by a wetland delineator to provide a distinct location and boundary to use during the planning, design, and construction phases of a project.

Waste Materials/Contamination

Sites with known or potential contamination by petroleum, chemical spills, etc., should have a thorough assessment conducted by a qualified professional and result in a comprehensive site assessment. Details of this activity are beyond the scope of this manual. The MDEQ should be contacted for assessment procedures.

Cultural Resources

The presence of cultural resources within the area of potential effect (which includes the immediate project area and any off-site areas, such as borrow pits, fill-disposal or temporary-storage areas, and equipment-staging areas) should be considered. Care should be taken to avoid disturbing cultural resources; previously unknown or undocumented cultural resources should be reported to the Mississippi Department of Archives and History.

Threatened and Endangered Species

Habitat for threatened and endangered species should be evaluated. If potential exists for occurrence of such a species, a determination of its occurrence should be made by a qualified professional.

Step 3–Facility Plan Development

This step applies to sites that are in the planning stage where planning of the facilities has not been firmly determined. After analyzing the data about the site and determining any site limitations, the erosion- and sediment-control professional can assist the professional developing the overall site plan and formulate a site plan that is in harmony with the conditions unique to the site. An attempt should be made to locate the buildings, roads, and parking lots and to develop landscaping plans to exploit the strengths and overcome the limitations of the site. Ideally, there can be flexibility in the location of facilities to allow low-impact development concepts to be exploited. The following are some points to consider in making these decisions:

- Fit development to terrain. The development of an area should be tailored, as much as possible, to existing site conditions. For example, confine construction activities to the least critical areas. This will avoid unnecessary land disturbance while minimizing erosion, development costs, and land disturbances.

- Cluster buildings together. This minimizes the amount of disturbed area and concentrates utility lines and connections, while leaving more open, natural space. The cluster concept not only lessens the erodible area, it generally reduces runoff and development costs.

- Minimize impervious areas. Keep paved areas, such as parking lots and roads, to a minimum. This goes hand-in-hand with cluster developments in eliminating the need for duplicating parking areas, access roads, etc. The more land that is kept in vegetative cover, the more water will infiltrate, thus minimizing runoff and erosion. Consider the use of special paving products that will allow water to infiltrate or cellular blocks that have soil and vegetation components.

- Utilize the natural drainage system. If the natural drainage system of a site can be preserved instead of being replaced with storm sewers or concrete channels, the potential for downstream damages due to increased runoff can be reduced.

- Determine if there are any “environmentally sensitive” areas (areas of special concern) to be protected during and after project implementation. In general, most erosion- and sediment-control projects will have an overall beneficial effect to cultural resources since they would be protected from further environmental degradation.

Step 4–Planning for Erosion and Sediment Control and Stormwater Management

When the site-facility plan-layout has been developed, another plan is developed to minimize erosion on-site and delivery of sediment and turbid water off-site. Additional objectives may include those related to increased peaks and runoff associated with a development. These may account for flood control and off-site erosion control.

The following procedure is recommended for formulating the system of practices and measures for erosion and sediment control and stormwater management.

- Divide the site into drainage areas. Determine how runoff will travel over the site.

- Determine limits of clearing and grading. Decide exactly which areas must be disturbed in order to accommodate the proposed construction. Pay special attention to critical areas that can be avoided (areas with high potential for erosion and needing special treatment if disturbed). The important point in this activity is to minimize the areas to be disturbed.

- Select erosion- and sediment-control and stormwater management practices and measures using a systems concept. Practices and measures should be selected that are compatible and, as a system, can be expected to meet objectives for the development or activity.

Consider how erosion and sediment can be controlled in each small drainage area of the entire site. Remember, it is easier to control erosion than to contend with sediment after it has been carried downslope and downstream.

Plan to sequence construction so that no area remains exposed for unnecessarily long periods of time. On large projects, stage the construction, if possible, so that one area can be stabilized before another is disturbed. Sequencing and staging may influence the choice of practices.

The practices and measures in this manual are divided into six broad categories to support planning concepts: site preparation, surface stabilization, runoff conveyance, inlet protection, sediment control, and stream protection. Other categories that are sometimes used, such as vegetative, structural, and management measures, are imbedded into the six categories.

Again, review each drainage area, determine the categories that apply, and select practices to comprise a technically sound and cost-effective system.

- **Site Preparation** (Construction Exit Pad, Land Grading, and Topsoiling)

  A Construction Exit Pad should be planned for early installation at each access point where vehicles leave the disturbed area of a construction site and enter a public road. The stockpiling of topsoil should be done as an initial part of earthmoving. Most sites have enough topsoil available for stockpiling to provide adequate amounts for topsoiling the areas to be permanently vegetated. Land-grading techniques can be done to complement erosion-control systems.

- **Surface Stabilization** (Chemical Stabilization; Dust Control; Erosion Control Blanket; Housekeeping; Mulching; Permanent Seeding; Preservation of Vegetation; Retaining Wall; Shrub, Vine and Groundcover; Sodding; Temporary Seeding; and Tree Planting on Disturbed Areas)

  Most qualified design professionals agree that vegetative measures should be maximized to provide as much erosion and sediment control as possible. Structural measures are generally more costly than vegetative controls, but they are necessary on areas where vegetation and reinforcement with erosion control blankets or chemical measures will not provide adequate erosion control. Temporary practices from this category are needed on most sites, and final stabilization of all landscapes requires one or more practices from this category.

- **Runoff Conveyance** (Check Dam, Diversion, Drop Structure, Grass Swale, Lined Swale, Outlet Protection, Riprap-lined Channel, Subsurface Drain, and Temporary Slope Drain)

Diversions are particularly important in (1) diverting clean water away from a disturbed site; (2) preventing flows from eroding cut and fill slopes and; (3) breaking (reducing) slope lengths. The other practices in this category are needed to safely move concentrated flows of stormwater in channels. Concentrated flows are the potential cause of gullies, and the runoff-conveyance practices are used to prevent gully erosion. Subsurface drains are used to facilitate another practice, such as Grass Swale, in becoming successfully established and maintained. One or more practices from this category are needed on sites with channel flow.

- **Inlet Protection** (Block and Gravel Inlet Protection, Excavated Inlet Protection, Fabric Drop Inlet Protection, and Straw Bale Inlet Protection)

  Inlet protection control practices function primarily on the basis of filtering the sediment-laden water before it enters storm-sewer systems.

- **Sediment Control** (Brush/Fabric Barrier, Filter Strip, Floating Turbidity Barrier, Rock Filter Dam, Sediment Barrier, Sediment Basin, Straw Bale Sediment Trap, Surface Discharge Structures, and Flocculants and Polymers)

  Sediment-control practices function primarily on the basis that sediment-laden water will deposit at least part of its load while the water is ponded on the construction site by the practice. All of the sediment-control practices are considered temporary. The effectiveness of each practice is dependent upon the unique attribute of the practice, the texture of the sediment in suspension, and suspension time.

- **Stream Protection** (Buffer Zone, Channel Stabilization, Stream Diversion Channel, Streambank Protection, and Temporary Stream Crossing)

  These stream protection practices are primarily intended to be used to preserve or repair streams. Designing new channels is beyond the scope of this manual. One or more of these practices should be considered essential where a construction project includes a perennial or intermittent stream.

Step 5–Plan Assembly

The final step of plan development consists of compiling and consolidating the pertinent information into a site-specific plan for erosion control, sediment control and stormwater management. The major plan components are a <u>narrative</u> and a <u>site-plan</u> <u>map</u>. <u>Supporting data</u> are assembled to substantiate planning options considered and developed and to aid in review of a plan.

The following checklist may be used in assembling the narrative and site-plan map to be sure all major items are included.

Checklist for Plans

Narrative

Explain the solutions for existing and predicted problems in the narrative (tables and charts may be used to display information in a format that is easier to understand).

Project Description

Briefly describe the nature and purpose of the land-disturbing activity and the amount of disturbance involved.

Practices and Measures

Identify the practices and methods that will be used to control erosion on the site, prevent or minimize sediment from leaving the site, and address turbidity and hydrologic changes associated with the proposed project. Sequence and staging of construction activities to minimize disturbance and erosion should be addressed.

Inspections

Prescribe a schedule for inspections and repair of practices.

Maintenance

Include statement(s) explaining how the project will be maintained during construction until final stabilization. In some instances, maintenance that will be needed after construction should be included.

Site-Plan Map

The site-plan map is one or a series of maps or drawings pictorially explaining information contained in the narrative.

Site-Plan Label

The label should include the name of owner, name of site or facility, county name, location (township, range and section), name of qualified design professional, date plan was created and, if applicable, date of latest revision.

Existing Contours

The existing contours of the site should be shown on a map (the scale used for this map should be of sufficient scale for meaningful evaluations). The scale of the site plan may range from 1″ = 100 feet to 1″ = 20 feet. If existing contours cannot be shown, drainage-pattern arrows must be included.

Existing Vegetation

The existing tree lines, grassy areas, or unique vegetation should be shown on a map.

North Arrow

The direction of north in relation to the site should be shown. The top of all maps should be north, if practical.

Existing Drainage Patterns

The dividing lines and the direction of flow for the different drainage areas should be shown on a map.

Final Contours

Planned post-construction contours should be shown on a map.

Development Features

The outline of buildings, roads, drainage appurtenances, utilities, landscaping features, parking areas, improvements, impervious areas, topographic features, and similar man-made installations should be shown to scale and relative location.

Limits of Clearing and Grading

Areas that are to be cleared and graded should be outlined on a map.

Wetlands

The location of wetlands is important and should be shown accurately and, preferably, on the site map.

Cultural Resources

The locations of cultural resources should be shown accurately on the plan map and construction plans. Their accurate location is essential if these areas are to be avoided or protected during project construction.

Location of Practices and Legend

The locations of the erosion and sediment control and stormwater-management practices used on the site should be shown on a map. A combination of symbols and acronyms is used to identify the practices. A list of the acronyms is included at the end of this chapter under “Legend of Measures for Erosion and Sediment Control and Stormwater Management.”

Site Location or Vicinity Map (if required by regulatory agency)

Provide a small map locating the site in relation to the surrounding area. A portion of a 7.5-minute series USGS topographic map that covers the project area usually meets this requirement.

Supporting Data (relevant materials collected and generated during all stages of planning).

Existing Site Conditions

This material describes the existing topography, vegetation, and drainage.

Adjacent Areas

This material describes the adjacent and neighboring areas such as streams, lakes, residential areas, roads, etc., that might be affected by the land disturbance.

Soils

Include a brief description of the soils on the site giving relevant information such as soil names, mapping unit, erodibility, permeability, depth, texture, soil structure, and any other limitations. The boundaries of the different soil types should be shown on a map.

Critical Areas

Identify and describe areas on the site that have potential and/or serious erosion problems.

Areas of Special Concern

Include relevant information affecting planning on contaminated soils, new or innovative practices, stream alterations, wetlands, and cultural resources. If federal lands or federal funds are involved, a letter from the lead federal agency will be required stating that there would be no adverse effect to cultural resources and allowing the project to proceed as planned or amended. A similar letter from the Mississippi Department of Archives and History may be necessary if cultural resources are present on State and private lands.

Calculations and Design Data Needed During Planning

Include estimates used to evaluate practices that are chosen based on peak flows, acres of runoff, etc.

Legend of Measures for Erosion and Sediment Control and Stormwater Management

A listing of BMPs, their abbreviations, and sample symbols are provided on the next page. It should be noted that no universal symbols exist for erosion- and sediment-control measures. The symbols provided are not required and are only recommendations.

BEST MANAGEMENT PRACTICE (BMP)	ABBREVIATION	SYMBOL
SITE PREPARATION		
CONSTRUCTION PHASING/SEQUENCING	CPS	CPS
CONSTRUCTION EXIT PAD	CEP	SCE SCE-WR
CONTRUCTION ROAD STABILIZATION	CRS	CRS
LAND GRADING	LG	
TOPSOILING	TSG	PILE
SURFACE STABILIZATION		
CHEMICAL STABILIZATION	CHS	CS
DUST CONTROL	DC	DC
EROSION CONTROL BLANKET	ECB	
HOUSEKEEPING	HK	HK
MULCHING	MU	M
PERMANENT SEEDING	PS	PS
PRESERVATION OF VEGETATION	PV	P
RETAINING WALL	RW	
SHRUB, VINE & GROUNDCOVER PLANTING	SVG	GC
SODDING	SOD	S
TEMPORARY SEEDING	TS	TS
TREE PLANTING IN DISTURBED AREAS	TP	TP
RUNOFF CONVEYANCE		
CHECK DAM	CD	
DIVERSION	DV	D
DROP STRUCTURE	DS	
GRASS SWALE	GS	GW
LEVEL SPREADER	LVS	
LINED SWALE	LS	LW
OUTLET PROTECTION	OP	ROCK OUTLET PROTECTION PAVED FLUME (OP-4)
RIPRAP LINED SWALE	RS	RR
SUBSURFACE DRAIN	SD	
TEMPORARY SLOPE DRAIN	TDS	SD

INLET PROTECTION		
BLOCK/GRAVEL INLET PROTECTION	BIP	
EXCAVATED INLET PROTECTION	EIP	
FABRIC DROP INLET PROTECTION	FIP	
STRAW BALE INLET PROTECTION	SBIP	
SEDIMENT CONTROL		
BRUSH FABRIC BARRIER	BFB	
FILTER STRIP	FS	
FLOATING TURBIDITY BARRIER	FB	— FTB — FTB —
ROCK FILTER DAM	RD	CD
SEDIMENT BARRIER	SB	— SF — SF — (SF) (SBB)
SEDIMENT BASIN	SBN	
STRAW BALE SEDIMENT TRAP	SST	
FLOCCULANTS AND POLYMERS	FLC	FLC
STREAM PROTECTION		
BUFFER ZONE	BZ	BZ
CHANNEL STABILIZATION	CS	S
STREAMBANK PROTECTION	SP	V
TEMPORARY STREAM CROSSING	TSC	
STREAM DIVERSION CHANNEL	SDC	

* NO UNIVERSAL SYMBOLS. THESE ARE RECOMMENDATIONS AND ARE NOT REQUIRED.

Chapter 4
Best Management Practices Design

Introduction

This chapter provides detailed information for best management practices (BMPs) commonly used for the control of erosion and sediment on active construction sites. Practices for erosion and sediment control will be installed in accordance with an approved site plan. (Chapter 3 provides information on developing an erosion and sediment control plan, and Appendix D provides examples of such plans.) The plan should list the sequence of construction activities. Each construction activity contributing to erosion of soil or changes in sediment-laden runoff should have an appropriate practice or practices to control erosion, sediment, and runoff. Minimizing the area exposed to erosion at any one time can significantly reduce erosion and sediment occurrence on the site.

Proper installation and maintenance of structural and vegetative practices approved in the site plan will be considered essential for compliance with the plan or associated permit. This chapter includes practice design standards and construction specifications along with applicable drawings. Design limitations are provided to maintain design integrity, safety, and purpose of the practices.

Purpose of BMP Manual

The purpose of this manual is to assist designers, developers, owners, contractors, and local officials in determining what stormwater regulations apply to their situation, what the BMP to meet those regulations might be, and how to then design and maintain that particular erosion and sediment control BMP. It is intended to provide the competent design professional with the information necessary both to properly meet the minimum requirements of Mississippi's stormwater programs and to be able to design a stormwater BMP that meets the water quality objectives. However, it does not cover every aspect of the civil engineering and structural design necessary for proper BMP system design and construction, nor does it cover every site situation that may occur, or every possible erosion and sediment control solution. The design professional is responsible for the design and construction of a properly functioning BMP that meets all of the applicable regulations, including the water quality objectives, and that considers all the unique conditions of an individual site. Where the designer determines that conformance with this manual would create an unreasonable hardship or where an alternative design may be more appropriate, alternative designs, materials, and methodologies will be considered on a case-by-case basis.

This manual is meant to supplement (not supplant) Mississippi's stormwater regulations by explaining the BMPs that will be allowed and their design criteria, in an easy-to-understand manner. In addition, local communities are free to adopt more stringent requirements than those presented in this manual. In general, if any part of this manual lists requirements different from those imposed by any other ordinance, rule, regulation, or other provision of law, whichever provision is more restrictive or imposes higher protective standards for human or environmental health, safety, and welfare, shall control.

There are figures, example calculations, operation and maintenance items, etc., used throughout this manual. The intention is to provide the reader with visual assistance in device functions, siting, and concepts, as well as guidance on designing, operating, and maintaining specific BMPs. The figures, example calculations, operation and maintenance items, etc., will not represent the proper solution for every situation, and they may contain items that may not exactly fit the requirements listed in the section. The user of this manual must look at these items and use his or her professional judgment as to their proper use in a specific situation (however, any variance from a requirement must be clearly indicated). In the event of a conflict or inconsistency between the text of this manual and any heading, caption, figure, illustration, table, map, etc., the text shall control.

Also used throughout this manual is the phrase "design professional." This phrase is a generic title for a qualified, registered, Mississippi professional engineer, surveyor, soil scientist, or landscape architect, performing services only in his or her area of competence. Other individuals may be authorized as a "design professional," if they can demonstrate proper knowledge and ability to MDEQ.

Construction Phasing/Sequencing (CPS)

Practice Description

Construction phasing/sequencing is the coordination of the construction schedule with the necessary erosion, sediment, and stormwater BMP installation. The purpose of construction sequencing is to reduce the amount of on-site erosion and off-site sedimentation. The construction sequence is an orderly listing of all major land-disturbing activities together with the necessary erosion- and sedimentation-control measures planned for a project. This type of schedule guides the contractors on work to be done before other work is started so that serious erosion and sedimentation problems can be avoided. Construction sequencing also allows for a potential reduction in the amount of land area disturbed at any one time during construction.

Planning Considerations

Construction sequencing can ultimately lower the cost of construction by retaining sediment on-site. Studies have shown that land disturbances at construction sites can cause soils to be 2 to 40,000 times more erodible (Harbor, 1999). Erosion leads to sedimentation, often times off-site. Additional costs from permit non-compliance or sedimentation of wetlands or other sensitive areas can occur if stormwater controls are not properly installed. Proper construction phasing begins with preservation of natural vegetation. Existing vegetation should be preserved in areas where it is likely to have the most benefit to hydrology. Preserving as much native vegetation as possible can reduce the impacts of land-disturbance activities. Also, protecting nearby vegetated areas with proper erosion and sediment controls will help maintain the adjacent areas' natural hydrology and help prevent off-site erosion and sedimentation.

Design Criteria and Construction

Vegetation Protection

Identify and map areas requiring special protection, i.e., wetlands, buffer zones, filter strips, and trees. Be sure these areas are clearly marked on drawings, maps, and properly flagged on-site.

Access Points

Define areas for construction-site access, construction routes, and equipment parking. Construction-site access pads must be installed prior to land disturbances. See Construction-Exit Pad (CEP) for details.

Sediment Traps

Install sediment traps (basins, fences, outlet protection) after site access has been established. Additional sediment basins or fencing may be required as land grading begins. Installation information can be found in the *Sediment Control* section.

Runoff Controls

Controlling runoff can be accomplished through diversions, dikes, silt fence and outlet protection. These measures should be installed after sediment practices and before land grading. Additional runoff-control measures may be required during the course of construction. Additional information on runoff-control practices is available in the *Runoff Conveyance* section.

Runoff Conveyance Systems

Runoff conveyance can be accomplished through stabilization of stream banks, check dams, diversion, drop structures, channels or swales, inlet and outlet protection, temporary-slope drains, etc. Whenever possible, stabilize stream banks as early as possible. Install runoff conveyance systems with runoff controls and before land grading. Additional runoff conveyance measures may be required during the course of construction. Additional information is available in the *Runoff Conveyance* section.

Land Clearing and Grading

Begin site preparation including cutting, filling, and grading only after sediment and runoff controls are installed. Install additional control measures as needed.

Surface Stabilization

Surface stabilization includes temporary and permanent seeding, mulching, sodding and installing riprap. These items should be installed immediately on all disturbed areas where work has been completed or significantly delayed.

Building Construction

During the construction phase, any additional erosion and sediment controls should be installed as needed.

Landscaping and Final Stabilization

During the last phase of construction, all open areas should be stabilized through topsoiling, planting trees and shrubs, seeding, mulching, sodding, and final riprap placement. At this point, all non-biodegradable, temporary-control measures should be removed.

Common Problems

Consult with a qualified design professional if any of the following occur:

Sensitive areas such as wetlands have not been properly protected and have been impacted by sediment.

The site's erosion- and sediment-control plan does not adequately address stormwater issues on-site. If site limitations require changes to construction plan, be sure the erosion and sediment plan is amended.

Maintenance

Maintenance inspections should be conducted weekly and after rainfall events of ≥0.5 inch in a 24-hour period. All maintenance repairs should be made immediately after periods of rainfall. Pre-storm inspections can prevent BMP failures during large rain events.

References

BMPs from Volume 1

Chapter 4

BMPs from Volume 2

Chapter 2

Chapter 4

Construction-Exit Pad (CEP)

Practice Description

A construction-exit pad is a stone-base pad designed to provide a buffer area where mud- and caked-soil can be removed from the tires of construction vehicles to avoid transporting it onto public roads. This practice applies anywhere traffic will be leaving a construction site and moving directly onto a public road or street.

Planning Considerations

Roads and streets adjacent to construction sites should be kept clean for the general safety and welfare of the public. A construction-exit pad (Figure CEP-1) should be provided where mud can be removed from construction vehicle tires before they enter a public road.

If the action of the vehicle traveling over the gravel pad does not sufficiently remove the mud, or if the site is in a particularly sensitive area, a washing facility should be included with the pad (Figure CEP-2). When a washing facility is required, all wash water shall be diverted into a sediment trap or basin.

If the construction-exit pad is located in an area with soils that will not support traffic when wet, a geotextile liner located beneath the aggregate will be required to provide stability to the pad.

Construction of stabilized roads throughout the development site should be considered to lessen the amount of mud transported by vehicular traffic. The construction-exit pad should be located to provide for maximum use by construction vehicles. Consideration should be given to limiting construction vehicles to only one ingress and egress point. Measures may be necessary to make existing traffic use the construction-exit pad.

Design Criteria and Construction

Site Preparation

Remove all vegetation and other unsuitable material from the foundation area.

Grading

Grade and crown the area for positive drainage. Utilize a diversion to direct any surface flow away from the construction-exit pad. Any runoff from the pad should be diverted into a sediment trap or basin. Install a pipe under the pad, if needed, to maintain drainage ditches along public roads.

Aggregate Size

Aggregate should be Mississippi Department of Transportation Size 1 Stabilizer. Aggregate surface shall be left smooth and sloped for drainage.

Pad Dimensions

The exit pad shall have a minimum aggregate thickness of 6″. The exit pad must be a minimum of 50 feet long and shall provide for entering and parking the longest construction vehicles anticipated. MDOT Drawing ECD-15 provides an example of a stabilized construction entrance. The exit pad shall have a typical width of 20 feet, but may be narrower or wider to equal the full width of the vehicular egress.

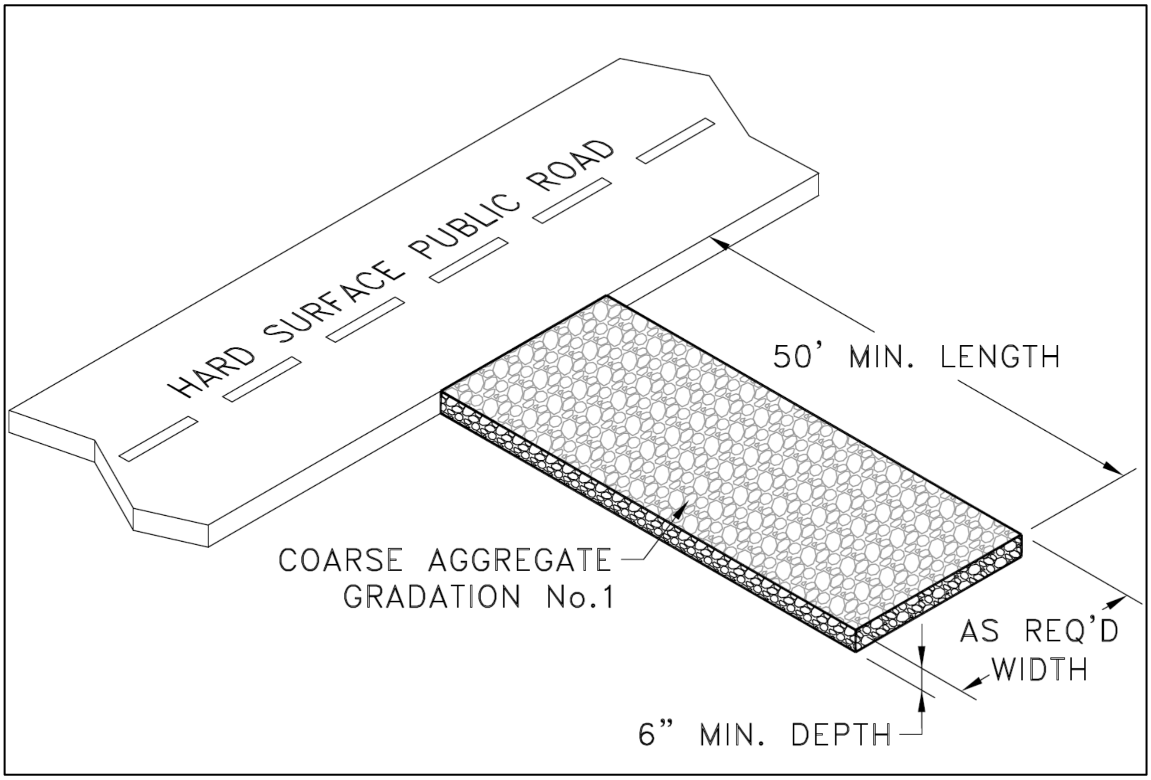


Figure CEP-1 Gravel Construction Exit

Geotextiles

A non-woven geotextile meeting the requirements shown in the table below for Class IV geotextiles should be used under the rock when the subgrade is soft or the blow count is less than 10.

Table CEP-1 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb) [2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 [3]	As specified max. #40 [3]	As specified max. #40 [3]	As specified max. #40 [3]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

[1] Heat-bonded or resin-bonded geotextile may be used for classes III and IV. They are particularly well suited to class IV. Needle-punched geotextile required for all other classes.

[2] Minimum average roll value (weakest principal direction).

[3] U.S. standard sieve size.

Washing

A washing facility shall be provided, if necessary, to prevent mud- and caked-soil from being transported to public streets and highways. It shall be constructed of concrete, stone, and/or other durable materials. Provisions shall be provided for the mud and other material to be carried away from the washing facility into a sediment trap or basin to allow for settlement of the sediment from the runoff before it is released from the site.

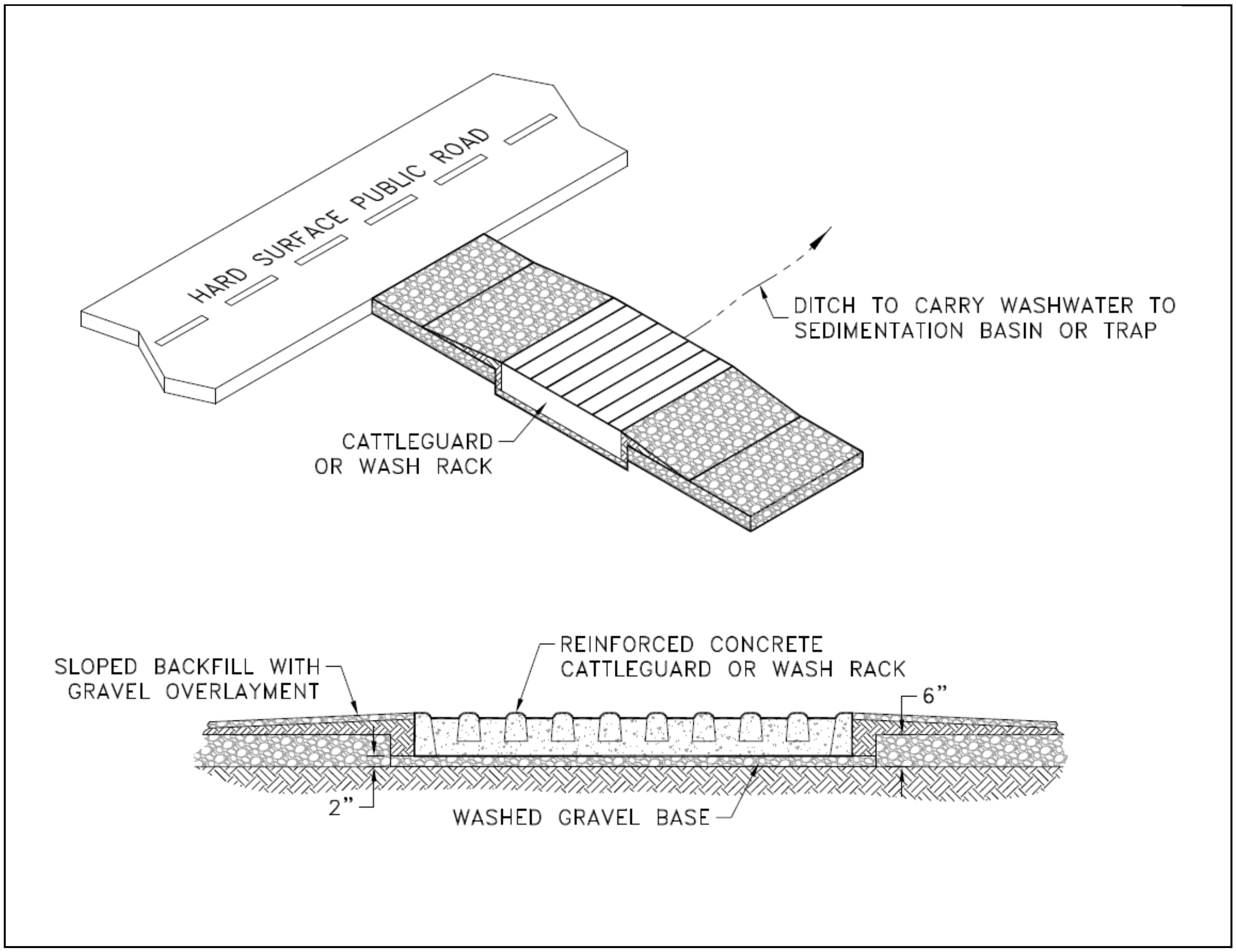


Figure CEP-2 Construction Exit with Wash Rack

Common Problems

Consult with a qualified design professional if any of the following occur:

Inadequate runoff control and sediment washes onto public road: install diversions or other runoff-control measures.

Ruts and muddy conditions develop as stone are pressed into soil: increase stone size or pad thickness, or add geotextile fabric.

Pad too short for heavy-construction traffic: consult design professional about extending pad to the necessary length

Maintenance

Remove large chunks of mud- or caked-soil from construction-exit pad daily to minimize sediment buildup.

Inspect stone pad and sediment-disposal area weekly and after storm events or heavy use.

Reshape pad as needed for drainage and runoff control.

Top-dress with clean-specified stone as needed to maintain effectiveness of the practice.

Immediately remove mud or sediment tracked or washed onto public road.

Repair any broken-road pavement immediately.

Remove unneeded exit-pad materials from areas where permanent vegetation will be established.

References

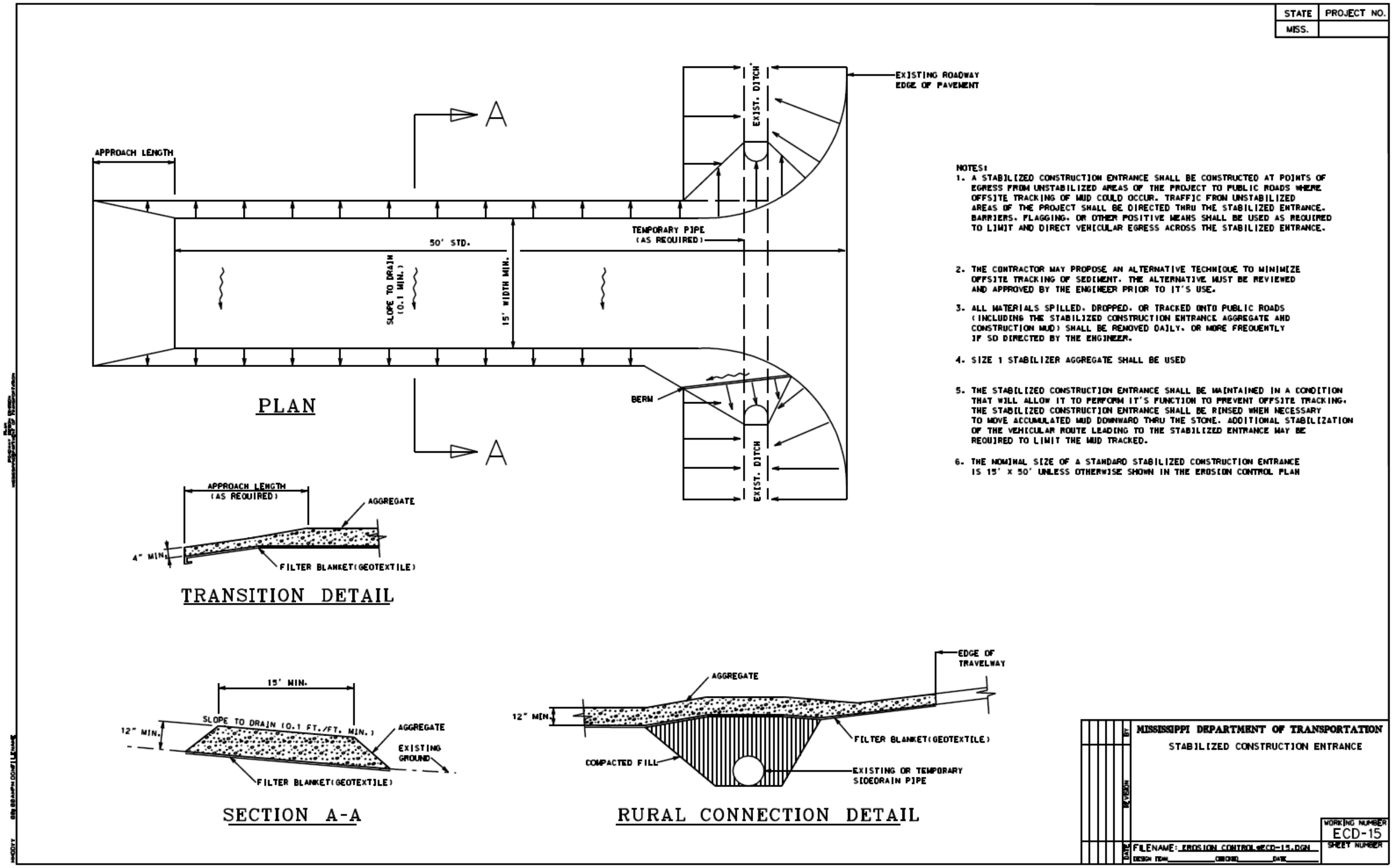
BMPs from Volume 1

Chapter 4

Construction Phasing/Sequencing (CPS)	4-3
Land Grading (LG)	4-16
Housekeeping (HK)	4-43
Preservation of Vegetation (PV)	4-64

MDOT Drawings Referenced

ECD-15 Stabilized Construction Entrance	4-11


STATE
PROJECT NO.
MISS.
EXISTING ROADWAY EDGE OF PAVEMENT
EXIST. DITCH
APPROACH LENGTH
A
A
TEMPORARY PIPE (AS REQUIRED)
50' STD.
SLOPE TO DRAIN (0.1 MIN.)
15' WIDTH MIN.
BERM
PLAN
NOTES:
1. A STABILIZED CONSTRUCTION ENTRANCE SHALL BE CONSTRUCTED AT POINTS OF EGRESS FROM UNSTABILIZED AREAS OF THE PROJECT TO PUBLIC ROADS WHERE OFFSITE TRACKING OF MUD COULD OCCUR. TRAFFIC FROM UNSTABILIZED AREAS OF THE PROJECT SHALL BE DIRECTED THRU THE STABILIZED ENTRANCE. BARRIERS, FLAGGING, OR OTHER POSITIVE MEANS SHALL BE USED AS REQUIRED TO LIMIT AND DIRECT VEHICULAR EGRESS ACROSS THE STABILIZED ENTRANCE.
2. THE CONTRACTOR MAY PROPOSE AN ALTERNATIVE TECHNIQUE TO MINIMIZE OFFSITE TRACKING OF SEDIMENT. THE ALTERNATIVE MUST BE REVIEWED AND APPROVED BY THE ENGINEER PRIOR TO IT'S USE.
3. ALL MATERIALS SPILLED, DROPPED, OR TRACKED ONTO PUBLIC ROADS (INCLUDING THE STABILIZED CONSTRUCTION ENTRANCE AGGREGATE AND CONSTRUCTION MUD) SHALL BE REMOVED DAILY, OR MORE FREQUENTLY IF SO DIRECTED BY THE ENGINEER.
4. SIZE 1 STABILIZER AGGREGATE SHALL BE USED
5. THE STABILIZED CONSTRUCTION ENTRANCE SHALL BE MAINTAINED IN A CONDITION THAT WILL ALLOW IT TO PERFORM IT'S FUNCTION TO PREVENT OFFSITE TRACKING. THE STABILIZED CONSTRUCTION ENTRANCE SHALL BE RINSED WHEN NECESSARY TO MOVE ACCUMULATED MUD DOWNWARD THRU THE STONE. ADDITIONAL STABILIZATION OF THE VEHICULAR ROUTE LEADING TO THE STABILIZED ENTRANCE MAY BE REQUIRED TO LIMIT THE MUD TRACKED.
6. THE NOMINAL SIZE OF A STANDARD STABILIZED CONSTRUCTION ENTRANCE IS 15' x 50' UNLESS OTHERWISE SHOWN IN THE EROSION CONTROL PLAN
APPROACH LENGTH (AS REQUIRED)
AGGREGATE
4" MIN.
FILTER BLANKET(GEOTEXTILE)
TRANSITION DETAIL
15' MIN.
SLOPE TO DRAIN (0.1 FT./FT. MIN.)
12" MIN.
AGGREGATE
EXISTING GROUND
FILTER BLANKET(GEOTEXTILE)
SECTION A-A
EDGE OF TRAVELWAY
AGGREGATE
12" MIN.
FILTER BLANKET(GEOTEXTILE)
COMPACTED FILL
EXISTING OR TEMPORARY SIDEDRAIN PIPE
RURAL CONNECTION DETAIL
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
STABILIZED CONSTRUCTION ENTRANCE
WORKING NUMBER
ECD-15
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-15.DGN

Construction Road Stabilization (CRS)

CRS

Practice Description

This practice describes the temporary stabilization of construction-access roads and parking areas. The purpose of this BMP is to reduce erosion of temporary and permanent roadbeds between the time of initial clearing and grading and final stabilizations.

Planning Considerations

A construction-exit pad should be provided in conjunction with stabilized construction roads where mud can be removed from construction-vehicle tires before they enter a public road.

If the construction-access road is located in an area with soils that will not support traffic when wet, a geotextile liner located beneath the aggregate will be required to provide stability to the pad.

Construction of stabilized roads throughout the development site should be designed so that construction vehicles are limited to only one ingress and egress point. The existing site contour should be followed as much as possible with slopes of the roads remaining less than 10 percent. Parking areas should be designed at naturally flat areas.

Permanent roads and parking areas should be paved as soon as possible after grading. However, it is understandable that funds for this purpose may not be available in the early phases of the development project. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate potential costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Design Criteria and Construction

Site Preparation

Remove all vegetation and other unsuitable material from the roadway area.

Grading

Stabilize the side slopes of all cuts and fills by grading all slopes to 2:1 or flatter for clay soils and 3:1 or flatter for sandy soils. All exposed slopes should be seeded and/or mulched as soon as possible (see Temporary Seeding, Mulching, and Dust Control).

Aggregate Size

A 6″ course of DOT No. 1 aggregate shall be applied immediately after grading or after the completion of the utility installation within the right-of-way. A geotextile may be applied to the roadbed for additional stability.

Drainage

Ensure that proper drainage is provided for and that all drainage along construction roads is directed to sediment control BMPs.

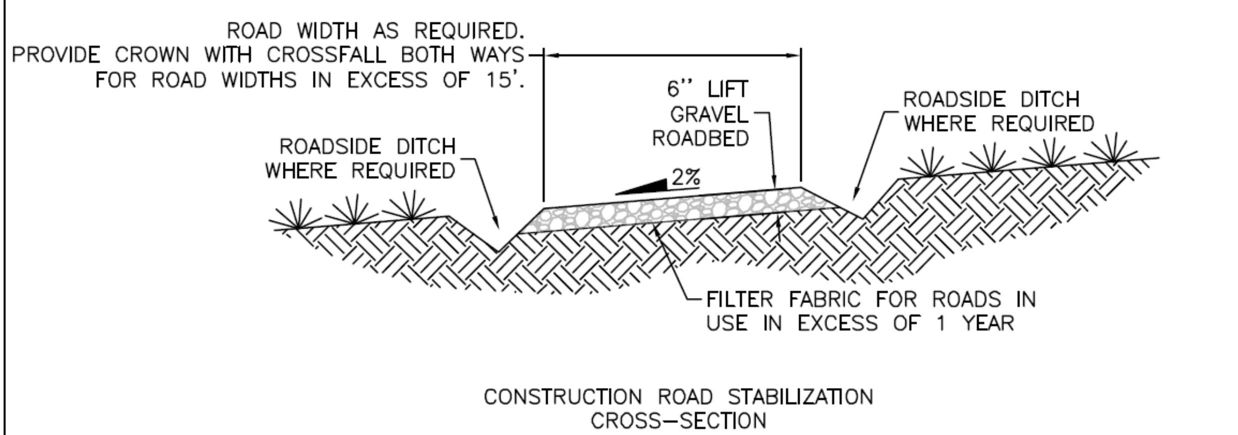


Figure CRS- 1 Construction Road Stabilization

Geotextiles

A non-woven geotextile meeting the requirements shown in the table below for Class IV geotextiles should be used under the rock when the subgrade is soft or the blow count is less than 10.

Table CEP-1 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb) [2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 [3]	As specified max. #40 [3]	As specified max. #40 [3]	As specified max. #40 [3]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

[1] Heat-bonded or resin-bonded geotextile may be used for classes III and IV. They are particularly well suited to class IV. Needle-punched geotextile required for all other classes.
[2] Minimum average roll value (weakest principal direction).
[3] U.S. standard sieve size.

Width

Roadbeds shall be at least 14feet wide for one-way traffic and 20feet wide for two-way traffic.

Vegetation

All roadside ditches, cuts, fills, and disturbed areas adjacent to parking areas and roads shall be stabilized with appropriate temporary or permanent vegetation according to the applicable practices contained in this manual.

Common Problems

Consult with a qualified design professional if any of the following occur:

Inadequate runoff control and sediment washes onto public road: install diversions or other runoff-control measures.

Ruts and muddy conditions develop as stone are pressed into soil: increase stone size or pad thickness, or add geotextile fabric.

Maintenance

Reshape roadway as needed for drainage and runoff control.

Inspect stone pad and sediment-disposal area weekly and after storm events or heavy use.

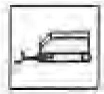
Top-dress with clean, specified stone, as needed, to maintain effectiveness of the practice.

References

BMPs from Volume 1

Chapter 4

Land Grading (LG)



Practice Description

Land grading is reshaping of the ground surface to provide suitable topography for buildings, facilities, and other land uses; to control surface runoff; and to minimize soil erosion and sedimentation, both during and after construction. This practice applies to the following sites: where the existing topography must be modified to prepare for another land use and/or where adapting proposed development to the existing landscape can reduce the erosion potential of the site and the cost of installing erosion- and sediment-control measures. In some instances, other practices such as diversions can be used to reduce the length of continuous slopes and reduce erosion potential.

Planning Considerations

A detailed plan should be developed by a qualified design professional for all land-grading activities at the project site. The plan should show all areas to be disturbed, the areas of cut, areas of fill, and the finished elevation for all graded areas.

The grading plan should be designed to protect existing vegetation where possible, especially around natural drainageways. Grading activities should be scheduled to minimize the area disturbed at any one time during the construction process. The plan should include provisions for stabilizing disturbed areas immediately after final grading is completed. Provisions should also be made to protect existing underground utilities. Finally, topsoil should be removed and stockpiled for use in revegetating the site.

The grading plan should also include necessary practices for controlling sediment and erosion at the site. These practices could include stable outlets and slope breaks.

Design Criteria and Construction

Site Preparation

A detailed survey of the construction site should be performed by a qualified surveyor prior to grading-plan development. This survey should include existing topographic information at the site including existing elevations, existing drainage patterns, locations of existing overhead and underground utilities, and construction-limit boundaries.

The grading plan should require that the existing topsoil at sites to be graded be removed as the first step in the grading process. The plan should include a location on the construction site where topsoil will be stockpiled. Stockpiled topsoil should be protected by temporary vegetation (see *Temporary Seeding Practice*) until it is used to cover disturbed areas.

The plan should include a schedule of disturbance activities that minimizes the area disturbed at any point in time. In areas where clearing of existing vegetation is planned, the area should be cleared and grubbed by removing trees, vegetation, roots, and other debris, such as trash. In areas to be filled, all loose or weak soil and oversized rocks should be removed from the area. The foundation of the area to be filled should consist of soil or rock material of adequate strength to support the proposed fill material and the structures to be built at the site. The exact depth of material to be removed should be determined by a qualified geotechnical professional according to accepted engineering standards.

Grading

A plan for placement of fill should be developed by a qualified geotechnical professional. The plan should specify the source of fill materials, which should be obtained on-site if possible. Materials used for fill, when placed according to the plans and specifications, should provide sufficient strength to support structures planned for construction at the location.

Loose fill material should be placed in layers not exceeding 9″ in thickness. The materials should be compacted at a moisture content and to a dry density that will produce the design-bearing strength required for structures planned at the site. A qualified geotechnical engineer should provide fill placement specifications using standard, accepted engineering practices.

Slope lengths at the site should be minimized using diversions as slope breaks to reduce erosion potential (see *Diversion Practice*). The following table gives guidance on the horizontal spacing of slope breaks:

Table LG-1 Guidelines for Spacing Slope Breaks

Slope	Spacing (Ft)
33-50%	20
25-33%	40
15-25%	60
10-15%	80
6-10%	120
3-6%	200
<3%	300

In areas where seepage and ground water are present, subsurface drains should be installed to improve slope stability or soil-bearing capacity (see *Subsurface Drain Practice*).

Steep slopes should be avoided if possible. Slopes that are to be vegetated should be 2 horizontal to 1 vertical or flatter. If the slope is to be maintained by a tractor or other equipment, the slope should be 3 horizontal to 1 vertical or flatter. Slopes should be designed to blend with surrounding topography as much as possible.

Erosion Control

The grading plan should include provisions for stabilization of graded areas immediately after final grading is completed. On areas that will have no additional disturbance, permanent vegetation should be applied immediately to the site (see *Permanent Seeding Practice*). On areas where work is to be interrupted or delayed for 14 working days or longer, such as topsoil stockpiles, the area should be stabilized using mulch or temporary seeding (see *Mulching* or *Temporary Seeding Practices*). Other stabilization measures such as erosion-control blankets, should be used in extreme conditions, such as steep slopes and channels.

Where practical, runoff from undisturbed off-site areas should be diverted around the construction site to prevent erosion on the disturbed areas (see *Diversion Practice*).

Sediment Control

Any required sediment-control practices should be installed before the land-disturbance activities in the drainage area of the sediment-control practice. Until disturbed areas can be stabilized, appropriate sediment-control measures will be maintained to minimize sediment delivery off-site. Measures should include as a minimum:

Sediment Barriers – Placed along toes of slopes and drainageways (see *Sediment Barrier Practice*).

Sediment Basins – Divert sediment-laden runoff to basins as needed to minimize off-site sedimentation (see *Sediment Basin Practice*).

Inlet Protection – Where sediment-laden runoff is diverted to on-site stormwater-drain inlets, the inlets should be protected with an appropriate sediment-control practice.

Stabilized Outlets – All runoff from the site should be conveyed in stabilized channels (see *Grass Swale, Lined Swale*, or *Channel Stabilization Practices*).

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on-site indicate grading plan will be ineffective or non-feasible.

Seepage is encountered during construction. It may be necessary to install drains.

Subgrade is soft or has high organic content and can hinder proper compaction of fill. It may be necessary to undercut and replace unsuitable subgrade soil.

Design specifications for sediment-control measures, seed variety, seeding dates, or other erosion-control measures or materials cannot be met. Substitutions may be required. Unapproved substitutions could result in erosion and lead to failure of sediment- and erosion-control measures.

Maintenance

Periodically check all graded areas and the related erosion and sediment-control practices for damage by equipment and especially after heavy rainfalls for damage by runoff.

Repair silt fences and other temporary, sediment-control measures.

Clean sediment out of adjacent diversions and other structures as needed.

Repair any failures that occur in surface stabilization measures, such as plantings.

References

BMPs from Volume 1

Chapter 4

Topsoiling (TSG)

Practice Description

Topsoiling is the removal of a desirable soil surface, referred to as topsoil, at a site prior to construction and using it on areas to be vegetated. Topsoiling a site usually improves the quality of the plant-growth medium at the site and increases the likelihood of successful plant establishment and performance. This practice applies to sites that are to be disturbed by excavation, compaction or filling, and to other areas where the subsoil is unsuitable for plant growth.

Planning Considerations

Topsoil is the surface layer of the soil profile, generally characterized as darker than the subsoil due to enrichment with organic matter. It is the major zone of root development and biological activity. Microorganisms that enhance plant growth thrive in this layer. Topsoil can usually be differentiated from subsoil by texture as well as color. Clay content usually increases in the subsoil.

The depth of topsoil may be quite variable. On severely eroded sites it may be non-existent.

Advantages of topsoil include its high organic-matter content, friable consistency (soil aggregates can be crushed with only moderate pressure), its available water-holding capacity, and nutrient content. Most often, it is superior to subsoil in the above characteristics. The texture and friability of topsoil are usually much more conducive to seedling emergence and root growth than subsoils.

In addition to being a better growth medium, topsoil is often less erodible than subsoils, and the coarse texture of topsoil increases infiltration capacity and reduces runoff.

Although topsoil provides an excellent growth medium, there are disadvantages to its use. Stripping, stockpiling, and reapplying topsoil, or importing topsoil, may not always be cost effective. Topsoiling can delay seeding or sodding operations, increasing the exposure time of denuded areas. Most topsoil contains weed seeds, and weeds may compete with desirable species.

In site planning, the option of topsoiling should be compared with that of preparing a seedbed in subsoil. The clay content of subsoils does provide high moisture availability and deter leaching of nutrients. When properly limed and fertilized, subsoils may provide a good growth medium, especially if there is adequate rainfall or irrigation water to allow root development in otherwise high-density material.

Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown. Topsoiling is a recommended procedure when establishing vegetation on shallow soils, soils containing potentially toxic materials, and soils of critically low-pH (high acid) levels.

If topsoiling is to be done, the following items should be considered:

- An adequate volume of topsoil should exist on the site. Topsoil will be spread at a compacted depth of 4″ or greater.

- The topsoil stockpile should be located so that it meets specifications and does not interfere with work on the site, block drainage, or release appreciable amounts of sediment.

- Allow sufficient time in scheduling for topsoil to be spread and bonded to the subsoil prior to seeding, sodding, or planting.

- Care must be taken not to apply topsoil to subsoil if the two soils have contrasting textures. Clayey topsoil over sandy subsoil is a particularly poor combination because as water creeps along the junction between the soil layers, sloughing of the topsoil may occur.

- If topsoil and subsoil are not properly bonded, water will not infiltrate into the soil profile evenly and it will be difficult to establish vegetation.

Design Criteria and Construction

Materials

Field exploration of the site should be made to determine if there is sufficient surface soil of good quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy-clay loam, and clay loam). It shall be free of debris, trash, stumps, rocks, roots, and noxious weeds, and shall give evidence of being able to support healthy vegetation. It shall contain no substance that is potentially toxic to plant growth.

Potential topsoil should be tested by a recognized laboratory. It should meet the following criteria:

- Organic-matter content should be not less than 1.0% by weight.

- The pH range should be from 6.0-7.5. If pH is less than 6.0, lime should be added in accordance with soil-test results or in accordance with the recommendations of the vegetative-establishment practice being used.

- Soluble salts shall not exceed 500 ppm.

- If additional off-site topsoil is needed, it should meet the standards stated above.

- The depth of material meeting the above qualifications should be at least 4″. Soil factors such as rock fragments, slope, depth to water table, and layer thickness affect the ease of excavation and spreading of topsoil.

Generally, the upper part of the soil, which is richest in organic matter, is most desirable; however, material excavated from deeper layers may be worth storing if it meets the other criteria listed above.

Stripping

Strip only those areas that will be affected by construction or development. A normal stripping depth is 4-6″, but deeper depths may be satisfactory if the soil is suitable and undercutting is allowable in locations such as buildings, water-impoundment structures, roadways, etc. Appropriate sediment-control measures such as sediment barriers, sediment basins, inlet protection, etc., should be in place before the topsoil is stripped. Stripping should not be done on areas intended to support conventional, on-site effluent, disposal lines (field lines).

Stockpiling

The stockpile location should be out of drainageways and traffic routes. Stockpiles should not be placed on steep slopes where undue erosion will take place. Measures should be taken to prevent erosion of the stockpiles. These would include

- Mulching the stockpile when it is left inactive for 14 days or longer.

- Planting temporary vegetation when the stockpile is to be inactive over 30 days.

- Covering the stockpile with plastic whenever the piles are small or any soil loss would damage existing buildings or facilities.

- Planting permanent vegetation when the stockpile use will be inactive over 12 months.

- In cases where the stockpile is small and will be removed in fewer than 14 days, it may be more practical to use a sediment barrier than an erosion-control practice.

Site Preparation

Areas to be covered with topsoil shall be excavated, graded, filled, and shaped to the proper lines, grades, and elevations before topsoil placement is started.

The subgrades should be checked for pH and limed if the pH is less than 6.0. Liming shall be done in accordance with soil tests and in relation to the seeding mixture to be planted. Incorporate lime to a depth of at least 2″ by discing.

Applying Topsoil

Immediately before placement of topsoil, the subsoil should be disced or scarified to a depth of 2″ to enhance bonding of the subsoil and topsoil. Topsoil should be uniformly spread to a minimally compacted depth of 4″. Required volumes of topsoil may be determined using Table TSG-1.

Table TSG-1 Volume of Soil Needed for Topsoiling

Depth to Spread (inches)	Cubic Yards Per 1,000 Sq. Ft.	Cubic Yards Per Acre
1	3.1	134
2	6.2	268
3	9.3	403
4	12.4	537
5	15.5	672
6	18.6	806

When applying topsoil, maintain needed erosion-control practices such as diversions, grass swales, lined swales, etc. Topsoil should not be spread when it or the subgrade is frozen or muddy.

Precautions should be taken to prevent layering of the topsoil over the subsoil. Mixing and bonding of the two soils should be enhanced by use of discing or cultivation tools.

Settling of the topsoil is necessary to bond the soils together, but undue compaction should be prevented. Light compaction is necessary to increase soil strength, reduce erosion, and enhance vegetation establishment. Excessive compaction should be prohibited as it increases runoff and inhibits seed germination and root development.

Surface irregularities that would impede drainage, increase erosion, or otherwise damage the site should be removed in final grading.

Common Problems

Consult with a qualified design professional if any of the following occur:

Depth of surface being stripped is significantly different than anticipated.

Topsoil appears to contain contaminants.

Topsoil appears too compacted during spreading; may need to loosen by discing or scarifying.

Maintenance

Inspect topsoiled areas frequently until vegetation is established.

Repair eroded or damaged areas and revegetate.

Repair sloughing on steep slopes—remove topsoil, roughen subgrade and respread topsoil.

Consult with a qualified design professional if drainage (wetness caused by seepage) or shallowness to bedrock (less than 24″) is involved.

References

BMPs from Volume 1

Chemical Stabilization (CHS)

CS

Practice Description

Chemical erosion control on construction sites in the Southeast usually involves a water-soluble anionic polyacrylamide product referred to as PAM. It is used to minimize soil erosion caused by water and wind. PAM is typically applied with temporary seeding and or mulching on areas where the timely establishment of temporary erosion control is so critical that seedings and mulching need additional reinforcement. It may be used alone on sites where no disturbances will occur until site work is continued and channel erosion is not a significant potential problem.

Only PAM is currently included in this practice.

Planning Considerations

Anionic PAM is available in emulsions, powders, and gel bars or logs. Anionic PAM should be used in combination with other Best Management Practices. The use of seed and mulch should be considered for providing erosion protection beyond the life of the anionic PAM. If the area where PAM is applied is disturbed after the application, the application will need to be repeated.

Following are additional considerations to enhance the use of or avoid problems with the use of anionic PAM:

- Use setbacks when applying anionic PAM near natural water bodies.

- Decreased performance by the PAM can be expected if the PAM is exposed to ultraviolet light or if there is a delay between mixing the PAM with water and applying it to the exposed soil.

- When used in flow concentration channels, PAM's effectiveness for stabilization is decreased.

- If seed is applied with the anionic PAM, mulch should be used to protect the seed.

- Never add water to PAM; add PAM slowly to water. If water is added to PAM, the PAM tends to clot and form "globs" that can clog dispensers. This will result in an increased risk of under-application of the product.

- Only use anionic PAM; not all polymers are PAM.

- Requests to use other products on permitted sites should be made to the Mississippi Department of Environmental Quality.

Design Criteria

Application rates shall conform to manufacturers' guidelines for application. The following specific criteria shall be followed:

Only the anionic form of PAM shall be used. Cationic PAM is toxic and shall NOT be used.

PAM and PAM mixtures shall be environmentally benign, harmless to fish, wildlife, and plants. PAM and PAM mixtures shall be non-combustible.

Anionic PAM, in pure form, shall have less than or equal to 0.05% acrylamide monomer by weight, as established by the Food and Drug Administration and the Environmental Protection Agency.

To maintain less than or equal to 0.05% of acrylamide monomer, the maximum application rate of PAM, in pure form, shall not exceed 200/pounds/acre/year. Do not over apply PAM. Excessive application of PAM can lower its infiltration rate or increase suspended solids in water, rather than promoting settling.

Users of anionic PAM shall obtain and follow all Material Safety Data Sheet requirements and manufacturers' recommendations.

Additives such as fertilizers, solubility promoters or inhibitors, etc. to PAM shall be non-toxic.

The manufacturer or supplier shall provide written application methods for PAM and PAM mixtures. The application method shall ensure uniform coverage to the target and avoid drift to non-target areas including waters of the state. The manufacturer or supplier shall also provide written instructions to ensure proper safety, storage, and mixing of the product.

Gel bars or logs of anionic PAM mixtures may be used in ditch systems. This application shall meet the same testing requirements as anionic PAM emulsions and powders.

To prevent exceeding the acrylamide monomer limit in the event of a spill, the anionic PAM in pure form shall not exceed 200 pounds/batch at 0.05% acrylamide monomer or 400 pounds/batch at 0.025% acrylamide monomer.

Application

Prior to the start of construction, the application of PAM should be designed by a qualified design professional and plans and specifications should be available to field personnel.

The application should conform to the design and specifications provided in the plans.

Site Preparation

Prepare site following design and specifications.

Equipment Preparation

If using a liquid application system, pump a surfactant through the injection system before and after injecting concentrated liquid PAM into sprinkler-irrigation systems to prevent valves and tubing from clogging.

PAM used in hydroseeding applications should be the last additive to the mix.

After use, rinse all PAM mixing and application equipment thoroughly with water to avoid formation of PAM residues. Rinse residue should be applied to soil areas to create binding to the soil structure and increase erosion reduction.

PAM Application

Site testing for a PAM product should be conducted before PAM application to verify PAM-product performance and test reports (recommendations) should be supplied to the design professional and contractor before product application.

Toxicity reports, following EPA/600/4-90/027F 24 Hr. Acute Static Screen Toxicity Test (daphnia sp.), should be provided by the supplier to the contractor before application of a PAM product (this is to assure that PAM applications from the recommended product will be non-toxic).

PAM should be mixed and/or applied in accordance with all Occupational Safety and Health Administration (OSHA) Material Safety Data Sheet requirements and the manufacturers' recommendations for the specified use conforming to all federal, state and local laws, rules and regulations.

Emulsion batches should be mixed following recommendations of a testing laboratory that determines the proper product and rate to meet site requirements.

Never add water to PAM, but instead add PAM slowly to water.

Dry form (powder) may be applied by hand spreader or a mechanical spreader.

Mixing with dry, silica sand will aid in spreading. Pre-mixing of dry form PAM into fertilizer, seed, or other soil amendments is allowed when specified in the design plan. Application method should ensure uniform coverage to the target area.

Installation Verification

Check all components of the practice during installation to ensure that specifications are being met.

Common Problems

Consult with a qualified design professional if any of the following occur:

Problems with application equipment clogging.

Application specifications for PAM cannot be met; alternatives may be required. Unapproved application techniques could lead to failure.

Visible erosion occurs after application.

Maintenance

An operation and maintenance plan must be prepared for use by the operator responsible for PAM application. Plan items should include the following items:

Reapply PAM to disturbed or tilled areas that require continued erosion control.

Maintain equipment to provide uniform application rates.

Rinse all PAM mixing and application equipment thoroughly with water to avoid formation of PAM residues and discharge rinse water to soil areas where PAM stabilization may be helpful.

Downgradient deposition from the use of PAM may require periodic sediment removal to maintain normal functions.

References

BMPs from Volume 1

Chapter 4

Mulching (MU) 4-48
Temporary Seeding (TS) 4-103

Dust Control (DC)

Practice Description

Dust control includes a wide range of techniques that prevent or reduce movement of wind-borne soil particles (dust) during land disturbing activities. This practice applies to construction routes and other disturbed areas where on-site and off-site damage or hazards may occur if dust is not controlled.

Planning Considerations

Construction activities that disturb soil can be a significant source of air pollution. Large quantities of dust can be generated, especially in “heavy” construction activities such as land grading for road construction and commercial, industrial, or subdivision development.

The scheduling of construction operations so that the least amount of area is disturbed at one time is important in planning for dust control.

The greatest dust problems occur during dry periods. Therefore, to the extent practicable, do not expose large areas of bare soil during drought conditions.

Where wind erosion is a potential cause of dust problems, preserving vegetation should be considered as a passive measure. Leave undisturbed buffer areas between graded areas wherever possible.

Installing temporary- or permanent- surface stabilization measures immediately after completing land grading will minimize dust problems.

Design Criteria and Construction

Dust-control requirements should be designed by a qualified design professional and plans and specifications should be made available to field personnel prior to start of construction. Whenever possible, leave vegetated-buffer areas undisturbed between graded areas.

Scheduling

Schedule construction operations so that the smallest area is disturbed at any one time.

Permanent Methods

Vegetative Cover

For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control. Establish vegetative cover according to the *Permanent Seeding* or *Temporary Seeding Practice*.

Topsoiling

This entails covering the surface with less erosive soil material. See *Topsoiling Practice* for guidance.

Stone

Stone used to stabilize construction roads can also be effective for dust control. Stone should be spread a minimum of 6″ thick over construction roads in the disturbed area. For heavily traveled roads or roads subjected to heavy loads, the stone thickness should be 8″ to 10″. A non-woven geotextile meeting the requirements shown in the Table DC-1 for Class IV geotextiles should be used under the rock when the subgrade is soft or the blow count is less than 10.

Temporary Methods

Mulches

Mulch offers a fast, effective means of controlling dust when properly applied. See *Mulching Practice* for guidelines on planning and installing the practice.

Temporary Vegetative Cover

For disturbed areas where no activity is anticipated for 14 days or longer, temporary seeding can effectively control dust. Establish vegetative cover according to *Temporary Seeding Practice* guidelines.

Calcium Chloride

Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist, but not so high as to cause water pollution or plant damage. Sites may need to be retreated because the product degrades over time.

Table DC-1 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb) [2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. no.40 [3]	As specified max. no.40 [3]	As specified max. no.40 [3]	As specified max. no.40 [3]
Permittivity sec–1	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

[1] Heat-bonded or resin-bonded geotextile may be used for classes III and IV. They are particularly well suited to class IV. Needle-punched geotextile are required for all other classes.
[2] Minimum average roll value (weakest principal direction).
[3] U.S. standard sieve size.

Spray-on Adhesives

Spray-on adhesives may be used on mineral soils for dust control. Traffic must be kept off treated areas to prevent the product from becoming ineffective. Examples of spray-on adhesives for use in dust control are listed in Table DC-2.

Table DC-2 Spray-on Adhesives for Dust Control on Mineral Soil

Material	Water Dilution	Type of Nozzle	Apply Gal/Ac
Latex Emulsion	12.5:1	Fine Spray	235
Resin In Water	4:1	Fine Spray	300

Chemical Stabilization (CHS)

PAM may be used on mineral soils for dust control. Traffic must be kept off treated areas to prevent the product from becoming ineffective. The manufacturer or supplier shall provide written application methods for PAM and PAM mixtures. The application method shall ensure uniform coverage to the target and avoid drift to non-target areas including waters of the State. The manufacturer or supplier shall also provide written instructions to ensure proper safety, storage, and mixing of the product. Refer to the *Planning Considerations for Chemical Stabilization* (*PAM*) *Practice* for planning considerations before deciding to use this product.

Sprinkling or Irrigation

Sprinkling is especially effective for dust control on haul roads and other traffic routes. Sprinkle the site until the surface is wet. Repeat as needed. Also, bare areas may be kept wet with irrigation to control dust as an emergency treatment.

Tillage

Tillage is used to roughen the site and bring clods and moist soil to the surface. This is a temporary emergency measure that can be used on large, open, disturbed areas as soon as soil blowing starts. Begin tilling on the windward edge of the site. The depth of tillage is determined by the depth to moist soil and the amount of moist soil desired at the surface. In sandy soils, the depth to moist soil may make tillage impractical.

Barriers

A board fence, wind fence, sediment fence, hay bales, or similar barriers can control air currents and blowing soil. Place barriers perpendicular to prevailing air currents at intervals about 15 times the barrier height.

Figure 1 Sand Fence (http://www.gulfmex.org/crp/7004/fence.jpg)

Street Cleaning

Use a street sweeper to remove the source materials.

Maintenance

Check construction site during vehicular traffic or windy conditions to see if measures are working adequately. Maintain dust-control measures continuously throughout dry-weather periods, until all disturbed areas have been stabilized.

References

BMPs from Volume 1

Chapter 4

Erosion Control Blanket (ECB)

Practice Description

To aid in controlling erosion on critical areas by providing a protective cover made of straw, jute, wood or other plant fibers; plastic, nylon, paper or cotton. This practice is best utilized on slopes and channels where the erosion hazard is high, and plant growth is likely to be too slow to provide adequate protective cover. Erosion control blankets are typically used as an alternative to mulching but can also be used to provide structural erosion protection. Some important factors in the choice of a blanket are: soil conditions, steepness of slope, length of slope, type and duration of protection required to establish desired vegetation, and probable sheer stress.

Planning Considerations

Care must be taken to choose the type of blanket that is most appropriate for the specific project needs. Fourteen classes of erosion control blankets are discussed in this practice. Manufacturer's instructions and recommendations, as well as a site visit by the qualified design professional and site-plan reviewer are highly recommended to determine a product's appropriateness.

Temporary Erosion Control Blankets

Benefits of using temporary, erosion-control blankets include the following:

- Protection of the seed and soil from raindrop impact and subsequent displacement.
- Thermal consistency and moisture retention for the seedbed area.
- Stronger and faster germination of grasses and legumes.

- Spreading stormwater runoff to prevent rill erosion of slopes.
- Prevention of sloughing of topsoil added to steeper slopes.
- Because temporary blankets will deteriorate in a short period of time, they provide no enduring reduction in erosion potential.

Table ECB-1 Types of Erosion Control Blankets

Type of Erosion Control	Main Use	Comments
Netting	Synthetic or natural fiber mesh installed over disturbed area to hold organic mulch and/or seed in place.	Provides minimal structural erosion resistance. Mulch applied using standard procedures.
Biodegradable Erosion Control Blanket	Natural fiber blanket held together by netting to provide temporary erosion protection on slopes up to 1:1; and channels with permissible shear stress up to 4 lbs./ft.	Provides 1- to 5-year protection from erosion. Metal staples used as anchors.
Permanent Erosion Control Blanket	Synthetic blanket material which provides permanent erosion control on slopes up to 1:1; channels with increased water flow velocities and increased shear stress.	Provides minimal protection from wave action around ponds and lakes. Permanent erosion control blankets extend the limits of vegetation. Metal staples used as anchors.
Turf Reinforcement Mat	3-dimensional permanent synthetic mat that provides a matrix to greatly reinforce the root system of the desired vegetation for permanent erosion protection in high flow channels and on critical slopes.	Provides a substantial increase in erosion resistance. May provide erosion protection equivalent to stone or concrete liners.

Permanent Erosion Control Blankets

Permanent erosion control blankets are also known as permanent-soil reinforcing mats or turf-reinforcement mats. Roots penetrate and become entangled in the matrix, forming a continuous anchorage for surface growth and promoting enhanced energy dissipation.

Benefits of using permanent, erosion-control blankets, in addition to the benefits gained from using a temporary blanket include the following:

Sediment from stormwater flows is deposited in the matrix providing a fine soil-growth medium for the development of roots.

In stormwater channels, blankets and the vegetative-root system form an erosion resistant cover which resists hydraulic uplift and shear forces of channel flows.

Tables ECB-2 and ECB-3 give typical applications of the different classes of erosion control blankets.

Table ECB-1 Temporary Erosion Control Blanket Classes and Applications

Class	Application
1.A	Designed for use on geotechnically stable slopes with gradients up to 5:1 and channels with shear stresses up to .25 pounds per square foot.
1.B	Designed for use on geotechnically stable slopes with gradients up to 4:1 and channels with shear stresses up to .5 pounds per square foot.
1.C	Designed for use on geotechnically stable slopes with gradients up to 3:1 and channels with shear stresses up to 1.5 pounds per square foot.
1.D	Designed for use on geotechnically stable slopes with gradients up to 2:1 and channels with shear stresses up to 1.75 pounds per square foot.
2.A	Designed for use on geotechnically stable slopes with gradients up to 5:1 and channels with shear stresses up to .25 pounds per square foot.
2.B	Designed for use on geotechnically stable slopes with gradients up to 4:1 and channels with shear stresses up to .5 pounds per square foot.
2.C	Designed for use on geotechnically stable slopes with gradients up to 3:1 and ch stresses up to 1.5 pounds per square foot.
2.D	Designed for use on geotechnically stable slopes with gradients up to 2:1 and channels with shear stresses up to 1.75 pounds per square foot.
3.A	Designed for use on geotechnically stable slopes with gradients up to 5:1 and channels with shear stresses up to .25 pounds per square foot.
3.B	Designed for use on geotechnically stable slopes with gradients up to 1.5:1 and channels with shear stresses up to 2 pounds per square foot.
4	Designed for use on geotechnically stable slopes with gradients up to 1:1 and channels with shear stresses up to 2.25 pounds per square foot.

Table ECB-3 Permanent Erosion Control Blanket Classes and Applications

Class	Application
5.A	Designed for use on geotechnically stable slopes with gradients up to 0.5:1 and channels with shear stresses up to 6 pounds per square foot.
5.B	Designed for use on geotechnically stable slopes with gradients up to 0.5:1 and channels with shear stresses up to 8 pounds per square foot.
5.C	Designed for use on geotechnically stable slopes with gradients up to 0.5:1 and channels with shear stresses up to 10 pounds per square foot.

Design Criteria and Construction

Prior to the start of construction, the application of erosion control blankets should be designed by a qualified design professional and plans and specifications should be available to field personnel.

Site Preparation

Grade the site in accordance with the approved design to a smooth and uniform surface, free of debris.

Add and incorporate topsoil where needed.

Make sure seedbed is firm, yet friable.

General

All blankets shall be nontoxic to vegetation and to the germination of seed and shall not be injurious to the unprotected skin of humans. Erosion control products shall be of sufficient strength to hold the prepared ground and, if applicable, cover material (mulch, sod, etc.) in place until an acceptable growth of natural or planted material is established.

Erosion control products shall be identified by a classification designation (Class 1.A, 1.B, 1.C, etc.) where the classification is based on the physical properties of the product.

Class Designations and Durability

Erosion control products shall have the configurations and durability as shown in Tables ECB-4 and ECB-5.

Table ECB-4 Typical Configuration and Durability of Temporary Erosion Control Blankets

Class Designation	Usual Configuration	Typical Durability
1.A Ultra-short term mulch control netting	Mulch control netting consisting of rapidly degrading photodegradable synthetic mesh or woven biodegradable natural fiber netting.	3 months
1.B Ultra-short term netless erosion control blanket	An erosion control blanket composed of processed rapidly degrading natural and/or polymer fibers mechanically interlocked or chemically adhered together to form a continuous matrix.	3 months
1.C Ultra-short term single net erosion control blanket or open weave textile	An erosion control blanket composed of processed degradable natural and/or polymer fibers mechanically bound together by a single rapidly degrading, synthetic or natural fiber netting to form a continuous matrix. Or an open weave textile composed of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.	3 months
1.D Ultra-short term double net erosion control blankets	An erosion control blanket composed of processed natural or polymer fibers mechanically bound between 2 rapidly degrading, synthetic or natural fiber nettings to form a continuous matrix.	3 months
2.A Short-term mulch control netting	Mulch control netting consisting of photodegradable synthetic mesh or woven biodegradable natural fiber netting.	12 months
2.B Short-term netless erosion control blanket	An erosion control blanket composed of processed degradable natural and/or polymer fibers mechanically interlocked or chemically adhered together to form a continuous matrix.	12 months
2.C Short-term single net erosion control blanket or open weave textile	An erosion control blanket composed of processed degradable natural and/or polymer fibers mechanically bound together by a single degradable, synthetic or natural fiber netting to form a continuous matrix. Or an open weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.	12 months
2.D Short-term double net erosion control blanket	An erosion control blanket composed of processed natural or polymer fibers mechanically bound between 2 synthetic or natural fiber nettings to form a continuous matrix.	12 months
3.A Extended-term mulch control netting	Mulch control netting consisting of a slow degrading synthetic mesh or woven natural fiber netting.	24 months
3.B Extended-term erosion control blanket or open weave textile	An erosion control blanket composed of processed slow degrading natural and/or polymer fibers mechanically bound together between 2 slow degrading synthetic or natural fiber nettings to form a continuous matrix. Or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	24 months
4 Long-term erosion control blanket or open weave textile	An erosion control blanket composed of processed slow degrading natural and/or polymer fibers mechanically bound together between 2 slow degrading synthetic or natural fiber nettings to form a continuous matrix. Or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	36 months

Table ECB-5 Typical Configuration and Durability of Permanent Erosion Control Blankets

Class Designation	Usual Configuration	Typical Durability
5.A Permanent turf reinforcement mat	A non-degradable turf reinforcement mat with sufficient thickness, strength and void space for permanent erosion protection and vegetation reinforcement.	Permanent
5.B Permanent turf reinforcement mat	A non-degradable turf reinforcement mat with sufficient thickness, strength and void space for permanent erosion protection and vegetation reinforcement.	Permanent
5.C Permanent turf reinforcement mat	A non-degradable turf reinforcement mat with sufficient thickness, strength and void space for permanent erosion protection and vegetation reinforcement.	Permanent

Materials Physical Requirements

A properly designed erosion control blanket installation requires selection of a product manufactured with physical properties to withstand the stresses the product will be subjected to for the design life of the product. Table ECB-6 gives the minimum physical requirements for each class of blanket.

Table ECB-6 Minimum Physical Requirements For Erosion Control Blankets

	Property				
Class	Minimum Tensile Strength (pounds/ft.) (ASTM D 4595) [1]	Minimum Permissible Shear Stress (pounds/sq. ft.) (ASTM D 6460)[2, 5]	Maximum "C" Factor for Temporary Products (ASTM D 6459)[3, 5]	UV Stability (Minimum % tensile retention) for Permanent Products (ASTM D 4355) (500 hour exp.)	Minimum Thickness (inches) For Permanent Products (ASTM D 6525)[4]
1.A [6]	5	0.25	0.10 @ 5:1	N/A	N/A
1.B	5	0.50	0.10 @ 4:1	N/A	N/A
1.C	50	1.50	0.15 @ 3:1	N/A	N/A
1.D	75	1.75	0.20 @ 2:1	N/A	N/A
2.A [6]	5	0.25	0.10 @ 5:1	N/A	N/A
2.B	5	0.50	0.10 @ 4:1	N/A	N/A
2.C	50	1.50	0.15 @ 3:1	N/A	N/A
2.D	75	1.75	0.20 @ 2:1	N/A	N/A
3.A [6]	25	0.25	0.10 @ 5:1	N/A	N/A
3.B	100	2.00	0.25 @ 1.5:1	N/A	N/A
4	125	2.25	0.25 @ 1:1	N/A	N/A
5.A [7]	125	6.00	N/A	80	0.25
5.B [7]	150	8.00	N/A	80	0.25
5.C [7]	175	10.00	N/A	80	0.25

1 Minimum average roll values, machine direction. For turf reinforcement mats used in field conditions with high loading and/or high survivability requirements tensile strengths of 3000 pounds/ft or greater.

2 Minimum shear stress the rolled erosion control products or turf reinforcement mats can sustain without physical damage or excess erosion (>.5″ of soil loss) during a 30 minute flow event in large scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council Test Method no. 3. For temporary products the permissible shear stress levels were established for each class based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.03 to 0.05.

3 "C" factor calculated as ratio of soil loss from rolled erosion control product protected slope (tested at the specified gradient) to soil loss from unprotected (control) plot in large scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council Test Method no.2.

4 Minimum average roll values.

5 Other large scale test methods may be determined acceptable.

6 Obtain maximum "C" factor and allowable shear stress for mulch control nettings with the netting used in conjunction with pre-applied mulch material.

7 For turf reinforcement mats containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

Product Placement

The erosion control product should be placed immediately after completion of the preparation of the area where the product will be placed.

Follow the manufacturer's recommendations for installation or use the following instructions. If there is a conflict, follow the manufacturer's recommendations. Strips shall be rolled out flat, parallel to the direction of flow, in flumes and ditches. On steep cut or fill slopes, strips shall be rolled out flat, and perpendicular to the direction of flow to reduce rill erosion. When 2 or more strips are required to cover an area, they shall overlap at least 3″ (75 mm); however, excelsior blankets will not require lapping but are to be butted together and stapled with half of each staple located in each of the adjoining blankets. Ends of strips shall overlap at least 6″ (150 mm) with the upgrade section on top. The upslope end (anchor slot) of each strip shall be buried in 6″ (150 mm) vertical slots, and soil tamped firmly against it. Figure ECB-1 shows typical erosion control blanket installation. When conditions are warranted by the opinion of the qualified design professional, any other edge exposed to excessive flow shall be buried as noted above. The erosion control product shall be spread evenly and smoothly, and shall be in contact with the soil at all points. The product should not be stretched tight in such a manner that the material "tents" over the soil surface. If the manufacturer's recommendations for installation of the erosion control product are different that those given here, the Contractor will be required to follow the more stringent of the two.

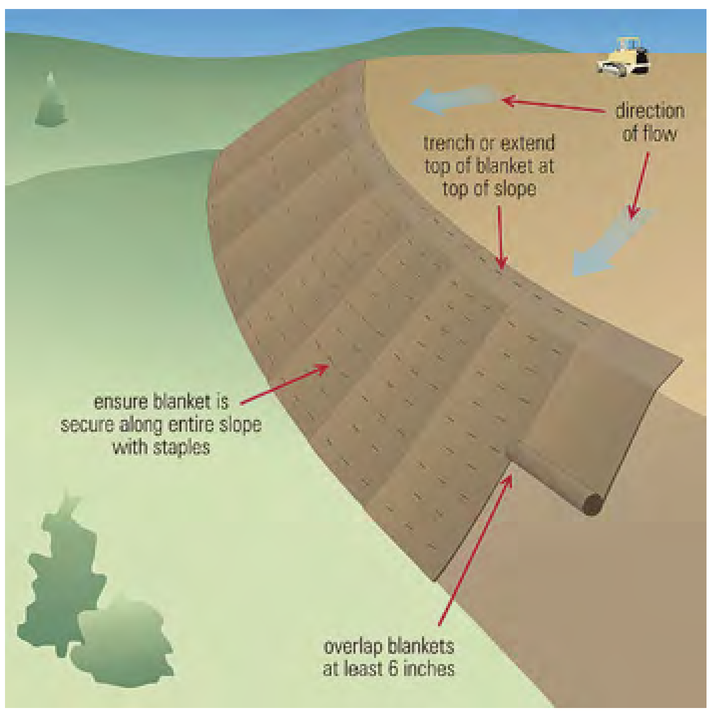


Figure ECB - 1 Erosion Control Blanket Placement (Source: EPA)

Check slots shall be 24″ (600 mm) minimum width and separate strips of erosion control product placed at right angles to the direction of water flow immediately prior to placing the general covering of the product. Check slots shall be made by burying a tight fold of the product vertically in the soil a minimum of 6″ (150 mm) deep, and tamping and stapling the fold in place. Check slots shall be placed so that one check slot, junction slot, or anchor slot of the erosion control product occurs every 50 feet (15 m) of slope. If the manufacturer's recommendations for the installation of check slots are different than those given here, the Contractor will be required to follow the more stringent of the two.

Each strip shall be stapled in 3 rows, at each edge and the center, with staples spaced not more than 3 feet (900 mm) longitudinally. Check slots and ends of strips shall be stapled at 9″ (225 mm) intervals across their width.

For temporary blankets, staples should be U-shaped wire with an 11-gauge thickness or greater. Staples should be of sufficient thickness for soil penetration without undue distortion. The legs of the staples shall be at least 6″ long with a crown of 1″. Appropriate biodegradable staples can be used in lieu of wire staples.

Permanent blankets shall be anchored in one of two ways. Blankets can be anchored using sound wood stakes, 1″ by 3″ stock sawn in a triangular shape. The length of the stakes shall be from 12″ to 18″ depending upon the soil compaction at the site. Stakes shall be installed on 4 feet centers along each edge of the blanket. Blankets can also be anchored using U shaped staples of 11 gauge steel or greater with a minimum leg length of 8″ and a 2″ crown.

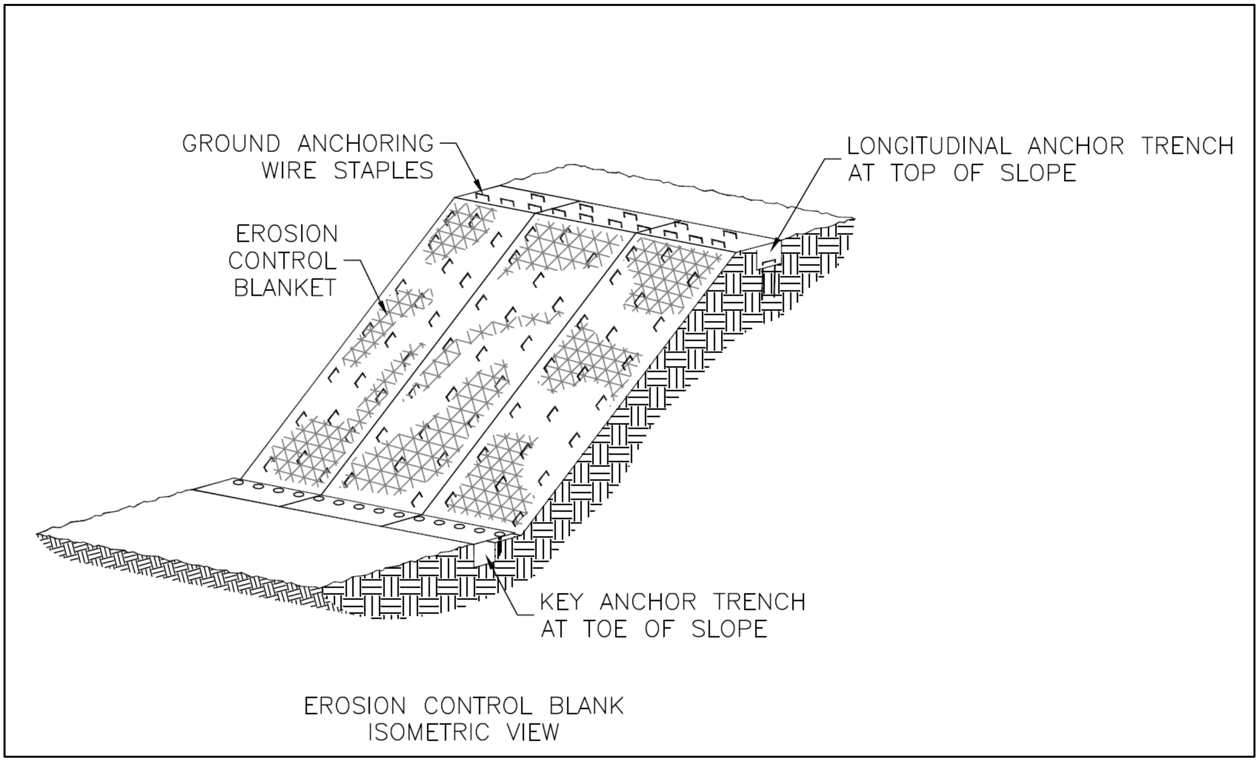


Figure ECB - 2 Erosion Control Blanket Detail

Construction Verification

Check finished grade, dimensions and staple spacing of erosion control blankets. Check materials for compliance with specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

Movement of the blanket or erosion under the blanket is observed.

Poor contact between the soil and the erosion control blanket results in surface water flowing under rather than over the blanket, causing erosion; retrench or reanchor to direct water over blanket.

Blanket inadequately or improperly stapled results in tenting, blanket movement or displacement; reinstall and ensure blanket is properly anchored.

Unstable slope results in blanket or slope failure; determine cause of slope failure, stabilize slope and reinstall blanket.

Variations in topography on site indicate erosion control mat will not function as intended; changes in plan may be needed, or a blanket with a shorter or longer life may be needed.

Design specifications for seed variety, seeding dates or erosion control materials cannot be met; substitution may be required. Unapproved substitutions could result in failure to establish vegetation or breach of contract.

Maintenance

Inspect after storm events until vegetation is established for erosion or undermining beneath the blankets. If any area shows erosion, pull back that portion of the blanket, add tamped soil and reseed; then resecure the blankets.

If blankets should become dislocated or damaged, repair or replace and resecure immediately.

References

BMPs from Volume 1

Chapter 4

Housekeeping Practices (HK)

HK

Practice Description

Housekeeping practices describes the various activities and measures, in addition to the specific practices used for erosion and sediment control that are essential during construction for the protection of environmental quality. Housekeeping is applicable at all construction sites.

Planning Considerations

In addition to the sediment- and erosion-control practices included in the manual that deal directly with sediment and erosion control, some general housekeeping practices are essential to the pollution prevention aspect of a Stormwater Pollution Prevention Plan. Housekeeping addresses these practices. Included in the practice are the following different areas:

- Inspection and Maintenance Procedures
- Materials Inventory
- Spill Prevention and Material Management Practices
- Spill Controls
- Hazardous Products
- Air Emissions (excessive odor)
- Other Good Housekeeping Practices (i.e. fugitive spray, excessive noise and aesthetics)

Design Criteria

Inspection and Maintenance Procedures

The following inspection and maintenance procedures need to be followed to maintain adequate sediment and erosion controls:

- All control measures need to be inspected at least once per week and following any accumulation of rainfall of 1/2″ or more within a 24-hour period.
- All measures need to be maintained in good working order. If a repair is necessary, it should be initiated within 24 hours of report.
- Silt fence and straw bales need to be inspected weekly for proper anchorage and leakage underneath. Silt fencing should also be inspected for tears.
- Built-up sediment needs to be removed from silt barriers when it has reached ½ of the height of the barrier. Sediment needs to be placed in a stabilized site to prevent re-entry into the same site or another entrapment area.
- Sediment basins need to be inspected for depth of sediment on a monthly basis and built-up sediment needs to be removed when ½ of the basin volume is filled.
- Temporary and permanent seeding and plantings need to be inspected for bare spots, washouts and healthy growth. A person should be designated to be responsible for maintaining planted areas until growth has reached 1″ in height and the area planted has 70% ground cover.

Materials Inventory

A materials list should be compiled for items that will be stored outside on the site during construction. For example:

_______ Pipe, fittings and joint compounds for underground utility piping
_______ Gravel and stone bedding material
_______ Concrete forming materials
_______ Other (specify) ______________________________
____
____
____

NOTE: Fuels, oils and other petroleum products; forming oils and compounds; fertilizers; pesticides; strippers; detergents; cleaners; or any other hazardous or toxic compounds should not be stored outside on the site unless specifically agreed upon by all responsible parties, including those persons responsible for enforcing local ordinances and policies. On-site storage should meet all local, state and federal rules regarding secondary containment. Additionally, local ordinances may require fencing and security measures for storage of these products.

Spill Prevention and Material Management Practices

Petroleum Products

All vehicles kept on the site need to be monitored for leaks and receive regular preventive maintenance to reduce the chance of leakage. A Spill Prevention Control and Countermeasures (SPCC) plan should be developed for the facility to address the safe storage, handling and clean up of petroleum products and other chemicals. Petroleum products should be stored in tightly sealed containers, that are clearly labeled. If petroleum products are stored on site, a secondary containment facility will be required if the cumulative storage capacity of all tanks, greater than 55 gallons, at the site exceeds 1,320 gallons.

Fueling & Servicing

No fueling, servicing, maintenance, or repair of equipment or machinery should be done within 50 feet of a stream, or within 100 feet of a stream classified for public water supply (PWS), with special designation, protected vegetation (tree drip-line), or a sinkhole.

Mud Tracking

A stabilized construction entrance needs to be designated on the plan. The practice construction exit pad provides design details for planning such an entrance.

Only designated entrances should be used for construction access to the site. The General Contractor should be responsible for keeping mud cleaned from adjoining streets on a daily basis if needed.

Concrete Trucks

Concrete trucks should be allowed to wash only in locations where discharge is directed to a sediment basin. It is not permissible to discharge concrete wash directly to streams or storm drains. Alkalinity and chemical additives could be harmful to fish, stream bottom macroinvertebrates and wildlife.

Disposal of Oil

No fuels, oils, lubricants, solvents, or other hazardous materials can be disposed of on the site. All hazardous material must be properly disposed of in accordance with State law.

Trash/Solid Waste

The General Contractor is responsible for disposing of all solid waste from the site in accordance with State law. Dumpsters or other collection facilities must be provided as needed. Solid waste may not be buried on the site.

Sanitary Waste

The General Contractor is responsible for providing sanitary facilities on the site. Sanitary waste may be disposed only in locations having a State permit.

Other Discharges

Water for pressure testing sanitary sewers, flushing water lines, sand blasting, concrete cleansing, etc., may be discharged only in approved areas. Discharge of hydrostatic test water may require additional permitting, particularly if chlorinated public water is used.

Spill Controls

In addition to the good housekeeping practices and material management practices listed previously, the following procedures need to be followed for spill prevention and clean-up:

- Manufacturer's recommended methods for spill cleanup needs to be clearly posted and site personnel need to be made aware of the procedures and the location of the information and cleanup supplies. Refer to material safety data sheets (Material Safety Data Sheet).

- Material and equipment necessary for spill cleanup needs to be kept in the material storage area on-site. Equipment and materials include, but are not limited to; brooms, dust pans, mops, rags, gloves, goggles, absorbent clay (kitty litter), sand, sawdust, absorbent mats, and plastic and metal trash containers specifically for this purpose.

- All spills need to be cleaned up immediately after discovery and properly containerized for proper disposal. Burial is not acceptable.

- The spill area must be kept well ventilated and personnel need to wear appropriate protective clothing to prevent injury from contact with a hazardous substance.

- Spills of toxic or hazardous material must be reported immediately to the appropriate state or local government agency, regardless of the size.

- The spill prevention plan needs to be adjusted to include measures to prevent this type of spill from being repeated, and the plan needs to show how to clean up the spill if another one does occur.

Contaminated Soils

Removal of contaminated soils and underground storage tanks should be based on information provided by the Mississippi Department of Environmental Quality following a proper site assessment.

Hazardous Products

Products must be kept in original containers unless they are not resealable. If product is transferred to a new container, it must be properly marked and labeled.

Original labels and material safety data sheets should be retained.

If surplus product must be disposed, disposal must be done in accordance with Mississippi Department of Environmental Quality regulations.

Air Emissions

Open burning must meet the criteria found in the State of Mississippi's Air Emissions Regulations found in APCS-1, Section 3.7. Other considerations are discussed below.

Burning

Burning on the site may require a permit from the Mississippi Forestry Commission. County or city ordinances may also apply. Starting disposal fires with diesel fuel or old tires is not a recommended practice. The use of burn pits with fans to generate hot disposal fires decreases the fire disposal time and minimizes smoke.

Dust Control

Apply measures that minimize dust. Stabilizing areas with mulch as soon as possible can minimize dust. Watering should be provided in unstabilized areas (See *Dust Control Practice*).

Other Good Housekeeping Practices

In addition to the foregoing, the following good housekeeping practices need to be followed during the construction of the project:

- An effort should be made to store only enough products to do the job.
- All materials stored on-site should be stored in a neat, orderly manner in their appropriate containers and, if possible, under a roof or other enclosure.
- Products should be kept in their original containers with the original manufacturer's label.
- Whenever possible, all of a product should be used up before disposing of the container.
- Manufacturer's recommendations for proper use and disposal must be followed (see Material Safety Data Sheet).
- The site superintendent should inspect daily to ensure proper usage, storage and disposal of materials.
- Fertilizers need to be applied only in the minimum amounts recommended by the manufacturer.
- All paint containers need to be tightly sealed and stored when not required for use. Excess paint shall not be dumped into the storm sewer system but should be properly disposed of according to manufacturer's instructions (see Material Safety Data Sheet) and State regulations.
- The site should be kept clean and well groomed (trash picked up regularly, weeds mowed and signs maintained).
- Offsite fugitive spray from dust control, sand blasting and pressure washing must be minimized to the extent possible.
- Locate activities that generate odors and noise as far from surrounding properties as possible (this item includes portable toilets, burn sites, fueling areas, equipment repair areas and dumpsters).

References

BMPs from Volume 1

Chapter 4

Dust Control (DC) 4-29

Mulching (MU)

Practice Description

Mulching is the application of plant residues such as straw or other suitable materials to the soil surface. Mulch protects the soil surface from the erosive force of raindrop impact and reduces the velocity of overland flow. It helps seedlings germinate and grow by conserving moisture, protecting against temperature extremes and controlling weeds. Mulch also maintains the infiltration capacity of the soil. Mulch can be applied to seeded areas to help establish plant cover. It can also be used in unseeded areas to protect against erosion over the winter or until final grading and shaping can be accomplished except in areas with concentrated flow.

Planning Considerations

Surface mulch is the most effective, practical means of controlling runoff and erosion on disturbed land prior to vegetation establishment. Mulch absorbs the energy associated with raindrops and thereby minimizes soil-particle detachment, which is the initiation step of erosion.

Mulch also reduces soil moisture loss by evaporation, prevents crusting and sealing of the soil surface, moderates soil temperatures, and provides a suitable microclimate for seed germination.

Organic mulches such as straw, wood chips and shredded bark have been found to be very effective mulch materials. Materials containing weed and grass seeds that may compete with establishing vegetation should not be used. Also, decomposition of some wood products can tie up significant amounts of soil nitrogen, making it necessary to modify fertilization rates or add fertilizer with the mulch.

A variety of erosion-control blankets have been developed in recent years for use as mulch, particularly in critical areas such as waterways and channels. Various types of netting materials are also available to anchor organic mulches.

The choice of materials for mulching should be based on soil conditions, season, type of vegetation to establish, and size of the area. Properly applied and tacked mulch is always beneficial. Mulching is especially important when conditions of germination are not optimum, such as midsummer and early winter, and on difficult sites with cut slopes, or fill slopes and droughty soils.

Straw is the most commonly used material in conjunction with seeding. Wheat straw is the mostly commonly used straw, and can be spread by hand or with a mulch blower. If the site is susceptible to blowing wind, the straw should be tacked down with a tackifier, a crimper, or a disk to prevent loss. Some site developers always require that straw mulch be tacked by an approved method.

Wood chips are suitable for areas that will not be closely mowed, and around ornamental plantings. Chips do not require tacking. Because they decompose slowly, they must be treated with 12 pounds of nitrogen per ton to prevent nutrient deficiency in plants. They can be an inexpensive mulch if the chips are obtained from trees cleared on the site.

Wood fiber refers to short cellulose fibers applied as a slurry in hydroseeding operations. Wood-fiber hydroseeder slurries may be used to tack straw mulch on steep slopes, critical areas, and where harsh climatic conditions exist.

Compost, peanut hulls, and pine straw are organic materials that potentially make excellent mulches but may only be available locally or seasonally. Creative use of these materials may reduce costs.

Jute mesh or the various types of netting is very effective in holding mulch in place on waterways and slopes before grasses become established.

Erosion-control blankets promote seedling growth in the same way as organic mulches and are suited for use in areas with concentrated flows (see *Erosion-Control Blanket Practice*).

Design Criteria and Installation

Mulching should be designed by a qualified design professional and plans and specifications should be made available to field personnel prior to start of construction.

Site Preparation

Divert runoff water from areas above the site that will be mulched.

Remove stumps, roots, and other debris from the construction area.

Grade area as needed to permit the use of equipment for seeding, mulching, and maintenance. Shape area so that it is relatively smooth.

If the area will be seeded, follow seeding specifications in the design plan and apply mulch immediately after seeding.

Spreading the Mulch

Select a mulch material based on the site and practice requirements, availability of material, and availability of labor and equipment. Table MU-1 lists commonly used mulches.

Uniformly spread organic mulches by hand or with a mulch blower at a rate which provides about 75% ground cover. When spreading straw mulch by hand, divide the area to be mulched into sections of approximately 1000 sq. ft. and place 70-90 pounds of straw (1 ½ to 2 bales) in each section to facilitate uniform distribution. Caution, an over-application of wheat straw will reduce stand success – do not over-apply wheat straw when mulching a seeding application!

Anchor straw- or wood-cellulose mulch by one of the following methods:

- Crimp with a weighted, straight, notched disc or a mulch-anchoring tool to punch the straw into the soil.
- Tack with a liquid tackifier designed to hold mulch in place. Use suitable spray equipment and follow manufacturer's recommendations.
- In more erosive areas, cover with netting, using a degradable natural or synthetic mesh. The netting should be anchored according to manufacturer's specifications (see *Erosion-Control Blanket Practice*).
- On steep slopes and other areas needing a higher degree of protection, use one of the following: 1) heavy natural nets without additional mulch; 2) synthetic netting with additional mulch or; 3) erosion control mats/blankets. These areas include grassed waterways, swales and diversion channels.
- Install netting and mats/blankets according to manufacturer's specifications making sure materials are properly anchored (see *Erosion-Control Blanket Practice*).

Table MU-1 Mulching Materials and Application Rates

Material	Rate Per Acre and (Per 1000 ft.^{2})	Notes
Straw with Seed	1 ½-2 tons (70 lbs-90 lbs)	Spread by hand or machine to attain 75% groundcover; anchor when subject to blowing.
Straw Alone (no seed)	2 ½-3 tons (115 lbs-160 lbs)	Spread by hand or machine; anchor when subject to blowing.
Wood Chips	5-6 tons (225 lbs-270 lbs)	Treat with 12 lbs. nitrogen/ton.
Bark	35 cubic yards (0.8 cubic yard)	Can apply with mulch blower.
Pine Straw	1-2 tons (45 lbs-90 lbs)	Spread by hand or machine; will not blow like straw.
Peanut Hulls	10-20 tons (450 lbs-900 lbs)	Will wash off slopes. Treat with 12 lbs. nitrogen/ton.

Liquid-mulch binders can also be used to tack mulch subject to being blown away by wind. Applications of liquid-mulch binders and tackifiers should be heaviest at the edges of areas and at crests of ridges and banks, to resist wind. Binders should be applied uniformly to the rest of the area. Binders may be applied after mulch is spread or may be sprayed into the mulch as it is being blown onto the soil. Applying straw and binder together is the most effective method. Liquid binders include an array of commercially available synthetic binders.

Straw mulch may also be anchored with lightweight plastic, cotton, jute, wire or paper netting which is stapled over the mulch. The manufacturer's recommendations on stapling netting should be followed.

Verification of Installation

Check materials and installation for compliance with specifications.

Common Problems

Consult with qualified design professional if either of the following occurs:

Variations in topography on site indicate the mulching materials will not function as intended; changes in plan may be needed.

Design specifications for mulching materials or seeding requirements cannot be met; substitution may be required. Unapproved substitutions could result in erosion or seeding failure.

Problems that require remedial actions:

Erosion, washout and poor plant establishment; repair eroded surface, reseed, re-mulch and anchor mulch.

Mulch is lost to wind or stormwater runoff; reapply mulch and anchor appropriately by crimping, netting or tacking.

Maintenance

Inspect all mulched areas periodically and after rainstorms for erosion and damage to the mulch. Repair promptly and restore to original condition. Continue inspections until vegetation is well established. Keep mower height high if plastic netting is used to prevent netting from wrapping around mower blades or shaft.

References

BMPs from Volume 1

Chapter 4

Erosion-Control Blanket (ECB)	4-33
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Permanent Seeding (PS)

Practice Description

Permanent seeding is the establishment of perennial vegetation on disturbed areas from seed. Permanent vegetation provides economical long-term erosion control and helps prevent sediment from leaving the site. This practice is used when vegetation is desired and appropriate to permanently stabilize the soil.

Planning Considerations

The advantages of seeding over other means of establishing plants include the smaller initial cost, lower labor input, and greater flexibility of method.

Disadvantages of seeding include potential for erosion during the establishment stage, seasonal limitations on suitable seeding dates, and weather-related problems such as droughts.

The probability of successful plant establishment can be maximized through good planning. The selection of plants for permanent vegetation must be site specific. Factors that should be considered are types of soils, climate, establishment rate, and management requirements of the vegetation. Other factors that may be important are wear, mowing tolerance, and salt tolerance of vegetation.

Plant selection for permanent vegetation should be based on plant characteristics, site and soil conditions, time of year of planting, method of planting, and the intended use of the vegetated area. Climate factors can vary widely in Mississippi. Important plant attributes are discussed in *Vegetation Establishment for Erosion and Sediment Control* in Chapter 2.

Plant selection may include companion plants to provide quick cover on difficult sites, late seedings, or where the desired permanent cover may be slow to establish. Annuals are usually used for companion plants and should be selected carefully to prevent using a species that provide so much competition that it prevents the establishment of the desired species.

Seeding properly carried out within the optimum dates has a higher probability of success. It is also possible to have satisfactory establishment when seeding outside these dates. However, as plantings are deviated from the optimum dates, the probability of failure increases rapidly. Seeding dates should be taken into account in scheduling land-disturbing activities.

Site quality impacts both short-term and long-term plant success. Sites that have compacted soils, soils that are shallow to rock, or have textures that are too clayey or too sandy should be modified whenever practical to improve the potential for plant growth and long-term cover success.

The operation of equipment is restricted on slopes steeper than 3:1, severely limiting the quality of the seedbed that can be prepared. Provisions for establishment of vegetation on steep slopes can be made during final grading. In construction of fill slopes, for example, the last 4-6″ might not be compacted. A loose, rough seedbed with irregularities that hold seeds and lime and fertilizer is essential for hydroseeding. Cut slopes should be roughened (see *Land Grading Practice*).

Proper mulching is critical to protect against erosion on steep slopes. When using straw, anchor with netting. On slopes steeper than 2:1, jute, excelsior, or synthetic matting may be required.

The use of irrigation (temporary or permanent) will greatly improve the success of vegetation establishment.

Design Criteria and Installation

Prior to start of construction, plant materials, seeding rates and planting dates should be specified by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the installation process.

Permanent seeding should be done during the specified planting period whenever possible. When sites are only available for planting outside of the recommended planting period, either an out-of-season permanent seeding, a temporary seeding, mulching or chemical stabilization will be more appropriate than leaving the surface bare for an extended period. If lime and fertilizer application rates are not specified, take soil samples during final grading from the top 6″ in each area to be seeded. Submit samples to a soil testing laboratory for lime and fertilizer recommendations.

Scheduling

The schedule for work at the site should consider the recommended planting period and whenever practical, the site work should accommodate seeding during the recommended planting period.

Plant Selection

Select plants that can be expected to meet planting objectives. To simplify plant selection, use Figure PS-1 Geographical Areas for Species Adaptation and Table PS-1, Commonly Used Plants for Permanent Cover. Mixtures commonly specified by the Mississippi Department of Transportation are an appropriate alternative for plantings on rights-of-ways. Additional information related to plantings in Mississippi is found in Chapter 2 under the section *Vegetation for Erosion and Sediment Control*.

The plants used for temporary vegetation may be used for companion plants provided the seeding rate is reduced by one half. See the *Temporary Seeding Practice* for additional information on establishing temporary vegetation. **Ryegrass or other highly competitive plants should not be used as a companion plant**.

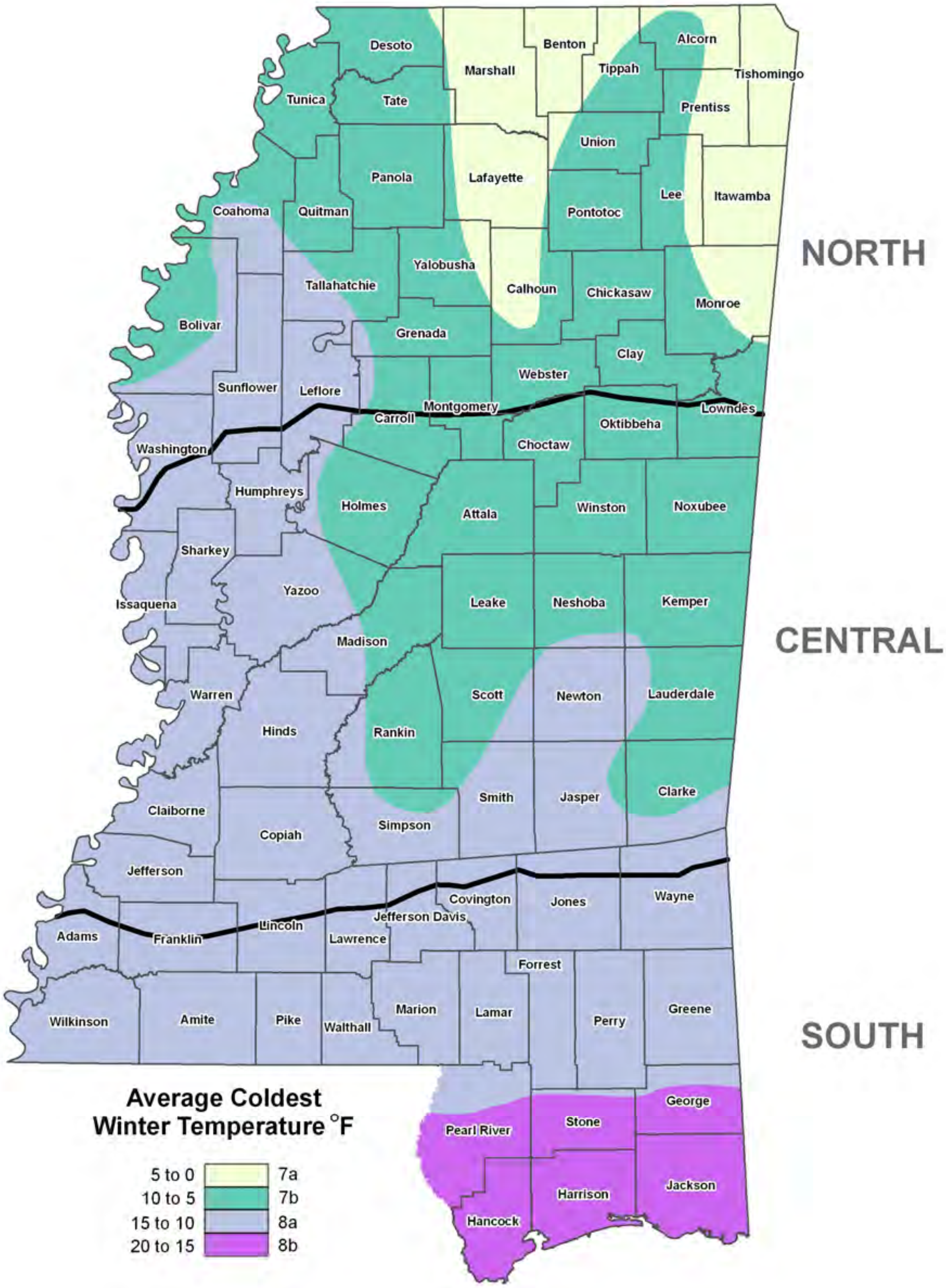

Figure PS-2 Geographical Areas for Species Adaptation

Table PS-1 Commonly Used Plants for Permanent Cover with Seeding Rates and Dates

Species	Seeding Rates/Ac	Planting Time	Desired pH Range	Fertilization Rate/Acre	Method of Establish-ment	Zone of Adaptability	Native / Introduced
Common Bermuda	15 lbs. alone 10lbs. mix	3/1 – 7/15 9/1 – 11/30	6.0 – 7.0	600 lbs. 13-13-13	Seed or sod	All	Introduced * Potential for Invasive-ness
Bahia	40 lbs. alone 30 lbs. mix	3/1 – 7/15 9/1 – 11/30	6.0 – 7.0	600 lbs. 13-13-13	Seed	Central and South	Introduced
Fescue	40 lbs. alone 30 lbs. mix	9/1 – 11/30	6.0 – 7.0	600 lbs. 13-13-13	Seed	North and Central	Native
Saint Augustine	--	3/1 – 7/15	6.0 – 7.0	600 lbs. 13-13-13	Sod only	Central and South	Native
Centipede	4 lbs. alone 2.5 lbs mix	3/1 – 715	6.0 – 7.0	600 lbs. 13-13-13	Seed or sod	All	Introduced
Carpet Grass	15 lbs. alone 10 lbs. mix	3/1 – 7/15	6.0 – 7.0	600 lbs. 13-13-13	Seed or sod	All	Native
Zoysia Grass	--	3/1 – 7/15	6.0 – 7.0	600 lbs. 13-13-13	Sod only	All	Introduced
Creeping Red Fescue	30 lbs. alone 22.5 lbs. mix	9/1 – 11/30	6.0 – 7.0	600 lbs. 13-13-13	Seed	All	Native
Weeping Lovegrass	10 lbs. alone 5 lbs. mix	3/1 – 7/15	6.0 – 7.0	600 lbs. 13-13-13	Seed	All	Introduced
***Wheat**	90 lbs. alone	9/1 – 11/30	6.0 – 7.0	600 lbs 13-13-13	Seed	All	Native
***Ryegrass**	30 lbs.	9/1 – 11/30	6.0 – 7.0	600 lbs 13-13-13	Seed	All	Native
***White Clover**	5 lbs.	9/1 – 11/30	6.0 – 7.0	400 lbs 6-24-24	Seed	All	Introduced
***Crimson Clover**	15 lbs.	9/1 – 11/30	6.0 – 7.0	400 lbs 6-24-24	Seed	All	Introduced
Sericea Lespedeza	40 lbs.	3/1 – 7/15 9/1 – 11/30	6.0 – 7.0	400 lbs. 13-13-13	Seed	All	Introduced
***Hairy Vetch**	30 lbs.	9/1 – 11/30	6.0 – 7.0	400 lbs 6-24-24	Seed	All	Introduced
***Browntop Millet**	40 lbs. alone 15 lbs. mix	4/1 – 8/30	6.0 – 7.0	600 lbs 13-13-13	Seed	All	Introduced

* Note on Annuals: For permanent seeding, annuals can only be used in a mixture with perennials.

Seedbed Requirements

Establishment of vegetation should not be attempted on sites that are unsuitable due to compaction or inappropriate soil texture, poor drainage, concentrated overland flow, or steepness of slope until measures have been completed to correct these problems. To maintain a good stand of vegetation, the soil must meet certain minimum requirements as a growth medium. A good growth medium should have these attributes:

- Sufficient pore space to permit root penetration.
- Enough fine-grained soil material (silt and clay) to maintain adequate moisture and nutrient supply.
- Sufficient depth of soil to provide an adequate root zone. The depth to rock or impermeable layers such as hardpans should be 12″ or more, except on slopes steeper than 2:1 where topsoiling is not feasible.
- A favorable pH range for plant growth, usually 6.0-6.5.
- Sufficient nutrients (nitrogen, phosphorus and potassium) for initial plant establishment.
- Freedom from large roots, branches, stones, or large clods. Clods and stones may be left on slopes steeper than 3:1 if they are to be hydroseeded.

If any of the above attributes are not met; i.e., if the existing soil is too dense, coarse, shallow or acidic to foster vegetation – chiseling, topsoil, or special amendments should be used to improve soil conditions. The soil conditioners described below may be beneficial or topsoil may be applied (for guidance on topsoiling see *Topsoiling Practice*). These amendments should only be necessary where soils have limitations that make them poor for plant growth or for turf establishment.

- Peat-appropriate types are sphagnum moss peat, reed-sedge peat, or peat humus, all from fresh-water sources. Peat should be shredded and conditioned in storage piles for at least 6 months after excavation.
- Sand-should be clean and free of toxic materials.
- Vermiculite-use horticultural grade.
- Rotted manure-use stable or cattle manure not containing undue amounts of straw or other bedding materials.
- Thoroughly rotted sawdust-should be free of stones and debris. Add 6 lbs of nitrogen to each cubic yard.

Soil Amendments

Liming Materials

Lime (Agricultural limestone) should have a neutralizing value of not less than 90 percent calcium carbonate equivalent and 90 percent will pass through a 10-mesh sieve and 50 percent will pass through a 60-mesh sieve.

Selma chalk should have a neutralizing value of not less than 80-percent calcium carbonate equivalent and 90 percent will pass through a 10-mesh sieve.

Other liming materials that may be selected should be provided in amounts that provide equal value to the criteria listed for agricultural lime or be used in combination with agricultural limestone or Selma chalk to provide equivalent values to agricultural limestone.

Plant Nutrients

Commercial grade fertilizers that comply with current Mississippi Fertilizer Laws should be used to supply nutrients required to establish vegetation.

Rates of Soil Amendments

Lime and fertilizer needs should be determined by soil tests. Soil testing is performed by the Mississippi State University Extension Service Soil Testing Laboratory and provides recommendations based on field tests on Mississippi soils. The local county Cooperative Extension Service can provide information on obtaining soil tests. Commercial laboratories that make recommendations based on soil analysis may be used.

When soil tests are not available, use the following rates for application of soil amendments.

Lime (Agricultural Limestone or Equivalent – see Liming Materials)

Sandy soils: Use 1 ton/acre (exception on sandy soils – if the cover will be tall fescue and clover use 2 tons/acre).

Clayey soils: 2 tons/acre.
(Do not apply lime to alkaline soils).

Fertilizer

Grasses alone: Use 400 lbs/acre of 8-24-24 or the equivalent. Apply 30 lbs of additional nitrogen when grass has emerged and begun growth (approximately 0.8lbs/1000 ft^2).

Grass-legume mixtures: Use 800 to 1200 lbs/acre of 5-10-10 or the equivalent.

Legumes Alone: Use 800 to 1200 lbs/acre of 0-10-10 or the equivalent.

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil test recommendations to local fertilizer dealer for bulk fertilizer blends. This may be more economical than bagged fertilizer.

Application of Soil Amendments

Apply lime and fertilizer evenly and incorporate into the top 6″ of soil by disking, chiseling, or other suitable means during seedbed preparation. Operate machinery on the contour.

Seedbed Preparation

Install necessary sediment-control practices before seedbed preparation and complete grading according to the approved plan.

Grade and loosen the soil to a smooth, firm surface to enhance rooting of seedlings and reducing rill erosion. Break up large clods and loosen compacted, hard, or crusted-soil surfaces with a disk, ripper, chisel, harrow or other tillage equipment. Avoid preparing the seedbed under excessively wet conditions. Operate the equipment on the contour.

For broadcast seeding and drilling, tillage, as a minimum, should adequately loosen the soil to a depth of at least 6″, alleviate compaction, and smooth and firm the soil for the proper placement of seed.

For no-till drilling, the soil surface does not need to be loosened unless the site has surface compaction.

Incorporate lime and fertilizer to a depth of at least 6″ with a disk or rotary tiller on slopes of up to 3:1. On steeper slopes, lime and fertilizer may be applied to the surface without incorporation. Lime and fertilizer may be applied through hydroseeding equipment; however, fertilizer should not be added to the seed mixture during hydroseeding. Lime may be added with the seed mixture.

Planting Methods

Seeding

Use certified seed for permanent seeding whenever possible. Certified seed is inspected by the Mississippi Crop Improvement Association to meet high quality standards and will be tagged with a “Certified Seed” tag. (Note: all seed sold in Mississippi is required by law to be tagged to identify seed purity, germination, and presence of weed seeds. Seed must meet state standards for content of noxious weeds.)

Seeding dates are determined using Figure PS-1 and Table PS-1.

Inoculate legume seed with the *Rhizobium* bacteria appropriate to the species of legume. Details of legume inoculation are located in Chapter 2 in the part on *Vegetation for Erosion and Sediment Control* under Inoculation of Legumes.

Seed should be uniformly planted with a cyclone seeder, a drill seeder, a cultipacker seeder, or by hand on a fresh, firm, friable seedbed. If the seedbed has been sealed by rainfall, it should be disked so the seed will be sown into a freshly prepared seedbed.

When using broadcast-seeding methods, subdivide the area into workable sections and determine the amount of seed needed for each section. Apply one-half the seed while moving back and forth across the area, making a uniform pattern; then apply the second half in the same way, but moving at right angles to the first pass.

Cover broadcast seed by raking or chain dragging; then firm the surface with a roller or cultipacker to provide good seed contact. Small grains should be planted no more than 1″ deep and grasses and legume seed no more than ½″ deep.

Hydroseeding

Surface roughening is particularly important when hydroseeding, as a roughened slope will provide some natural coverage for lime, fertilizer, and seed. The surface should not be compacted or smooth. Fine seedbed preparation is not necessary for hydroseeding operations; large clods, stones, and irregularities provide cavities in which seeds can lodge.

Mix seed, inoculant if required, and a seed carrier with water and apply as a slurry uniformly over the area to be treated. The seed carrier should be a cellulose fiber, natural wood fiber or other approved fiber mulch material which is dyed an appropriate color to facilitate uniform application of seed. Use the correct legume inoculant at 4 times the recommended rate when adding inoculant to a hydroseeder slurry. The mixture should be applied within one hour after mixing to reduce damage to seed.

Fertilizer should not be mixed with the seed-inoculant mixture because fertilizer salts may damage seed and reduce germination and seedling vigor.

Fertilizer may be applied with a hydroseeder as a separate operation after seedlings are established.

Agricultural lime is usually applied as a separate operation and spread in dry form. It is not normally applied with a hydraulic seeder because it is abrasive and, also, may clog the system. On the other hand, liquid lime is applied with a hydraulic seeder but because of cost is used primarily to provide quick action for benefit of plants during their seedling stage with the bulk of liming needs to be provided by agricultural lime. Dry lime may be applied with the fertilizer mixture.

Sprigging

Hybrid Bermuda grass cannot be grown from seed and must be planted vegetatively. Vegetative methods of establishing common and hybrid Bermuda grass, centipede grass and zoysia include sodding, plugging and sprigging (see *Sodding Practice*).

When sprigs are planted with a sprigging machine, furrows should be 4-6″ deep and 2 feet apart. Place sprigs no farther than 2 feet apart in the row and so that at least one rooting node is in the furrow.

Broadcasting of sprigs is not recommended as the practice requires additional vegetative material and is an unreliable method of planting. Hand planting of sprigs is recommended instead with furrows 4-6″ deep and 2 feet apart. Place sprigs no farther than 2 feet apart in the row and so that at least one rooting node is in the furrow.

Mulching

The use of mulch provides instant cover and helps ensure establishment of vegetation under normal conditions and is essential to seeding success under harsh site conditions (see *Mulching Practice*). Harsh site conditions include slopes steeper than 3:1 and adverse soils (shallow, rocky, or high in clay or sand). Areas with concentrated flow should be treated differently and require sod, a hydromulch formulated for channels or an appropriate erosion control blanket.

Irrigation

Moisture is essential for seed germination and vegetation establishment. Supplemental irrigation can be very helpful in assuring adequate stands in dry seasons or to speed development of full cover. It is a requirement for establishment of vegetation from sod and sprigs and should be used elsewhere when feasible. However, irrigation is rarely critical for low-maintenance vegetation planted at the appropriate time of the year.

Water application rates must be carefully controlled to prevent runoff. Inadequate or excessive amounts of water can be more harmful than no supplemental water.

Installation Verification

Check materials and installation for compliance with specifications during installation of products.

Common Problems

Consult with a qualified design professional if the following occurs:

Design specifications for seed variety, seeding dates or mulching cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Seeding at the wrong time of the year results in an inadequate stand. Reseed according to specifications of a qualified design professional (see recommendations under *Maintenance*)

Inadequate mulching results in an inadequate stand, bare spots or eroded areas-prepare seedbed, reseed, cover seed evenly and tack or tie down mulch, especially on slopes, ridges and in channels (see recommendations under *Maintenance*).

Maintenance

Generally, a stand of vegetation cannot be determined to be fully established until vegetative cover has been maintained for 1 year from planting.

Reseeding

Inspect seedlings monthly for stand survival and vigor. Also, inspect the site for erosion.

If stand is inadequate identify the cause of failure (choice of plant materials, lime and fertilizer quantities, poor seedbed preparation or weather) and take corrective action. If vegetation fails to grow, have the soil tested to determine whether pH is in the correct range or nutrient deficiency is a problem.

Stand conditions, particularly the coverage, will determine the extent of remedial actions such as seedbed preparation and reseeding. A qualified design professional should be consulted to advise on remedial actions. Consider drill seeding where possible.

Eroded areas should be addressed appropriately by filling and/or smoothing, and reapplication of lime, fertilizer, seed and mulch.

Fertilizing

Satisfactory establishment may require refertilizing the stand in the second growing season. Follow soil test recommendations or the specifications provided to establish and maintain the planting.

Mowing

Mow vegetation on structural practices such as embankments and grass-lined channels to prevent woody plants from invading.

Other areas should be mowed to compliment the use of the site.

Certain species can be weakened by mowing regimes that significantly reduce their food reserves stored for the next growing season: fescue should not be mowed close during the summer; sericea should not be mowed close in late summer.

Bermuda grass is tolerant of most mowing regimes and can be mowed often and close, if so desired, during its growing season.

References

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Appendix G

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Preservation of Vegetation (PV)

Practice Description

Preservation of vegetation is the avoidance of an area during land disturbing and construction activities to prevent mechanical and other injury to desirable plants in the planned landscape. The practice provides erosion and sediment control and is applicable where vegetative cover is desired and the existing plant community is compatible with the planned landscape.

Planning Considerations

Preservation of vegetation requires good site management to minimize the impact of construction activities on existing vegetation.

Plants to save should be identified prior to any construction activity.

Proper maintenance, especially during construction, is important to ensure healthy vegetation that can control erosion.

Different species, soil types, and climatic conditions will require different maintenance activities.

Design Criteria and Installation

Preservation requirements should be designed by a qualified design professional and plans should be made available to field personnel prior to start of construction

Mark Plant Area for Retention

Groups of plants and individual trees to be retained should be located on a plan map.

Limits of clearing should be planned outside the drip line of groups or individual trees to be saved. The clearing should never be closer than 5 feet to the trunk of a tree.

Flagging or other appropriate means of marking the site of the groups of plants and individual trees to be retained should be required before construction begins. Individual trees to be retained should be marked with a highly visible paint or surveyor's ribbon in a band circling the tree at a height visible to equipment operators.

Plant Protection

Restrict construction equipment, vehicular traffic, stockpiles of construction materials, topsoil etc., from the areas where plants are retained and restrict these activities from occurring within the drip line of any tree to be retained. Trees being removed shall not be pushed into trees to be retained. Equipment operators shall not clean any of their equipment by slamming it against trees to be retained.

Restrict burning of debris within 100 feet of the plants being preserved. Fires shall be limited in size to prevent damage to any nearby trees.

Toxic material shall not be stored any closer than 100 feet to the drip line of any trees to be retained. Toxic materials shall be managed and disposed of according to state laws.

Fencing and Armoring

Groups of plants and trees should be protected by fencing or armoring where necessary (See Figure PV-l). The following types of fencing or armoring may be used:

- Board Fence; a board fence may be constructed with 4″ square posts set securely in the ground and protruding at least 4 feet above the ground. A minimum of 2 horizontal boards should be placed between the posts. The fence should be placed at the limits of the clearing around the drip line of the tree. If it is not practical to erect a fence at the drip line, construct a triangular fence near the trunk. The limits of clearing will still be the drip line as the root zone within the drip line will still require protection.

- Cord Fence; Posts at least 2″ square or 2″ in diameter set securely in the ground and protruding at least 4 feet above the ground; posts should be placed at the limits of clearing with 2 rows of cord ¼″ or thicker at least 2 feet apart running between posts with strips of surveyor's tape tied securely to the string at intervals of 3 feet or less.

- Earth Berms; Temporary earth berms may be constructed. The base of the berm on the tree side should be located along the limits of clearing. Earth berms may not be used for this purpose if their presence will create drainage patterns that cause erosion.

- Additional Trees; Additional trees may be left standing as protection between the trees to be retained and the limits of clearing. However, in order for this alternative to be used, trees in the buffer must be no more than 6 feet apart to prevent passage of equipment and material through the buffer.

- Plan for these additional trees to be evaluated prior to the completion of construction and either given sufficient treatment to ensure survival or be removed.

- Trunk Armoring; As a last resort, a tree may be armored with burlap wrapping and 2″ studs wired vertically no more than 2″ apart to a height of 5 feet. The armoring should encircle the tree trunk. Nothing should ever be nailed to a tree. The root zone within the drip line will still require protection.

- Fencing and armoring devices should be in place before any construction work is done and should be kept in good condition for the duration of construction activities. Fencing and armoring should not be removed until the completion of the construction project.

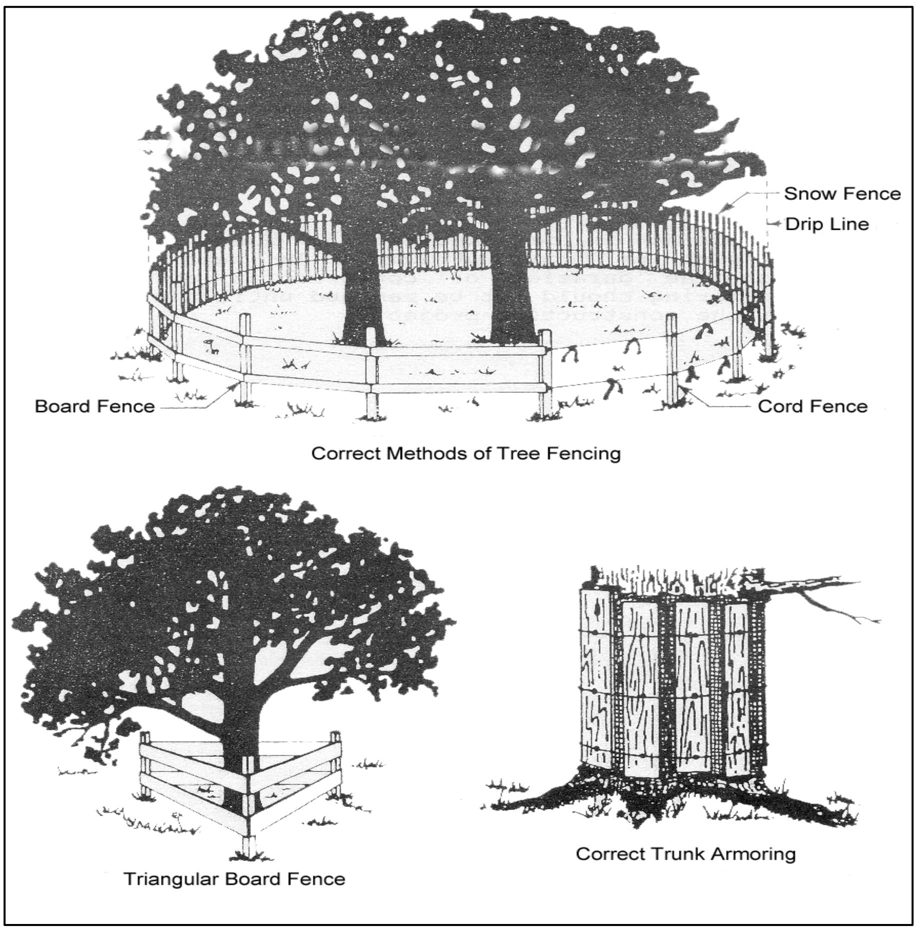


Figure PV- 1 Fencing and Armoring

Raising the Grade

When the ground level must be raised around an existing tree or group of trees, several methods may be used to insure survival.

A well may be created around a group of trees or an individual tree slightly beyond the drip line to retain the natural soil in the area of the feeder roots (see Figure PV-2).

When the well alternative is not practical or desirable, remove vegetation and organic matter from beneath the tree or trees for a distance of 3 feet beyond the drip line and loosen the surface soil to a depth of approximately 3″ without damaging the roots.

Apply fertilizer in the root area of the tree to be retained. A soil test is the best way to determine what type of fertilizer to use. In the absence of a soil test, fertilizer should be applied at the rate of 1 to 2 pounds of 10-8-6 or 10-6-4 per inch of diameter at breast height (dbh) for trees under 6″ dbh and at the rate of 2 to 4 pounds of 10-8-6 or 10-6-4 per inch of dbh for trees over 6″ dbh.

A dry well shall be constructed so as to allow for tree trunk diameter growth (see Figure PV-3). A space of at least 1 foot between the tree trunk and the well wall is adequate for old, slow growing trees. Clearance for younger trees shall be at least 2 feet. The well shall be high enough to bring the top just above the level of the proposed fill. The well wall shall taper slightly away from the tree trunk at a rate of 1″ per foot of wall height.

The well wall shall be constructed of large stones, brick, building tile, concrete blocks, or cinder blocks. Openings should be left through the wall of the well to allow for free movement of air and water. Mortar shall only be used near the top of the well and only above the porous fill.

Drain lines composed of 4″ high quality drain tiles shall begin at the lowest point inside the well and extend outward from the tree trunk in a wheel and spoke pattern with the trunk as the hub. Radial drain lines shall slope away from the well at a rate of ⅛″ per foot. The circumference line of tiles should be located beneath the drip line of the trees. Vertical tiles or pipes shall be placed over the intersections of the two tile systems if a fill of more than 2 feet is contemplated. Vertical tiles shall be held in place with stone fill. Tile joints shall be tight. A few radial tiles shall extend beyond each intersection and shall slope sharply downward to insure good drainage. Tar paper or its approved equivalent shall be placed over the tile and/or pipe joints to prevent clogging and large stone shall be placed around and over drain tiles and/or pipes for protection.

A layer of 2″ to 6″ stone shall be placed over the entire area under the tree from the well outward at least as far as the drip line. For fills up to 2 feet deep, a layer of stone 8″ to 12″ thick should be adequate.

A thick layer of this stone not to exceed 30″ will be needed for deeper fills. A layer of ¾″ to 1″ stone covered by straw, fiberglass mat, or a manufactured filter fabric shall be used to prevent soil from clogging the space between stones. Cinders shall not be used as fill material. Filling shall be completed with porous soil such as topsoil until the desired grade is reached. This soil shall be suitable to sustain specified vegetation.

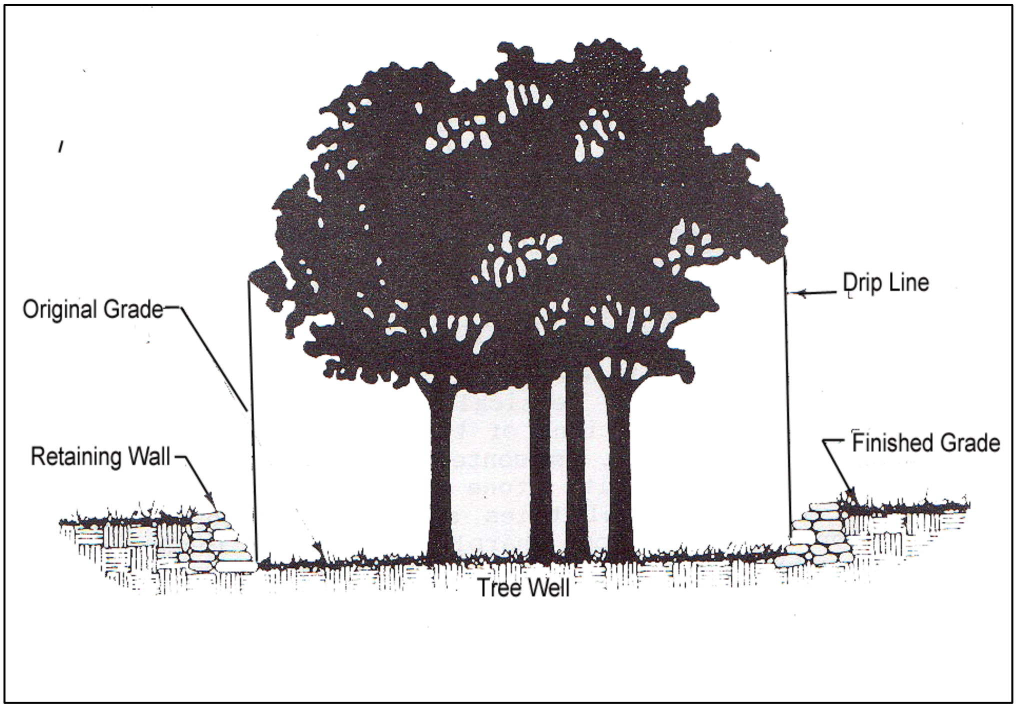


Figure PV- 2 Tree Well

Crushed stone shall be placed inside the dry well over the openings of the radial tiles to prevent clogging. The area between the trunk and the well wall shall either be covered by an iron grate or filled with a 50-50 mixture of crushed charcoal and sand to prevent anyone from falling into the dry well.

Where water drainage through the soil is not a problem, coarse gravel in the fill may be substituted for the tile. This material has sufficient porosity to ensure air drainage. Instead of the vertical tiles or pipes in the system, stones, crushed rock and gravel may be added so that the upper level of these porous materials slants toward the surface in the vicinity below the drip line.

Raising the grade on only one side of a tree or group of trees may be accomplished by constructing only half of one of these systems.

Lowering the Grade

Shrubs and trees shall be protected from the harmful grade cuts by the construction of a tree wall (see Figure PV-4). Following excavation, all tree roots that are exposed and/or damaged shall be trimmed cleanly and covered with moist peat moss, burlap or other suitable material to keep them from drying out.

The wall shall be constructed of large stones, brick, building tile, concrete block or cinder block. The wall should be backfilled with topsoil, peat moss, or other organic matter to retain moisture and aid in root development. Apply fertilizer and water thoroughly. The tree plants should be pruned to reduce the leaf surface in proportion to the amount of root loss. Drainage should be provided through the wall so water will not accumulate behind the wall. Lowering the grade on one side of the tree or group of trees can be accomplished by constructing only half of this system.

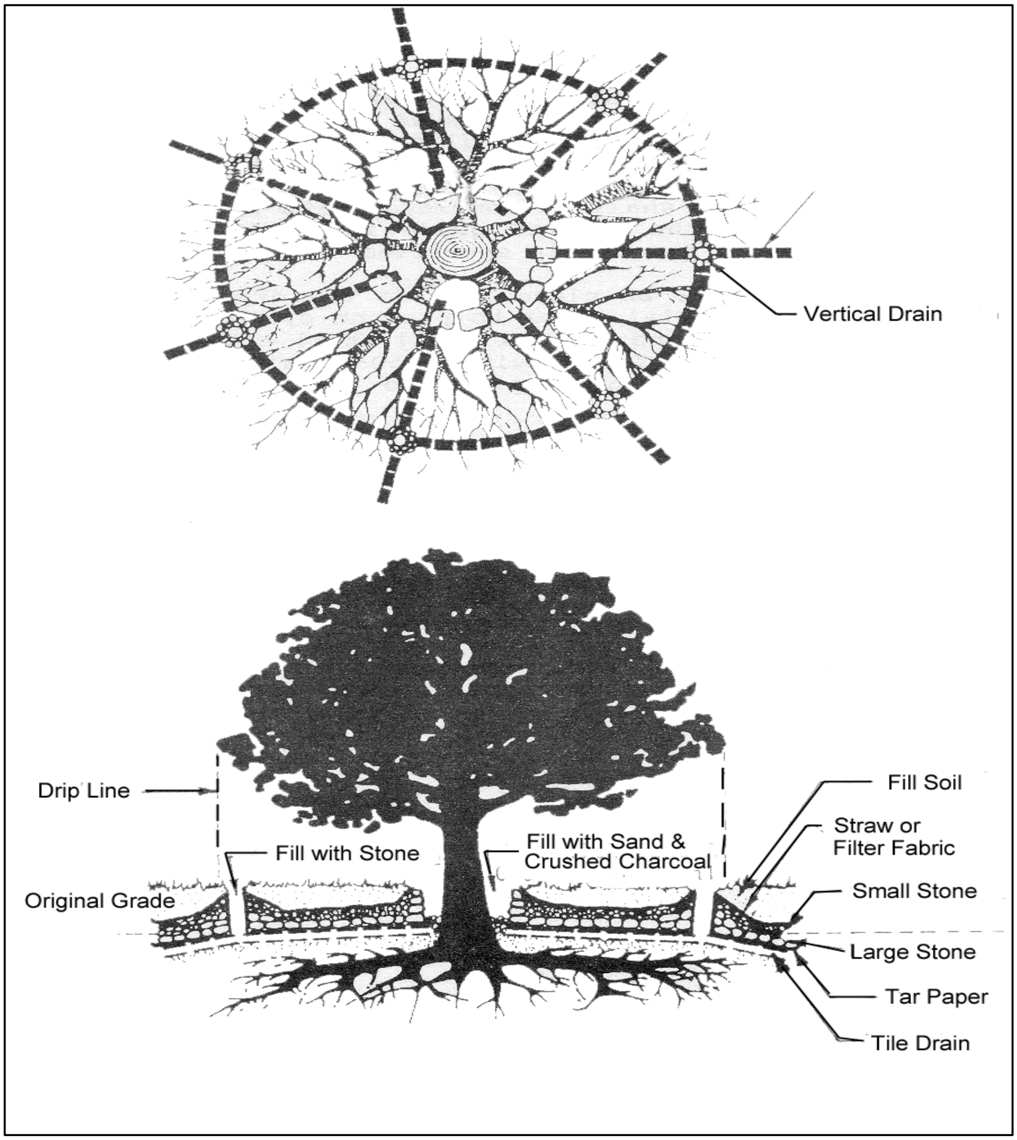


Figure PV- 3 Tree Well Detail

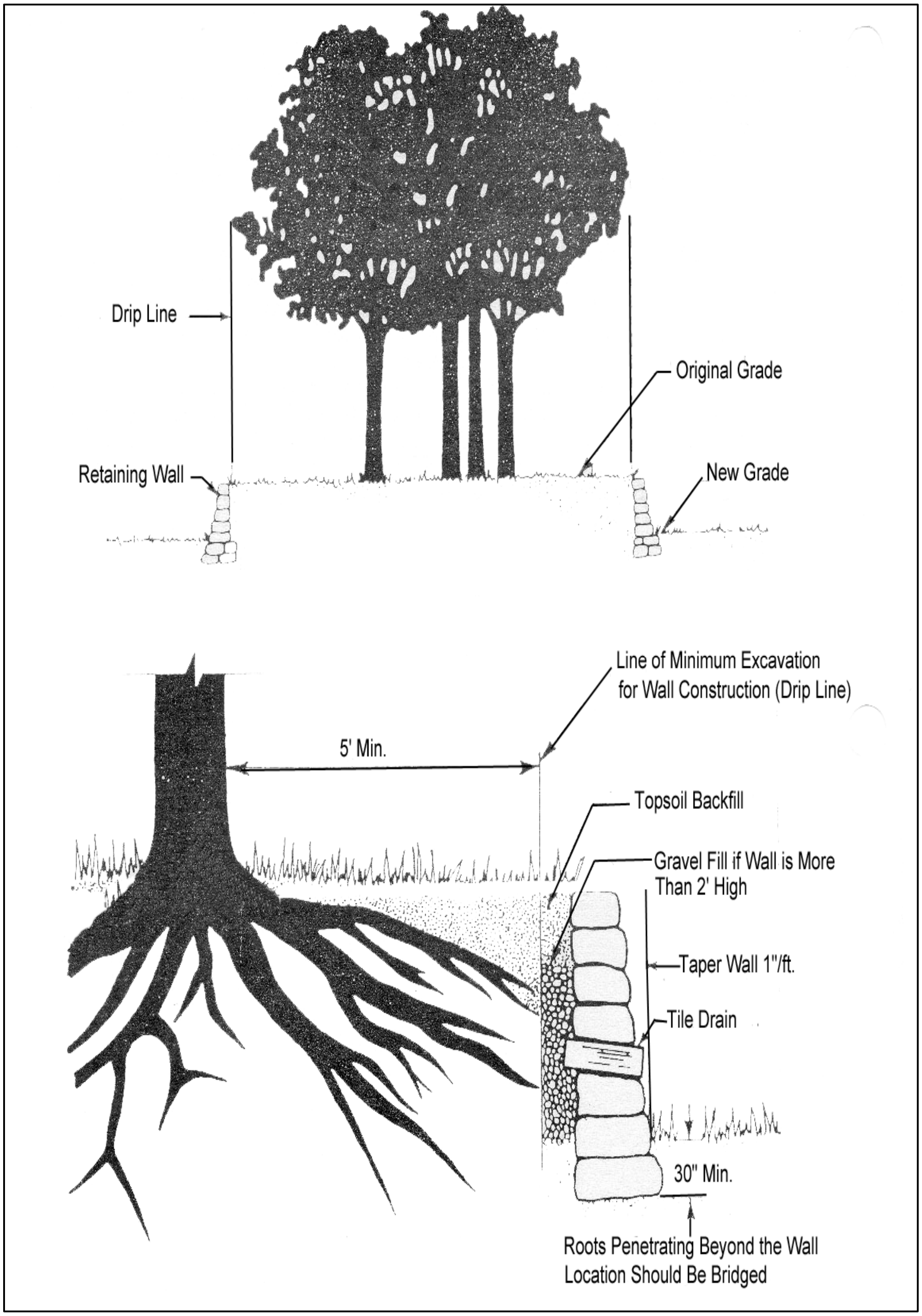


Figure PV- 4 Tree Wall Detail

Trenching and Tunneling

Trenching should be done as far away from the trunks of trees as possible, preferably outside the branches or crown spreads of trees, to reduce the amount of root area damaged or killed by trenching activities. When possible trenches should avoid large roots or root concentrations. This can be accomplished by curving the trench or by tunneling under large roots and areas of heavy root concentration. Tunneling under a species that does not have a large tap root may be preferable to trenching beside it as it has less impact on root systems (see Figure PV-5).

Roots should not be left exposed to the air but should be covered with soil as soon as possible or protected and kept moist with burlap or peat moss until the trench or tunnel can be filled. The ends of damaged and cut roots shall be cut off smoothly and moist peat moss, burlap or topsoil should be placed over the exposed area.

Trenches and tunnels shall be filled as soon as possible. Care should be taken to ensure that air spaces are not left in the soil. Peat moss or other organic matter shall be added to the fill material as an aid to inducing and developing root growth. The tree should be fertilized and mulched to stimulate new root growth and enhance general tree vigor. If a large part of the root system has been damaged the crown leaf surface area should be reduced in proportion to the root damage. This may be accomplished by pruning 20-30 percent of the crown foliage. If the roots are damaged during the winter the crown should be pruned before the next growing season. If roots are cut during the growing season, pruning should be done immediately.

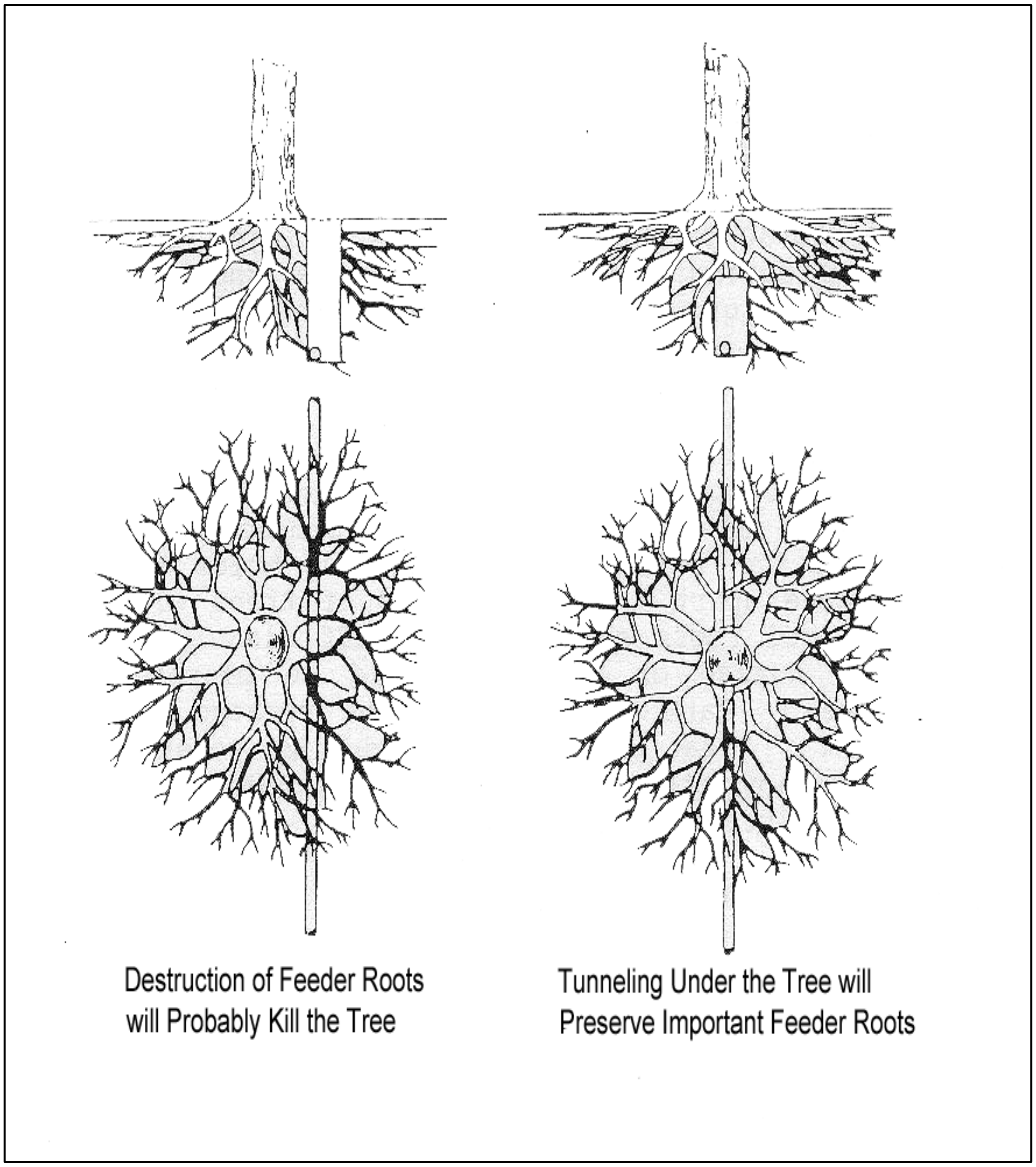


Figure PV- 5 Trenching vs. Tunneling

Treating Damaged Trees

When trees are damaged during construction activities certain maintenance practices can be applied to protect the health of the tree.

Soil aeration may be needed if the soil has been compacted. The soil around trees can be aerated by punching holes 1 foot deep and 18″ apart under the crown of trees with an iron pipe.

Damaged roots should be cut off cleanly and moist peat moss, burlap or topsoil should be placed over the exposed area. Bark damage should be treated by removing loose bark.

Tree limbs damaged during construction or removed for any other reason shall be cut off above the collar at the branch junction.

Trees that have been stressed or damaged should be fertilized to aid their recovery.

Trees should be fertilized in the spring or fall. Fall applications are preferred.

Fertilizer should be applied to the soil over the feeder roots. In no case should it be applied closer than 3 feet to the trunk. Root systems of trees extend some distance beyond the drip line. The area to be fertilized should be increased by ¼ the area of the crown. A soil test is the best way to determine what type of fertilizer to use. In the absence of a soil test, fertilizer should be applied at the rate of 1 to 2 pounds of 10-8-6 or 10-6-4 per inch of dbh for trees under 6″ dbh and at the rate of 2 to 4 pounds of 10-8-6 or 10-6-4 per inch of dbh for trees over 6″ dbh.

A ground cover or organic mulch layer should be maintained around trees to prevent erosion, protect roots and to conserve water.

Verification of Practice

Check to determine that specifications are met as the areas are identified for retention, as the plants are protected during construction and that damaged plants are treated or replaced.

Common Problems

Consult with a qualified design professional if any of the following occur:

Soil compaction appears to be retarding plant growth or affecting plant health.

Damage to plants appears to be severe and life threatening.

Plants appear to be of poor quality and are undesirable for retention.

Problems during construction that require remedial actions:

Erosion – eroded areas should be vegetated to grass or a suitable ground cover.

Severely damaged trees, shrubs or vines should be replaced.

Maintenance

Enhance and maintain plant growth and health according to the maintenance plan. This may involve applying fertilizer, spreading mulch and pruning trees and shrubs.

Replace dead plants as needed to maintain desired landscape cover. Additional information about plantings is found in practices *Permanent Seeding, Shrub, Vine and Groundcover Planting, and Tree Planting on Disturbed Areas*.

References

BMPs from Volume 1

Chapter 4

Retaining Wall (RW)

Practice Description

A retaining wall is a constructed wall used to eliminate steep slopes between areas that have abrupt changes in grade. This practice is used to replace cut or fill slopes in confined areas or where a wall is necessary to achieve stable slopes. A retaining wall can be constructed of reinforced concrete, treated timbers, gabions, reinforced earth (a system of face panels and buried reinforcement strips), and other manufactured products such as interlocking concrete blocks.

Planning Considerations

Retaining walls should be used in conjunction with steep cut or fill slopes, that may be unstable due to steepness, space limitations, or poor soil conditions to stabilize the site. Retaining walls may be used to relieve the need to construct cuts into steep hillsides or on small lots where fill toe-outs or slope cut-outs would go off of the property being developed. Retaining walls may be required to achieve the best or intended use of the property.

Retaining walls can be constructed from the following materials:

- Reinforced concrete
- Concrete cribbing
- Geotextile-wrapped face wall
- Geotextile-reinforced steep slopes
- Modular blocks
- Treated timbers

Each case is different and the type of retaining wall to be used should be selected by a qualified design professional based on the particular site conditions and what best meets the needs of the site. In most cases, treated timber is the least desirable material because of its potential to decay.

Figure 1: Retaining wall made of gabions

Design Criteria and Construction

The design of a retaining wall is or can be a complicated engineering procedure. There are many factors to consider. Each case is different and requires a different set of considerations and a different design.

The qualified design professional should consider the stresses and forces outside and within the wall as well as allowable height and minimum thickness. Other considerations are foundation design with respect to loadings, bearing values of soils and footing dimensions. Additional design factors include safety hazards, drainage aspects and appearance.

Each retaining wall requires a specific engineering design which requires the capabilities of a competent qualified design professional. Retaining walls are engineering structures that affect public property, life and welfare of citizens. Mississippi law which regulates the practice of professional engineering in the State of Mississippi must be followed on structures such as retaining walls. The State Board of Registration for Professional Engineers and Land Surveyors in Jackson is responsible for administering the provisions of the law.

Site Preparation

At least 3 days prior to construction, contact the Mississippi One-Call System, Inc (1-800-227-6477) to identify, locate and mark all underground utilities within the project area. See **Appendix C** for more information about Mississippi One-Call and utility markings.

Clear installation area of debris and obstacles, such as tree and stumps, that might hinder grading and installation of the wall.

Grading

Grade existing embankments according to the design plan to provide a stable slope until construction of the retaining wall is complete.

Grade the top of the embankments according to the design plan to direct stormwater runoff around the area where retaining walls are being constructed.

Installation of Wall

Concrete Wall Installation

The placement of reinforcing steel, the construction of forms, concrete batching, mixing, placement, curing, and finishing should be in accordance with the project specifications and the American Concrete Institute (ACI) standards. The concrete mix quantities, air entrainment, slump, temperature, and compressive strength should be in accordance with the plans for the job.

Compressive strength of the concrete should be verified by laboratory tests on representative cylinders made during concrete placement.

Drains and weep holes should be installed as shown on the design plans.

Modular Block Wall Installation

Prepare a leveling pad of compacted, crushed rock (typically 6″ thick and 18″ wide). Place the first row of modular blocks on the leveling pad (not a footing, as the geosynthetic reinforcement will bear the weight of the block and the backfill). Install additional modular blocks and geosynthetic reinforcement (geogrid or geotextile) according to design plans.

Timber Wall Installation

Timbers should be new pressure-treated (usually 0.6 pcf for ground contact) members having a design life consistent with that of the project and free of splits and deep cracks.

Proper tiebacks are essential to the stability of timber retaining walls. Install tiebacks according to design plans.

Manufactured Products Installation

Specifications for manufactured products should be provided by the manufacturer or in the design plan. Inspect all such materials for damage prior to installation.

Drain Installation

Install drains as specified in the design plans.

Backfill Installation

Backfill for all wall types should be placed carefully in layers not exceeding 8″ (loose) and compacted with hand-operated tampers. The degree of compaction should be provided as specified in the design plans. Before compacting, the soil should be moistened or dried as necessary to obtain the optimum moisture content specified. Backfill should not be placed on surfaces that are muddy, frozen or contain frost or ice.

Backfill for retaining walls built of manufactured products such as reinforced earth or interlocking concrete blocks should be placed according to manufacturer's recommendations. Tiebacks or geosynthetic reinforcements should be placed as specified in the design plans.

Nonwoven geotextile fabric should be used behind timber or modular block walls to help keep soil in place.

Erosion Control

Stabilize all bare areas according to the vegetation plan.

Safety

Steep slopes are subject to collapse and can be a safety hazard to persons in the area. No person should work adjacent to steep slopes without shoring protection or properly sloping the embankment.

Construction Verification

Check finished retaining wall for conformance with design plans and specifications.

Check for cracks or movement of the retaining wall.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate retaining wall will not function as intended.

Seepage is encountered during construction. It may be necessary to install drains.

Poor foundation soils are encountered under the proposed wall location.

Design specifications for concrete, timbers, backfill or other materials cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

High soil and water pressures result in structural failure of the wall—consult qualified design professional and rebuild according to revised plan and specifications.

Maintenance

Inspect retaining walls periodically and after heavy rains for cracks, undercutting of the foundation, piping erosion, wetness or movement.

Repair problems determined during inspections. Repair cracks according to manufacturer's recommendations.

References

The following references may be useful in the application/installation of this practice.

BMPs from Volume 1

Chapter 4

Permanent Seeding (PS) 4-53

Appendices Volume

Appendix C

Mississippi One-Call & 811 Color Coding C-1

Shrub, Vine, and Groundcover Planting (SVG)

GC

Practice Description

Shrub, vine and groundcover planting is the practice of establishing shrubs, vines or groundcover to stabilize soil in areas where establishing grass is difficult and mowing is not feasible. The practice is especially suited for steep slopes where aesthetics are important. Incidental benefits include providing food and shelter for wildlife, windbreaks or screens and improved aesthetics.

Planning Considerations

Shrubs, vines and groundcovers provide alternatives to grasses and legumes as low-maintenance, long-term erosion control. However, they are normally planted only for special, high-value applications, or for aesthetic reasons, because there is additional cost and labor associated with their use.

Very few of these plants can be dependably planted from seed, and none are capable of providing the rapid cover possible with grasses. Consequently, short-term stabilization efforts must involve using dependable mulch along with special cultural practices to ensure establishment.

Shrubs vary in form and differ from most trees in that multiple stems arise from a common base.

Shrubs can be used to attain additional benefits including the following:

- Increase the aesthetic value of plantings
- Provide visual screening and protective barriers
- Enhance windbreaks
- Provide food and cover for wildlife
- Accelerate the transition to a diverse landscape
- Provide post-construction landscaping

Groundcovers differ in growth rate and shade tolerance. Some are suitable only as part of a high-maintenance landscape; others can be used to stabilize large areas with little maintenance.

Competition from volunteer plants inhibits development and maintenance of the groundcover. Thick durable mulch such as shredded bark (not chips) or pine straw can prevent erosion and reduce weed competition.

Mulch is beneficial to plants at most stages of development but is particularly important for new plantings.

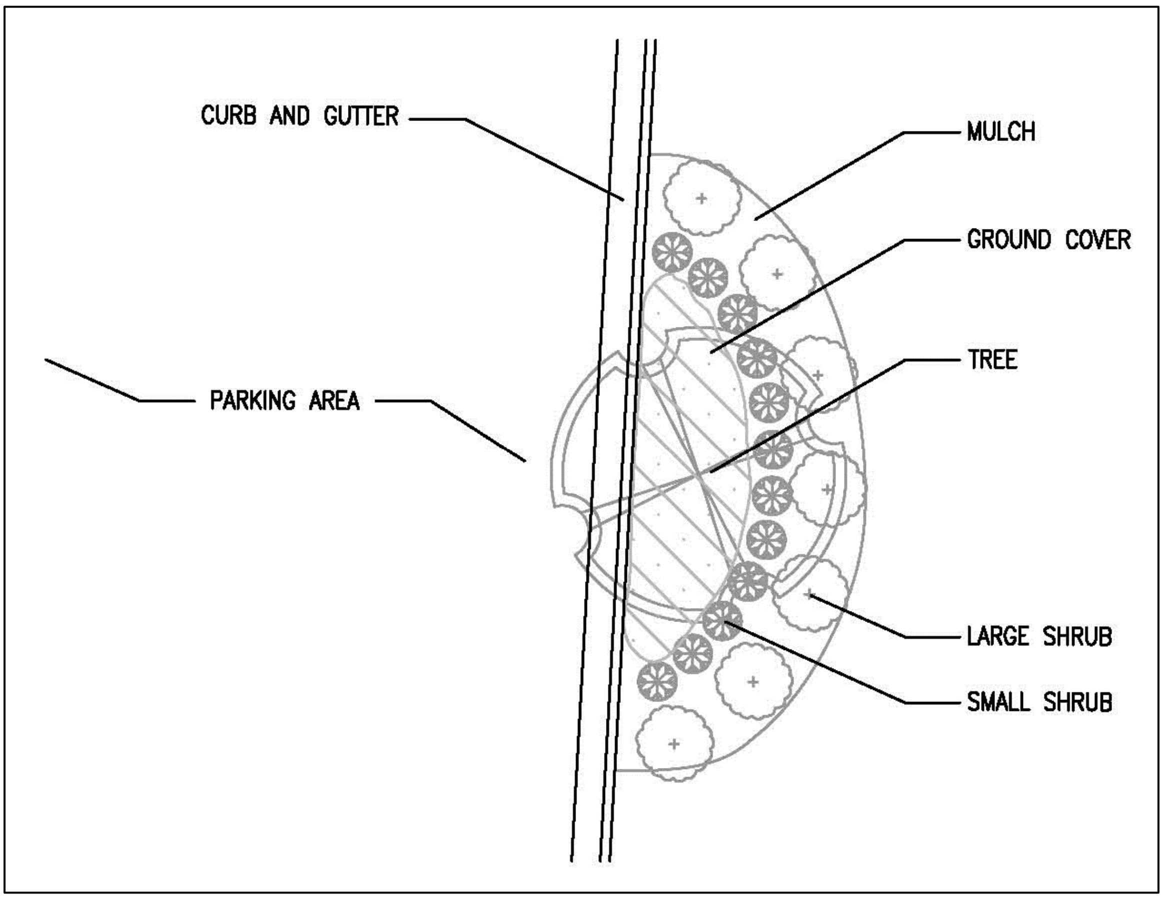


Figure SVG-1 Sample Planting Design Plan

Design Criteria

Plant Selection

Specific characteristics and requirements of recommended species are given in Tables SVG-1 through SVG-5 *Plants Suitable for Shrub, Vine and Groundcover Planting* in Mississippi. Other suitable plants may be identified by qualified design professionals based on plant suitability information including plant adaptation zones (see Figure SVG-2). Exotic invasive species should not be planted!

Site Preparation

Remove debris and other undesirable objects and smooth the area to accommodate the planting and mulching. Sites should be prepared in strips along the contour or at individual spots. Additional preparation will vary according to the type of plant and is discussed later under *Planting*.

On steep slopes, till the soil in contour rows or dig single holes for each plant. Blend the needed lime, fertilizer, and organic material with the soil removed from each hole or furrow. Mix fertilizer thoroughly with the soil before planting, and use it sparingly to avoid burning roots. To eliminate harmful competition from weeds, an appropriate preemergent herbicide may be useful if weeding is not practical.

Soil Amendments

Fertilizer and lime requirements are plant specific and the prescription for a planting should be based on a soil test or a plan prepared by a qualified design professional.

Soils low in organic matter may be improved by incorporating peat, compost, aged sawdust or well-rotted manure.

To eliminate competition from weeds, an appropriate preemergent herbicide may be useful if mechanical weeding is not practical or desired.

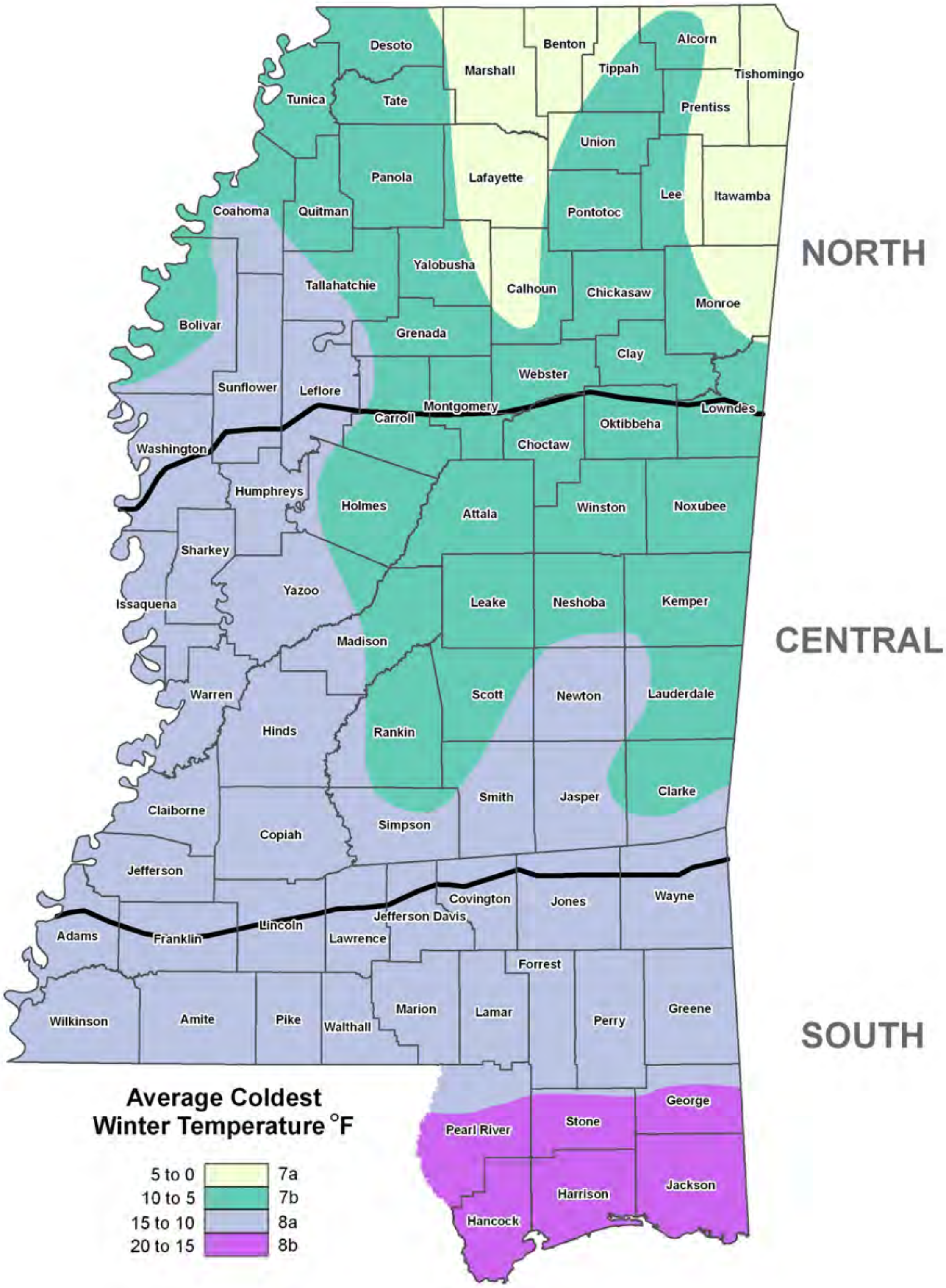


Figure SVG-2 Plant Adaption Zones

Table SVG-1 Plants Suitable for Groundcover Planting in Mississippi

Botanical Name and Common Name	**Size**	**Foliage**	**Exposure**	**Native/ Introduced**
Bugleweed *Ajuga reptans*	3″-6″	Deciduous	Shade	Introduced
Cast iron plant *Aspidistra elatior*	30″-36″	Evergreen	Shade	Introduced
Holly fern *Cyrtomium falcatum*	24″-30″	Evergreen	Shade	Introduced
English ivy *Hedera helix*	30-40 ft.	Evergreen	Shade	Introduced (May be Invasive)
Liriope a.k.a. Lillyturf *Liriope muscari*	12″-18″	Evergreen	Sun/Shade	Introduced
Moneywort *Lysimachia nummularia*	3″-18″	Deciduous	Sun/Part Sun	Introduced
Monkey grass *Ophiopogon japonicus*	6″-8″	Evergreen	Sun/Shade	Introduced
Stonecrop *Sedum acre*	4″-12″	Evergreen	Sun	Introduced
Asian jasmine *Trachelospermum asiaticum*	12″-10’	Evergreen	Sun/Shade	Introduced
Periwinkle *Vinca major*	12″-3’	Evergreen	Part Shade	Introduced (May be Invasive)
Littleleaf periwinkle *Vinca minor*	10″-3’	Evergreen	Part Shade	Introduced (May be Invasive)
Daylily *Hemerocallis spp.*	30″-36″	Evergreen/ Deciduous	Sun	Introduced
Wild ginger *Asarum canadense*	4″-6″	Evergreen	Shade	Native
Confederate jasmine *Trachelospermum jasminoides*	12″-10’	Evergreen	Sun	Introduced
Ardisia *Ardisia crenata*	24″-24″	Evergreen	Shade	Introduced
Japanese ardisia *Ardisia japonica*	10″-10″	Evergreen	Shade	Introduced
Butterfly iris *Bietes vegeta*	24″-24″	Herbaceous	Sun	Introduced
Louisiana iris *Iris spp.*	36″-36″	Evergreen	Sun	Introduced
Indigo *Indigofera kirilowii*	24″-24″	Deciduous	Part Shade	Introduced

Table SVG-2 Plants Suitable for Vine Planting in Mississippi

Botanical Name and Common Name	**Size**	**Foliage**	**Exposure**	**Support Needed**	**Native / Introduced**
Coral vine *Antigonon leptopus*	Grows to 40’	Deciduous	Sun/Part sun	Yes	Introduced
Crossvine *Bignonia capreolatar*	Grows to 60’	Evergreen	Sun/Shade	No	Native
Trumpet creeper *Campsis radicans*	Grows to 30’	Deciduous	Sun/part sun	No	Native
Autumn clematis *Clematis paniculata*	Grows to 30’	Deciduous	Sun	Yes	Introduced
Yellow jessamine *Gelsemium sempervirens*	Grows to 25’	Evergreen	Sun/Part sun	Yes	Native
Climbing hydrangea *Hydrangea petiolaris*	Grows to 50’	Deciduous	Sun/Part Shade	No	Native
Coral honeysuckle *Lonicera sempervirens*	Grows to 20’	Evergreen	Sun/ Part shade	Yes	Native
Lady banks’ rose *Rosa banksiae*	Grows to 20’	Evergreen	Sun	Yes	Introduced
Confederate jasmine *Trachelospermum jasminoides*	Grows to 25’	Evergreen	Sun/Part sun	Yes	Introduced
Virginia creeper *Parthenocissus quinquefolia*	Grows to 40’	Deciduous	Sun/Shade	No	Native
Muscadine grape *Vitis rotundifolia*	Grows to 30’	Deciduous	Sun/Part sun	Yes	Native
American wisteria *Wisteria frutescens*	Grows to 30’	Deciduous	Sun/Part sun	Yes	Native (very aggressive)
Dutchman’s pipe *Aristolochia macrophylla*	Grows to 30’	Deciduous	Shade	Yes	Native
Passion flower *Passiflora incarnate*	Grows to 20’	Deciduous	Sun/Part sun	Yes	Native

Table SVG-3 Plants Suitable for Small Shrub Planting in Mississippi

Botanical Name and Common Name	**Normal Height**	**Foliage**	**Exposure**
Callicarpa Americana American Beautyberry	4-6 ft.	Deciduous	Part Shade
Calycanthus floridus Sweetshrub	6-10 ft.	Deciduous	Full Sun to Shade
Clethra alnifolia Summersweet	2-4 ft.	Deciduous	Full Sun to Part Sun
Fothergilla major Witch Alder	6-10 ft.	Deciduous	Full Sun to Part Sun
Gaylussacia dumosa Dwarf Huckleberry	4-6 ft.	Deciduous	Full Sun to Part Sun
Hydrangea quercifolia Oakleaf Hydrangea	6 ft.	Deciduous	Part Sun to Shade
Illicium floridanum Star Anise	8 ft.	Evergreen	Shade to Part Sun
Itea Virginica Virginia Sweetspire	3-6 ft.	Deciduous	Full Sun to Part Sun
Leucothoe axillaris Leucothoe	3 ft.	Evergreen	Full Sun to Part Sun
Lyonia lucida Lyonia	3 ft.	Evergreen	Part Sun to Shade
Sabal minor Dwarf Palmetto	6 ft.	Evergreen	Full Sun to Part Sun
Viburnum dentatum Arrow-wood Virburnum	5-9 ft.	Deciduous	Full Sun to Part Sun

Table SVG-4 Plants Suitable for Medium Shrub Planting in Mississippi

Botanical Name and Common Name	Normal Height	Foliage	Exposure
Aesculus pavia Red Buckeye	10 ft.	Deciduous	Full Sun to Part Shade
Baccharis halimifolia Groundsel Bush	12 ft.	Evergreen	Part Shade
Cephalanthus occidentalis Buttonbush	10 ft.	Deciduous	Full Sun to Part Sun (needs a lot of water)
Ilex verticillata Winterberry Holly	6-10 ft.	Deciduous	Full Sun to Part Sun
Rhododendron austrinum Yellow Native Azalea	12 ft.	Deciduous	Part Sun to Shade
Rhododendron canescens Honeysuckle Azalea	12 ft.	Deciduous	Part Sun to Shade
Styrax americana Snowbell	10 ft.	Deciduous	Full Sun to Part Sun
Vaccinium elliottii Elliott's Blueberry	12 ft.	Deciduous	Full Sun to Part Sun

Table SVG-5   Plants Suitable for Large Shrub Planting in Mississippi

Botanical Name and Common Name	**Normal Height**	**Foliage**	**Exposure**
Alnus serrulata Tag Alder	15 ft.	Deciduous	Sun to shade
Chionanthus virginicus Fringe Tree	20 ft.	Deciduous	Full Sun to Part Sun
Cliftonia monophylla Buckwheat Tree	6-12 ft.	Evergreen	Full Sun to Part Sun
Hamamelis virginiana Witch Hazel	8-20 ft.	Deciduous	Full Sun to Shade
Ilex coriacea Bigleaf Gallberry Holly	15 ft.	Evergreen	Full Sun to Part Sun
Kalmia latifolia Mountain Laurel	5-10 ft.	Evergreen	Full Sun to Part Sun
Osmanthus americanus American Sweet Olive	20 ft.	Evergreen	Full Sun to Part Sun
Rhododendron serrulatum Summer Azalea	15 ft.	Deciduous	Part Sun to Shade
Rhus typhina Staghorn Sumac	20 ft.	Deciduous	Full Sun to Part Sun
Vaccinium arboretum Tree Huckleberry	20 ft.	Evergreen	Full Sun to Part Sun

Table SVG-6 Plants Suitable for Ornamental Grass Planting in Mississippi

Botanical Name and Common Name	Height and Spread	Exposure
Andropogon virginicus Broomsedge	2-3 ft. / 1-2 ft.	Sun to Part Sun
Carex sp. Carex	1-1.5 ft. / 1.5 ft.	Sun to Shade
Pennisetum alopecuroides Fountain Grass	3 ft. / 4 ft.	Full Sun
Miscanthus sinensis Miscanthus (maiden grass)	4-7 ft. / 4-5 ft.	Full Sun to Part Sun
Cortaderia selloana Pampass Grass (Not reliable in North MS)	12 ft. / 6 ft.	Full Sun to Light Shade
Chasmanthium latifolium River Oats	2-5 ft. / 2-3 ft.	Full Sun to Partial Shade
Phalaris arundinacea Variegated Ribbon Grass	3-4 ft. / 4 ft.	Full to Partial Sun

Planting

In the absence of a site-specific planting plan consider the following guidelines.

Shrubs

Late winter (before leaves emerge) is the best time for planting deciduous shrubs and early fall is the best for evergreens. Shrubs grown and marketed in containers can be planted anytime during the year except when the ground is frozen.

Individual Shrubs with Root Ball

Provide a relatively large area for initial root development. The hole should be dug to a depth that allows the root ball to extend 1″ above the soil surface. The top diameter of the hole should be as big around as 2-3 times the diameter of the root ball. As soil is added the hole should be filled with water to moisten the soil until the filling of the hole is complete.

Shrubs in Prepared Beds

Till or spade a bed to a depth of 8″ to 12″. Contrary to the individual planting, soil amendments, such as peat or compost at a rate of 1 part amendment to 3 parts native soil, are beneficial to shrubs because they provide a uniform root environment across the bed area. Organic soil amendments enable plants to respond positively to water and fertilizers when they are applied. The hole for the shrub planted in a bed area should be a few inches wider in diameter than the root ball.

Plants in Containers

Remove container plants from their containers, cutting the container if necessary. If the plant is root-bound (roots circling the outside of the root ball), score the root-ball from top to bottom about 4 times, cutting about ¼ ″ deep with a knife, or gently massage the root ball until roots point outward. Place the shrub into the hole. Using only the native backfill, add soil back to the hole until it is ½ to ⅔ full. Water in the backfill soil around the root ball. Add soil to ground level and thoroughly water again. A small dike may be formed around the edge of the planting hole to hold water around the root ball if the plant is in sandy soils or on slopes. *Caution: in a dense clay soil, trapping additional water in the root zone can be detrimental because water drains poorly and creates an extended period of wetness.*

Bare Root Plants

Soak bare root plants in water. When planting, spread the roots in the hole and gradually add soil. Firm the soil, being careful to avoid breaking roots. Fill the hole with water, and allow it to drain. Then fill the hole with soil, and water again thoroughly.

Burlapped Plants

Cut any wire or string that is around plants stems. Do not remove the burlap. Fold the burlap back so it will be buried by soil. Burlap which is allowed to remain exposed after planting can act as a wick, causing the root ball to dry out. Follow the same procedure for filling the hole as that described for container plants.

Vine and Groundcovers

Most groundcovers are planted from container-grown nursery stock. Planting density determines how quickly full cover is achieved; a 1 foot spacing is often used for rapid cover. Large plants such as junipers can be spaced on 3 foot centers. Transplanting to the prepared seedbed can be done using a small trowel or a spade. Make a hole large enough to accommodate the roots and soil. Backfill and firm the soil around the plant, water immediately, and keep well watered until established. Water slowly and over longer periods to allow for infiltration and reduce runoff.

When to plant

Late winter (before leaves emerge) is the best time for planting deciduous shrubs and early fall is the best for evergreen shrubs. Assuming the plants are well-watered during the summer, shrubs grown in containers can be planted anytime during the year except when the ground is frozen.

Vines and groundcovers are best planted in early fall or early spring.

Mulching

Once plants are installed, add mulch. On steep slopes or highly erodible soils, install erosion control netting or matting prior to planting, and tuck plants into the soil through slits in the net. Plant in a staggered pattern (see *Mulching Practice* for more details on mulching).

Watering

Shrubs

Water shrubs immediately after planting and keep well watered for the first few weeks. Apply water weekly if rainfall does not supply 1″ of water per week. Be conscious of plants that have been in the ground for less than 1 year and water them regularly and thoroughly during extended dry periods.

Vines and Groundcover

Water vines and groundcover immediately after planting and keep well watered until established. Vines and groundcover need about an inch of water a week for the first 2 years after planting.

Verification of Practice

Check all components of the practice during installation to ensure that specifications are being met.

Common Problems

Consult with a qualified design professional if any of the following occur:

Soil compaction at planting time appears so significant that it will prevent adequate plant growth. Compaction should be addressed during site preparation.

Design specifications for plants (species, variety, planting dates) and mulch cannot be met. Unapproved substitutions could lead to failure.

Problems that require remedial actions:

Erosion, washout and poor plant establishment – repair eroded surface, replant, reapply mulch and anchor.

Mulch is lost to wind or stormwater runoffs – reapply mulch and anchor.

Maintenance

Replant shrubs, vines or groundcovers where needed to maintain adequate cover for erosion control. Repair eroded surfaces by reapplying the previous treatment and determine if an additional practice is needed, i.e. installing erosion netting. Maintain shrubs, vines and ground covers with applications of fertilizer and mulching. Reapply mulch that is lost to wind, stormwater runoff or decomposition.

Shrubs, vines and groundcovers need about an inch of water a week for the first 2 years after planting. When rain does not supply this need, shrubs should be watered deeply not less than once a week.

Fertilization needs should be determined by a professional because different plants have different needs. In the absence of a recommendation from a landscape professional, a soil test is the best way to determine what nutrient elements are needed. Fertilizer formulations of 12-4-8 or 15-0-15 can be used in the absence of a soil test. Apply 2 lbs of fertilizer per 1000 ft^2 of area.

References

Volume 1

Chapter 2

Vegetation for Erosion and Sediment Control 2-10

Chapter 4

Land Grading (LG) 4-16
Topsoiling (TSG) 4-20
Mulching (MU) 4-48
Permanent Seeding (PS) 4-53
Temporary Seeding (TS) 4-103

Appendices Volume

Appendix G

MDOT Vegetation Schedule G-1

Sodding (SOD)

S

Practice Description

Sodding is the use of a transplanted vegetative cover to provide immediate erosion control in disturbed areas. Sodding is well suited for stabilizing erodible areas such as grass-lined channels, slopes around storm drain inlets and outlets, diversions, swales, and slopes and filter strips that cannot be established by seed or that need immediate cover.

Planning Considerations

Advantages of sod include immediate erosion control, nearly year-round establishment capability, less chance of failure than with seeding, and rapid stabilization of surfaces for traffic areas, channel linings, or critical areas.

Initially it is more costly to install sod than to plant seed; however, the higher cost may be justified for specific situations where sod performs better than a seeded cover. Sodding may be more cost-efficient in the long term.

Sod can be laid during the times of the year when seeded grasses may fail, provided there is adequate water available for irrigation in the early establishment period. Irrigation is essential at all times of the year to establish sod.

Sod placed around drop inlets can prevent erosion around the inlet and help maintain the necessary grade around the inlet.

The site to be sodded should be prepared for the sod before it is delivered so that the sod can be installed immediately. Leaving sod stacked or rolled can cause severe damage and loss of plant material.

Design Criteria and Installation

Prior to start of installation, design and installation guidelines should be specified by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the installation process.

Sod Selection

The species of sod selected should be adapted to both the site and the intended purpose. Species used in Mississippi include Bermuda, zoysia, centipede, St. Augustine, fescue, and Rye grass. Species selection is primarily determined by region, availability, and intended use. Use Tables SOD-l and SOD-2 and Figure SOD-1 for guidance in selecting and maintaining sod.

Table SOD-1 Grasses Adapted for Sodding in Mississippi

Species	Variety	Applications
Warm Season Grasses		
Bermuda Grass	La Prima, Yukon	Full Sun
Centipede	No Improved Varieties	Mostly Sunny to Full Sun
Zoysia	Zenith, Compadre	Mostly Sunny to Full Sun
St. Augustine	Bitterblue, Raleigh, Common	Partial Sun, Wet Areas
Cool Season Grasses		
Fescue – Turf Type	Combat Extreme	Partial Sun
Rye Grass	OSP Ryegrass	Winter Overseed

Surface Preparation

Prior to laying sod, clear the soil surface of trash, debris, roots, branches, stones, and clods larger than 2″ in diameter. Fill or level low spots in order to avoid standing water. Rake or harrow the site to achieve a smooth and mowable final grade. Apply appropriate soil amendments prior to final disking. Complete soil preparation by disking, chiseling or other appropriate means and then rolling or cultipacking to firm the soil. Limit the of heavy equipment on the area to be sodded, particularly when the soil is wet, as this may cause excessive compaction and make it difficult for the sod to penetrate the soil and develop the root system that it should attain.

Table SOD-2 Adaptation and Maintenance of Grasses Used for Sodding

Cool Season Grasses	Leaf Texture	Establish Rate	Nitrogen Use	Water Use	Drought Tolerance	Salinity Tolerance	Shade Tolerance	Fertility Needs	Wear Resistance	Mowing Height	Cold Tolerance	Acid Soil Tolerance	Thatching Tendency	Heat Tolerance
Bentgrass - Creeping	Fine	Moderate to Fast	Low to Moderate	High	Poor to Moderate	High	Poor to Moderate	High	Low	Low	Low	Medium to High	High	High
Bentgrass - Colonial	Fine	Moderate to Fast	Low	Moderate	Poor to Moderate	Moderate	Moderate	High	Low	Low	Low	Medium to High	High	High
Bluegrass - Kentucky	Moderate to Fine	Slow	Moderate to High	Moderate to High	Good	Moderate	Poor	Medium	Medium to High	Medium	High	Medium	Medium	Medium
Bluegrass - Rough	Moderate to Fine	Slow	Moderate to High	Moderate to High	Poor	Moderate	Excellent	Medium	Medium	Medium	High	Medium	Medium	Medium
Fescue - Chewings	Fine	Moderate	Moderate to Low	Moderate	Good to Excellent	Low	Excellent	Low	Low	Medium	Medium to High	Medium to High	Low to Medium	Low to Medium
Fescue - Hard	Fine	Slow to Moderate	Low to very Low	Moderate	Excellent	Low to Moderate	Excellent	Low	Low	Medium	Medium to High	Medium to High	Low to Medium	Low to Medium
Fescue - Creeping	Fine	Moderate	Low to Moderate	Moderate	Good	Low	Excellent	Low	Low	Medium	High	Medium to High	Low to Medium	Low to Medium
Fescue - Turf Type	Moderate to Coarse	Moderate	Moderate to High	Low to Moderate	Excellent	Low	Good to Excellent	Low to Medium	Medium to High	Medium to High	Medium	High	Low	High
Rye Grass - Perennial	Fine to Moderate	Very Fast	Moderate to High	Moderate to High	Good	Poor to Moderate	Poor to Moderate	Medium	Low to Medium	Low to Medium	Medium	Medium	Low	Medium to High
Warm Grasses	**Leaf Texture**	**Establish Rate**	**Nitrogen Use**	**Water Use**	**Drought Tolerance**	**Salinity Tolerance**	**Shade Tolerance**	**Fertility Needs**	**Wear Resistance**	**Mowing Height**	**Cold Tolerance**	**Acid Soil Tolerance**	**Thatching Tendency**	**Heat Tolerance**
Bahiagrass	Coarse to very Coarse	Slow to Moderate	Low	Low	Excellent	Excellent	Moderate to Good	Low	Medium to High	High	Low	Low	Medium to High	High
Bermudagrass	Fine to Moderate	Moderate to Fast	Moderate	Moderate to High	Excellent	Very Good	Poor	Medium	High	Low to Medium	Low to Medium	Medium	Medium	High
Blue Grama	Fine to Moderate	Slow to Moderate	Low	Low	Excellent	Moderate	Very Poor	Low	Low	High	High	Low	Low	High
Buffalograss	Moderate to Coarse	Slow to Moderate	Low	Low	Excellent	Moderate	Very Poor	Low	Low	High	High	Low	Low	High
St. Augustine Grass	Coarse	Moderate to Fast	Low	High	Low	Low	Excellent	Low	Medium to High	Low	Medium to High	Medium to High	High	Low
Centipedegrass	Moderate to Coarse	Slow	Low	Low	Good	Moderate	Moderate to Good	Low	Low	Medium to High	Medium to High	High	Medium	High
Seashore Paspalum	Moderate	Moderate	Moderate	Moderate	Excellent	Excellent	Good	Medium to High	Medium to High	Low	Medium	Low	Medium to High	High
Zoysia grass	Fine to Medium	Slow to Moderate	Moderate	Moderate	Excellent	Good	Moderate to Good	Low to Medium	Medium to High	Low to Medium	High	Low to Medium	Medium to High	High

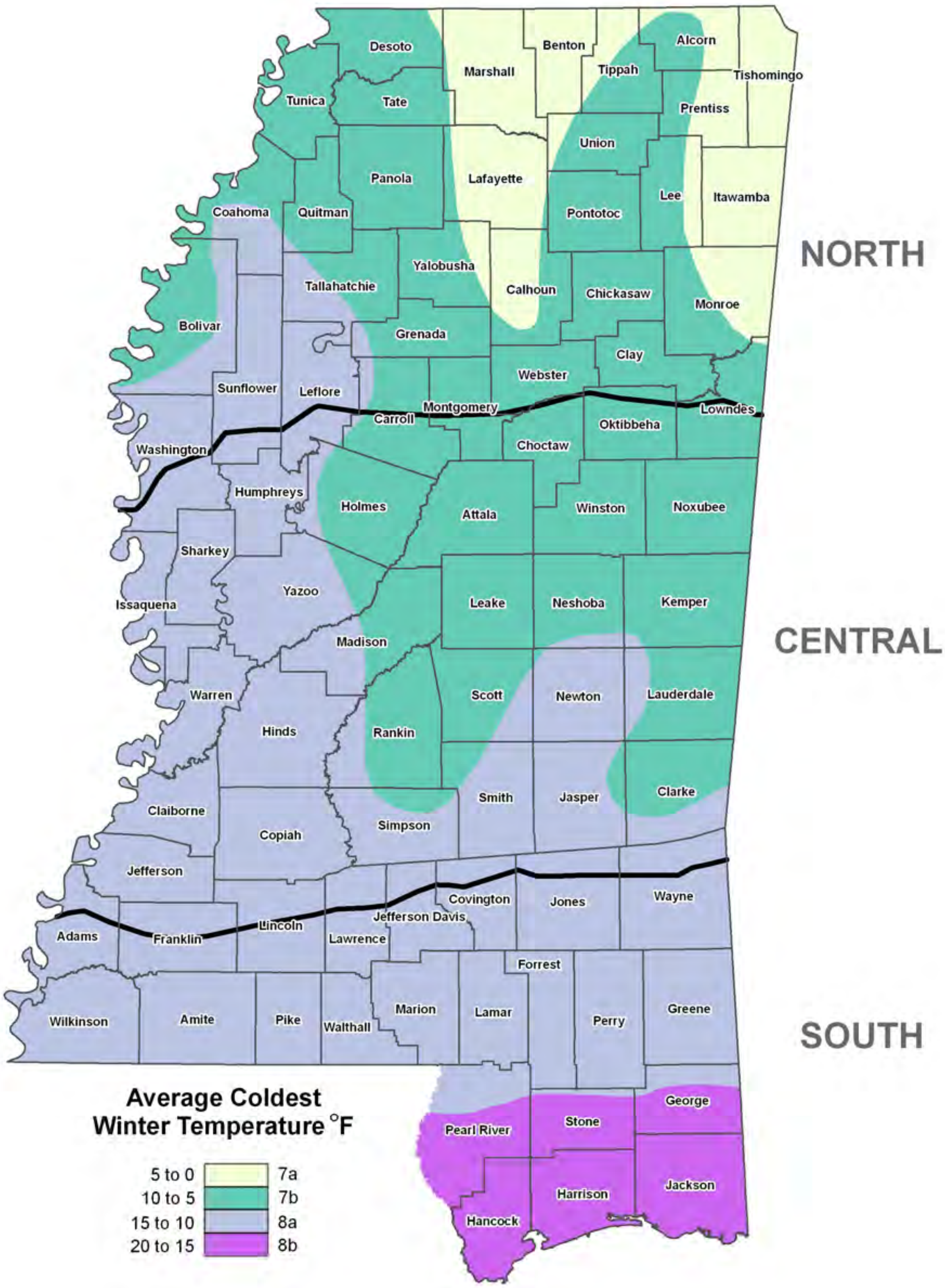


Figure SOD-1 Geographical Areas for Species Adaptation

Soil Amendments

Test soil to determine the requirements for lime and fertilizer. Soil tests may be conducted by Mississippi State University Extension Service Soil Testing Laboratory or other laboratories that make recommendations based on soil analysis. When soil test recommendations are unavailable, the following soil amendments may be sufficient:

- Agricultural limestone at a rate of 2 tons per acres (90lbs per 1000 sq. ft.). Other liming materials that may be selected should be provided in amounts that provide equal value to agricultural lime.

- Fertilizer at a rate of 1000 lbs per acre (25 lbs per 1000 sq. ft.) of 10-10-10.

- Equivalent nutrients may be applied with other fertilizer formulations. The soil amendments should be spread evenly over the treatment area and incorporated into the top 6″ of soil by disking, chiseling or other effective, means. If topsoil is applied, follow specifications given in the *Topsoiling Practice*. Minor surface smoothing may be necessary after incorporation of soil amendments.

Installing the Sod

A step-by-step procedure for installing sod is illustrated in Figure SOD-2 and described below.

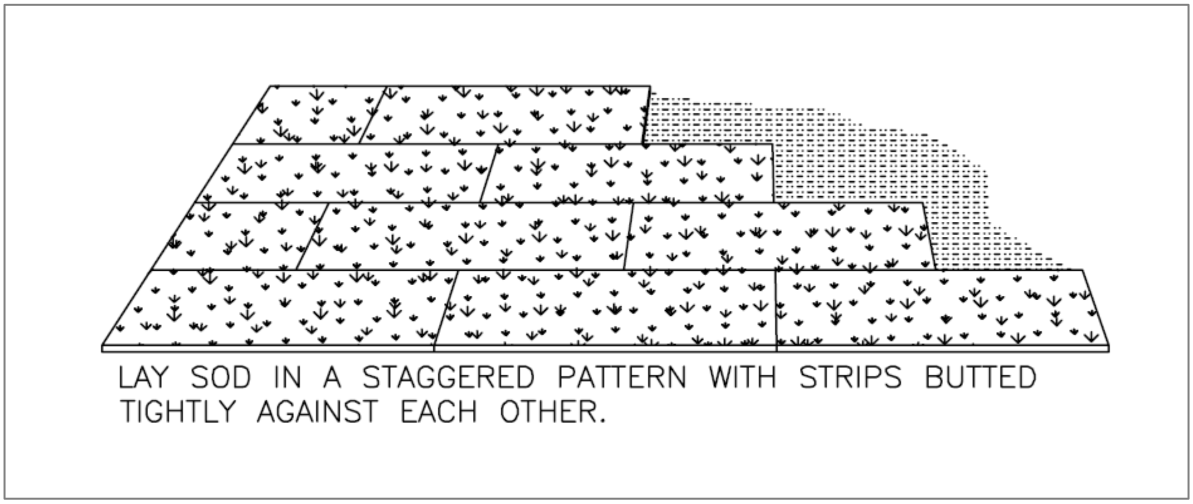


Figure SOD-2 Typical Installation of Grass Sod

Moistening the sod after it is unrolled helps maintain its viability. Store it in the shade during installation.

Rake the soil surface to break the crust just before laying sod. During the summer, lightly irrigate the soil, immediately before laying the sod to cool the soil and reduce root burning and dieback.

Do not lay sod on gravel, frozen soils, or soils that have been recently sterilized or treated with herbicides.

Lay the first row of sod in a straight line with subsequent rows placed parallel to and butting tightly against each other. Stagger strips in a brick-like pattern. (see Figure SOD – 2). Be sure that the sod is not stretched or overlapped and that all joints are butted tightly to prevent voids. Use a knife or sharp spade to trim and fit irregularly shaped areas.

Install strips of sod with their longest dimension perpendicular to the slope/waterflow direction. On slopes 3:1 or greater, in grass swales or wherever erosion may be a problem, secure sod with pegs or staples. Jute or other netting material may be pegged over the sod for extra protection on critical areas (see Figure SOD – 3).

As sodding of clearly defined areas is completed, use a weighted roller on the sod to provide firm contact between roots and soil.

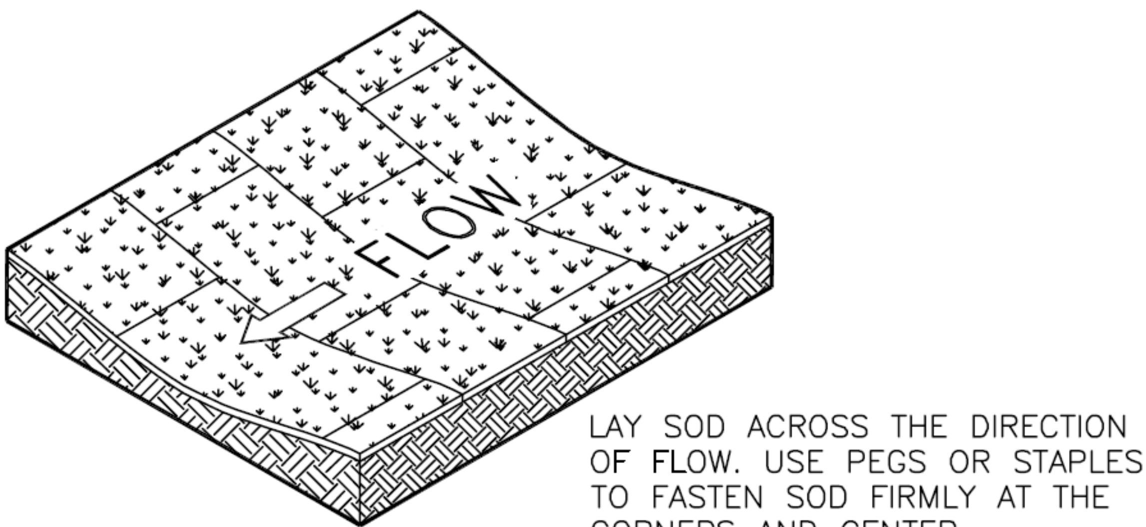


Figure SOD-3 Installation of Sod in Areas with Channel Flows

Irrigation

Immediately after laying the sod, roll or tamp it to provide firm contact between roots and soil, then irrigate sod deeply so that the underside of the sod pad and the soil 6″ below the sod is thoroughly wet.

Keep sodden areas moist to a depth of 4″ until the grass takes root. This can be determined by gently tugging on the sod. Resistance indicates that rooting has occurred.

Mowing should not be attempted until the sod is firmly rooted, usually in 2 to 3 weeks.

Construction Verification

Check materials and installation for compliance with specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate the sodding materials will not function as intended; changes in plan may be needed.

Design specifications for sod variety cannot be met or irrigation is not possible; substitution or seeding may be required. Unapproved substitutions could result in erosion or sodding failure.

Sod laid on poorly prepared soil or unsuitable surface and grass dies because it is unable to develop a root system with the soil: remove dead sod, prepare surface properly and resod.

Sod not adequately irrigated after installation; may cause root dieback or grass does not root rapidly and is subject to drying out: irrigate sod and underlying soil to a depth of 4″ and keep moist until roots are established.

Sod not anchored properly may be loosened by runoff: use guidance under Site Preparation to repair the damaged areas, lay healthy sod, anchor properly and irrigate as planned.

Slow growth due to lack of nitrogen: apply additional fertilizer.

Maintenance

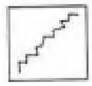
- See Table SOD-2 for maintenance guidelines for sod.
- Keep sod moist until it is fully rooted.
- Mow to a height of 2″ to 3″ after sod is well-rooted, in 2 to 3 weeks. Do not remove more than ⅓ of the leaf blade in any mowing.
- Permanent, fine turf areas require yearly fertilization. Fertilize warm-season grass in late spring to early summer; cool-season grass in early fall and late winter.

References

BMPs from Volume 1

Land Grading (LG) 4-16

Surface Roughening (SR)



Practice Description

Roughening a sloping bare soil surface with horizontal depressions helps control erosion by aiding the establishment of vegetative cover with seed, reducing runoff velocity, and increasing infiltration. The depressions also trap sediment on the face of the slope. This practice is especially appropriate for soils that are frequently disturbed and on piles of excavated soils.

Roughening methods include stair-step grading, grooving and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used. The final face of the slopes should not be bladed or scraped to give a smooth hard finish.

Planning Considerations

Surface roughening should be considered for all slopes. The amount of roughening required depends on the steepness of the slope and the type of soil. Stable sloping rocky faces may not require roughening or stabilization, while erodible slopes steeper than 3:1 require special surface roughening.

Design Criteria and Installation

Surface roughening is to be done only after cuts and fill are to final grade and shape.

Cut Slope Roughening (Areas not to be mowed)

Use stair-step grades or groove cut slopes with a gradient steeper than 3:1. Use stair-step grading on any erodible material soft enough to be ripped with a bulldozer. Do not make individual vertical cuts more than 2 feet in soft materials or more than 3 feet in rocky materials.

Grooving

Grooving uses machinery to create a series of ridges and depressions that run across the slope (on the contour). Groove using any appropriate implement that can be safely operated on the slope, such as disks, tillers, spring harrows, or the teeth on a front-end loader bucket. Do not make such grooves less than 3 inches deep nor more than 15 inches apart.

Fill Slope Roughening (Areas not to be mowed)

Place fill slopes with a gradient steeper than 3:1 in lifts not to exceed 9 inches, and make sure each lift is properly compacted. Insure that the face of the slope consists of loose, uncompacted fill 4 to 6 inches deep. Use grooving, as described above, to roughen the face of the slopes, if necessary. Do not blade or scrape the final slopes face.

Cuts, Fills, and Graded Areas That Will Be Mowed

Make mowed slopes no steeper than 3:1. Roughen these areas to shallow grooves by normal tilling, dishing, harrowing, or use of cultipacker-seeder. Make the final pass of any such tillage implement on the contour. Make grooves formed by such implements close together (less than 10 inches) and not less than 1 inch deep. Excessive roughness is undesirable where moving is planned.

Roughening with Tracked Machinery

Limit roughening with tracked machinery to sandy soils to avoid undue compacting of the soil surface. Tracking is generally not as effective as other roughening methods described. Operate tracked machinery up and down the slopes to leave horizontal depressions in the soil. Do not back-blade during the final grading operation.

Seeding

Immediately seed and mulch roughened areas to obtain optimum seed germination and growth.

Figure 3 Rill Erosion

Common Problems

Tracking in the wrong direction, perpendicular to the slope, can accelerate rill erosion.

Maintenance

Inspect roughened areas after storms to see if re-roughening is needed. Regular inspection should indicate where additional erosion and sediment-control measures are needed. If rills appear, fill, regrade, and reseed them immediately. Use proper *Dust Control* methods.

References

BMPs from Volume 1

Temporary Seeding (TS)

TS

Practice Description

Temporary seeding is the establishment of fast-growing annual vegetation from seed on disturbed areas. Temporary vegetation provides economical erosion control for up to a year and reduces the amount of sediment moving off the site.

This practice applies where short-lived vegetation can be established before final grading or in a season not suitable for planting the desired permanent species. It helps prevent costly maintenance operations on other practices such as sediment basins and sediment barriers. In addition, it reduces problems of mud and dust production from bare soil surfaces during construction. Temporary or permanent seeding is necessary to protect earthen structures such as dikes, diversions, grass-lined channels and the banks and dams of sediment basins.

Planning Considerations

Temporary vegetative cover can provide significant short-term erosion and sediment reduction before establishing perennial vegetation.

Temporary vegetation will reduce the amount of maintenance associated with sediment basins.

Temporary vegetation is used to provide cover for no more than 1 year. Permanent vegetation should be established at the proper planting time for permanent vegetative cover.

Certain plants species used for temporary vegetation will produce large quantities of residue which can provide mulch for establishment of the permanent vegetation.

Proper seedbed preparation and selection of appropriate species are important with this practice. Failure to follow establishment guidelines and recommendations carefully may result in an inadequate or short-lived stand of vegetation that will not control erosion.

The selection of plants for temporary vegetation must be site specific. Factors that should be considered are types of soils, climate, establishment rates, and management requirements of the vegetation. Other factors that may be important are wear, mowing tolerance, and salt tolerance of vegetation.

Seeding properly carried out within the optimum dates has a higher probability of success. It is also possible to have satisfactory establishment when seeding outside these dates. However, as plantings are deviated from the optimum dates, the probability of failure increases rapidly. Seeding dates should be taken into account in scheduling land-disturbing activities.

Site quality impacts both short-term and long-term plant success. Sites that have compacted soils should be modified whenever practical to improve the potential for plant growth.

The operation of equipment is restricted on slopes steeper than 3:1, severely limiting the quality of the seedbed that can be prepared. Provisions for establishment of vegetation on steep slopes can be made during final grading. In construction of fill slopes, for example, the last 4-6″ might not be compacted. A loose, rough seedbed with irregularities that hold seeds and fertilizer is essential for hydroseeding. Cut slopes should be roughened (see practice *Land Grading*).

Good mulching practices are critical to protect against erosion on steep slopes. When using straw, anchor with netting or asphalt. On slopes steeper than 2:1, jute, excelsior, or synthetic matting may be required to protect the slope.

The use of irrigation (temporary or permanent) will greatly improve the success of vegetation establishment.

Design Criteria and Installation

Prior to start of installation, plant materials, seeding rates and planting dates should be specified by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the installation process.

Scheduling

Plantings should be made during the specified planting period if possible. When sites become available to plant outside of the recommended planting period, either temporary seeding, mulching or chemical stabilization will be more appropriate than leaving the surface bare for an extended period. If lime and fertilizer application rates are not specified, take soil samples during the final grading operation from the top 6″ in each area to be seeded. Submit samples to a soil testing laboratory for lime and fertilizer recommendations.

Plant Selection

Select plants that can be expected to meet planting objectives. To simplify plant selection, use Table TS-1, *Commonly Used Plants for Temporary Cover* and Figure TS-1, *Geographical Areas for Species Adaptation and Seeding Dates*. Seeding mixtures commonly specified by the Mississippi Department of Transportation are an appropriate alternative for plantings on rights-of-ways. Additional information related to plantings in Mississippi is found in Chapter 2 in the section *Non-woody Vegetation for Erosion and Sediment Control*.

Table TS-l Commonly Used Plants for Temporary Cover

Species	Seeding Rates/Ac	Planting Time	Desired pH Range	Fertilization Rate/Acre	Method of Establishment	Zone of Adaptability
Wheat	90 lbs. alone	9/1 – 11/30	6.0 – 7.0	600 lbs. 13-13-13	Seed	All
Ryegrass	30 lbs.	9/1 – 11/30	6.0 – 7.0	600 lbs. 13-13-13	Seed	All
White Clover	5 lbs	9/1 – 11/30	6.0 – 7.0	400 lbs. 13-13-13	Seed	All
Crimson Clover	25 lbs. alone 15 lbs. mix	9/1 – 11/30	6.0 – 7.0	400 lbs. 13-13-13	Seed	All
Hairy Vetch	30 lbs.	9/1 – 11/30	6.0 – 7.0	400 lbs. 13-13-13	Seed	All
Browntop Millet	40 lbs. alone 15 lbs. mix	4/1 – 8/30	6.0 – 7.0	600 lbs. 13-13-13	Seed	All

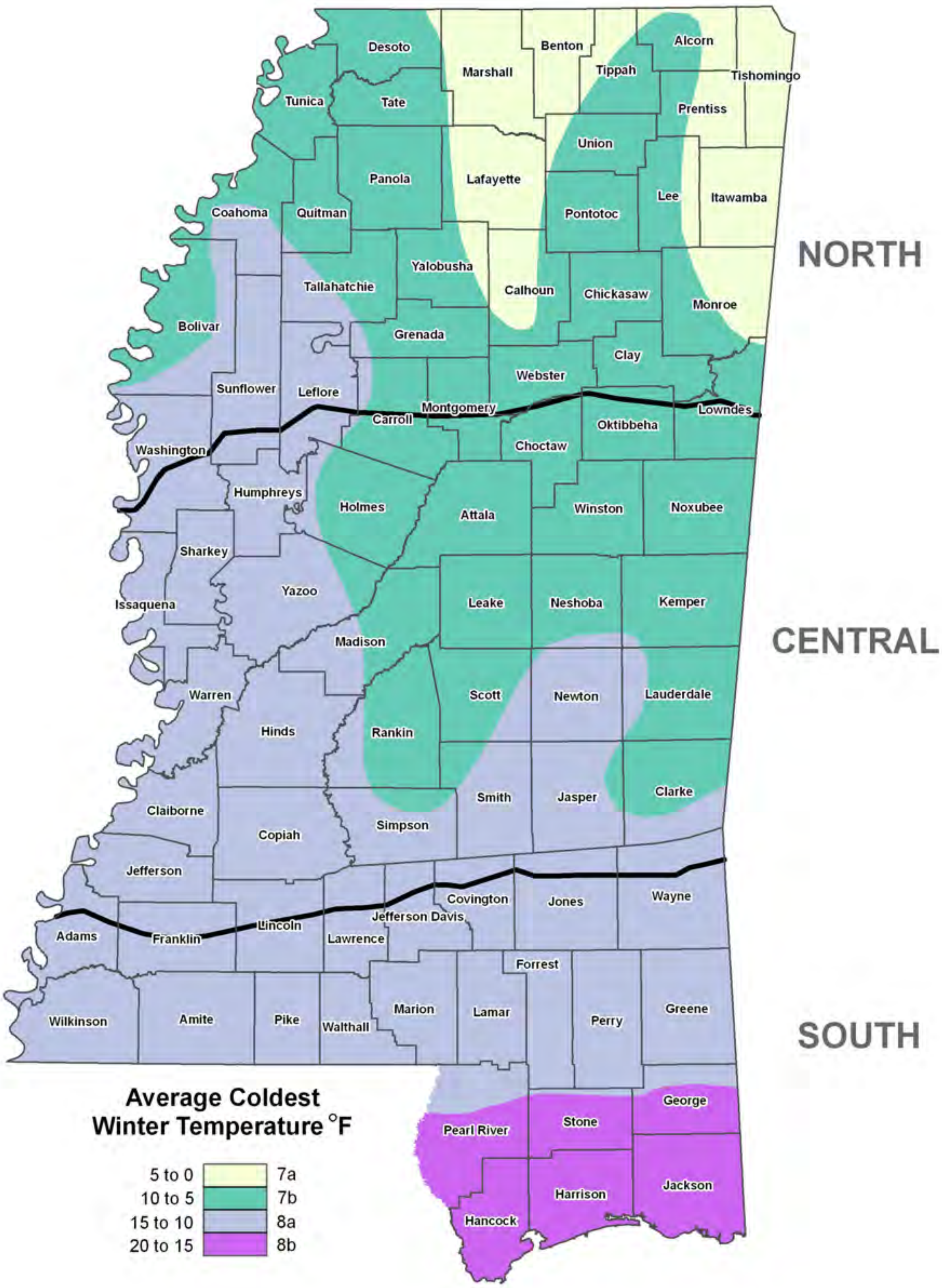


Figure TS- 1 Geographical Areas for Species Adaptation

Site Preparation and Soil Amendments

Complete grading and shaping before applying soil amendments, if needed, to provide a surface on which equipment can safely and efficiently be used to apply soil amendments and accomplish seedbed preparation and seeding. Incorporate lime and fertilizer into the top 6″ of soil during seedbed preparation.

Lime

Apply lime according to soil-test recommendations. If a soil test is not available, use 1 ton of agricultural limestone or equivalent per acre on coarse-textured soils and 2 tons per acre on fine textured soils. Do not apply lime to alkaline soils or to areas that have been limed during the preceding 2 years. Other liming materials that may be selected should be provided in amounts that provide equal value to the criteria listed for agricultural lime or be used in combination with agricultural limestone or Selma chalk to provide equivalent values to agricultural limestone.

Fertilizer

Apply fertilizer according to soil-test results. If a soil test is not available, apply 8-24-24 fertilizer.

When vegetation has emerged in a stand and is growing, 30 to 40 lbs/acre (approximately 0.8 lbs/1000 ft^2) of additional nitrogen fertilizer should be applied.

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil-test recommendations to local fertilizer dealer for bulk-fertilizer blends. This may be more economical than bagged fertilizer.

Seedbed Preparation

Good seedbed preparation is essential to successful plant establishment. A good seedbed is well pulverized, loose, and smooth. If soils become compacted during grading, loosen them to a depth of 6″ to 8″ using a ripper or chisel plow.

If rainfall has caused the surface to become sealed or crusted, loosen it just prior to seeding by disking, raking, harrowing, or other suitable methods. When hydroseeding methods are used, the surface should be left with a more irregular surface of clods.

Planting Methods

Seeding

Evenly apply seed using a cyclone seeder (broadcast), drill seeder, cultipacker seeder, or hydroseeder. Broadcast seeding and hydroseeding are appropriate for steep slopes where equipment cannot operate safely. Small grains should be planted no more than 1″ deep, and grasses and legumes no more than ½″ deep. Seed that are broadcast must be covered by raking or chain dragging, and then lightly firmed with a roller or cultipacker.

Hydroseeding

Surface roughening is particularly important when hydroseeding, as a roughened slope will provide some natural coverage for lime, fertilizer, and seed. The surface should not be compacted or left smooth. Fine seedbed preparation is not necessary for hydroseeding operations; large clods, stones, and irregularities provide cavities in which seeds can lodge.

Mix seed, use an inoculant if required, and mix a seed carrier with water and apply as slurry uniformly over the area to be treated. The seed carrier should be a cellulose fiber, natural-wood fiber or other approved fiber-mulch material which is dyed an appropriate color to facilitate uniform application of seed. Use the correct legume inoculant at 4 times the recommended rate when adding inoculant to a hydroseeder slurry. The mixture should be applied within one hour after mixing to reduce damage to seed.

Fertilizer should not be mixed with the seed-inoculant mixture because fertilizer salts may damage seed and reduce germination and seedling vigor. Fertilizer may be applied with a hydroseeder as a separate operation after seedlings are established.

Mulching

The use of an appropriate mulch provides instant cover and helps ensure establishment of vegetative cover under normal conditions and is essential to seeding success under harsh site conditions (see the *Mulching Practice* for guidance). Harsh site conditions include the following: slopes steeper than 3:1 and adverse soils (soils that are shallow to rock, rocky, or high in clay or sand). Areas with concentrated flow should be treated differently and require a hydromulch formulated for channels or use of an appropriate erosion control blanket.

Verification of Installation

Check materials and installation for compliance with specifications during installation of products.

Common Problems

Consult with a qualified design professional if the following occurs:

Design specifications for seed variety, seeding dates or mulching cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Seeding outside of the recommendations results in an inadequate stand. Reseed according to specifications of a qualified design professional (see recommendations under Maintenance).

Maintenance

Reseeding

Inspect seedings weekly until a stand is established and at least monthly thereafter for stand survival and vigor. Also, inspect the site for erosion.

Eroded areas should be addressed appropriately by filling and/or smoothing, and a reapplication of lime, fertilizer, seed and mulch.

A stand should be uniform and dense for best results. Stand conditions, particularly the vegetative coverage, will determine the extent of remedial actions, such as seedbed preparation and reseeding. A qualified design professional should be consulted to advise on remedial actions. Consider no-till planting.

Fertilizing

If vegetation fails to grow, have the soil tested to determine whether its pH is in the correct range or whether nutrient deficiency is a problem.

Satisfactory establishment may require refertilizing the stand, especially if the planting is made early in the planting season. Follow soil-test recommendations or the specifications provided to establish the planting.

Mowing

Temporary plantings may be mowed and baled or simply mowed to complement the use of the site.

Millet, rye, and wheat may be mowed, but no lower than 6″ (closer mowing may damage the stand).

Ryegrass is tolerant of most mowing regimes and may be mowed often and as close as 4″ to 6″ if this regime is started before it attains tall growth (over 8″).

Bermuda grass is tolerant of most mowing regimes and can be mowed often and close, if so desired, during its growing season.

References

Volume 1

Chapter 2

Chapter 4

Appendices Volume

Appendix G

Tree Planting On Disturbed Areas (TP)

Practice Description

Tree planting on disturbed areas is planting trees on construction sites or other disturbed areas to stabilize the soil. The practice reduces erosion and minimizes the maintenance requirements after a site is stabilized. The practice is applicable to those areas where tree cover is desired and is compatible with the planned use of the area, particularly on steep slopes and adjacent to streams. Tree planting is usually used with other cover practices such as permanent seeding or sodding.

Planning Considerations

Control grass and legume cover when seeded in combination with planted trees to reduce competition for moisture, nutrients and sunlight.

Select trees that are adapted to soil and climate.

Avoid planting species that are invasive or may become a nuisance.

Avoid trees that have undesirable characteristics.

Select trees that will improve aesthetics and provide food and cover for wildlife.

Design Criteria and Installation

Tree-planting requirements should be designed by a qualified design professional and plans and specifications should be made available to field personnel prior to start of planting.

Planting Bare-rooted Tree Seedlings

Site Preparation

Compacted soil should be ripped or chiseled on the contour to permit adequate root development and proper tree growth. Debris should be removed from the site to facilitate tree planting.

Planting Methods

Tree seedlings may be planted by hand or machine. Any tool or piece of equipment that gives satisfactory results may be used. Dibble bars, mattocks, augers, post-hole diggers and shovels may be used to plant trees by hand. Wildland tree-planting machines should be used on rough areas or areas with clayey or compacted soils. Old-field tree planters should be limited to areas with light soils that are not compacted. On sloping land, planting should be done on the contour. Bare-rooted tree-seedling planting techniques are outlined in Figure TP-1. Additional planting techniques for bare-root plants are available on MDOT drawing PD-1 found at the end of this practice.

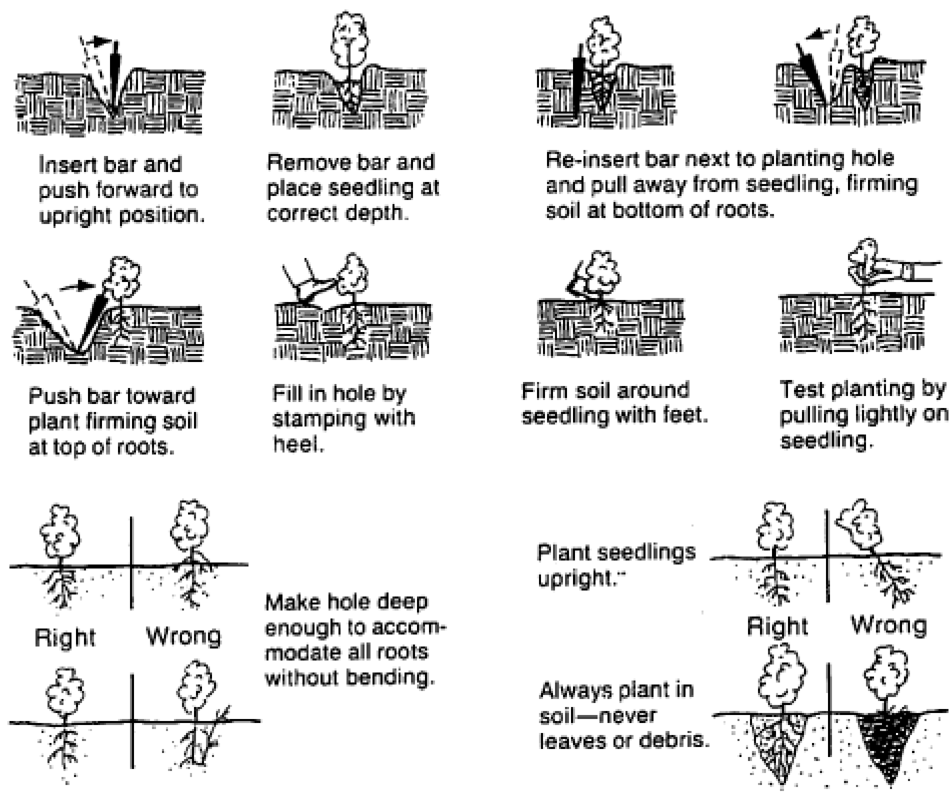


Figure TP- 1 Planting Bare-Root Seedlings

When to Plant

Bare-root seedlings should be planted from December 1 to March 15. Planting should be done when the soil is neither too dry nor too wet. Planting should be avoided during freezing weather and when the ground is frozen.

Planting Rate

To control erosion, pines should be planted at a rate of 600 to 700 trees per acre and hardwoods should be planted at a rate of 300 to 500 trees per acre. Severely eroding areas should be planted at the rate of 600 to 900 trees per acre for both pine and hardwood species.

Depth of Planting

Trees should be planted deeper than they grew in the nursery. Plant small stock 1″ deeper and medium to large stock ½″ deeper. On most soils, longleaf pine seedlings should be planted ¼″ deeper than they grew in the nursery.

Condition of Roots

Roots should be planted straight down and not twisted, balled, nor U-shaped. Soil should be packed firmly around the planted seedlings. No air pockets should be left in either machine furrows or holes made by planting tools.

Care of Seedlings

The roots of seedlings must be kept moist and cool at all times. After lifting, seedlings should not be exposed to sun, wind, heat, dry air or freezing cold before they are planted. Baled seedlings may be kept up to 3 weeks if they are properly stacked, watered, and kept in a cool place. When planting is delayed, the roots of seedlings should be covered with moist soil (heeled-in) or the seedlings should be placed in cold storage.

During planting, the roots of seedlings must be kept moist and only one seedling should be planted at a time. At the end of each day, loose seedlings should be either repacked in wet moss or heeled-in.

Mulching

Mulching may be necessary on sloping land to reduce erosion. Mulch with wood chips, bark, pine needles, peanut hulls, etc. to a depth of no more than 3″. Mulch should not be placed against the trunk of the tree.

Planting Balled and Burlapped and Container-Grown Trees

The best time to plant hardwood trees is in late winter (before leaves emerge) and the best time to plant evergreens is in early fall. However, these plants may be planted anytime of the year except when the ground is frozen. Watering is essential during dry periods.

Site Preparation

The planting hole should be dug deep and wide enough to allow proper placement of the root ball. The final level of the root ball's top should be level with the ground surface (See Figure TP-2).

As the hole is dug, the topsoil should be kept separate from the subsoil. If possible, the subsoil should be replaced with topsoil. If topsoil is unavailable, the subsoil can be improved by mixing in ⅓ volume of peat moss or well-rotted manure.

Heavy or poorly drained soils are not good growth media for trees. When it is necessary to transplant trees into such soils, extra care should be taken.

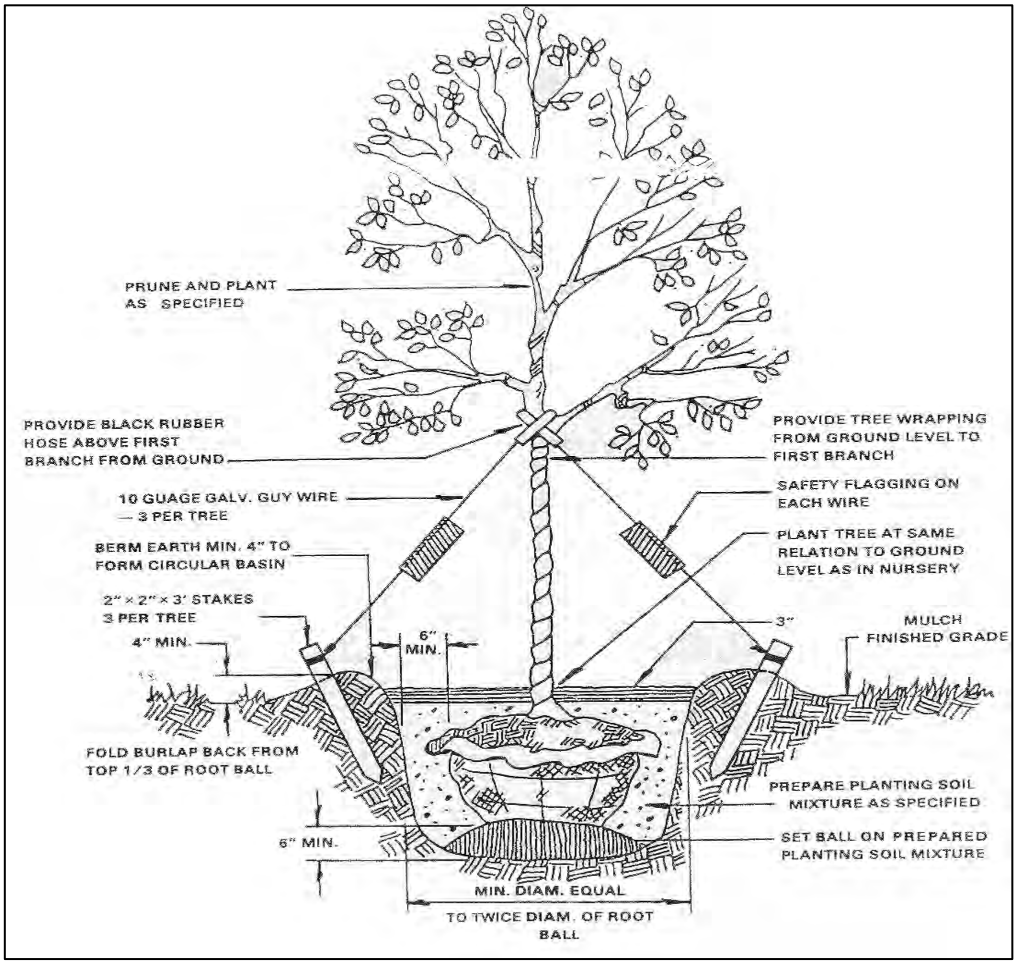


Figure TP- 2 Tree Planting Diagram

Tree Preparation

The proper digging of a tree includes the conservation of as much of the root system as possible, particularly the fine roots. Soil adhering to the roots should be damp when the tree is dug, the tree roots should be kept moist until planting. The soil ball should be 12″ in diameter for each inch of diameter of the trunk. The tree should be carefully excavated and the soil ball wrapped in burlap and tied with rope. Use of a mechanical tree spade is also acceptable.

Any trees that are to be transported for a long distance should have the branches bound with a soft rope to prevent damage.

Planting the Tree

Depth of planting must be close to the original depth. The tree may be set just a few inches higher than in its former location, especially if soil is poorly drained. Do not set the tree lower than before. Soil to be placed around the root ball should be moist but not wet.

Set the tree in the hole and if the tree is balled and burlapped, remove the rope which holds the burlap. Loosen the burlap and remove completely if practical. Do not break the soil of the root ball. Fill the hole with soil halfway and add water to settle the soil and eliminate air pockets. When the water has drained off, fill the hole the remainder of the way. Use extra soil to form a shallow basin around the tree. This will help retain water.

Newly planted trees may need artificial support to prevent excessive swaying. Stakes and guy wires may be used (see Figure TP-2). Guying should be loose enough to allow some movement of the tree. Planting and guying techniques for balled and burlapped and container plants are available on MDOT drawing PD-1 found at the end of this practice.

Mulching

Mulching may be necessary on sloping land to reduce erosion and should be used around balled and burlapped trees and container grown trees to help conserve soil moisture and reduce competition from weeds and grass. Apply mulch using wood chips, bark, pine needles, peanut hulls etc. to a depth of no more than 3″. Mulch should not be placed against the trunk of the tree.

Verification of Installation

Check all components of the practice during installation to ensure that specifications are being met.

Common Problems

Consult with a qualified design professional if any of the following occur:

Soil compaction can prevent adequate tree growth. Compaction should be addressed during site preparation.

Design specifications for trees (species, planting dates) and mulch cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Problems that require remedial actions:

Erosion, washout and poor tree establishment – repair eroded surface, replant, reapply mulch and anchor.

Mulch is lost to wind or stormwater runoff – reapply mulch and anchor.

Maintenance

Replant dead trees where needed to maintain adequate cover for erosion control.

Periodic fertilization may be beneficial on poor sites to maintain satisfactory tree growth. Transplanted trees should be fertilized 1 year or so after planting. A soil test is the best way to determine what elements are needed. Fertilizer formulations of 10-8-6 or 10-6-4 can be used in the absence of a soil test. About 2 lbs. of fertilizer should be used for each inch of tree diameter measured at 4.5 feet above the ground.

Fertilizer must come in contact with the roots to benefit a tree. The easiest way to apply fertilizer is to simply broadcast it under the tree and over the root system. As a tree grows, the roots will grow well beyond the drip line. This should be taken into account when applying fertilizer by the broadcast method. Another way to apply fertilizer is to make holes in the tree's root area with a bar or auger. Holes should be 18″ deep, spaced about 2 feet apart, and located around the drip line of the tree. Distribute the fertilizer evenly into these holes and close the holes with the heel of the shoe or by filling with topsoil or peat moss. Trees should be fertilized in late winter or early spring before leaves emerge.

References

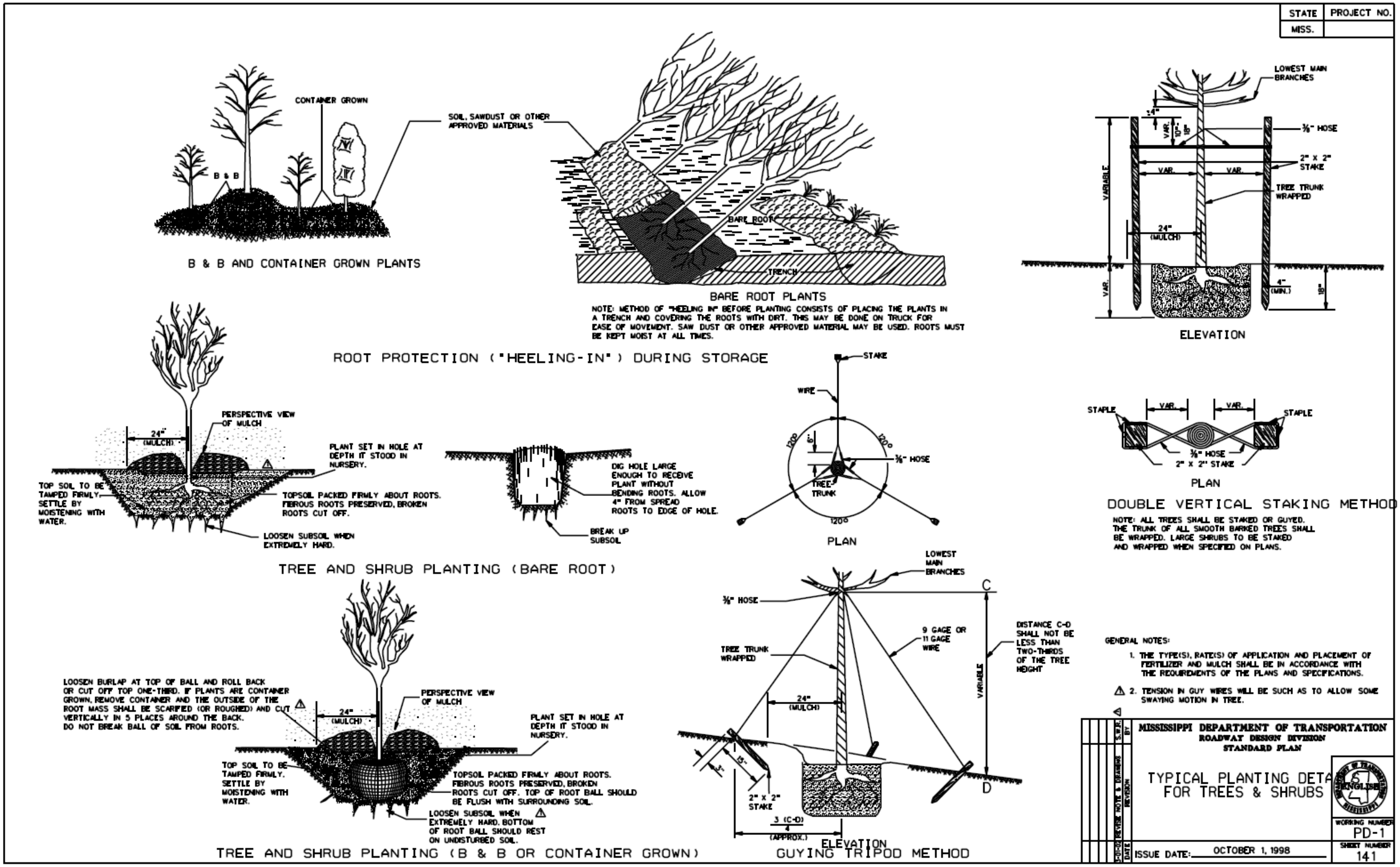
BMPs from Volume 1

Chapter 4

Mulching (MU) 4-48

MDOT Drawing PD-1

Typical Planting Details for Trees and Shrubs 4-116



STATE
PROJECT NO.
MISS.
CONTAINER GROWN
B & B
B & B AND CONTAINER GROWN PLANTS
SOIL, SAWDUST OR OTHER APPROVED MATERIALS
BARE ROOT
TRENCH
BARE ROOT PLANTS
NOTE: METHOD OF "HEELING IN" BEFORE PLANTING CONSISTS OF PLACING THE PLANTS IN A TRENCH AND COVERING THE ROOTS WITH DIRT. THIS MAY BE DONE ON TRUCK FOR EASE OF MOVEMENT. SAW DUST OR OTHER APPROVED MATERIAL MAY BE USED. ROOTS MUST BE KEPT MOIST AT ALL TIMES.
ROOT PROTECTION ("HEELING-IN") DURING STORAGE
LOWEST MAIN BRANCHES
⅜" HOSE
2" X 2" STAKE
TREE TRUNK WRAPPED
VARIABLE
VAR.
24" (MULCH)
4" (MIN.)
18"
ELEVATION
PERSPECTIVE VIEW OF MULCH
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY. SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF.
LOOSEN SUBSOIL WHEN EXTREMELY HARD.
TREE AND SHRUB PLANTING (BARE ROOT)
DIG HOLE LARGE ENOUGH TO RECEIVE PLANT WITHOUT BENDING ROOTS. ALLOW 4" FROM SPREAD ROOTS TO EDGE OF HOLE.
BREAK UP SUBSOIL
STAKE
WIRE
120°
TREE TRUNK
PLAN
STAPLE
⅜" HOSE
2" X 2" STAKE
PLAN
DOUBLE VERTICAL STAKING METHOD
NOTE: ALL TREES SHALL BE STAKED OR GUYED. THE TRUNK OF ALL SMOOTH BARKED TREES SHALL BE WRAPPED. LARGE SHRUBS TO BE STAKED AND WRAPPED WHEN SPECIFIED ON PLANS.
LOOSEN BURLAP AT TOP OF BALL AND ROLL BACK OR CUT OFF TOP ONE-THIRD. IF PLANTS ARE CONTAINER GROWN, REMOVE CONTAINER AND THE OUTSIDE OF THE ROOT MASS SHALL BE SCARFIED (OR ROUGHED) AND CUT VERTICALLY IN 5 PLACES AROUND THE BACK. DO NOT BREAK BALL OF SOIL FROM ROOTS.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF. TOP OF ROOT BALL SHOULD BE FLUSH WITH SURROUNDING SOIL.
LOOSEN SUBSOIL WHEN EXTREMELY HARD. BOTTOM OF ROOT BALL SHOULD REST ON UNDISTURBED SOIL.
TREE AND SHRUB PLANTING (B & B OR CONTAINER GROWN)
9 GAGE OR 11 GAGE WIRE
DISTANCE C-D SHALL NOT BE LESS THAN TWO-THIRDS OF THE TREE HEIGHT
C
D
15"
2" X 2" STAKE
3 (C-D) / 4 (APPROX.)
ELEVATION
GUYING TRIPOD METHOD
GENERAL NOTES:
1. THE TYPE(S), RATE(S) OF APPLICATION AND PLACEMENT OF FERTILIZER AND MULCH SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE PLANS AND SPECIFICATIONS.
2. TENSION IN GUY WIRES WILL BE SUCH AS TO ALLOW SOME SWAYING MOTION IN TREE.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN
TYPICAL PLANTING DETAILS FOR TREES & SHRUBS
ENGLISH
WORKING NUMBER
PD-1
SHEET NUMBER
141
ISSUE DATE: OCTOBER 1, 1998

Check Dam (CD)

Practice Description

A check dam is a small barrier or dam constructed across a swale, drainage ditch or other area of concentrated flow for the purpose of reducing channel erosion. Channel erosion is reduced because check dams flatten the gradient of the flow channel and slow the velocity of channel flow. Most check dams are constructed of rock, but hay bales, logs and other materials may be acceptable. Contrary to popular opinion, most check dams trap an insignificant volume of sediment.

This practice applies in small open channels and drainageways, including temporary and permanent swales. It is not to be used in a live stream. Situations of use include areas in need of protection during establishment of grass and areas that cannot receive a temporary or permanent non-erodible lining for an extended period of time.

Planning Considerations

Check dams are used in concentrated flow areas to provide temporary channel stabilization during the intense runoff periods associated with construction disturbances. Check dams may be constructed of rock, logs, hay bales or other suitable material, including manufactured products. MDOT Drawing ECD-4 at the end of this practice shows the typical application of check dam structures. Most check dams are constructed of rock. Rock may not be acceptable in some installations because of aesthetics; therefore, alternative types of check dams need to be considered.

Rock check dams

Rock check dams (Figures CD-1 and CD-2) are usually installed with backhoes or other suitable equipment, but hand labor is likely needed to complete most installations to the quality needed. The rock is usually purchased, and some locations in the state may not have rock readily available. The use of rock should be considered carefully in areas to be mowed. Some rock may be washed away during heavy rain events and should be removed before each mowing operation. Additional installation drawings are provided at the end of this practice as MDOT Drawings ECD-8 and ECD-9.

Log check dams

Log check dams (Figure CD-3) are more economical from a materials cost standpoint since logs can usually be salvaged from clearing operations. The time and labor required would be greater for log check dams. Increased labor costs would offset the reduced material costs. Log check dams would not be permanent but may last long enough to get grass linings established.

Hay bale check dams

Check dams constructed of hay bales (Figure CD-4) have the shortest life of the materials discussed and are only used as a temporary means to help establish a channel to vegetation. MDOT Drawing ECD-5 is provided at the end of this practice and shows more specifics for hay bale check dams. MDOT Drawing ECD-6 shows typical details for a straw wattle ditch check as an alternative to hay bale check dams. Hay bale check dams should not be used where permanent watercourse protection is needed and should be used only in concentrated-flow areas where only minimal runoff occurs.

Without proper installation, which is rarely done, hay bale check dams always fail.

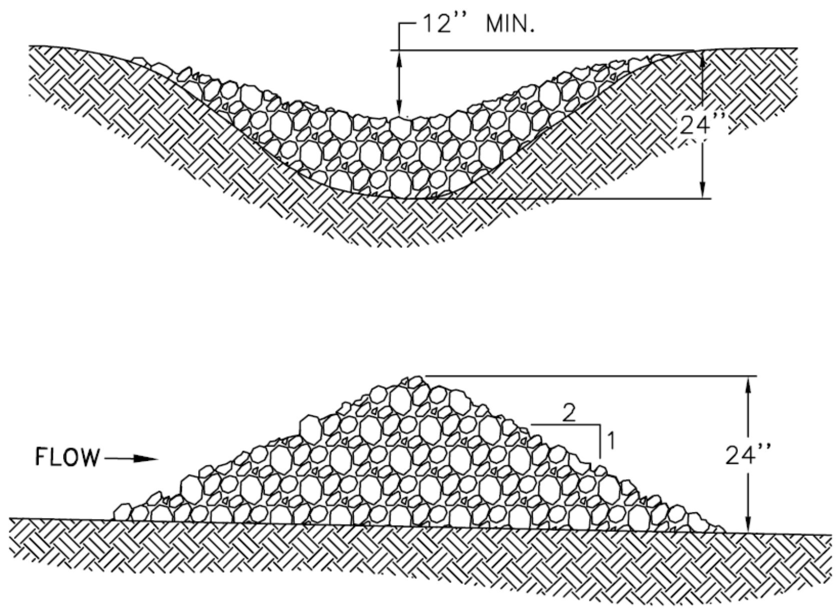


Figure CD-1 Profile of Typical Rock Check Dams

Check dams should be planned to be compatible with the other features such as streets, walks, trails, sediment basins and rights-of-way or property lines. Check dams are normally constructed in series, and the dams should be located at a normal interval from other grade controls such as culverts or sediment basins.

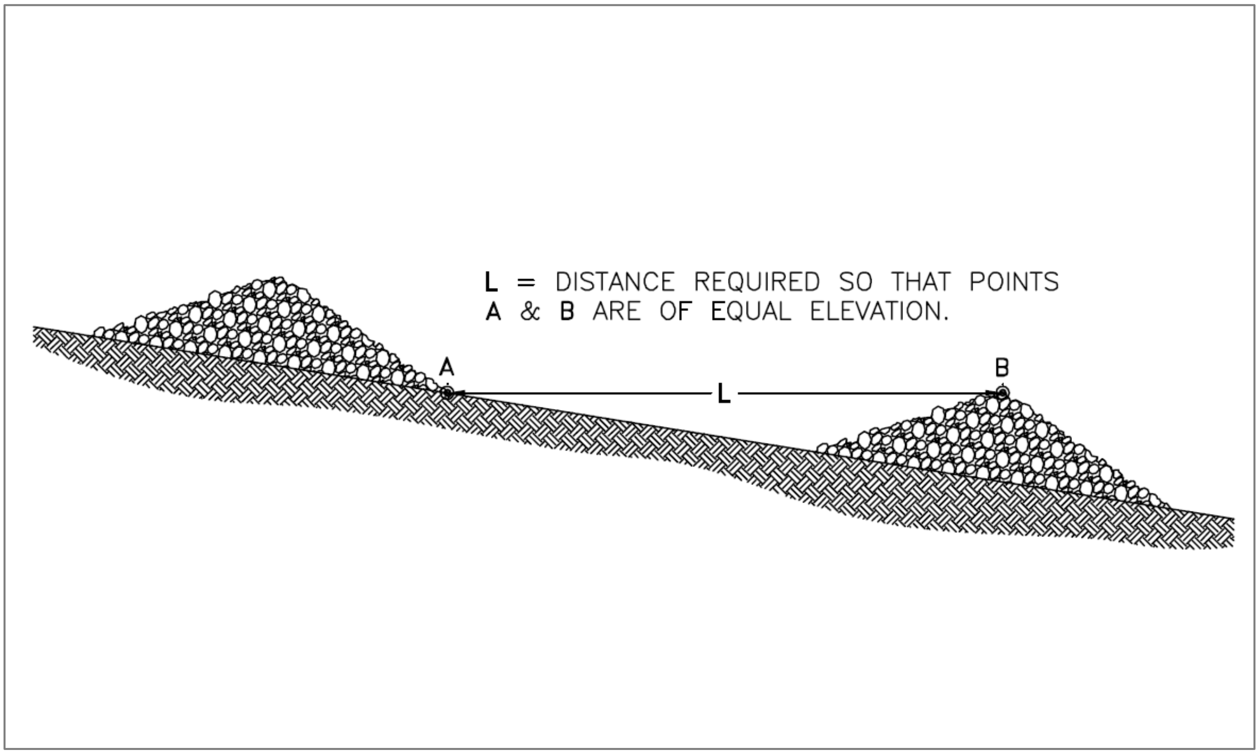


Figure CD-2 Cross Section of Typical Rock Check Dam

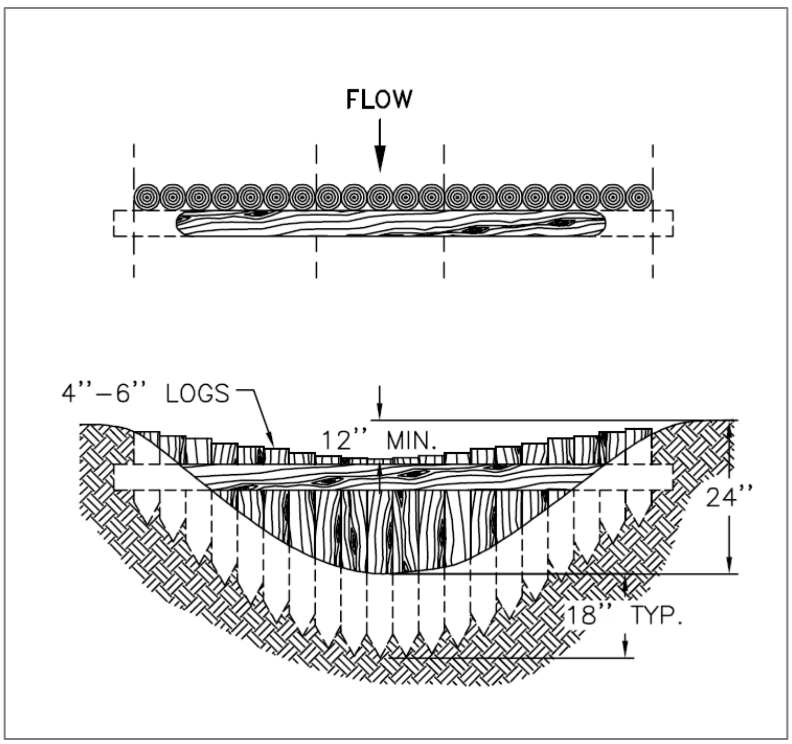


Figure CD-3 Typical Log Check Dam

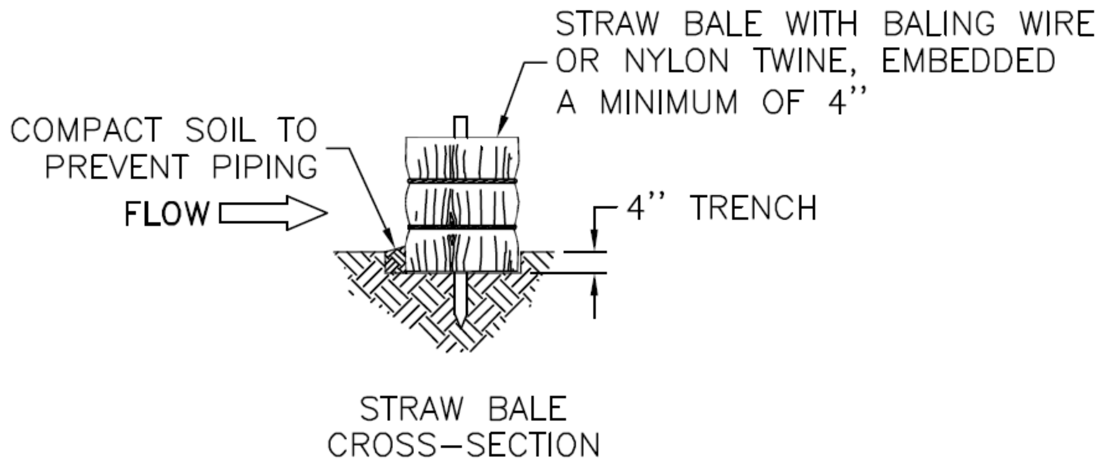


Figure CD-4 Typical Hay Bale Check Dam
(NOTE: **Without proper installation, which is rarely done, hay bale check dams always fail.**)

Design Criteria and Installation

Formal design is not required. The following limiting factors should be adhered to when designing check dams.

Drainage Area

Ten acres or less (rock or logs).

Maximum Height

Two feet when drainage area is less than 5 acres.

Three feet when drainage area is 5 to 10 acres.

Depth of Flow

Six inches when drainage area is less than 5 acres.

Twelve inches when drainage area is 5 to 10 acres.

The top of dam, perpendicular to flow, should be parabolic. The center of the dam should be constructed lower than the ends. The elevation of the center of the dam should be lower than the ends by the depth of flow listed above.

Side Slopes

2:1 or flatter.

Spacing

Elevation of the toe of the upstream dam is at or below elevation of the crest of the downstream dam.

Keyway

The rock or log check dam should be keyed into the channel bottom and abutments to a depth of 12 to 24″. The keyway width should be at least 12″. The keyway is to prevent erosion around the end of and beneath the dam. Hay bale check dams should be embedded into the soil at least 3″.

Rock Check Dams

Rock check dams should be constructed of durable rock riprap. Rock material diameter should be 2″ to 15″.

In soils where failure by piping of soils into the rock is likely, a geotextile will be used as a filter to separate the soils from the rock. Geotextile should conform to the requirements of type I geotextile in Table CD-1.

Table CD-1 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb) [2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. no.40 [3]	As specified max. no.40 [3]	As specified max. no.40 [3]	As specified max. no.40 [3]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextile is required for all other classes.
2 Minimum average roll value (weakest principal direction).
3 U.S. standard sieve size.

Site Preparation

Determine location of any underground utilities.

Locate and mark the site for each check dam in strategic locations (to avoid utilities and optimize effectiveness of each structure in flattening channel grade).

Remove debris and other unsuitable material that would interfere with proper placement of the check dam materials.

Excavate a shallow keyway (12″-24″ deep and at least 12″ wide) across the channel and into each abutment for each check dam.

Materials Installation

As specified, install a non-woven geotextile fabric in the keyway in sandy or silty soils. This may not be required in clayey soils.

Construct the dam with a minimum 2:1 side slope over the keyway and securely embed the dam into the channel banks. Position rock to form a parabolic top, perpendicular to channel flow, with the center portion at the elevation shown in the design so that the flow goes over the structure and not around the structure.

Erosion and Sediment Control

Install vegetation (temporary or permanent seeding) or mulching to stabilize other areas disturbed during the construction activities.

Construction Verification

Check finished size, grade and shape for compliance with standard drawings and materials list (check for compliance with specifications if included in contract specifications).

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate check dam will not function as intended. Change in plan will be needed.

Materials specified in the plan are not available.

Maintenance

Inspect the check dam for rock displacement and abutments for erosion around the ends of the dam after each significant rainfall event. If the rock appears too small, add additional stone and use a larger size.

Inspect the channel after each significant rainfall event. If channel erosion exceeds expectations, consult with the design professional and consider adding another check dam to reduce channel flow grade.

Sediment should be removed if it reaches a depth of ½ the original dam height. If the area behind the dam fills with sediment, there is a greater likelihood that water will flow around the end of the check dam and cause the practice to fail.

Check dams may be removed when their useful life has been completed. The area where check dams are removed should be seeded and mulched immediately unless a different treatment is prescribed. In some instances check dams should be left as a permanent measure to support channel stability.

References

BMPs from Volume 1

Chapter 4

MDOT Drawing ECD-4

MDOT Drawing ECD-5

MDOT Drawing ECD-6

MDOT Drawing ECD-7

MDOT Drawing ECD-8

MDOT Drawing ECD-9

MDOT Drawing ECD-20

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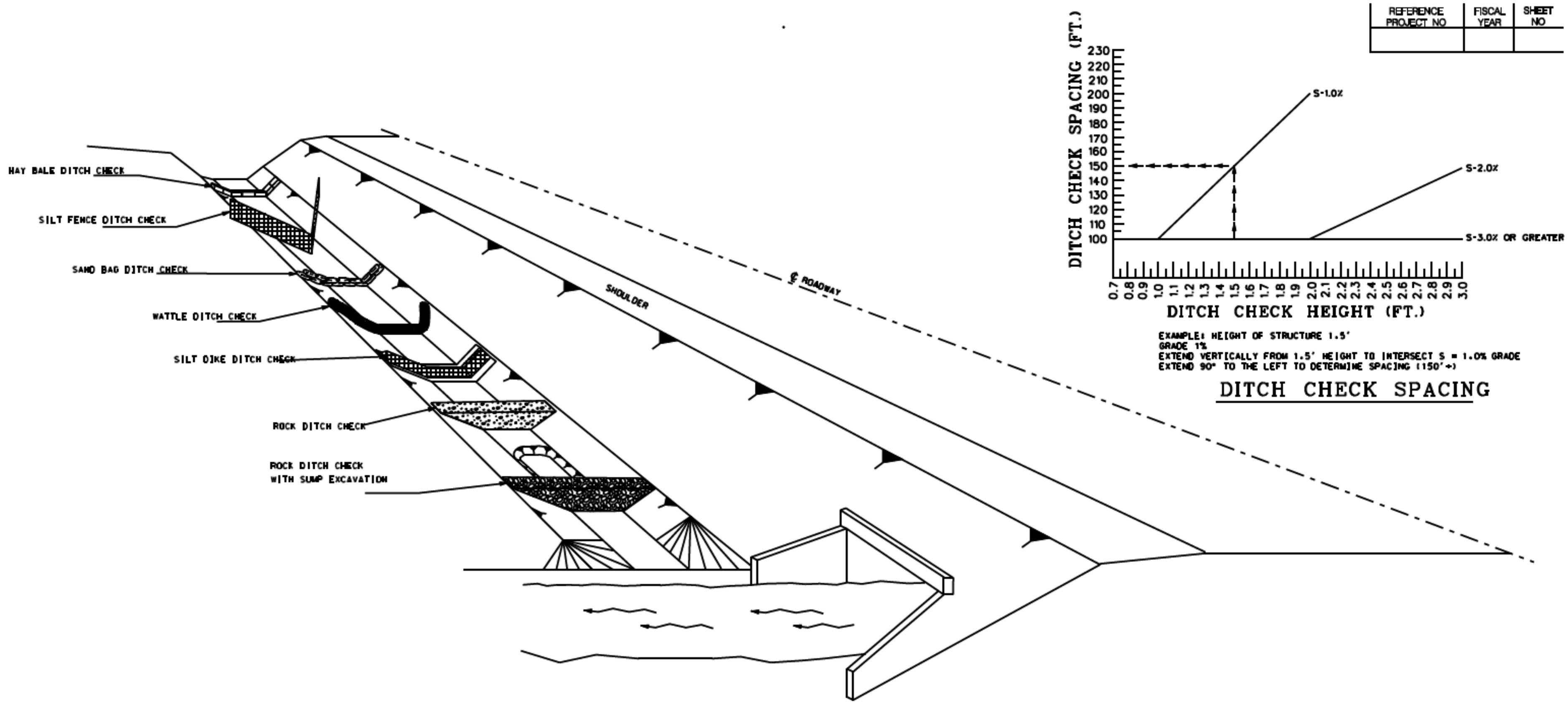
REFERENCE PROJECT NO	FISCAL YEAR	SHEET NO



NOTES:

1. THE DITCH CHECK PERSPECTIVE ILLUSTRATES A TOOL BOX OF TEMPORARY PRACTICES THAT MAY BE USED. DITCH CHECKS ARE INSTALLED TO CONTROL RUNOFF VELOCITY AND THUS REDUCE EROSION AND PROVIDE FOR TRAPPING OF SEDIMENTS.
2. SELECTION OF THE APPROPRIATE DITCH CHECK SHOULD BE A FUNCTION OF CONSTRUCTION PHASE, DRAINAGE AREA, DITCH GRADIENT, SOIL TYPE ECONOMY AND SAFETY.
3. DITCH CHECKS CAN BE REMOVED FOR MAINTENANCE AND/OR REPLACEMENT BUT MUST REMAIN IN PLACE UNTIL UPSLOPE AREAS HAVE BEEN PERMANENTLY STABILIZED. MAINTENANCE INCLUDES REMOVAL OF SEDIMENT BEGINNING WHEN SEDIMENT ACCUMULATION REACHES 1/3 THE CAPACITY OR HEIGHT OF THE STRUCTURE AND NEVER ALLOWING FOR SEDIMENT TO ACCUMULATE MORE THAN 1/2 THE VOLUME OR HEIGHT OF THE DITCH CHECK STRUCTURE.
4. HAY BALES ARE USED TO INTERCEPT LOW VOLUME FLOWS IN LOW TO MODERATE GRADIENT DITCHES.
5. SILT FENCE DITCH CHECKS ARE USED WHERE IT HAS BEEN DETERMINED THAT HAY BALE CHECKS ARE INADEQUATE. SILT FENCE DITCH CHECKS ARE USED TO INTERCEPT LOW VOLUME FLOWS IN LOW TO MODERATE GRADIENT DITCHES.
6. SAND BAG DITCH CHECKS ARE USED FOR VELOCITY REDUCTION AND MINIMAL SEDIMENT TRAPPING IN CONCRETE PAVED DITCHES OR IN DITCHES THAT HAVE ROCKY BOTTOMS.
7. WATTLE DITCH CHECKS ARE APPROPRIATE FOR VELOCITY REDUCTION AND CONTROL OF SEDIMENT TRANSPORT UNDER LOW TO MEDIUM FLOW CONDITIONS.
8. SILT DIKES CAN BE USED IN DITCHES WITH CONCENTRATED FLOWS WITHIN THE CLEAR ZONE WHERE RIPRAP CAN NOT BE USED. AS CONSTRUCTION PROGRESSES.
9. ROCK DITCH CHECK WITH SUMP EXCAVATION CAN BE PLACED IN DITCHES TO ASSURE ON-SITE SEDIMENT TRAPPING REQUIREMENTS ARE MET. DITCH CHECK WITH SUMP EXCAVATION IS USED WHEN DITCHES RECEIVE DRAINAGE FROM CUT OR FILL SLOPES OR OTHER CRITICAL AREAS WHERE SOIL EROSION IS EXPECTED. DRAINAGE AREA FOR A TEMPORARY SEDIMENT TRAP SHALL NOT EXCEED 3 ACRES. THEY CAN BE USED IN SERIES TO INCREASE ON-SITE SEDIMENT TRAPPING EFFICIENCY.
10. IN GENERAL, DITCH CHECKS SHOULD NOT BE PLACED IN LIVE STREAMS.
11. CONFIGURATION AND SPACING MAY BE ADJUSTED IF APPROVED BY THE ENGINEER TO ACCOMODATE TRAVELWAY SAFETY, WATER FLOW, OR SOIL AND INSTALLATION CHALLENGES.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

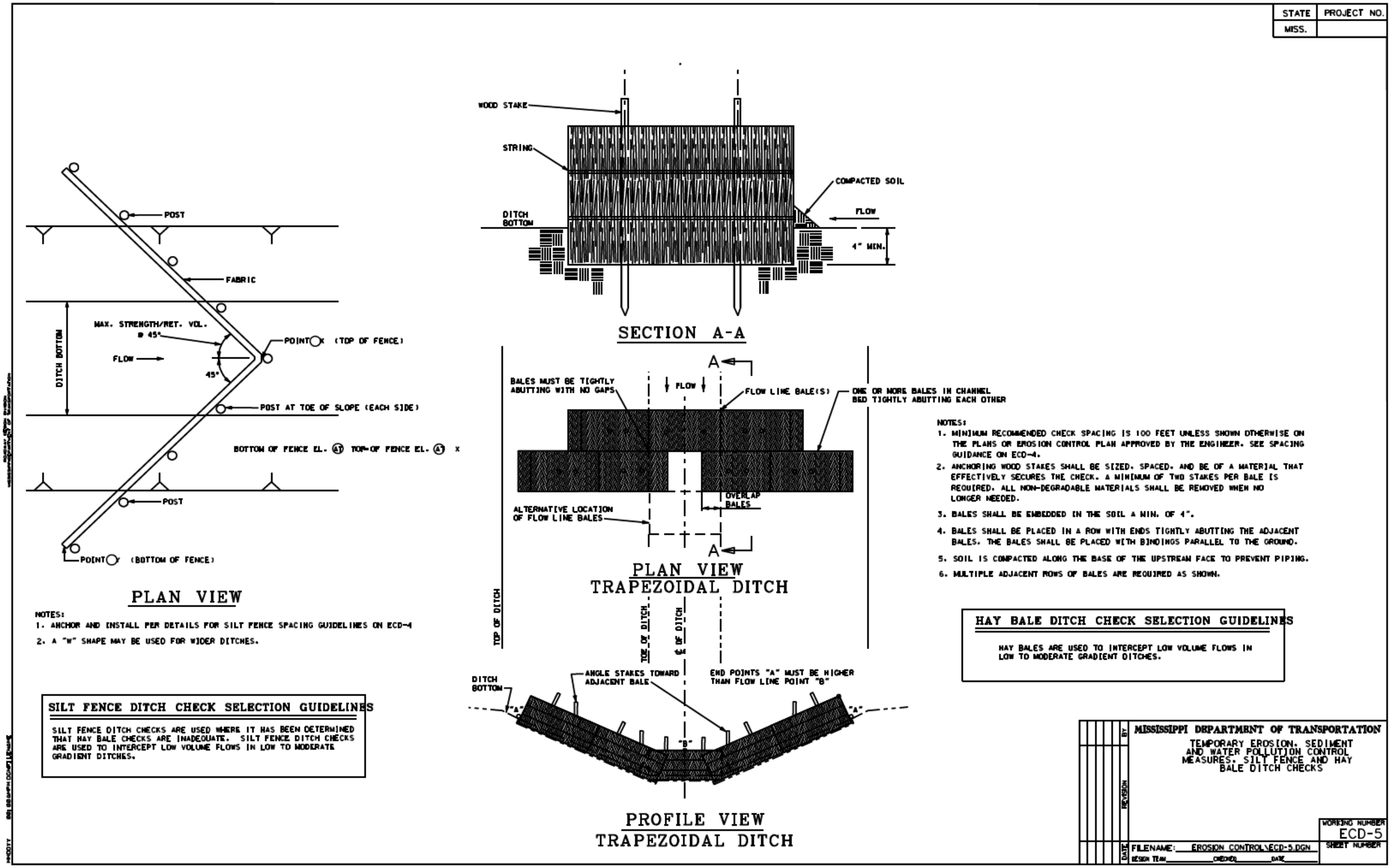
DITCH CHECK STRUCTURES,
TYPICAL APPLICATIONS AND DETAILS

WORKING NUMBER: ECD-4

SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-4.DGN

DESIGN TEAM ________ CHECKED ________ DATE ________


STATE
PROJECT NO.
MISS.
WOOD STAKE
STRING
COMPACTED SOIL
DITCH BOTTOM
FLOW
4" MIN.
SECTION A-A
POST
FABRIC
MAX. STRENGTH/RET. VOL. @ 45°
FLOW
45°
DITCH BOTTOM
POINT X (TOP OF FENCE)
POST AT TOE OF SLOPE (EACH SIDE)
BOTTOM OF FENCE EL. TOP OF FENCE EL. X
POST
POINT Y (BOTTOM OF FENCE)
PLAN VIEW
NOTES:
1. ANCHOR AND INSTALL PER DETAILS FOR SILT FENCE SPACING GUIDELINES ON ECD-4
2. A "W" SHAPE MAY BE USED FOR WIDER DITCHES.
SILT FENCE DITCH CHECK SELECTION GUIDELINES
SILT FENCE DITCH CHECKS ARE USED WHERE IT HAS BEEN DETERMINED THAT HAY BALE CHECKS ARE INADEQUATE. SILT FENCE DITCH CHECKS ARE USED TO INTERCEPT LOW VOLUME FLOWS IN LOW TO MODERATE GRADIENT DITCHES.
BALES MUST BE TIGHTLY ABUTTING WITH NO GAPS
FLOW
FLOW LINE BALE(S)
ONE OR MORE BALES IN CHANNEL BED TIGHTLY ABUTTING EACH OTHER
OVERLAP BALES
ALTERNATIVE LOCATION OF FLOW LINE BALES
A
A
PLAN VIEW
TRAPEZOIDAL DITCH
TOP OF DITCH
TOE OF DITCH
℄ OF DITCH
DITCH BOTTOM
ANGLE STAKES TOWARD ADJACENT BALE
END POINTS "A" MUST BE HIGHER THAN FLOW LINE POINT "B"
"A"
"B"
"A"
PROFILE VIEW
TRAPEZOIDAL DITCH
NOTES:
1. MINIMUM RECOMMENDED CHECK SPACING IS 100 FEET UNLESS SHOWN OTHERWISE ON THE PLANS OR EROSION CONTROL PLAN APPROVED BY THE ENGINEER. SEE SPACING GUIDANCE ON ECD-4.
2. ANCHORING WOOD STAKES SHALL BE SIZED, SPACED, AND BE OF A MATERIAL THAT EFFECTIVELY SECURES THE CHECK. A MINIMUM OF TWO STAKES PER BALE IS REQUIRED. ALL NON-DEGRADABLE MATERIALS SHALL BE REMOVED WHEN NO LONGER NEEDED.
3. BALES SHALL BE EMBEDDED IN THE SOIL A MIN. OF 4".
4. BALES SHALL BE PLACED IN A ROW WITH ENDS TIGHTLY ABUTTING THE ADJACENT BALES. THE BALES SHALL BE PLACED WITH BINDINGS PARALLEL TO THE GROUND.
5. SOIL IS COMPACTED ALONG THE BASE OF THE UPSTREAM FACE TO PREVENT PIPING.
6. MULTIPLE ADJACENT ROWS OF BALES ARE REQUIRED AS SHOWN.
HAY BALE DITCH CHECK SELECTION GUIDELINES
HAY BALES ARE USED TO INTERCEPT LOW VOLUME FLOWS IN LOW TO MODERATE GRADIENT DITCHES.
BY
REVISION
DATE
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
TEMPORARY EROSION, SEDIMENT AND WATER POLLUTION CONTROL MEASURES, SILT FENCE AND HAY BALE DITCH CHECKS
WORKING NUMBER
ECD-5
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-5.DGN
DESIGN TEAM
CHECKED
DATE

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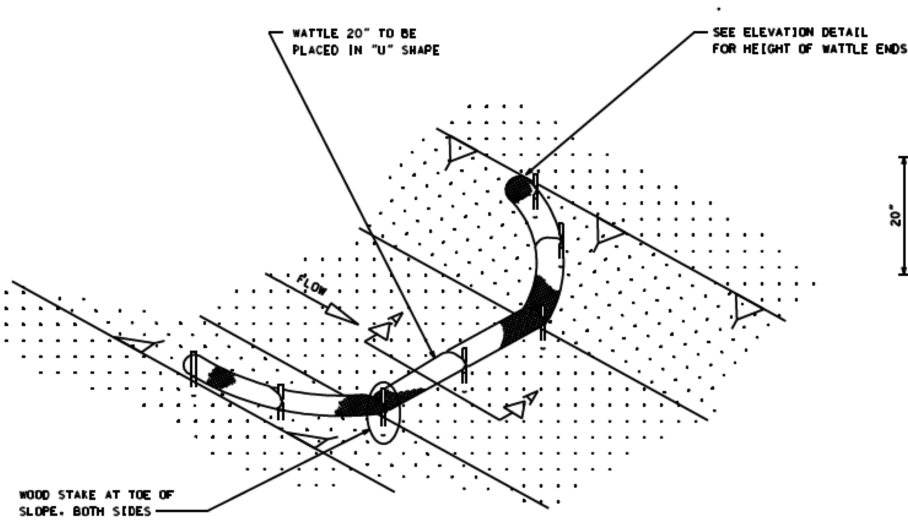
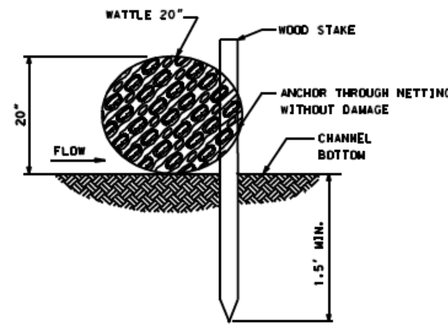


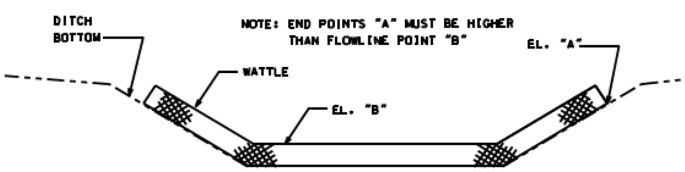
DETAIL (DITCH CHECK)



SECTION A-A

NOTES:

1. MINIMUM RECOMMENDED PLACEMENT INTERVAL BETWEEN WATTLE DITCH CHECK IS 100' UNLESS SHOWN OTHERWISE ON THE PLANS OR EROSION CONTROL PLAN APPROVED BY THE ENGINEER. SEE SPACING GUIDANCE ON ECD-4
2. ANCHORING WOOD STAKES SHALL BE SIZED, SPACED, DRIVEN, AND BE OF A MATERIAL THAT EFFECTIVELY SECURES THE CHECK. STAKE SPACING SHALL BE A MAXIMUM OF THREE FEET. ALL NON-DEGRADABLE MATERIALS SHALL BE REMOVED WHEN NO LONGER NEEDED.
3. TRENCHING OF WATTLES MAY BE NECESSARY IF PIPING BECOMES EVIDENT.
4. WATTLES SHOULD NOT BE USED IN HARD BOTTOM CHANNELS.



ELEVATION DETAIL

WATTLE DITCH CHECK SELECTION GUIDELINES

WATTLE DITCH CHECKS ARE APPROPRIATE FOR VELOCITY REDUCTION AND CONTROL OF SEDIMENT TRANSPORT UNDER LOW TO MEDIUM FLOW CONDITIONS.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

DETAILS OF EROSION CONTROL
WATTLE DITCH CHECK

BY | REVISION | DATE

WORKING NUMBER ECD-6

SHEET NUMBER

FILENAME: EROSION CONTROL#ECD-6.DGN

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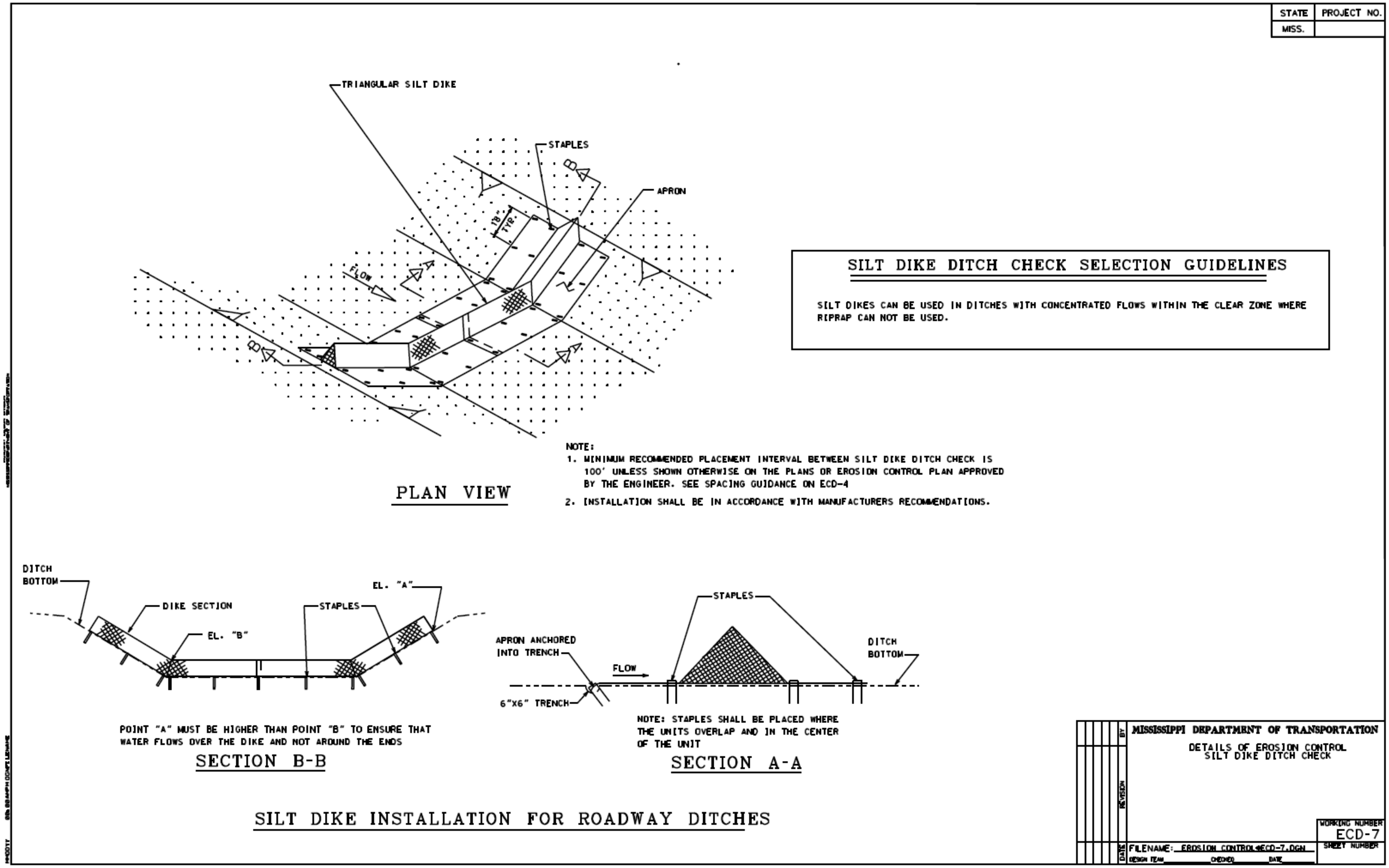
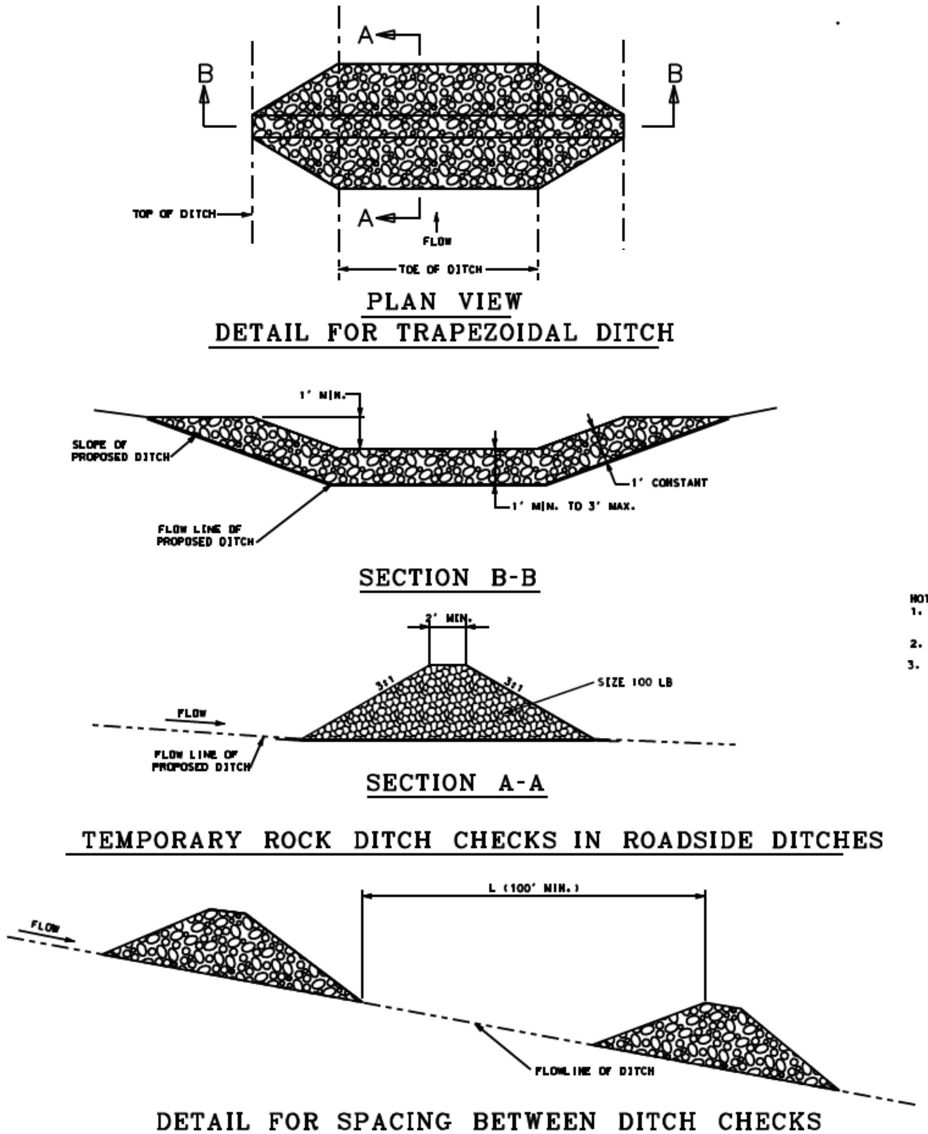

STATE
PROJECT NO.
MISS.
TRIANGULAR SILT DIKE
STAPLES
APRON
18" TYP.
FLOW
B
PLAN VIEW
NOTE:
1. MINIMUM RECOMMENDED PLACEMENT INTERVAL BETWEEN SILT DIKE DITCH CHECK IS 100' UNLESS SHOWN OTHERWISE ON THE PLANS OR EROSION CONTROL PLAN APPROVED BY THE ENGINEER. SEE SPACING GUIDANCE ON ECD-4
2. INSTALLATION SHALL BE IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATIONS.
SILT DIKE DITCH CHECK SELECTION GUIDELINES
SILT DIKES CAN BE USED IN DITCHES WITH CONCENTRATED FLOWS WITHIN THE CLEAR ZONE WHERE RIPRAP CAN NOT BE USED.
DITCH BOTTOM
DIKE SECTION
EL. "B"
STAPLES
EL. "A"
POINT "A" MUST BE HIGHER THAN POINT "B" TO ENSURE THAT WATER FLOWS OVER THE DIKE AND NOT AROUND THE ENDS
SECTION B-B
APRON ANCHORED INTO TRENCH
6"X6" TRENCH
FLOW
STAPLES
DITCH BOTTOM
NOTE: STAPLES SHALL BE PLACED WHERE THE UNITS OVERLAP AND IN THE CENTER OF THE UNIT
SECTION A-A
SILT DIKE INSTALLATION FOR ROADWAY DITCHES
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF EROSION CONTROL
SILT DIKE DITCH CHECK
BY
REVISION
DATE
WORKING NUMBER
ECD-7
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-7.DGN
DESIGN TEAM
CHECKED
DATE



NOTES:

1. MINIMUM SPACING FOR ROCK DITCH CHECKS SHALL BE 100 FEET OR EROSION CONTROL PLAN APPROVED BY THE ENGINEER. SEE SPACING GUIDANCE ON ECD-4
2. ROCK DITCH CHECKS MAY ALSO BE CHOKED WITH FABRIC.
3. SIZE 300 LB RIP RAP MAY BE USED FOR SPECIFED APPLICATIONS AS SHOWN ON EROSION CONTROL PLAN

STATE	PROJECT NO.
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MISSISSIPPI DEPARTMENT OF TRANSPORTATION

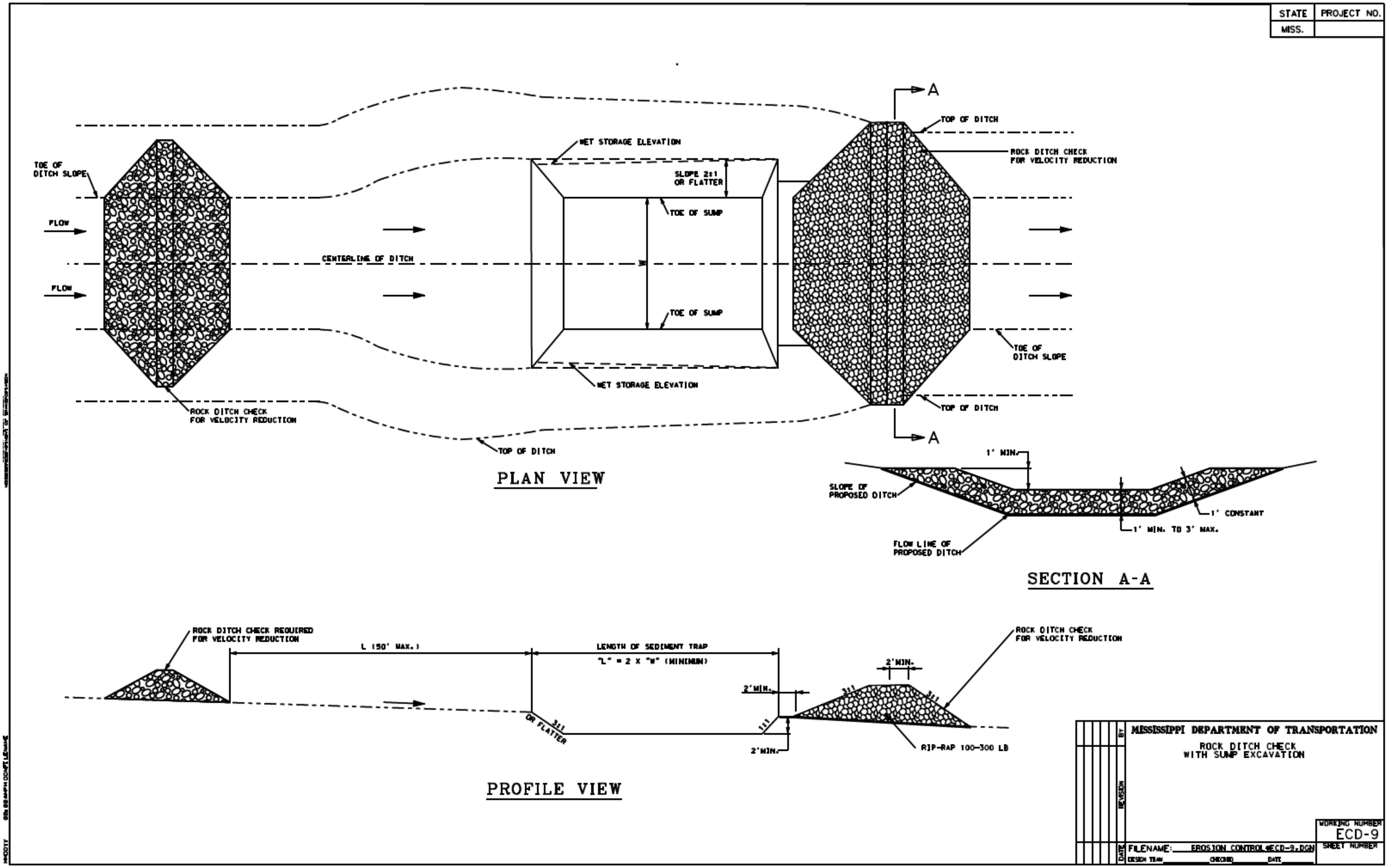
ROCK DITCH CHECK

WORKING NUMBER ECD-8

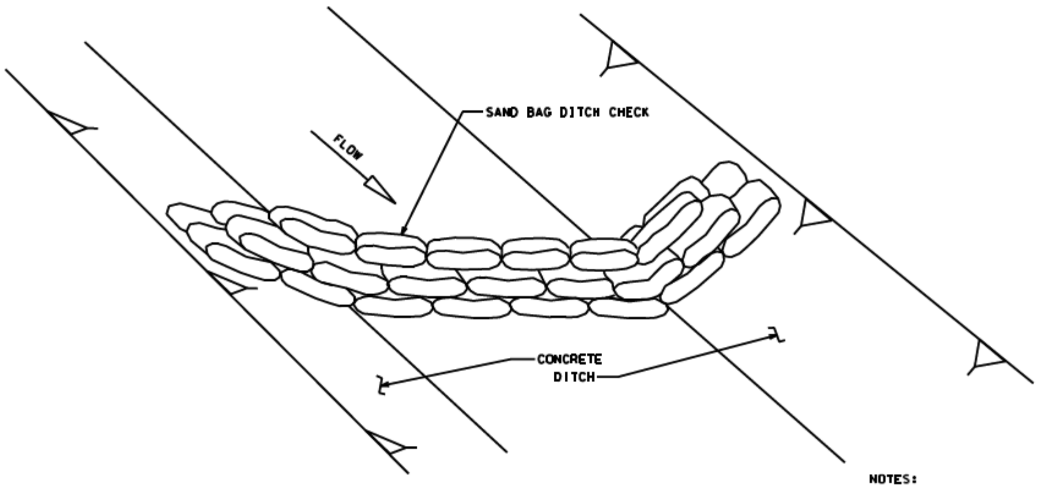
SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-8.DGN

DESIGN TEAM ___ CHECKED ___ DATE ___


STATE
PROJECT NO.
MISS.
TOP OF DITCH
ROCK DITCH CHECK FOR VELOCITY REDUCTION
WET STORAGE ELEVATION
SLOPE 2:1 OR FLATTER
TOE OF DITCH SLOPE
FLOW
TOE OF SUMP
CENTERLINE OF DITCH
W
WET STORAGE ELEVATION
ROCK DITCH CHECK FOR VELOCITY REDUCTION
TOP OF DITCH
A
PLAN VIEW
1' MIN.
SLOPE OF PROPOSED DITCH
1' CONSTANT
1' MIN. TO 3' MAX.
FLOW LINE OF PROPOSED DITCH
SECTION A-A
ROCK DITCH CHECK REQUIRED FOR VELOCITY REDUCTION
L (50' MAX.)
LENGTH OF SEDIMENT TRAP
"L" = 2 X "W" (MINIMUM)
2' MIN.
3:1
OR FLATTER
1:1
RIP-RAP 100-300 LB
PROFILE VIEW
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROCK DITCH CHECK WITH SUMP EXCAVATION
WORKING NUMBER
ECD-9
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-9.DGN

STATE	PROJECT NO.
MISS.	



DETAIL (DITCH CHECK)

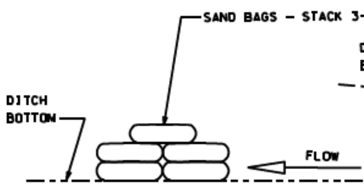
NOTES:

1. MINIMUM RECOMMENDED PLACEMENT INTERVAL BETWEEN SAND BAG DITCH CHECK IS 100' UNLESS SHOWN OTHERWISE ON THE PLANS OR APPROVED BY THE ENGINEER. SEE SPACING GUIDANCE ON ECD-4.

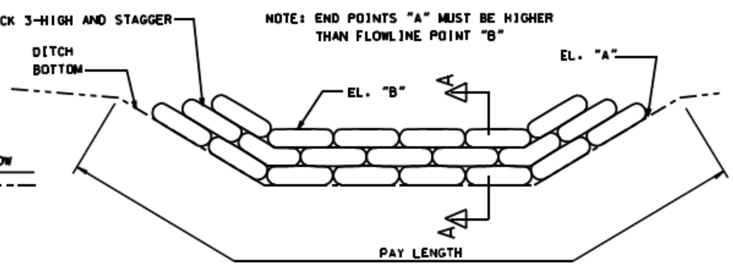
2. PREVENTING SEDIMENT FROM ENTERING A PAVED DITCH IS PREFERABLE TO CAPTURING SEDIMENT WITHIN PAVED DITCH.

SAND BAG DITCH CHECK SELECTION GUIDELINES

SAND BAG DITCH CHECKS ARE USED FOR VELOCITY REDUCTION AND MINIMAL SEDIMENT TRAPPING IN CONCRETE PAVED DITCHES OR IN DITCHES THAT HAVE ROCKY BOTTOMS.



SECTION A-A



ELEVATION DETAIL

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

DETAILS OF EROSION CONTROL
SANDBAG DITCH CHECK

WORKING NUMBER
ECD-20
SHEET NUMBER

FILENAME: EROSION CONTROL-ECD-20.DGN
DESIGN TEAM ______ CHECKED ______ DATE ______

Diversion (DV)

Practice Description

A diversion is a watercourse constructed across a slope consisting of an excavated channel, a compacted ridge, or a combination of both. Most diversions are constructed by excavating a channel and using the excavated material to construct a ridge on the downslope side of the channel. Right-of-way diversions and temporary diversions are sometimes constructed by making a ridge, often called a berm, from fill material.

This practice applies to sites where stormwater runoff can be redirected to permanently protect structures or areas downslope from erosion, sediment, and excessive wetness or localized flooding. Diversions may be used to temporarily divert stormwater runoff to protect disturbed areas and slopes or to retain sediment on-site during construction.

Perimeter protection is sometimes used to describe both permanent and temporary diversions used at either the upslope or downslope side of a construction area.

Right-of-way diversions, sometimes referred to as water bars, are used to shorten the flow length on a sloping right-of-way and reduce the erosion potential of the stormwater runoff.

Water Bar

Planning Considerations

Diversions are designed to intercept and carry excess water to a stable outlet.

Diversions can be useful tools for managing surface water flows and preventing soil erosion. On moderately sloping areas, they may be placed at intervals to trap and divert sheet flow before it has a chance to concentrate and cause rill and gully erosion. Simple water bars illustrate this concept (Figure DV-1).

Diversions may be placed at the top of cut or fill slopes to keep runoff from upgradient drainage areas off the slope. Diversions are also typically built at the base of steeper slopes to protect flatter developed areas that cannot withstand runoff water from outside areas. They can also be used to protect structures, parking lots, adjacent properties, and other special areas from flooding.

Diversions are preferable to other types of man-made stormwater conveyance systems because they more closely simulate natural flow patterns and characteristics. Flow velocities are generally kept to a minimum. When properly coordinated into the landscape design of a site, diversions can he visually pleasing as well as functional.

As with any earthen structure, it is very important to establish adequate vegetation as soon as possible after installation. It is usually important to stabilize the drainage area above the diversion so that sediment will not enter and accumulate in the diversion channel.

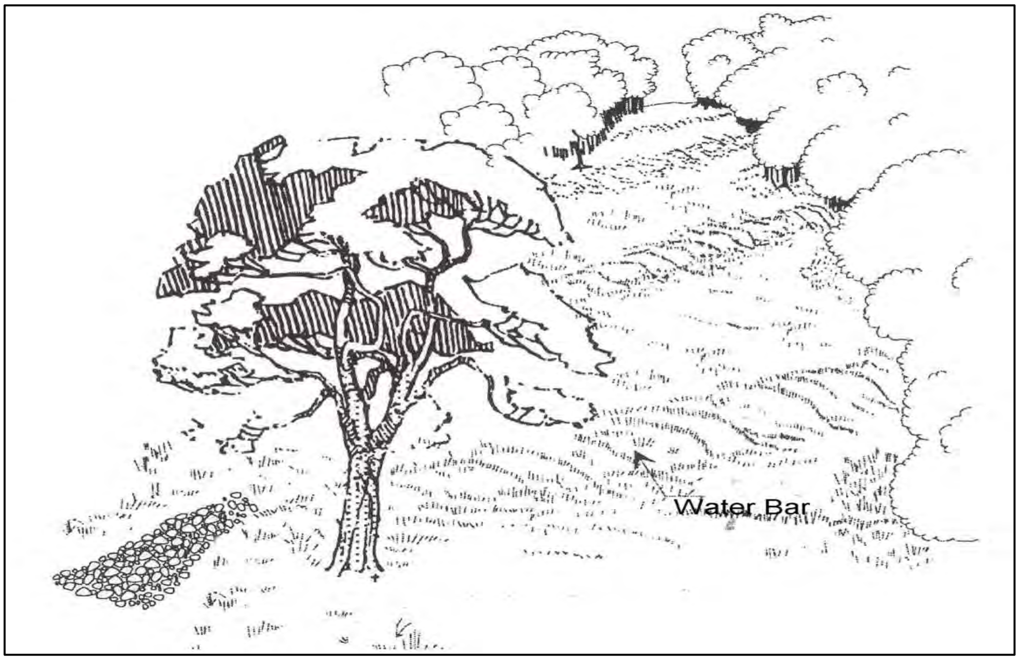


Figure DV-1 Water Bar

Design Considerations

Location

The location of the diversion should be determined by considering outlet conditions, topography, land use, soil type, length of slope, seepage (where seepage is a problem) and the development layout. Outlets must be stable after the diversion empties stormwater flow into it; therefore, care should be exercised in the location selection of the diversion and its outlet.

Capacity

The diversion channel must have a minimum capacity to carry the runoff expected from a storm frequency meeting the requirements of Table DV-l with a freeboard of at least 0.3 foot (Figure DV-2).

The storm frequency should be used to determine the required channel capacity, Q (peak rate of runoff). The peak rate of runoff should be determined using the Natural Resources Conservation Service runoff curve number (RCN) method or other equivalent methods.

Table DV-1 Design Frequency

Diversion Type	Typical Area of Protection	24-Hour Design Storm Frequency
Temporary	Construction Areas	2-year
	Building Sites	5-year
Permanent	Agricultural Land	10-year
	Mined Reclamation Area	10-year
	Recreation Areas	10-year
	Isolated Buildings	25-year
	Urban areas, Residential, School, Industrial Areas, etc.	50-year

Diversions designed to protect homes, schools, industrial buildings, roads, parking lots, and comparable high-risk areas, and those designed to function in connection with other structures, should have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved.

Velocities

Diversions should be designed so that the design velocities are as high as will be safe for the planned type of protective vegetation and the expected maintenance, to minimize sediment deposition in the channel. Maximum permissible velocities are dependent upon the erosion resistance of the soil (Table DV-2) and the quality of the vegetation maintained.

Table DV-2 Permissible Velocities

Soil Texture	Velocity in Feet/Second		
	Conditions of Vegetation		
	Poor	Fair	Good
Sand, Silt, Sandy Loam, Silt Loam	1.5	2.0	3.0
Silty Clay Loam, Sandy Clay Loam	2.5	3.0	4.0
Clay	3.0	4.0	5.0

Channel Design

The diversion channel may be parabolic, trapezoidal or v-shaped, as shown in Figure DV-2 and should be designed in accordance with the procedure shown at the end of this practice. Land slope must be considered when choosing channel dimensions. On steeper slopes, narrow and deep channels may be required. On more gentle slopes, broad, shallow channels can be used to facilitate maintenance.

Ridge Design

The supporting ridge cross section should meet the configuration and requirements of Figure DV-2.

The side slopes should be no steeper than 2:1. Side slopes should be flatter, 5:1 to 10:1, when the diversion is to be permanent with mowing and other maintenance activities performed on or around it.

The width of the ridge at the design water elevation should be a minimum of 4 feet. The minimum freeboard should be 0.3 foot.

The design should include a 10% settlement factor.

Outlet

Diversions should have adequate outlets that will convey concentrated runoff without erosion. Acceptable outlets include practices such as *Grass Swale*, *Lined Swale, Drop Structure*, *Sediment Basin*, and *Stormwater Detention Basins*.

Stabilization

Unless otherwise stabilized, the ridge and channel should be seeded within 13 days of installation in accordance with the applicable seeding practice, *Permanent Seeding or Temporary Seeding.*

Disturbed areas draining into the diversion should be seeded and mulched prior to or at the time the diversion is constructed in accordance with the *Permanent Seeding*, *Temporary Seeding*, or *Mulching Practices* (whichever is applicable).

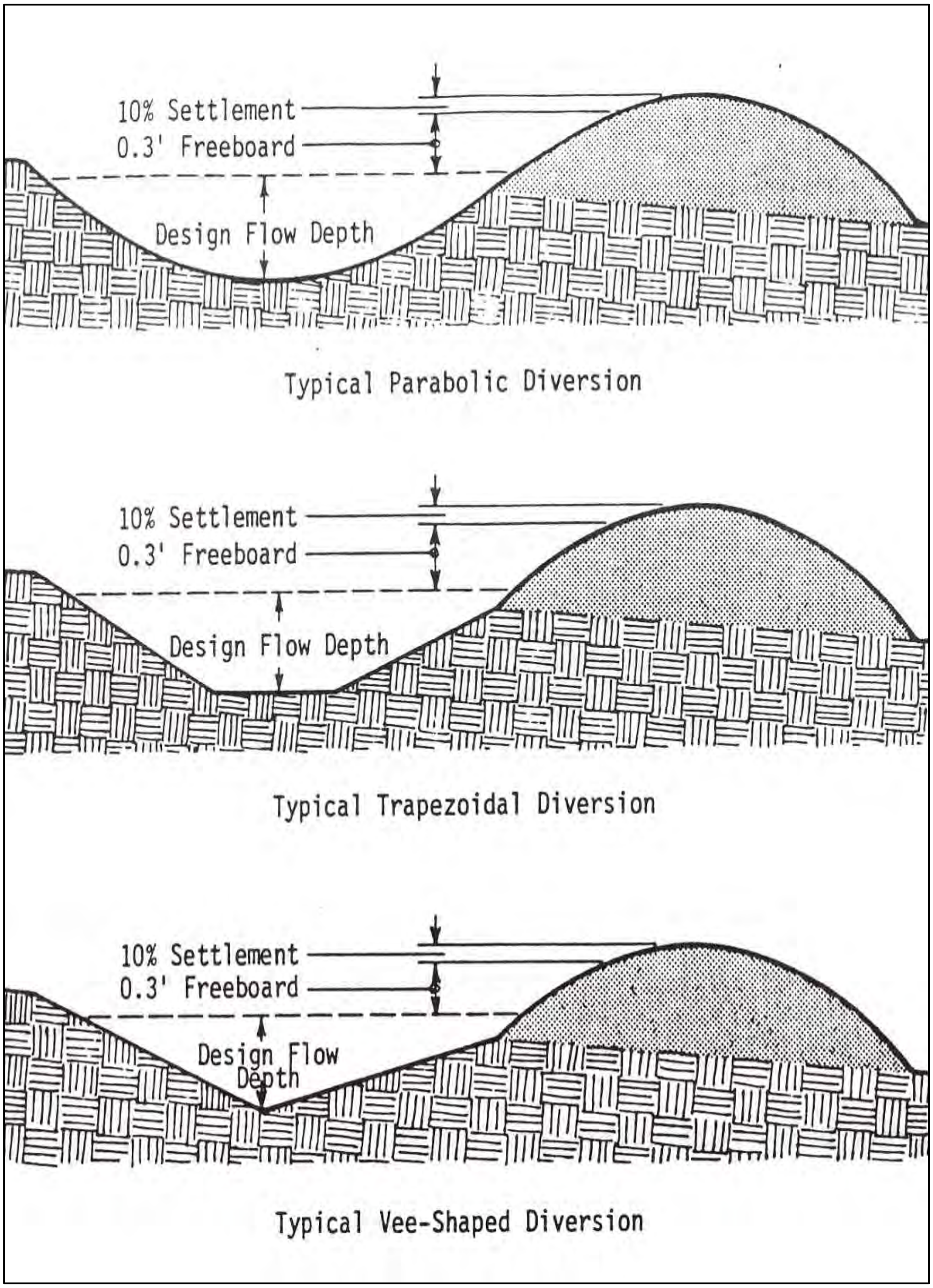


Figure DV-2 Typical Diversions Detail

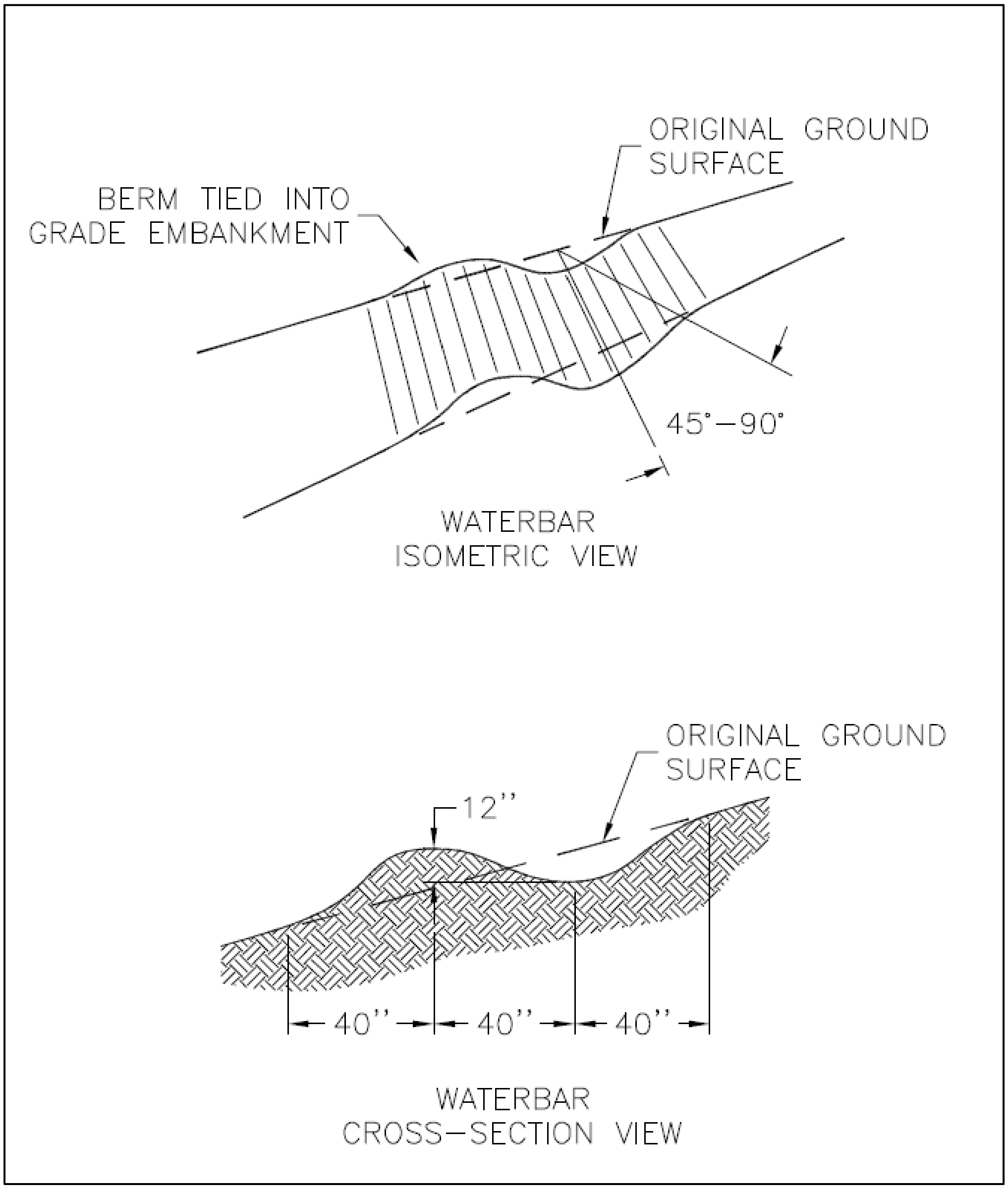


Figure DV-3 Water Bar Detail

Design Criteria

Tables DV-l through DV-16 may be used to facilitate the design of grass-lined diversions with parabolic cross sections. These tables are based on a retardance of "D" (vegetation newly cut) to determine V_1 for stability considerations. To determine channel capacity, choose a retardance of "C" when proper maintenance is expected; otherwise, design channel capacity based on retardance "B." Refer to Table DV-2 for maximum permissible velocities. The permissible velocities guide the selection of V_1 and should not be exceeded. It is good practice to use a value for V_1 that is significantly less than the maximum allowable when choosing a design cross section. When velocities approach the maximum allowable, flatter grades should be evaluated or a more erosion-resistant liner such as erosion control blanket or riprap should be considered. After the diversion dimensions are selected in the design tables, the top width should be increased by 4 feet and the depth by 0.3 foot for freeboard.

Example Problem

Given

Q: 30 cfs
Grade: 1%
Soil: Sandy clay loam
Condition of vegetation expected: fair
Maintenance: low; will be cut only twice a year.
Site will allow a top width of 26 feet.

Find

Diversion top width and depth that will be stable and fit site conditions.

Solution

From Table DV-2, use maximum permissible velocity of 3.0 ft/sec.

Since maintenance will be low, use “B” retardance for capacity.

From Table DV-4, use retardance “D” and “B”;
Grade 1.00 Percent Top width = 21.0 feet + 4 feet = 25.0 feet.

Depth = 1.6 feet + 0.3 foot = 1.9 feet.

V_2 = 1.3 ft/sec.

Note: V_1 < 3.0 ft/sec.; Top width < 26 feet, design O.K.

Note: It is good practice to select a cross section that will give a velocity, V_1, well below the maximum allowable whenever site conditions permit. Wide, shallow cross sections are more stable and require less maintenance. It is always prudent to evaluate flatter design grades in order to best fit diversions to the site and keep velocities well below maximum allowable.

Table DV-3 Parabolic Diversion Design Chart (Retardance “D” and “B,” Grade 0.50%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 0.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15	10.0	2.2	1.0																								
20	13.7	2.1	1.0	8.4	2.7	1.3																					
25	17.4	2.1	1.0	11.3	2.4	1.4																					
30	21.0	2.0	1.0	13.9	2.3	1.4																					
35	24.6	2.0	1.1	16.4	2.3	1.4	10.7	2.8	1.8																		
40	28.5	2.0	1.0	18.9	2.3	1.4	12.6	2.7	1.8																		
45	31.9	2.0	1.1	21.4	2.3	1.4	14.4	2.6	1.8																		
50	35.5	2.0	1.1	23.9	2.2	1.4	16.2	2.5	1.8	9.9	3.4	2.2															
55	39.0	2.0	1.1	26.3	2.2	1.4	17.9	2.5	1.8	11.9	3.1	2.3															
60	42.5	2.0	1.1	28.8	2.2	1.4	19.7	2.5	1.8	13.2	3.0	2.3															
65	46.1	2.0	1.1	31.6	2.2	1.4	21.4	2.5	1.8	14.5	2.9	2.3															
70	49.6	2.0	1.1	34.0	2.2	1.4	23.1	2.5	1.8	15.8	2.9	2.3	11.0	3.6	2.6												
75	53.1	2.0	1.1	36.4	2.2	1.4	24.9	2.5	1.8	17.1	2.8	2.3	12.7	3.4	2.7												
80	56.6	2.0	1.1	38.8	2.2	1.4	26.6	2.5	1.8	18.4	2.8	2.3	13.7	3.3	2.7												
85	60.2	2.0	1.1	41.2	2.2	1.4	28.3	2.5	1.8	19.7	2.8	2.3	14.8	3.2	2.7												
90	63.7	2.0	1.1	43.6	2.2	1.4	30.0	2.4	1.8	20.9	2.8	2.3	15.9	3.2	2.7												
95	67.2	2.0	1.1	46.1	2.2	1.4	31.7	2.4	1.8	22.1	2.8	2.3	16.9	3.1	2.7												
100	70.8	2.0	1.1	48.5	2.2	1.4	33.7	2.4	1.8	23.4	2.8	2.3	17.9	3.1	2.7	12.3	3.9	3.1									
105	74.3	2.0	1.1	50.9	2.2	1.4	35.4	2.4	1.8	24.5	2.7	2.4	18.9	3.1	2.7	13.7	3.7	3.1									
110	77.8	2.0	1.1	53.3	2.2	1.4	37.1	2.4	1.8	25.8	2.7	2.4	19.9	3.1	2.7	14.6	3.6	3.1									
115	81.4	2.0	1.1	55.7	2.2	1.4	38.7	2.4	1.8	27.0	2.7	2.4	20.8	3.0	2.7	15.4	3.6	3.1									
120	84.9	2.0	1.1	58.1	2.2	1.4	40.4	2.4	1.9	28.2	2.7	2.4	21.8	3.0	2.7	16.3	3.5	3.1									
125	88.4	2.0	1.1	60.6	2.2	1.4	42.1	2.4	1.9	29.4	2.7	2.4	22.8	3.0	2.7	17.1	3.5	3.1									
130	92.0	2.0	1.1	63.0	2.2	1.4	43.8	2.4	1.9	30.6	2.7	2.4	23.8	3.0	2.7	17.9	3.5	3.1									
135	95.5	2.0	1.1	65.4	2.2	1.4	45.4	2.4	1.9	31.8	2.7	2.4	24.8	3.0	2.7	18.7	3.4	3.2									
140	99.0	2.0	1.1	67.8	2.2	1.4	47.1	2.4	1.9	33.1	2.7	2.4	25.7	3.0	2.8	19.4	3.4	3.2									
145	102.6	2.0	1.1	70.2	2.2	1.4	48.8	2.4	1.9	34.3	2.7	2.4	26.7	3.0	2.8	20.2	3.4	3.2	13.5	4.4	3.6						
150	106.1	2.0	1.1	72.6	2.2	1.4	50.5	2.4	1.9	35.5	2.7	2.4	27.7	3.0	2.8	21.0	3.4	3.2	14.4	4.3	3.6						

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-4 Parabolic Diversion Design Char (Retardance “D” and “B,” Grade 1.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 1.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	9.7	1.6	1.0	6.2	2.0	1.2																					
15	14.8	1.5	1.0	10.2	1.7	1.3	6.5	2.2	1.5																		
20	20.2	1.5	1.0	13.8	1.7	1.3	9.6	1.9	1.6																		
25	25.1	1.5	1.0	17.4	1.7	1.3	12.2	1.9	1.6	8.5	2.2	2.0															
30	30.1	1.5	1.0	21.0	1.6	1.3	14.9	1.8	1.7	10.6	2.1	2.1															
35	35.1	1.5	1.0	24.7	1.6	1.3	17.5	1.8	1.7	12.6	2.0	2.1	8.9	2.4	2.5												
40	40.1	1.5	1.0	28.2	1.6	1.3	20.0	1.8	1.7	14.5	2.0	2.1	10.5	2.3	2.5												
45	45.1	1.5	1.0	31.7	1.6	1.3	22.5	1.8	1.7	16.4	2.0	2.1	12.1	2.2	2.5	8.2	2.8	2.9									
50	50.2	1.5	1.0	35.2	1.6	1.3	25.4	1.8	1.7	18.3	2.0	2.1	13.6	2.2	2.5	10.0	2.6	2.9									
55	55.2	1.5	1.0	38.8	1.6	1.3	27.9	1.8	1.7	20.3	1.9	2.1	15.1	2.2	2.5	11.2	2.5	3.0									
60	60.2	1.5	1.0	42.3	1.6	1.3	30.4	1.8	1.7	22.2	1.9	2.1	16.6	2.1	2.5	12.4	2.4	3.0									
65	65.2	1.5	1.0	45.8	1.6	1.3	32.9	1.8	1.7	24.0	1.9	2.1	18.0	2.1	2.5	13.6	2.4	3.0	8.9	3.1	3.5						
70	70.2	1.5	1.0	49.3	1.6	1.3	35.5	1.8	1.7	25.9	1.9	2.1	19.5	2.1	2.6	14.8	2.4	3.0	10.6	2.8	3.5						
75	75.2	1.5	1.0	52.8	1.6	1.3	38.0	1.8	1.7	28.2	1.9	2.1	20.9	2.1	2.6	16.0	2.3	3.0	11.5	2.8	3.5						
80	80.2	1.5	1.0	56.3	1.6	1.3	40.5	1.8	1.7	30.0	1.9	2.1	22.3	2.1	2.6	17.1	2.3	3.0	12.5	2.7	3.5						
85	85.2	1.5	1.0	59.8	1.6	1.3	43.0	1.8	1.7	31.9	1.9	2.1	23.7	2.1	2.6	18.3	2.3	3.0	13.5	2.7	3.6	9.8	3.3	3.9			
90	90.2	1.5	1.0	63.3	1.6	1.3	45.6	1.8	1.7	33.6	1.9	2.1	25.2	2.1	2.6	19.4	2.3	3.1	14.4	2.6	3.6	10.9	3.1	3.9			
95	95.2	1.5	1.0	66.9	1.6	1.3	48.1	1.8	1.7	35.5	1.9	2.1	26.6	2.1	2.6	20.5	2.3	3.1	15.3	2.6	3.6	12.0	3.0	3.9			
100	100.2	1.5	1.0	70.4	1.6	1.3	50.6	1.8	1.7	37.4	1.9	2.1	28.0	2.1	2.6	21.6	2.3	3.1	16.2	2.6	3.6	12.9	2.9	4.0			
105	105.3	1.5	1.0	73.9	1.6	1.3	53.1	1.8	1.7	39.2	1.9	2.1	29.8	2.1	2.6	22.8	2.3	3.1	17.1	2.6	3.6	13.7	2.9	4.0	10.8	3.4	4.3
110	110.3	1.5	1.0	77.4	1.6	1.3	55.7	1.8	1.7	41.1	1.9	2.1	31.3	2.1	2.6	23.9	2.3	3.1	18.0	2.6	3.6	14.4	2.9	4.0	12.0	3.2	4.3
115	115.3	1.5	1.0	80.9	1.6	1.3	58.2	1.8	1.7	42.9	1.9	2.1	32.7	2.1	2.6	25.0	2.3	3.1	18.9	2.5	3.6	15.2	2.8	4.0	12.7	3.2	4.3
120	120.3	1.5	1.0	84.4	1.6	1.3	60.7	1.8	1.7	44.8	1.9	2.1	34.1	2.1	2.6	26.1	2.2	3.1	19.7	2.5	3.6	16.0	2.8	4.0	13.4	3.1	4.3
125	125.3	1.5	1.0	88.0	1.6	1.3	63.2	1.8	1.7	46.7	1.9	2.1	35.5	2.1	2.6	27.2	2.2	3.1	20.6	2.5	3.6	16.8	2.8	4.0	14.1	3.1	4.3
130	130.3	1.5	1.0	91.5	1.6	1.3	65.8	1.8	1.7	48.5	1.9	2.1	36.9	2.1	2.6	28.4	2.2	3.1	21.5	2.5	3.6	17.4	2.8	4.0	14.8	3.1	4.3
135	135.3	1.5	1.0	95.0	1.6	1.3	68.3	1.8	1.7	50.4	1.9	2.1	38.3	2.1	2.6	29.5	2.2	3.1	22.4	2.5	3.6	18.2	2.8	4.0	15.5	3.0	4.3
140	140.3	1.5	1.0	98.5	1.6	1.3	70.8	1.8	1.7	52.2	1.9	2.1	39.7	2.0	2.6	30.6	2.2	3.1	23.2	2.5	3.6	18.9	2.7	4.0	16.1	3.0	4.4
145	145.3	1.5	1.0	102.0	1.6	1.3	73.3	1.8	1.7	54.1	1.9	2.1	41.1	2.0	2.6	32.1	2.2	3.0	24.1	2.5	3.6	19.7	2.7	4.0	16.8	3.0	4.4
150	150.3	1.5	1.0	105.5	1.6	1.3	75.9	1.8	1.7	56.0	1.9	2.1	42.5	2.0	2.6	33.2	2.2	3.0	25.0	2.5	3.6	20.4	2.7	4.1	17.5	2.9	4.4

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-5 Parabolic Diversion Design Chart (Retardance “D” and “B,” Grade 2.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 2.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	7.1	1.2	0.9												
10	14.7	1.2	0.9	9.5	1.3	1.2	7.0	1.4	1.5						
15	22.0	1.2	0.9	14.5	1.3	1.2	10.9	1.4	1.5	8.0	1.5	1.8	5.5	1.9	2.1
20	29.3	1.2	0.9	19.6	1.2	1.2	14.6	1.3	1.5	10.9	1.5	1.9	8.1	1.6	2.3
25	36.6	1.2	0.9	24.4	1.2	1.2	18.5	1.3	1.5	13.8	1.4	1.9	10.4	1.6	2.3
30	43.9	1.2	0.9	29.3	1.2	1.2	22.2	1.3	1.6	16.6	1.4	1.9	12.7	1.5	2.3
35	51.2	1.2	0.9	34.2	1.2	1.2	25.8	1.3	1.6	19.6	1.4	1.9	14.9	1.5	2.3
40	58.5	1.2	0.9	39.0	1.2	1.2	29.5	1.3	1.6	22.4	1.4	1.9	17.1	1.5	2.3
45	65.8	1.2	0.9	43.9	1.2	1.2	33.2	1.3	1.6	25.2	1.4	1.9	19.3	1.5	2.3
50	73.1	1.2	0.9	48.8	1.2	1.2	36.8	1.3	1.6	28.0	1.4	1.9	21.7	1.5	2.3
55	80.4	1.2	0.9	53.6	1.2	1.2	40.5	1.3	1.6	30.7	1.4	1.9	23.9	1.5	2.3
60	87.7	1.2	0.9	58.5	1.2	1.2	44.2	1.3	1.6	33.5	1.4	1.9	26.0	1.5	2.3
65	95.0	1.2	0.9	63.4	1.2	1.2	47.9	1.3	1.6	36.3	1.4	1.9	28.2	1.5	2.3
70	102.3	1.2	0.9	68.2	1.2	1.2	51.6	1.3	1.6	39.1	1.4	1.9	30.3	1.5	2.3
75	109.6	1.2	0.9	73.1	1.2	1.2	55.2	1.3	1.6	41.9	1.4	1.9	32.5	1.5	2.3
80	116.9	1.2	0.9	78.0	1.2	1.2	58.9	1.3	1.6	44.7	1.4	1.9	34.6	1.5	2.3
85	124.2	1.2	0.9	82.9	1.2	1.2	62.6	1.3	1.6	47.4	1.4	1.9	36.8	1.5	2.3
90	131.5	1.2	0.9	87.7	1.2	1.2	66.3	1.3	1.6	50.2	1.4	1.9	39.0	1.5	2.3
95	138.8	1.2	0.9	92.6	1.2	1.2	69.9	1.3	1.6	53.0	1.4	1.9	41.1	1.5	2.3
100	146.1	1.2	0.9	97.5	1.2	1.2	73.6	1.3	1.6	55.8	1.4	1.9	43.3	1.5	2.3
105	153.4	1.2	0.9	102.3	1.2	1.2	77.3	1.3	1.6	58.6	1.4	1.9	45.4	1.5	2.3
110	160.7	1.2	0.9	107.2	1.2	1.2	81.0	1.3	1.6	61.4	1.4	1.9	47.6	1.5	2.3
115	168.0	1.2	0.9	112.1	1.2	1.2	84.7	1.3	1.6	64.2	1.4	1.9	49.8	1.5	2.3
120	175.3	1.2	0.9	117.0	1.2	1.2	88.3	1.3	1.6	67.0	1.4	1.9	51.9	1.5	2.3
125	182.6	1.2	0.9	121.8	1.2	1.2	92.0	1.3	1.6	69.7	1.4	1.9	54.1	1.5	2.3
130	189.9	1.2	0.9	126.7	1.2	1.2	95.7	1.3	1.6	72.5	1.4	1.9	56.2	1.5	2.3
135	197.3	1.2	0.9	131.6	1.2	1.2	99.4	1.3	1.6	75.3	1.4	1.9	58.4	1.5	2.3
140	204.6	1.2	0.9	136.5	1.2	1.2	103.1	1.3	1.6	78.1	1.4	1.9	60.6	1.5	2.3
145	211.9	1.2	0.9	141.3	1.2	1.2	106.7	1.3	1.6	80.9	1.4	1.9	62.7	1.5	2.3
150	219.2	1.2	0.9	146.2	1.2	1.2	110.4	1.3	1.6	83.7	1.4	1.9	64.9	1.5	2.3

Q CFS	V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5												
10												
15												
20	5.5	2.1	2.8									
25	7.9	1.8	2.7									
30	9.7	1.7	2.7	7.3	2.0	3.1						
35	11.5	1.7	2.7	8.9	1.9	3.2						
40	13.3	1.6	2.8	10.4	1.8	3.2	8.0	2.1	3.6			
45	15.0	1.6	2.8	11.8	1.8	3.2	9.2	2.0	3.7			
50	16.7	1.6	2.8	13.2	1.8	3.2	10.5	1.9	3.7	7.9	2.3	4.1
55	18.5	1.6	2.8	14.6	1.7	3.2	11.7	1.9	3.7	9.2	2.2	4.1
60	20.2	1.6	2.8	16.0	1.7	3.2	12.8	1.9	3.7	10.2	2.1	4.1
65	22.1	1.6	2.8	17.4	1.7	3.3	14.0	1.9	3.7	11.3	2.1	4.2
70	23.8	1.6	2.8	18.8	1.7	3.3	15.2	1.9	3.7	12.3	2.1	4.2
75	25.5	1.6	2.8	20.1	1.7	3.3	16.2	1.8	3.7	13.2	2.0	4.2
80	27.2	1.6	2.8	21.5	1.7	3.3	17.4	1.8	3.8	14.2	2.0	4.2
85	28.9	1.6	2.8	22.9	1.7	3.3	18.6	1.8	3.8	15.1	2.0	4.2
90	30.6	1.6	2.8	24.6	1.7	3.2	19.8	1.8	3.8	16.1	2.0	4.2
95	32.3	1.6	2.8	25.9	1.7	3.3	20.8	1.8	3.8	17.0	2.0	4.2
100	34.0	1.6	2.8	27.3	1.7	3.3	21.9	1.8	3.8	18.0	2.0	4.2
105	35.7	1.6	2.8	28.6	1.7	3.3	23.0	1.8	3.8	18.9	2.0	4.2
110	37.3	1.6	2.8	30.0	1.7	3.3	24.1	1.8	3.8	19.8	2.0	4.2
115	39.0	1.6	2.8	31.3	1.7	3.3	25.3	1.8	3.8	20.8	2.0	4.2
120	40.7	1.6	2.8	32.7	1.7	3.3	26.7	1.8	3.7	21.7	2.0	4.2
125	42.4	1.6	2.8	34.1	1.7	3.3	27.8	1.8	3.7	22.6	1.9	4.3
130	44.1	1.6	2.8	35.4	1.7	3.3	28.9	1.8	3.7	23.5	1.9	4.3
135	45.8	1.6	2.8	36.8	1.7	3.3	30.0	1.8	3.7	24.5	1.9	4.3
140	47.5	1.6	2.8	38.1	1.7	3.3	31.1	1.8	3.7	25.4	1.9	4.3
145	49.2	1.6	2.8	39.5	1.7	3.3	32.3	1.8	3.7	26.4	1.9	4.3
150	50.9	1.6	2.8	40.8	1.7	3.3	33.4	1.8	3.7	27.3	1.9	4.3

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet. Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-6 Parabolic Diversion Design Chart (Retardance "D" and "B," Grade 4.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 4.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	10.1	0.9	0.8	7.0	1.0	1.1	4.9	1.1	1.4																		
10	20.6	0.9	0.8	14.4	0.9	1.1	10.3	1.0	1.4	7.9	1.1	1.8	6.1	1.2	2.1	4.5	1.4	2.4									
15	30.7	0.9	0.8	21.5	0.9	1.1	15.7	1.0	1.4	12.0	1.1	1.8	9.4	1.1	2.1	7.4	1.2	2.5	6.8	1.4	2.8						
20	40.9	0.9	0.8	28.6	0.9	1.1	20.9	1.0	1.4	16.3	1.0	1.8	12.8	1.1	2.1	10.1	1.2	2.5	8.0	1.3	2.9	6.3	1.4	3.3			
25	51.1	0.9	0.8	35.8	0.9	1.1	26.1	1.0	1.4	20.3	1.0	1.8	16.0	1.1	2.1	12.7	1.2	2.5	10.2	1.3	2.9	8.2	1.4	3.4	6.5	1.5	3.8
30	61.3	0.9	0.8	42.9	0.9	1.1	31.4	1.0	1.4	24.4	1.0	1.8	19.2	1.1	2.1	15.2	1.2	2.5	12.3	1.3	2.9	10.0	1.3	3.4	8.1	1.5	3.8
35	71.5	0.9	0.8	50.1	0.9	1.1	36.6	1.0	1.4	28.3	1.0	1.8	22.4	1.1	2.1	18.0	1.2	2.5	14.4	1.2	2.9	11.7	1.3	3.4	9.6	1.4	3.8
40	81.8	0.9	0.8	57.2	0.9	1.1	41.8	1.0	1.5	32.4	1.0	1.8	25.6	1.1	2.1	20.6	1.2	2.5	16.5	1.2	2.9	13.5	1.3	3.4	11.1	1.4	3.8
45	92.0	0.9	0.8	64.4	0.9	1.1	47.0	1.0	1.5	36.4	1.0	1.8	28.8	1.1	2.1	23.1	1.2	2.5	18.8	1.2	2.9	15.2	1.3	3.4	12.8	1.4	3.9
50	102.2	0.9	0.8	71.5	0.9	1.1	52.2	1.0	1.5	40.5	1.0	1.8	32.0	1.1	2.1	25.7	1.2	2.5	20.9	1.2	2.9	17.0	1.3	3.4	14.0	1.4	3.9
55	112.4	0.9	0.8	78.7	0.9	1.1	57.5	1.0	1.5	44.5	1.0	1.8	35.2	1.1	2.1	28.2	1.2	2.5	23.0	1.2	2.9	18.9	1.3	3.4	15.4	1.4	3.9
60	122.6	0.9	0.8	85.8	0.9	1.1	62.7	1.0	1.5	48.5	1.0	1.8	38.4	1.1	2.2	30.8	1.2	2.5	25.1	1.2	2.9	20.6	1.3	3.4	16.9	1.4	3.9
65	132.8	0.9	0.8	93.0	0.9	1.1	67.9	1.0	1.5	52.8	1.0	1.8	41.5	1.1	2.2	33.4	1.2	2.5	27.2	1.2	2.9	22.3	1.3	3.4	18.3	1.4	3.9
70	143.1	0.9	0.8	100.1	0.9	1.1	73.1	1.0	1.5	56.8	1.0	1.8	44.7	1.1	2.2	35.9	1.2	2.5	29.2	1.2	2.9	24.0	1.3	3.4	20.0	1.4	3.9
75	153.3	0.9	0.8	107.3	0.9	1.1	78.3	1.0	1.5	60.7	1.0	1.8	47.9	1.1	2.2	38.5	1.2	2.5	31.3	1.2	2.9	25.7	1.3	3.4	21.4	1.4	3.9
80	163.6	0.9	0.8	114.4	0.9	1.1	83.6	1.0	1.5	64.7	1.0	1.8	51.1	1.1	2.2	41.0	1.2	2.5	33.4	1.2	2.9	27.4	1.3	3.4	22.8	1.4	3.9
85	173.7	0.9	0.8	121.6	0.9	1.1	88.8	1.0	1.5	68.8	1.0	1.8	54.3	1.1	2.2	43.6	1.2	2.5	35.5	1.2	2.9	29.1	1.3	3.4	24.2	1.4	3.9
90	183.9	0.9	0.8	128.7	0.9	1.1	94.0	1.0	1.5	72.8	1.0	1.8	57.5	1.1	2.2	46.2	1.2	2.5	37.6	1.2	2.9	30.8	1.3	3.4	25.7	1.4	3.9
95	194.1	0.9	0.8	135.9	0.9	1.1	99.2	1.0	1.5	76.6	1.0	1.8	60.7	1.1	2.2	48.7	1.2	2.5	39.7	1.2	2.9	32.5	1.3	3.4	27.1	1.4	3.9
100	204.4	0.9	0.8	143.0	0.9	1.1	104.4	1.0	1.5	80.9	1.0	1.8	63.9	1.1	2.2	51.3	1.2	2.5	41.7	1.2	2.9	34.2	1.3	3.4	28.5	1.3	3.9
105	214.6	0.9	0.8	150.2	0.9	1.1	109.7	1.0	1.5	84.9	1.0	1.8	67.1	1.1	2.2	53.9	1.2	2.5	43.8	1.2	2.9	35.9	1.3	3.4	29.9	1.3	3.9
110	224.8	0.9	0.8	157.4	0.9	1.1	114.9	1.0	1.5	89.0	1.0	1.8	70.3	1.1	2.2	56.4	1.2	2.5	45.9	1.2	2.9	37.6	1.3	3.4	31.3	1.3	3.9
115	235.0	0.9	0.8	164.5	0.9	1.1	120.1	1.0	1.5	93.0	1.0	1.8	73.5	1.1	2.2	59.0	1.2	2.5	48.0	1.2	2.9	39.3	1.3	3.4	32.7	1.3	3.9
120	245.2	0.9	0.8	171.7	0.9	1.1	125.3	1.0	1.5	97.1	1.0	1.8	76.7	1.1	2.2	61.5	1.2	2.5	49.9	1.2	3.0	41.0	1.3	3.4	34.2	1.3	3.9
125	255.5	0.9	0.8	178.8	0.9	1.1	130.5	1.0	1.5	101.1	1.0	1.8	79.9	1.1	2.2	64.1	1.2	2.5	52.0	1.2	3.0	42.7	1.3	3.4	35.6	1.3	3.9
130	265.7	0.9	0.8	186.0	0.9	1.1	135.8	1.0	1.5	105.1	1.0	1.8	83.0	1.1	2.2	66.7	1.2	2.5	54.1	1.2	3.0	44.4	1.3	3.4	37.0	1.3	3.9
135	275.9	0.9	0.8	193.1	0.9	1.1	141.0	1.0	1.5	109.2	1.0	1.8	86.2	1.1	2.2	69.2	1.2	2.5	56.1	1.2	3.0	46.1	1.3	3.4	38.4	1.3	3.9
140	286.1	0.9	0.8	200.3	0.9	1.1	146.2	1.0	1.5	113.2	1.0	1.8	89.4	1.1	2.2	71.8	1.2	2.5	58.2	1.2	3.0	47.8	1.3	3.4	39.9	1.3	3.9
145	296.3	0.9	0.8	207.4	0.9	1.1	151.4	1.0	1.5	117.3	1.0	1.8	92.6	1.1	2.2	74.4	1.2	2.5	60.3	1.2	3.0	49.6	1.3	3.4	41.3	1.3	3.9
150	306.5	0.9	0.8	214.6	0.9	1.1	156.7	1.0	1.5	121.3	1.0	1.8	95.8	1.1	2.2	78.9	1.2	2.5	62.4	1.2	3.0	51.3	1.3	3.4	42.7	1.3	3.9

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-7 Parabolic Diversion Design Chart (Retardance "D" and "B," Grade 6.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 6.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	12.4	0.7	0.8	8.7	0.8	1.0	6.2	0.9	1.4	4.7	1.0	1.8	3.5	1.2	1.9												
10	24.7	0.7	0.8	17.6	0.8	1.0	12.8	0.9	1.4	9.8	0.9	1.7	7.8	1.0	2.0	6.2	1.0	2.3	4.9	1.1	2.7						
15	37.1	0.7	0.8	26.4	0.8	1.1	19.2	0.8	1.4	15.0	0.9	1.7	11.8	0.9	2.0	9.5	1.0	2.4	7.7	1.1	2.7	6.2	1.2	3.1	5.0	1.3	3.5
20	49.4	0.7	0.8	35.1	0.8	1.1	25.6	0.8	1.4	19.9	0.9	1.7	16.0	0.9	2.0	12.9	1.0	2.4	10.4	1.0	2.8	8.5	1.1	3.2	7.0	1.2	3.6
25	61.8	0.7	0.8	43.9	0.8	1.1	32.0	0.8	1.4	24.9	0.9	1.7	19.9	0.9	2.0	16.1	1.0	2.4	13.1	1.0	2.8	10.8	1.1	3.2	8.9	1.2	3.6
30	74.1	0.7	0.8	52.7	0.8	1.1	38.4	0.8	1.4	29.9	0.9	1.7	23.8	0.9	2.1	19.3	1.0	2.4	15.9	1.0	2.8	13.0	1.1	3.2	10.8	1.1	3.6
35	86.5	0.7	0.8	61.5	0.8	1.1	44.8	0.8	1.4	34.8	0.9	1.7	27.8	0.9	2.1	22.5	1.0	2.4	18.5	1.0	2.8	15.4	1.1	3.2	12.7	1.1	3.6
40	98.9	0.7	0.8	70.2	0.8	1.1	51.2	0.8	1.4	39.8	0.9	1.7	31.8	0.9	2.1	25.7	1.0	2.4	21.2	1.0	2.8	17.6	1.1	3.2	14.5	1.1	3.6
45	111.2	0.7	0.8	79.0	0.8	1.1	57.6	0.8	1.4	44.8	0.9	1.7	35.7	0.9	2.1	29.0	1.0	2.4	23.8	1.0	2.8	19.8	1.1	3.2	16.6	1.1	3.6
50	123.6	0.7	0.8	87.8	0.8	1.1	64.0	0.8	1.4	49.7	0.9	1.7	39.7	0.9	2.1	32.2	1.0	2.4	26.4	1.0	2.8	22.0	1.1	3.2	18.4	1.1	3.6
55	136.0	0.7	0.8	96.6	0.8	1.1	70.4	0.8	1.4	54.7	0.9	1.7	43.6	0.9	2.1	35.4	1.0	2.4	29.1	1.0	2.8	24.2	1.1	3.2	20.2	1.1	3.7
60	148.3	0.7	0.8	105.3	0.8	1.1	76.8	0.8	1.4	59.7	0.9	1.7	47.6	0.9	2.1	38.6	1.0	2.4	31.7	1.0	2.8	26.3	1.1	3.2	22.0	1.1	3.7
65	160.6	0.7	0.8	114.1	0.8	1.1	83.2	0.8	1.4	64.7	0.9	1.7	51.6	0.9	2.1	41.8	1.0	2.4	34.3	1.0	2.8	28.5	1.1	3.2	23.8	1.1	3.7
70	173.0	0.7	0.8	122.9	0.8	1.1	89.6	0.8	1.4	69.6	0.9	1.7	55.5	0.9	2.1	45.0	1.0	2.4	37.0	1.0	2.8	30.7	1.1	3.2	25.6	1.1	3.7
75	185.4	0.7	0.8	131.7	0.8	1.1	96.0	0.8	1.4	74.6	0.9	1.7	59.5	0.9	2.1	48.2	1.0	2.4	39.6	1.0	2.8	32.9	1.1	3.2	27.4	1.1	3.7
80	197.7	0.7	0.8	140.4	0.8	1.1	102.3	0.8	1.4	79.6	0.9	1.7	63.5	0.9	2.1	51.4	1.0	2.4	42.2	1.0	2.8	35.1	1.1	3.2	29.3	1.1	3.7
85	210.1	0.7	0.8	149.2	0.8	1.1	108.7	0.8	1.4	84.5	0.9	1.7	67.4	0.9	2.1	54.7	1.0	2.4	44.9	1.0	2.8	37.3	1.1	3.2	31.1	1.1	3.7
90	222.4	0.7	0.8	158.0	0.8	1.1	115.1	0.8	1.4	89.5	0.9	1.7	71.4	0.9	2.1	57.9	1.0	2.4	47.5	1.0	2.8	39.5	1.1	3.2	32.9	1.1	3.7
95	234.8	0.7	0.8	166.8	0.8	1.1	121.5	0.8	1.4	94.5	0.9	1.7	75.4	0.9	2.1	61.1	1.0	2.4	50.2	1.0	2.8	41.7	1.1	3.2	34.7	1.1	3.7
100	247.1	0.7	0.8	175.5	0.8	1.1	127.9	0.8	1.4	99.5	0.9	1.7	79.3	0.9	2.1	64.3	1.0	2.4	52.8	1.0	2.8	43.9	1.1	3.2	36.6	1.1	3.7
105	259.5	0.7	0.8	184.3	0.8	1.1	134.3	0.8	1.4	104.4	0.9	1.7	83.3	0.9	2.1	67.5	1.0	2.4	55.4	1.0	2.8	46.1	1.1	3.2	38.4	1.1	3.7
110	271.8	0.7	0.8	193.1	0.8	1.1	140.7	0.8	1.4	109.4	0.9	1.7	87.3	0.9	2.1	70.7	1.0	2.4	58.1	1.0	2.8	48.2	1.1	3.2	40.2	1.1	3.7
115	284.2	0.7	0.8	201.9	0.8	1.1	147.1	0.8	1.4	114.4	0.9	1.7	91.2	0.9	2.1	73.9	1.0	2.4	60.7	1.0	2.8	50.4	1.1	3.2	42.0	1.1	3.7
120	296.6	0.7	0.8	210.7	0.8	1.1	153.5	0.8	1.4	119.3	0.9	1.7	95.2	0.9	2.1	77.2	1.0	2.4	63.3	1.0	2.8	52.6	1.1	3.2	43.9	1.1	3.7
125	308.9	0.7	0.8	219.4	0.8	1.1	159.9	0.8	1.4	124.3	0.9	1.7	99.2	0.9	2.1	80.4	1.0	2.4	66.0	1.0	2.8	54.8	1.1	3.2	45.7	1.1	3.7
130	321.3	0.7	0.8	228.2	0.8	1.1	166.3	0.8	1.4	129.3	0.9	1.7	103.1	0.9	2.1	83.6	1.0	2.4	68.6	1.0	2.8	57.0	1.1	3.2	47.5	1.1	3.7
135	333.6	0.7	0.8	237.0	0.8	1.1	172.7	0.8	1.4	134.3	0.9	1.7	107.1	0.9	2.1	86.8	1.0	2.4	71.3	1.0	2.8	59.2	1.1	3.2	49.3	1.1	3.7
140	346.0	0.7	0.8	245.8	0.8	1.1	179.1	0.8	1.4	139.2	0.9	1.7	111.0	0.9	2.1	90.0	1.0	2.4	73.9	1.0	2.8	61.4	1.1	3.2	51.2	1.1	3.7
145	358.3	0.7	0.8	254.5	0.8	1.1	185.5	0.8	1.4	144.2	0.9	1.7	115.0	0.9	2.1	93.2	1.0	2.4	76.5	1.0	2.8	63.6	1.1	3.2	53.0	1.1	3.7
150	370.7	0.7	0.8	263.3	0.8	1.1	191.9	0.8	1.4	149.2	0.9	1.7	119.0	0.9	2.1	96.4	1.0	2.4	79.2	1.0	2.8	65.8	1.1	3.2	54.8	1.1	3.7

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second. Depth "D" does not include allowance for freeboard or settlement.

Table DV-8 Parabolic Diversion Design Chart (Retardance “D” and “B,” Grade 8.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 8.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	14.0	0.7	0.8	10.1	0.7	1.0	7.4	0.8	1.3	5.5	0.8	1.6	4.4	0.9	1.9	3.4	1.0	2.1									
10	28.0	0.7	0.8	20.1	0.7	1.0	15.0	0.8	1.3	11.3	0.8	1.7	9.1	0.8	2.0	7.4	0.9	2.3	6.0	0.9	2.6	4.9	1.0	3.0	3.6	1.2	3.3
15	41.9	0.7	0.8	30.1	0.7	1.0	22.4	0.8	1.3	17.0	0.8	1.7	13.9	0.8	2.0	11.4	0.9	2.3	9.2	0.9	2.7	7.8	1.0	3.0	6.3	1.0	3.4
20	55.9	0.7	0.8	40.1	0.7	1.0	29.9	0.8	1.3	22.6	0.8	1.7	18.5	0.8	2.0	15.1	0.9	2.3	12.5	0.9	2.7	10.2	1.0	3.1	8.5	1.0	3.5
25	69.9	0.7	0.8	50.1	0.7	1.0	37.3	0.8	1.3	28.2	0.8	1.7	23.1	0.8	2.0	18.8	0.9	2.3	15.6	0.9	2.7	13.0	0.9	3.1	10.8	1.0	3.5
30	83.9	0.7	0.8	60.1	0.7	1.0	44.8	0.8	1.3	33.9	0.8	1.7	27.7	0.8	2.0	22.6	0.9	2.3	18.6	0.9	2.7	15.6	0.9	3.1	13.0	1.0	3.5
35	97.9	0.7	0.8	70.1	0.7	1.0	52.3	0.8	1.3	39.5	0.8	1.7	32.3	0.8	2.0	26.3	0.9	2.3	21.7	0.9	2.7	18.2	0.9	3.1	15.3	1.0	3.5
40	111.8	0.7	0.8	80.2	0.7	1.0	59.7	0.8	1.3	45.1	0.8	1.7	36.9	0.8	2.0	30.1	0.9	2.3	24.8	0.9	2.7	20.8	0.9	3.1	17.6	1.0	3.5
45	125.8	0.7	0.8	90.2	0.7	1.0	67.2	0.8	1.3	50.8	0.8	1.7	41.5	0.8	2.0	33.8	0.9	2.3	27.9	0.9	2.7	23.3	0.9	3.1	19.7	1.0	3.5
50	139.8	0.7	0.8	100.2	0.7	1.0	74.7	0.8	1.3	56.4	0.8	1.7	46.1	0.8	2.0	37.6	0.9	2.3	31.0	0.9	2.7	25.9	0.9	3.1	21.9	1.0	3.5
55	153.8	0.7	0.8	110.2	0.7	1.0	82.1	0.8	1.3	62.1	0.8	1.7	50.7	0.8	2.0	41.3	0.9	2.3	34.1	0.9	2.7	28.5	0.9	3.1	24.0	1.0	3.5
60	167.8	0.7	0.8	120.2	0.7	1.0	89.6	0.8	1.3	67.7	0.8	1.7	55.3	0.8	2.0	45.1	0.9	2.3	37.2	0.9	2.7	31.1	0.9	3.1	26.2	1.0	3.5
65	181.7	0.7	0.8	130.3	0.7	1.0	97.0	0.8	1.3	73.3	0.8	1.7	60.0	0.8	2.0	48.8	0.9	2.3	40.3	0.9	2.7	33.7	0.9	3.1	28.4	1.0	3.5
70	195.7	0.7	0.8	140.3	0.7	1.0	104.5	0.8	1.3	79.0	0.8	1.7	64.5	0.8	2.0	52.6	0.9	2.3	43.4	0.9	2.7	36.3	0.9	3.1	30.6	1.0	3.5
75	209.7	0.7	0.8	150.3	0.7	1.0	112.0	0.8	1.3	84.6	0.8	1.7	69.2	0.8	2.0	56.3	0.9	2.3	46.5	0.9	2.7	38.9	0.9	3.1	32.8	1.0	3.5
80	223.7	0.7	0.8	160.3	0.7	1.0	119.4	0.8	1.3	90.3	0.8	1.7	73.8	0.8	2.0	60.1	0.9	2.3	49.6	0.9	2.7	41.4	0.9	3.1	36.0	1.0	3.5
85	237.7	0.7	0.8	170.3	0.7	1.0	126.9	0.8	1.3	95.9	0.8	1.7	78.4	0.8	2.0	63.8	0.9	2.3	52.7	0.9	2.7	44.0	0.9	3.1	37.1	1.0	3.5
90	251.6	0.7	0.8	180.3	0.7	1.0	134.4	0.8	1.3	101.6	0.8	1.7	83.0	0.8	2.0	67.6	0.9	2.3	55.8	0.9	2.7	46.6	0.9	3.1	39.3	1.0	3.5
95	265.6	0.7	0.8	190.4	0.7	1.0	141.8	0.8	1.3	107.2	0.8	1.7	87.6	0.8	2.0	71.3	0.9	2.3	58.9	0.9	2.7	49.2	0.9	3.1	41.5	1.0	3.5
100	270.8	0.7	0.8	200.4	0.7	1.0	149.3	0.8	1.3	112.8	0.8	1.7	92.2	0.8	2.0	75.1	0.9	2.3	62.0	0.9	2.7	51.8	0.9	3.1	43.7	1.0	3.5
105	293.6	0.7	0.8	210.4	0.7	1.0	156.8	0.8	1.3	118.5	0.8	1.7	96.8	0.8	2.0	78.9	0.9	2.3	65.1	0.9	2.7	54.4	0.9	3.1	45.9	1.0	3.5
110	307.6	0.7	0.8	220.4	0.7	1.0	164.2	0.8	1.3	124.1	0.8	1.7	101.4	0.8	2.0	82.6	0.9	2.3	68.2	0.9	2.7	57.0	0.9	3.1	48.0	1.0	3.5
115	321.6	0.7	0.8	230.4	0.7	1.0	171.7	0.8	1.3	129.8	0.8	1.7	106.1	0.8	2.0	86.4	0.9	2.3	71.3	0.9	2.7	59.6	0.9	3.1	50.2	1.0	3.5
120	335.5	0.7	0.8	240.5	0.7	1.0	179.1	0.8	1.3	135.4	0.8	1.7	110.7	0.8	2.0	90.1	0.9	2.3	74.4	0.9	2.7	62.2	0.9	3.1	52.4	1.0	3.5
125	349.5	0.7	0.8	250.5	0.7	1.0	186.6	0.8	1.3	141.0	0.8	1.7	115.3	0.8	2.0	93.9	0.9	2.3	77.5	0.9	2.7	64.7	0.9	3.1	54.6	1.0	3.5
130	363.5	0.7	0.8	260.5	0.7	1.0	194.1	0.8	1.3	146.7	0.8	1.7	119.9	0.8	2.0	97.6	0.9	2.3	80.6	0.9	2.7	67.3	0.9	3.1	56.8	1.0	3.5
135	377.5	0.7	0.8	270.5	0.7	1.0	201.5	0.8	1.3	152.3	0.8	1.7	124.5	0.8	2.0	101.4	0.9	2.3	83.7	0.9	2.7	69.9	0.9	3.1	59.0	1.0	3.5
140	391.5	0.7	0.8	280.5	0.7	1.0	209.0	0.8	1.3	158.0	0.8	1.7	129.1	0.8	2.0	105.1	0.9	2.3	86.8	0.9	2.7	72.5	0.9	3.1	61.1	1.0	3.5
145	405.4	0.7	0.8	290.6	0.7	1.0	216.5	0.8	1.3	163.6	0.8	1.7	133.7	0.8	2.0	108.9	0.9	2.3	89.9	0.9	2.7	75.1	0.9	3.1	63.3	1.0	3.5
150	419.4	0.7	0.8	300.6	0.7	1.0	223.9	0.8	1.3	169.3	0.8	1.7	138.3	0.8	2.0	112.6	0.9	2.3	93.0	0.9	2.7	77.7	0.9	3.1	65.5	1.0	3.5

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet. Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-9 Parabolic Diversion Design Chart (Retardance “D” and “B,” Grade 10.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "B"

Grade 10.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	15.3	0.6	0.8	11.1	0.7	1.0	8.1	0.7	1.3	6.3	0.7	1.6	4.6	0.8	1.9	4.0	0.9	2.2	3.1	1.0	2.4						
10	30.6	0.6	0.8	22.1	0.7	1.0	16.5	0.7	1.3	12.8	0.7	1.6	10.0	0.8	2.0	8.4	0.8	2.2	6.9	0.8	2.6	5.7	0.9	2.9	4.7	1.0	3.3
15	45.9	0.6	0.8	33.2	0.7	1.0	24.7	0.7	1.3	19.2	0.7	1.6	15.0	0.8	2.0	12.7	0.8	2.2	10.5	0.8	2.6	8.7	0.9	3.0	7.3	0.9	3.3
20	61.2	0.6	0.8	44.2	0.7	1.0	32.9	0.7	1.3	25.6	0.7	1.6	20.0	0.8	2.0	17.0	0.8	2.2	14.1	0.8	2.6	11.8	0.9	3.0	9.8	0.9	3.4
25	76.5	0.6	0.8	55.3	0.7	1.0	41.1	0.7	1.3	32.0	0.7	1.6	25.0	0.8	2.0	21.2	0.8	2.3	17.6	0.8	2.6	14.7	0.9	3.0	12.5	0.9	3.4
30	91.8	0.6	0.8	66.3	0.7	1.0	49.3	0.7	1.3	38.3	0.7	1.6	29.9	0.8	2.0	25.4	0.8	2.2	21.1	0.8	2.6	17.7	0.8	3.0	15.0	0.9	3.3
35	107.1	0.6	0.8	77.4	0.7	1.0	57.5	0.7	1.3	44.7	0.7	1.6	34.9	0.8	2.0	29.7	0.8	2.3	24.6	0.8	2.6	20.6	0.8	3.0	17.5	0.9	3.4
40	122.4	0.6	0.8	88.4	0.7	1.0	65.7	0.7	1.3	51.1	0.7	1.6	39.9	0.8	2.0	33.9	0.8	2.3	28.1	0.8	2.6	23.5	0.8	3.0	20.0	0.9	3.4
45	137.8	0.6	0.8	99.5	0.7	1.0	73.9	0.7	1.3	57.5	0.7	1.6	44.9	0.8	2.0	38.0	0.8	2.3	31.6	0.8	2.6	26.5	0.8	3.0	22.5	0.9	3.4
50	153.1	0.6	0.8	110.6	0.7	1.0	82.1	0.7	1.3	63.9	0.7	1.6	49.9	0.8	2.0	42.2	0.8	2.3	35.1	0.8	2.6	29.4	0.8	3.0	25.0	0.9	3.4
55	168.4	0.6	0.8	121.6	0.7	1.0	90.3	0.7	1.3	70.3	0.7	1.6	54.9	0.8	2.0	46.4	0.8	2.3	38.6	0.8	2.6	32.3	0.8	3.0	27.5	0.9	3.4
60	183.7	0.6	0.8	132.7	0.7	1.0	98.6	0.7	1.3	76.7	0.7	1.6	59.9	0.8	2.0	50.7	0.8	2.3	42.1	0.8	2.6	35.3	0.8	3.0	30.0	0.9	3.4
65	199.0	0.6	0.8	143.7	0.7	1.0	106.7	0.7	1.3	83.1	0.7	1.6	64.8	0.8	2.0	54.9	0.8	2.3	45.6	0.8	2.6	38.2	0.8	3.0	32.5	0.9	3.4
70	214.3	0.6	0.8	154.8	0.7	1.0	115.0	0.7	1.3	89.4	0.7	1.6	69.8	0.8	2.0	59.1	0.8	2.3	49.1	0.8	2.6	41.2	0.8	3.0	35.0	0.9	3.4
75	229.6	0.6	0.8	165.8	0.7	1.0	123.2	0.7	1.3	95.8	0.7	1.6	74.8	0.8	2.0	63.3	0.8	2.3	52.6	0.8	2.6	44.1	0.8	3.0	37.4	0.9	3.4
80	244.9	0.6	0.8	176.9	0.7	1.0	131.4	0.7	1.3	102.2	0.7	1.6	79.8	0.8	2.0	67.6	0.8	2.3	56.1	0.8	2.6	47.0	0.8	3.0	39.9	0.9	3.4
85	260.2	0.6	0.8	187.9	0.7	1.0	139.6	0.7	1.3	108.6	0.7	1.6	84.8	0.8	2.0	71.8	0.8	2.3	59.6	0.8	2.6	50.0	0.8	3.0	42.3	0.9	3.4
90	275.5	0.6	0.8	199.0	0.7	1.0	147.8	0.7	1.3	115.0	0.7	1.6	89.8	0.8	2.0	76.0	0.8	2.3	63.1	0.8	2.6	52.9	0.8	3.0	44.8	0.9	3.4
95	290.8	0.6	0.8	210.0	0.7	1.0	156.0	0.7	1.3	121.4	0.7	1.6	94.8	0.8	2.0	80.2	0.8	2.3	66.6	0.8	2.6	55.8	0.8	3.0	47.3	0.9	3.4
100	306.1	0.6	0.8	221.1	0.7	1.0	164.2	0.7	1.3	127.8	0.7	1.6	99.8	0.8	2.0	84.4	0.8	2.3	70.1	0.8	2.6	58.8	0.8	3.0	49.7	0.9	3.4
105	321.4	0.6	0.8	232.2	0.7	1.0	172.4	0.7	1.3	134.2	0.7	1.6	104.7	0.8	2.0	88.7	0.8	2.3	73.6	0.8	2.6	61.7	0.8	3.0	52.2	0.9	3.4
110	336.7	0.6	0.8	243.2	0.7	1.0	180.6	0.7	1.3	140.5	0.7	1.6	109.7	0.8	2.0	92.9	0.8	2.3	77.1	0.8	2.6	64.7	0.8	3.0	54.7	0.9	3.4
115	352.0	0.6	0.8	254.3	0.7	1.0	188.8	0.7	1.3	146.9	0.7	1.6	114.7	0.8	2.0	97.1	0.8	2.3	80.6	0.8	2.6	67.6	0.8	3.0	57.2	0.9	3.4
120	367.3	0.6	0.8	265.3	0.7	1.0	197.1	0.7	1.3	153.3	0.7	1.6	119.7	0.8	2.0	101.3	0.8	2.3	84.1	0.8	2.6	70.6	0.8	3.0	59.7	0.9	3.4
125	382.6	0.6	0.8	276.4	0.7	1.0	205.3	0.7	1.3	159.7	0.7	1.6	124.7	0.8	2.0	105.6	0.8	2.3	87.6	0.8	2.6	73.5	0.8	3.0	62.2	0.9	3.4
130	397.9	0.6	0.8	287.4	0.7	1.0	213.5	0.7	1.3	166.1	0.7	1.6	129.7	0.8	2.0	109.8	0.8	2.3	91.1	0.8	2.6	76.4	0.8	3.0	64.7	0.9	3.4
135	413.2	0.6	0.8	298.5	0.7	1.0	221.7	0.7	1.3	172.5	0.7	1.6	134.7	0.8	2.0	114.0	0.8	2.3	94.6	0.8	2.6	79.3	0.8	3.0	67.2	0.9	3.4
140	428.6	0.6	0.8	309.5	0.7	1.0	229.9	0.7	1.3	178.9	0.7	1.6	139.7	0.8	2.0	118.2	0.8	2.3	98.1	0.8	2.6	82.3	0.8	3.0	69.6	0.9	3.4
145	443.9	0.6	0.8	320.6	0.7	1.0	238.1	0.7	1.3	185.3	0.7	1.6	144.6	0.8	2.0	122.4	0.8	2.3	101.7	0.8	2.6	85.2	0.8	3.0	72.1	0.9	3.4
150	459.2	0.6	0.8	331.7	0.7	1.0	246.3	0.7	1.3	191.8	0.7	1.6	149.6	0.8	2.0	126.7	0.8	2.3	105.2	0.8	2.6	88.2	0.9	3.0	74.6	0.9	3.4

RETARDANCE "D" AND "B"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-10 Parabolic Diversion Design Chart (Retardance "D" and "C," Grade .50%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15	8.4	1.6	1.7																								
20	11.7	1.5	1.7	7.1	2.0	2.2																					
25	14.9	1.5	1.7	9.7	1.8	2.2																					
30	18.0	1.5	1.7	12.0	1.7	2.2																					
35	21.0	1.5	1.7	14.2	1.7	2.2	9.3	2.1	2.7																		
40	24.4	1.5	1.7	16.3	1.7	2.2	10.9	2.0	2.7																		
45	27.4	1.5	1.7	18.5	1.7	2.2	12.5	2.0	2.7																		
50	30.5	1.5	1.7	20.6	1.7	2.2	14.1	1.9	2.7	8.7	2.6	3.3															
55	33.5	1.5	1.7	22.7	1.7	2.2	15.7	1.9	2.7	10.4	2.4	3.3															
60	36.6	1.5	1.7	24.8	1.7	2.2	17.2	1.9	2.7	11.7	2.3	3.3															
65	39.6	1.5	1.7	27.3	1.7	2.2	18.8	1.9	2.7	12.9	2.3	3.3															
70	42.6	1.5	1.7	29.4	1.7	2.2	20.3	1.9	2.7	14.0	2.2	3.3	9.8	2.8	3.8												
75	45.7	1.5	1.7	31.4	1.7	2.2	21.8	1.9	2.7	15.2	2.2	3.3	11.3	2.7	3.8												
80	48.7	1.5	1.7	33.5	1.7	2.2	23.3	1.9	2.7	16.3	2.2	3.3	12.2	2.6	3.8												
85	51.7	1.5	1.7	35.6	1.6	2.2	24.8	1.9	2.7	17.4	2.2	3.3	13.2	2.5	3.8												
90	54.8	1.5	1.7	37.7	1.6	2.2	26.3	1.9	2.7	18.5	2.2	3.3	14.2	2.5	3.8												
95	57.8	1.5	1.7	39.8	1.6	2.2	27.8	1.9	2.7	19.6	2.2	3.3	15.1	2.5	3.8												
100	60.9	1.5	1.7	41.9	1.6	2.2	29.7	1.9	2.7	20.7	2.2	3.3	16.0	2.5	3.8	11.0	3.2	4.3									
105	63.9	1.5	1.7	44.0	1.6	2.2	31.2	1.9	2.7	21.8	2.2	3.3	16.9	2.5	3.8	12.3	3.0	4.3									
110	66.9	1.5	1.7	46.1	1.6	2.2	32.6	1.9	2.7	22.9	2.2	3.3	17.8	2.4	3.8	13.1	2.9	4.3									
115	70.0	1.5	1.7	48.1	1.6	2.2	34.1	1.9	2.7	24.0	2.1	3.3	18.7	2.4	3.8	13.9	2.9	4.3									
120	73.0	1.5	1.7	50.2	1.6	2.2	35.6	1.9	2.7	25.1	2.1	3.3	19.6	2.4	3.8	14.6	2.9	4.3									
125	76.1	1.5	1.7	52.3	1.6	2.2	37.1	1.9	2.7	26.2	2.1	3.3	20.5	2.4	3.8	15.4	2.8	4.3									
130	79.1	1.5	1.7	54.4	1.6	2.2	38.5	1.9	2.7	27.3	2.1	3.3	21.3	2.4	3.8	16.1	2.8	4.3									
135	82.1	1.5	1.7	56.5	1.6	2.2	40.0	1.9	2.7	28.4	2.1	3.3	22.2	2.4	3.8	16.9	2.8	4.3									
140	85.2	1.5	1.7	58.6	1.6	2.2	41.5	1.9	2.7	29.4	2.1	3.3	23.1	2.4	3.8	17.6	2.8	4.3									
145	88.2	1.5	1.7	60.7	1.6	2.2	43.0	1.9	2.7	30.5	2.1	3.3	24.0	2.4	3.8	18.3	2.8	4.3	12.3	3.7	4.9						
160	91.3	1.5	1.7	62.8	1.6	2.2	44.5	1.9	2.7	31.6	2.1	3.3	24.8	2.4	3.8	19.0	2.7	4.3	13.1	3.5	4.9						

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-11 Parabolic Diversion Design Chart (Retardance “D” and “C,” Grade 1.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	8.2	1.2	1.6	5.2	1.4	2.0																					
15	12.6	1.1	1.6	8.7	1.3	2.1	5.5	1.6	2.6																		
20	17.1	1.1	1.6	11.8	1.2	2.1	8.2	1.4	2.6																		
25	21.4	1.1	1.6	14.9	1.2	2.1	10.5	1.4	2.6	7.3	1.6	3.1															
30	25.7	1.1	1.6	18.0	1.2	2.1	12.8	1.4	2.6	9.1	1.6	3.2															
35	29.9	1.1	1.6	21.2	1.2	2.1	15.0	1.3	2.6	10.9	1.5	3.1	7.8	1.8	3.7												
40	34.2	1.1	1.6	24.3	1.2	2.1	17.3	1.3	2.6	12.6	1.5	3.1	9.2	1.7	3.7												
45	38.5	1.1	1.6	27.3	1.2	2.1	19.5	1.3	2.6	14.3	1.5	3.1	10.6	1.7	3.7	7.2	2.2	4.3									
50	42.7	1.1	1.6	30.3	1.2	2.1	21.9	1.3	2.6	16.0	1.5	3.2	11.9	1.7	3.7	8.8	2.0	4.3									
55	47.0	1.1	1.6	33.3	1.2	2.1	24.1	1.3	2.6	17.7	1.5	3.2	13.3	1.7	3.7	9.9	1.9	4.3									
60	51.3	1.1	1.6	36.3	1.2	2.1	26.3	1.3	2.6	19.3	1.5	3.2	14.6	1.7	3.7	11.0	1.9	4.3									
65	55.5	1.1	1.6	39.4	1.2	2.1	28.5	1.3	2.6	21.0	1.5	3.2	15.9	1.6	3.7	12.1	1.9	4.3	8.0	2.5	4.9						
70	59.8	1.1	1.6	42.4	1.2	2.1	30.7	1.3	2.6	22.7	1.5	3.2	17.1	1.6	3.7	13.2	1.9	4.3	9.5	2.3	4.8						
75	64.1	1.1	1.6	45.4	1.2	2.1	32.9	1.3	2.6	24.6	1.5	3.1	18.5	1.6	3.7	14.2	1.8	4.3	10.4	2.2	4.9						
80	68.3	1.1	1.6	48.4	1.2	2.1	35.0	1.3	2.6	26.2	1.5	3.1	19.8	1.6	3.7	15.2	1.8	4.3	11.3	2.2	4.9						
85	72.6	1.1	1.6	51.5	1.2	2.1	37.2	1.3	2.6	27.9	1.5	3.1	21.0	1.6	3.7	16.3	1.8	4.3	12.1	2.2	4.9	8.8	2.7	5.4			
90	76.9	1.1	1.6	54.5	1.2	2.1	39.4	1.3	2.6	29.5	1.5	3.1	22.3	1.6	3.7	17.3	1.8	4.3	13.0	2.1	4.9	9.8	2.6	5.4			
95	81.1	1.1	1.6	57.5	1.2	2.1	41.6	1.3	2.6	31.1	1.5	3.1	23.6	1.6	3.7	18.3	1.8	4.3	13.8	2.1	4.9	10.9	2.5	5.3			
100	85.4	1.1	1.6	60.5	1.2	2.1	43.8	1.3	2.6	32.7	1.5	3.1	24.9	1.6	3.7	19.3	1.8	4.3	14.6	2.1	4.9	11.6	2.4	5.4			
105	89.7	1.1	1.6	63.6	1.2	2.1	46.0	1.3	2.6	34.4	1.5	3.1	26.5	1.6	3.7	20.3	1.8	4.3	15.4	2.1	4.9	12.4	2.4	5.4	9.7	2.8	5.8
110	94.0	1.1	1.6	66.6	1.2	2.1	48.2	1.3	2.6	36.0	1.5	3.1	27.7	1.6	3.7	21.3	1.8	4.3	16.2	2.1	4.9	13.1	2.4	5.4	10.8	2.6	5.8
115	98.2	1.1	1.6	69.6	1.2	2.1	50.4	1.3	2.6	37.6	1.5	3.1	29.0	1.6	3.7	22.3	1.8	4.3	17.0	2.1	4.9	13.8	2.3	5.4	11.5	2.6	5.8
120	102.5	1.1	1.6	72.6	1.2	2.1	52.5	1.3	2.6	39.3	1.5	3.1	30.2	1.6	3.7	23.3	1.8	4.3	17.9	2.1	4.9	14.5	2.3	5.4	12.2	2.6	5.8
125	106.8	1.1	1.6	75.7	1.2	2.1	54.7	1.3	2.6	40.9	1.5	3.1	31.5	1.6	3.7	24.3	1.8	4.3	18.7	2.1	4.9	15.2	2.3	5.4	12.8	2.5	5.8
130	111.0	1.1	1.6	78.7	1.2	2.1	56.9	1.3	2.6	42.5	1.5	3.1	32.7	1.6	3.7	25.3	1.8	4.3	19.4	2.1	4.9	15.9	2.3	5.4	13.4	2.5	5.8
135	115.3	1.1	1.6	81.7	1.2	2.1	59.1	1.3	2.6	44.2	1.5	3.1	34.0	1.6	3.7	26.3	1.8	4.3	20.2	2.0	4.9	16.6	2.3	5.4	14.1	2.5	5.8
140	119.6	1.1	1.6	84.7	1.2	2.1	61.3	1.3	2.6	45.8	1.5	3.1	35.2	1.6	3.7	27.3	1.8	4.3	21.0	2.0	4.9	17.2	2.3	5.4	14.7	2.5	5.8
145	123.8	1.1	1.6	87.8	1.2	2.1	63.5	1.3	2.6	47.5	1.5	3.1	36.5	1.6	3.7	28.7	1.8	4.3	21.8	2.0	4.9	17.9	2.3	5.4	15.3	2.5	5.8
150	128.1	1.1	1.6	90.8	1.2	2.1	65.7	1.3	2.6	49.1	1.5	3.1	37.8	1.6	3.7	29.7	1.8	4.3	22.6	2.0	4.9	18.6	2.3	5.4	15.9	2.4	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table DV-12 Parabolic Diversion Design Chart (Retardance “D” and “C,” Grade 2.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 2.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	5.9	0.9	1.5																								
10	12.4	0.8	1.5	8.1	0.9	2.0	5.9	1.0	2.5																		
15	18.5	0.8	1.5	12.3	0.9	2.0	9.3	1.0	2.5	6.8	1.1	3.0	4.7	1.4	3.5												
20	24.7	0.8	1.5	16.7	0.9	2.0	12.5	1.0	2.5	9.4	1.1	3.0	7.0	1.2	3.6	4.7	1.5	4.1									
25	30.8	0.8	1.5	20.8	0.9	2.0	15.9	1.0	2.4	11.8	1.1	3.0	9.0	1.2	3.5	6.8	1.3	4.1									
30	37.0	0.8	1.5	25.0	0.9	2.0	19.0	1.0	2.5	14.3	1.1	3.0	11.0	1.2	3.5	8.5	1.3	4.1	6.4	1.5	4.7						
35	43.2	0.8	1.5	29.1	0.9	2.0	22.2	1.0	2.5	16.9	1.0	3.0	12.9	1.1	3.5	10.1	1.3	4.1	7.8	1.4	4.7						
40	49.3	0.8	1.5	33.3	0.9	2.0	25.3	1.0	2.5	19.3	1.0	3.0	14.8	1.1	3.5	11.6	1.3	4.1	9.1	1.4	4.7	7.1	1.6	5.2			
45	55.5	0.8	1.5	37.4	0.9	2.0	28.5	1.0	2.5	21.7	1.0	3.0	16.7	1.1	3.5	13.1	1.3	4.1	10.4	1.4	4.7	8.2	1.6	5.2			
50	61.7	0.8	1.5	41.6	0.9	2.0	31.7	1.0	2.5	24.1	1.0	3.0	18.8	1.1	3.5	14.7	1.2	4.1	11.7	1.4	4.7	9.3	1.5	5.3	7.1	1.8	5.8
55	67.8	0.8	1.5	45.7	0.9	2.0	34.8	1.0	2.5	26.5	1.0	3.0	20.7	1.1	3.5	16.2	1.2	4.1	12.9	1.4	4.7	10.4	1.5	5.3	8.2	1.7	5.8
60	74.0	0.8	1.5	49.9	0.9	2.0	38.0	1.0	2.5	28.9	1.0	3.0	22.6	1.1	3.5	17.7	1.2	4.1	14.1	1.4	4.7	11.4	1.5	5.3	9.2	1.7	5.8
65	80.2	0.8	1.5	54.0	0.9	2.0	41.1	1.0	2.5	31.4	1.0	3.0	24.5	1.1	3.5	19.5	1.2	4.1	15.4	1.3	4.7	12.4	1.5	5.3	10.1	1.7	5.8
70	86.3	0.8	1.5	58.2	0.9	2.0	44.3	1.0	2.5	33.8	1.0	3.0	26.3	1.1	3.5	21.0	1.2	4.1	16.6	1.3	4.7	13.5	1.5	5.3	11.0	1.6	5.8
75	92.5	0.8	1.5	62.3	0.9	2.0	47.5	1.0	2.5	36.2	1.0	3.0	28.2	1.1	3.5	22.4	1.2	4.1	17.8	1.3	4.7	14.5	1.5	5.3	11.8	1.6	5.8
80	98.7	0.8	1.5	66.5	0.9	2.0	50.6	1.0	2.5	38.6	1.0	3.0	30.1	1.1	3.5	23.9	1.2	4.1	19.0	1.3	4.7	15.5	1.5	5.3	12.7	1.6	5.8
85	104.8	0.8	1.5	70.6	0.9	2.0	53.8	1.0	2.5	41.0	1.0	3.0	32.0	1.1	3.5	25.4	1.2	4.1	20.3	1.3	4.7	16.5	1.5	5.3	13.6	1.6	5.8
90	111.0	0.8	1.5	74.8	0.9	2.0	57.0	1.0	2.5	43.4	1.0	3.0	33.8	1.1	3.5	26.9	1.2	4.1	21.8	1.3	4.6	17.5	1.5	5.3	14.4	1.6	5.8
95	117.2	0.8	1.5	78.9	0.9	2.0	60.1	1.0	2.5	45.8	1.0	3.0	35.7	1.1	3.5	28.4	1.2	4.1	23.0	1.3	4.6	18.6	1.5	5.3	15.3	1.6	5.8
100	123.3	0.8	1.5	83.1	0.9	2.0	63.3	1.0	2.5	48.2	1.0	3.0	37.6	1.1	3.5	29.9	1.2	4.1	24.2	1.3	4.6	19.6	1.5	5.3	16.2	1.6	5.8
105	129.5	0.8	1.5	87.3	0.9	2.0	66.4	1.0	2.5	50.6	1.0	3.0	39.5	1.1	3.5	31.4	1.2	4.1	25.4	1.3	4.6	20.6	1.5	5.3	17.0	1.6	5.8
110	135.7	0.8	1.5	91.4	0.9	2.0	69.6	1.0	2.5	53.0	1.0	3.0	41.3	1.1	3.5	32.9	1.2	4.1	26.6	1.3	4.7	21.6	1.4	5.3	17.9	1.6	5.8
115	141.8	0.8	1.5	95.6	0.9	2.0	72.8	1.0	2.5	55.4	1.0	3.0	43.2	1.1	3.5	34.4	1.2	4.1	27.9	1.3	4.7	22.6	1.4	5.3	18.7	1.6	5.8
120	148.0	0.8	1.5	99.7	0.9	2.0	75.9	1.0	2.5	57.9	1.0	3.0	45.1	1.1	3.5	35.9	1.2	4.1	29.1	1.3	4.7	23.9	1.4	5.2	19.5	1.6	5.8
125	154.1	0.8	1.5	103.9	0.9	2.0	79.1	1.0	2.5	60.3	1.0	3.0	47.0	1.1	3.5	37.4	1.2	4.1	30.3	1.3	4.7	24.8	1.4	5.2	20.4	1.6	5.8
130	160.3	0.8	1.5	108.0	0.9	2.0	82.3	1.0	2.5	62.7	1.0	3.0	48.8	1.1	3.5	38.9	1.2	4.1	31.5	1.3	4.7	25.8	1.4	5.3	21.2	1.6	5.8
135	166.5	0.8	1.5	112.2	0.9	2.0	85.4	1.0	2.5	65.1	1.0	3.0	50.7	1.1	3.5	40.3	1.2	4.1	32.7	1.3	4.7	26.8	1.4	5.3	22.1	1.6	5.8
140	172.6	0.8	1.5	116.3	0.9	2.0	88.6	1.0	2.5	67.5	1.0	3.0	52.6	1.1	3.5	41.8	1.2	4.1	33.9	1.3	4.7	27.8	1.4	5.3	22.9	1.6	5.8
145	178.8	0.8	1.5	120.5	0.9	2.0	91.8	1.0	2.5	69.9	1.0	3.0	54.5	1.1	3.5	43.3	1.2	4.1	35.1	1.3	4.7	28.8	1.4	5.3	23.7	1.6	5.8
150	185.0	0.8	1.5	124.6	0.9	2.0	94.9	1.0	2.5	72.3	1.0	3.0	56.4	1.1	3.5	44.8	1.2	4.1	36.3	1.3	4.7	29.8	1.4	5.3	24.6	1.6	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-13 Parabolic Diversion Design Chart (Retardance "D" and "C," Grade 4.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 4.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	8.5	0.6	1.4	5.9	0.7	1.8	4.1	0.8	2.3																		
10	17.2	0.6	1.4	12.1	0.7	1.8	8.8	0.7	2.3	6.7	0.8	2.8	5.2	0.9	3.3	3.8	1.0	3.9									
15	25.8	0.6	1.4	18.1	0.7	1.8	13.4	0.7	2.3	10.3	0.8	2.8	8.1	0.8	3.4	6.4	0.9	3.9	4.9	1.0	4.5						
20	34.4	0.6	1.4	24.2	0.7	1.8	17.8	0.7	2.3	13.9	0.8	2.8	10.9	0.8	3.4	8.7	0.9	3.9	6.9	1.0	4.5	5.5	1.1	5.0			
25	43.0	0.6	1.4	30.2	0.7	1.9	22.3	0.7	2.3	17.4	0.8	2.8	13.8	0.8	3.3	10.9	0.9	3.9	8.8	1.0	4.5	7.1	1.0	5.1	5.7	1.2	5.6
30	51.6	0.6	1.4	36.3	0.7	1.9	26.7	0.7	2.3	20.8	0.8	2.8	16.5	0.8	3.3	13.2	0.9	3.9	10.7	0.9	4.5	8.7	1.0	5.1	7.1	1.1	5.6
35	60.2	0.6	1.4	42.3	0.7	1.9	31.1	0.7	2.3	24.3	0.8	2.8	19.3	0.8	3.4	15.6	0.9	3.9	12.5	0.9	4.5	10.3	1.0	5.0	8.4	1.1	5.6
40	68.8	0.6	1.4	48.3	0.7	1.9	35.6	0.7	2.3	27.8	0.8	2.8	22.0	0.8	3.4	17.8	0.9	3.9	14.4	0.9	4.5	11.8	1.0	5.0	9.8	1.1	5.7
45	77.4	0.6	1.4	54.4	0.7	1.9	40.0	0.7	2.4	31.2	0.8	2.8	24.8	0.8	3.4	20.0	0.9	3.9	16.4	0.9	4.4	13.3	1.0	5.0	11.1	1.1	5.7
50	86.0	0.6	1.4	60.4	0.7	1.9	44.5	0.7	2.4	34.7	0.8	2.8	27.5	0.8	3.4	22.2	0.9	3.9	18.2	0.9	4.4	14.9	1.0	5.0	12.3	1.1	5.7
55	94.6	0.6	1.4	66.5	0.7	1.9	48.9	0.7	2.4	38.2	0.8	2.8	30.3	0.8	3.4	24.4	0.9	3.9	20.0	0.9	4.4	16.6	1.0	5.0	13.6	1.1	5.7
60	103.2	0.6	1.4	72.5	0.7	1.9	53.4	0.7	2.4	41.7	0.8	2.8	33.0	0.8	3.4	26.6	0.9	3.9	21.8	0.9	4.5	18.1	1.0	5.0	14.9	1.1	5.7
65	111.8	0.6	1.4	78.5	0.7	1.9	57.8	0.7	2.4	45.1	0.8	2.8	35.8	0.8	3.4	28.9	0.9	3.9	23.6	0.9	4.5	19.6	1.0	5.0	16.2	1.1	5.7
70	120.4	0.6	1.4	84.6	0.7	1.9	62.3	0.7	2.4	48.6	0.8	2.8	38.6	0.8	3.4	31.1	0.9	3.9	25.4	0.9	4.5	21.1	1.0	5.0	17.7	1.1	5.6
75	129.0	0.6	1.4	90.6	0.7	1.9	66.7	0.7	2.4	52.1	0.8	2.8	41.3	0.8	3.4	33.3	0.9	3.9	27.2	0.9	4.5	22.6	1.0	5.0	19.0	1.1	5.6
80	137.6	0.6	1.4	96.7	0.7	1.9	71.2	0.7	2.4	55.5	0.8	2.8	44.1	0.8	3.4	35.5	0.9	3.9	29.1	0.9	4.5	24.1	1.0	5.0	20.2	1.1	5.6
85	146.2	0.6	1.4	102.7	0.7	1.9	75.6	0.7	2.4	59.0	0.8	2.8	46.8	0.8	3.4	37.7	0.9	3.9	30.9	0.9	4.5	25.6	1.0	5.0	21.5	1.1	5.6
90	154.8	0.6	1.4	108.7	0.7	1.9	80.0	0.7	2.4	62.5	0.8	2.8	49.6	0.8	3.4	39.9	0.9	3.9	32.7	0.9	4.5	27.1	1.0	5.0	22.8	1.1	5.6
95	163.4	0.6	1.4	114.8	0.7	1.9	84.5	0.7	2.4	65.9	0.8	2.8	52.3	0.8	3.4	42.2	0.9	3.9	34.5	0.9	4.5	28.6	1.0	5.0	24.0	1.1	5.6
100	172.0	0.6	1.4	120.8	0.7	1.9	88.9	0.7	2.4	69.4	0.8	2.8	55.1	0.8	3.4	44.4	0.9	3.9	36.3	0.9	4.5	30.1	1.0	5.0	25.3	1.1	5.6
105	180.6	0.6	1.4	126.9	0.7	1.9	93.4	0.7	2.4	72.9	0.8	2.8	57.8	0.8	3.4	46.6	0.9	3.9	38.1	0.9	4.5	31.6	1.0	5.0	26.5	1.1	5.6
110	189.2	0.6	1.4	132.9	0.7	1.9	97.8	0.7	2.4	76.3	0.8	2.8	60.6	0.8	3.4	48.8	0.9	3.9	39.9	0.9	4.5	33.1	1.0	5.0	27.8	1.1	5.6
115	197.8	0.6	1.4	138.9	0.7	1.9	102.3	0.7	2.4	79.8	0.8	2.8	63.3	0.8	3.4	51.0	0.9	3.9	41.7	0.9	4.5	34.6	1.0	5.0	29.0	1.1	5.6
120	206.4	0.6	1.4	145.0	0.7	1.9	106.7	0.7	2.4	83.3	0.8	2.8	66.1	0.8	3.4	53.3	0.9	3.9	43.6	0.9	4.5	36.1	1.0	5.0	30.2	1.1	5.7
125	215.0	0.6	1.4	151.0	0.7	1.9	111.2	0.7	2.4	86.8	0.8	2.8	68.8	0.8	3.4	55.5	0.9	3.9	45.4	0.9	4.5	37.6	1.0	5.0	31.5	1.1	5.7
130	223.7	0.6	1.4	157.1	0.7	1.9	115.6	0.7	2.4	90.2	0.8	2.8	71.6	0.8	3.4	57.7	0.9	3.9	47.2	0.9	4.5	39.1	1.0	5.0	32.7	1.1	5.7
135	232.3	0.6	1.4	163.1	0.7	1.9	120.1	0.7	2.4	93.7	0.8	2.8	74.3	0.8	3.4	59.9	0.9	3.9	49.0	0.9	4.5	40.6	1.0	5.0	34.0	1.1	5.7
140	240.9	0.6	1.4	169.1	0.7	1.9	124.5	0.7	2.4	97.2	0.8	2.8	77.1	0.8	3.4	62.1	0.9	3.9	50.8	0.9	4.5	42.1	1.0	5.0	35.2	1.1	5.7
145	249.5	0.6	1.4	175.2	0.7	1.9	129.0	0.7	2.4	100.6	0.8	2.8	79.8	0.8	3.4	64.3	0.9	3.9	52.6	0.9	4.5	43.6	1.0	5.0	36.5	1.1	5.7
150	258.1	0.6	1.4	181.2	0.7	1.9	133.4	0.7	2.4	104.1	0.8	2.8	82.6	0.8	3.4	66.6	0.9	3.9	54.4	0.9	4.5	45.1	1.0	5.0	37.8	1.1	5.7

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table DV-14 Parabolic Diversion Design Chart (Retardance “D” and “C,” Grade 6.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 6.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	10.6	0.5	1.3	7.3	0.6	1.8	5.3	0.6	2.3	4.0	0.7	2.8	2.9	0.8	3.2												
10	21.1	0.5	1.3	14.7	0.6	1.8	10.9	0.6	2.3	8.4	0.7	2.8	6.6	0.7	3.2	5.3	0.8	3.8	4.2	0.8	4.3						
15	31.6	0.5	1.3	22.1	0.6	1.8	16.3	0.6	2.3	12.7	0.6	2.7	10.1	0.7	3.3	8.2	0.7	3.8	6.6	0.8	4.3	5.4	0.9	4.9	4.3	1.0	5.5
20	42.1	0.5	1.3	29.5	0.6	1.8	21.7	0.6	2.3	17.0	0.6	2.7	13.6	0.7	3.2	11.1	0.7	3.7	9.0	0.8	4.3	7.4	0.8	4.9	6.1	0.9	5.5
25	52.7	0.5	1.3	36.8	0.6	1.8	27.1	0.6	2.3	21.2	0.6	2.8	17.0	0.7	3.2	13.9	0.7	3.8	11.3	0.8	4.3	9.3	0.8	4.9	7.8	0.9	5.5
30	63.2	0.5	1.3	44.2	0.6	1.8	32.5	0.6	2.3	25.4	0.6	2.8	20.4	0.7	3.2	16.6	0.7	3.8	13.7	0.8	4.3	11.3	0.8	4.9	9.4	0.9	5.5
35	73.7	0.5	1.3	51.6	0.6	1.8	38.0	0.6	2.3	29.7	0.6	2.8	23.8	0.7	3.2	19.4	0.7	3.8	16.0	0.8	4.3	13.4	0.8	4.9	11.1	0.9	5.5
40	84.2	0.5	1.3	58.9	0.6	1.8	43.4	0.6	2.3	33.9	0.6	2.8	27.2	0.7	3.3	22.2	0.7	3.8	18.3	0.8	4.3	15.3	0.8	4.9	12.7	0.9	5.5
45	94.8	0.5	1.3	66.3	0.6	1.8	48.8	0.6	2.3	38.2	0.6	2.8	30.7	0.7	3.3	24.9	0.7	3.8	20.6	0.8	4.3	17.2	0.8	4.9	14.5	0.9	5.4
50	105.3	0.5	1.3	73.6	0.6	1.8	54.2	0.6	2.3	42.4	0.6	2.8	34.1	0.7	3.3	27.7	0.7	3.8	22.8	0.8	4.3	19.1	0.8	4.9	16.1	0.9	5.4
55	115.8	0.5	1.3	81.0	0.6	1.8	59.7	0.6	2.3	46.6	0.6	2.8	37.5	0.7	3.3	30.5	0.7	3.8	25.1	0.8	4.3	21.0	0.8	4.9	17.7	0.9	5.4
60	126.4	0.5	1.3	88.4	0.6	1.8	65.1	0.6	2.3	50.9	0.6	2.8	40.9	0.7	3.3	33.3	0.7	3.8	27.4	0.8	4.3	22.9	0.8	4.9	19.3	0.9	5.4
65	136.9	0.5	1.3	95.7	0.6	1.8	70.5	0.6	2.3	55.1	0.6	2.8	44.3	0.7	3.3	36.0	0.7	3.8	29.7	0.8	4.3	24.8	0.8	4.9	20.9	0.9	5.4
70	147.4	0.5	1.3	103.1	0.6	1.8	75.9	0.6	2.3	59.3	0.6	2.8	47.7	0.7	3.3	38.8	0.7	3.8	32.0	0.8	4.3	26.7	0.8	4.9	22.5	0.9	5.4
75	158.0	0.5	1.3	110.5	0.6	1.8	81.3	0.6	2.3	63.6	0.6	2.8	51.1	0.7	3.3	41.6	0.7	3.8	34.3	0.8	4.3	28.6	0.8	4.9	24.1	0.9	5.4
80	168.5	0.5	1.3	117.8	0.6	1.8	86.8	0.6	2.3	67.8	0.6	2.8	54.5	0.7	3.3	44.3	0.7	3.8	36.5	0.8	4.3	30.5	0.8	4.9	25.7	0.9	5.5
85	179.0	0.5	1.3	125.2	0.6	1.8	92.2	0.6	2.3	72.0	0.6	2.8	57.9	0.7	3.3	47.1	0.7	3.8	38.8	0.8	4.3	32.4	0.8	4.9	27.3	0.9	5.5
90	189.6	0.5	1.3	132.6	0.6	1.8	97.6	0.6	2.3	76.3	0.6	2.8	61.3	0.7	3.3	49.9	0.7	3.8	41.1	0.8	4.3	34.3	0.8	4.9	28.9	0.9	5.5
95	200.1	0.5	1.3	139.9	0.6	1.8	103.0	0.6	2.3	80.5	0.6	2.8	64.7	0.7	3.3	52.6	0.7	3.8	43.4	0.8	4.3	36.2	0.8	4.9	30.5	0.9	5.5
100	210.6	0.5	1.3	147.3	0.6	1.8	108.5	0.6	2.3	84.8	0.6	2.8	68.1	0.7	3.3	55.4	0.7	3.8	45.7	0.8	4.3	38.1	0.8	4.9	32.1	0.9	5.5
105	221.1	0.5	1.3	154.6	0.6	1.8	113.9	0.6	2.3	89.0	0.6	2.8	71.5	0.7	3.3	58.2	0.7	3.8	47.9	0.8	4.3	40.0	0.8	4.9	33.7	0.9	5.5
110	231.7	0.5	1.3	162.0	0.6	1.8	119.3	0.6	2.3	93.2	0.6	2.8	74.9	0.7	3.3	60.9	0.7	3.8	50.2	0.8	4.3	41.9	0.8	4.9	35.3	0.9	5.5
115	242.2	0.5	1.3	169.4	0.6	1.8	124.7	0.6	2.3	97.5	0.6	2.8	78.3	0.7	3.3	63.7	0.7	3.8	52.5	0.8	4.3	43.8	0.8	4.9	36.9	0.9	5.5
120	252.7	0.5	1.3	176.7	0.6	1.8	130.2	0.6	2.3	101.7	0.6	2.8	81.7	0.7	3.3	66.5	0.7	3.8	54.8	0.8	4.3	45.7	0.8	4.9	38.5	0.9	5.5
125	263.3	0.5	1.3	184.1	0.6	1.8	135.6	0.6	2.3	106.0	0.6	2.8	85.1	0.7	3.3	69.3	0.7	3.8	57.1	0.8	4.3	47.6	0.8	4.9	40.1	0.9	5.5
130	273.8	0.5	1.3	191.5	0.6	1.8	141.0	0.6	2.3	110.2	0.6	2.8	88.5	0.7	3.3	72.0	0.7	3.8	59.4	0.8	4.3	49.5	0.8	4.9	41.7	0.9	5.5
135	284.3	0.5	1.3	198.8	0.6	1.8	146.4	0.6	2.3	114.4	0.6	2.8	91.9	0.7	3.3	74.8	0.7	3.8	61.6	0.8	4.3	51.4	0.8	4.9	43.3	0.9	5.5
140	294.9	0.5	1.3	206.2	0.6	1.8	151.8	0.6	2.3	118.7	0.6	2.8	95.3	0.7	3.3	77.6	0.7	3.8	63.9	0.8	4.3	53.3	0.8	4.9	44.9	0.9	5.5
145	305.4	0.5	1.3	213.6	0.6	1.8	157.3	0.6	2.3	122.9	0.6	2.8	98.7	0.7	3.3	80.3	0.7	3.8	66.2	0.8	4.3	55.2	0.8	4.9	46.5	0.9	5.5
150	315.9	0.5	1.3	220.9	0.6	1.8	162.7	0.6	2.3	127.1	0.6	2.8	102.1	0.7	3.3	83.1	0.7	3.8	68.5	0.8	4.3	57.1	0.8	4.9	48.1	0.9	5.5

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table DV-15 Parabolic Diversion Design Chart (Retardance "D" and "C," Grade 8.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH' (D), AND V2 FOR RETARDANCE "C"

Grade 8.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	12.0	0.5	1.3	8.5	0.5	1.7	6.2	0.5	2.2	4.6	0.6	2.7	3.7	0.6	3.2	2.9	0.7	3.6									
10	24.1	0.5	1.3	16.9	0.5	1.7	12.6	0.5	2.2	9.6	0.6	2.7	7.8	0.6	3.2	6.3	0.6	3.7	5.1	0.7	4.2	4.2	0.8	4.8	3.2	0.9	5.3
15	36.1	0.5	1.3	25.3	0.5	1.7	18.9	0.5	2.2	14.4	0.6	2.7	11.8	0.6	3.2	9.7	0.6	3.7	7.9	0.7	4.2	6.5	0.7	4.8	5.4	0.8	5.3
20	48.1	0.5	1.3	33.8	0.5	1.7	25.2	0.5	2.2	19.2	0.6	2.7	15.8	0.6	3.2	12.9	0.6	3.7	10.7	0.7	4.2	8.8	0.7	4.8	7.4	0.8	5.3
25	60.1	0.5	1.3	42.2	0.5	1.7	31.5	0.5	2.2	24.0	0.6	2.7	19.7	0.6	3.2	16.2	0.6	3.7	13.4	0.7	4.2	11.2	0.7	4.7	9.3	0.8	5.3
30	72.1	0.5	1.3	50.6	0.5	1.7	37.8	0.5	2.2	28.8	0.6	2.7	23.6	0.6	3.2	19.4	0.6	3.7	16.1	0.7	4.2	13.5	0.7	4.8	11.3	0.7	5.3
35	84.1	0.5	1.3	59.1	0.5	1.7	44.1	0.5	2.2	33.6	0.6	2.7	27.6	0.6	3.2	22.6	0.6	3.7	18.7	0.7	4.2	15.7	0.7	4.8	13.3	0.7	5.3
40	96.2	0.5	1.3	67.5	0.5	1.7	50.4	0.5	2.2	38.4	0.6	2.7	31.5	0.6	3.2	25.8	0.6	3.7	21.4	0.7	4.2	17.9	0.7	4.8	15.2	0.7	5.3
45	108.2	0.5	1.3	76.0	0.5	1.7	56.7	0.5	2.2	43.2	0.6	2.7	35.4	0.6	3.2	29.0	0.6	3.7	24.1	0.7	4.2	20.2	0.7	4.8	17.1	0.7	5.3
50	120.2	0.5	1.3	84.4	0.5	1.7	63.0	0.5	2.2	48.0	0.6	2.7	39.4	0.6	3.2	32.3	0.6	3.7	26.8	0.7	4.2	22.4	0.7	4.8	19.0	0.7	5.3
55	132.2	0.5	1.3	92.8	0.5	1.7	69.3	0.5	2.2	52.8	0.6	2.7	43.3	0.6	3.2	35.5	0.6	3.7	29.4	0.7	4.2	24.7	0.7	4.8	20.9	0.7	5.3
60	144.2	0.5	1.3	101.3	0.5	1.7	75.6	0.5	2.2	57.6	0.6	2.7	47.2	0.6	3.2	38.7	0.6	3.7	32.1	0.7	4.2	26.9	0.7	4.8	22.8	0.7	5.3
65	156.3	0.5	1.3	109.7	0.5	1.7	81.8	0.5	2.2	62.4	0.6	2.7	51.2	0.6	3.2	41.9	0.6	3.7	34.8	0.7	4.2	29.1	0.7	4.8	24.7	0.7	5.3
70	168.3	0.5	1.3	118.2	0.5	1.7	88.1	0.5	2.2	67.2	0.6	2.7	55.1	0.6	3.2	45.2	0.6	3.7	37.5	0.7	4.2	31.4	0.7	4.8	26.6	0.7	5.3
75	180.3	0.5	1.3	126.6	0.5	1.7	94.4	0.5	2.2	72.0	0.6	2.7	59.0	0.6	3.2	48.4	0.6	3.7	40.1	0.7	4.2	33.6	0.7	4.8	28.5	0.7	5.3
80	192.3	0.5	1.3	135.0	0.5	1.7	100.7	0.5	2.2	76.8	0.6	2.7	63.0	0.6	3.2	51.6	0.6	3.7	42.8	0.7	4.2	35.9	0.7	4.8	30.3	0.7	5.3
85	204.3	0.5	1.3	143.5	0.5	1.7	107.0	0.5	2.2	81.6	0.6	2.7	66.9	0.6	3.2	54.9	0.6	3.7	45.5	0.7	4.2	38.1	0.7	4.8	32.2	0.7	5.3
90	216.4	0.5	1.3	151.9	0.5	1.7	113.3	0.5	2.2	86.4	0.6	2.7	70.8	0.6	3.2	58.1	0.6	3.7	48.1	0.7	4.2	40.3	0.7	4.8	34.1	0.7	5.3
95	228.4	0.5	1.3	160.3	0.5	1.7	119.6	0.5	2.2	91.2	0.6	2.7	74.8	0.6	3.2	61.3	0.6	3.7	50.8	0.7	4.2	42.6	0.7	4.8	36.0	0.7	5.3
100	240.4	0.5	1.3	168.8	0.5	1.7	125.9	0.5	2.2	96.0	0.6	2.7	78.7	0.6	3.2	64.5	0.6	3.7	53.5	0.7	4.2	44.8	0.7	4.8	37.9	0.7	5.3
105	252.4	0.5	1.3	177.2	0.5	1.7	132.2	0.5	2.2	100.8	0.6	2.7	82.6	0.6	3.2	67.8	0.6	3.7	56.2	0.7	4.2	47.1	0.7	4.8	39.8	0.7	5.3
110	264.4	0.5	1.3	185.7	0.5	1.7	138.5	0.5	2.2	105.6	0.6	2.7	86.6	0.6	3.2	71.0	0.6	3.7	58.8	0.7	4.2	49.3	0.7	4.8	41.7	0.7	5.3
115	276.5	0.5	1.3	194.1	0.5	1.7	144.8	0.5	2.2	110.4	0.6	2.7	90.5	0.6	3.2	74.2	0.6	3.7	61.5	0.7	4.2	51.5	0.7	4.8	43.6	0.7	5.3
120	288.5	0.5	1.3	202.5	0.5	1.7	151.1	0.5	2.2	115.2	0.6	2.7	94.4	0.6	3.2	77.4	0.6	3.7	64.2	0.7	4.2	53.8	0.7	4.8	45.5	0.7	5.3
125	300.5	0.5	1.3	211.0	0.5	1.7	157.4	0.5	2.2	120.0	0.6	2.7	98.4	0.6	3.2	80.7	0.6	3.7	66.9	0.7	4.2	56.0	0.7	4.8	47.4	0.7	5.3
130	312.5	0.5	1.3	219.4	0.5	1.7	163.7	0.5	2.2	124.8	0.6	2.7	102.3	0.6	3.2	83.9	0.6	3.7	69.5	0.7	4.2	58.3	0.7	4.8	49.3	0.7	5.3
135	324.5	0.5	1.3	227.9	0.5	1.7	170.0	0.5	2.2	129.6	0.6	2.7	106.2	0.6	3.2	87.1	0.6	3.7	72.2	0.7	4.2	60.5	0.7	4.8	51.2	0.7	5.3
140	336.6	0.5	1.3	236.3	0.5	1.7	176.3	0.5	2.2	134.4	0.6	2.7	110.2	0.6	3.2	90.3	0.6	3.7	74.9	0.7	4.2	62.7	0.7	4.8	53.1	0.7	5.3
145	348.6	0.5	1.3	244.7	0.5	1.7	182.6	0.5	2.2	139.2	0.6	2.7	114.1	0.6	3.2	93.6	0.6	3.7	77.6	0.7	4.2	65.0	0.7	4.8	55.0	0.7	5.3
150	360.6	0.5	1.3	253.2	0.5	1.7	188.9	0.5	2.2	144.0	0.6	2.7	118.0	0.6	3.2	96.8	0.6	3.7	80.2	0.7	4.2	67.2	0.7	4.8	56.9	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second
Depth "D" does not include allowance for freeboard or settlement

Table DV-16 Parabolic Diversion Design Chart (Retardance “D” and “C,” Grade 10.00%)

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 10.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	13.3	0.4	1.3	9.4	0.5	1.7	6.8	0.5	2.2	5.3	0.5	2.6	4.1	0.6	3.2	3.4	0.6	3.6	2.6	0.7	4.1						
10	26.6	0.4	1.3	18.7	0.5	1.7	13.8	0.5	2.2	10.9	0.5	2.6	8.5	0.6	3.2	7.1	0.6	3.6	5.9	0.6	4.1	4.9	0.7	4.7	4.0	0.7	5.3
15	39.9	0.4	1.3	28.0	0.5	1.7	20.7	0.5	2.2	16.3	0.5	2.6	12.8	0.6	3.2	10.9	0.6	3.6	9.0	0.6	4.1	7.5	0.6	4.7	6.3	0.7	5.2
20	53.2	0.4	1.3	37.4	0.5	1.7	27.6	0.5	2.2	21.7	0.5	2.7	17.0	0.6	3.2	14.5	0.6	3.6	12.1	0.6	4.1	10.2	0.6	4.6	8.5	0.7	5.2
25	66.5	0.4	1.3	46.7	0.5	1.7	34.5	0.5	2.2	27.1	0.5	2.7	21.3	0.6	3.2	18.1	0.6	3.6	15.1	0.6	4.1	12.7	0.6	4.7	10.8	0.7	5.2
30	79.8	0.4	1.3	56.1	0.5	1.7	41.4	0.5	2.2	32.5	0.5	2.7	25.5	0.6	3.2	21.7	0.6	3.6	18.1	0.6	4.1	15.2	0.6	4.7	12.9	0.7	5.2
35	93.1	0.4	1.3	65.4	0.5	1.7	48.3	0.5	2.2	37.9	0.5	2.7	29.8	0.6	3.2	25.3	0.6	3.6	21.1	0.6	4.1	17.8	0.6	4.7	15.1	0.7	5.2
40	106.4	0.4	1.3	74.7	0.5	1.7	55.2	0.5	2.2	43.3	0.5	2.7	34.0	0.6	3.2	29.0	0.6	3.6	24.1	0.6	4.1	20.3	0.6	4.7	17.2	0.7	5.2
45	119.7	0.4	1.3	84.1	0.5	1.7	62.1	0.5	2.2	48.8	0.5	2.7	38.3	0.6	3.2	32.6	0.6	3.6	27.2	0.6	4.1	22.8	0.6	4.7	19.4	0.7	5.2
50	133.0	0.4	1.3	93.4	0.5	1.7	69.0	0.5	2.2	54.2	0.5	2.7	42.5	0.6	3.2	36.2	0.6	3.6	30.2	0.6	4.1	25.4	0.6	4.7	21.5	0.7	5.2
55	146.3	0.4	1.3	102.8	0.5	1.7	75.9	0.5	2.2	59.6	0.5	2.7	46.8	0.6	3.2	39.8	0.6	3.6	33.2	0.6	4.1	27.9	0.6	4.7	23.7	0.7	5.2
60	159.6	0.4	1.3	112.1	0.5	1.7	82.8	0.5	2.2	65.0	0.5	2.7	51.0	0.6	3.2	43.4	0.6	3.6	36.2	0.6	4.1	30.5	0.6	4.7	25.9	0.7	5.2
65	172.9	0.4	1.3	121.4	0.5	1.7	89.7	0.5	2.2	70.4	0.5	2.7	55.3	0.6	3.2	47.1	0.6	3.6	39.2	0.6	4.1	33.0	0.6	4.7	28.0	0.7	5.2
70	186.2	0.4	1.3	130.8	0.5	1.7	96.6	0.5	2.2	75.8	0.5	2.7	59.5	0.6	3.2	50.7	0.6	3.6	42.2	0.6	4.1	35.5	0.6	4.7	30.2	0.7	5.2
75	199.5	0.4	1.3	140.1	0.5	1.7	103.5	0.5	2.2	81.2	0.5	2.7	63.8	0.6	3.2	54.3	0.6	3.6	45.2	0.6	4.1	38.1	0.6	4.7	32.3	0.7	5.2
80	212.8	0.4	1.3	149.5	0.5	1.7	110.5	0.5	2.2	86.7	0.5	2.7	68.0	0.6	3.2	57.9	0.6	3.6	48.3	0.6	4.1	40.6	0.6	4.7	34.5	0.7	5.2
85	226.1	0.4	1.3	158.8	0.5	1.7	117.4	0.5	2.2	92.1	0.5	2.7	72.3	0.6	3.2	61.5	0.6	3.6	51.3	0.6	4.1	43.1	0.6	4.7	36.6	0.7	5.2
90	239.4	0.4	1.3	168.1	0.5	1.7	124.3	0.5	2.2	97.5	0.5	2.7	76.5	0.6	3.2	65.2	0.6	3.6	54.3	0.6	4.1	45.7	0.6	4.7	38.8	0.7	5.2
95	252.7	0.4	1.3	177.5	0.5	1.7	131.2	0.5	2.2	102.9	0.5	2.7	80.8	0.6	3.2	68.8	0.6	3.6	57.3	0.6	4.1	48.2	0.6	4.7	40.9	0.7	5.2
100	266.0	0.4	1.3	186.8	0.5	1.7	138.1	0.5	2.2	108.3	0.5	2.7	85.0	0.6	3.2	72.4	0.6	3.6	60.3	0.6	4.1	50.7	0.6	4.7	43.1	0.7	5.2
105	279.3	0.4	1.3	196.2	0.5	1.7	145.0	0.5	2.2	113.7	0.5	2.7	89.3	0.6	3.2	76.0	0.6	3.6	63.3	0.6	4.1	53.3	0.6	4.7	45.2	0.7	5.2
110	292.6	0.4	1.3	205.5	0.5	1.7	151.9	0.5	2.2	119.2	0.5	2.7	93.5	0.6	3.2	79.6	0.6	3.6	66.4	0.6	4.1	55.8	0.6	4.7	47.4	0.7	5.2
115	305.9	0.4	1.3	214.9	0.5	1.7	158.8	0.5	2.2	124.6	0.5	2.7	97.8	0.6	3.2	83.3	0.6	3.6	69.4	0.6	4.1	58.3	0.6	4.7	49.5	0.7	5.3
120	319.2	0.4	1.3	224.2	0.5	1.7	165.7	0.5	2.2	130.0	0.5	2.7	102.0	0.6	3.2	86.9	0.6	3.6	72.4	0.6	4.1	60.9	0.6	4.7	51.7	0.7	5.3
125	332.5	0.4	1.3	233.5	0.5	1.7	172.6	0.5	2.2	135.4	0.5	2.7	106.3	0.6	3.2	90.5	0.6	3.6	75.4	0.6	4.1	63.4	0.6	4.7	53.8	0.7	5.3
130	345.8	0.4	1.3	242.9	0.5	1.7	179.5	0.5	2.2	140.8	0.5	2.7	110.5	0.6	3.2	94.1	0.6	3.6	78.4	0.6	4.1	66.0	0.6	4.7	56.0	0.7	5.3
135	359.1	0.4	1.3	252.2	0.5	1.7	186.4	0.5	2.2	146.2	0.5	2.7	114.8	0.6	3.2	97.7	0.6	3.6	81.4	0.6	4.1	68.5	0.6	4.7	58.1	0.7	5.3
140	372.4	0.4	1.3	261.6	0.5	1.7	193.3	0.5	2.2	151.7	0.5	2.7	119.0	0.6	3.2	101.3	0.6	3.6	84.4	0.6	4.1	71.0	0.6	4.7	60.3	0.7	5.3
145	385.7	0.4	1.3	270.9	0.5	1.7	200.2	0.5	2.2	157.1	0.5	2.7	123.3	0.6	3.2	105.0	0.6	3.6	87.5	0.6	4.1	73.6	0.6	4.7	62.5	0.7	5.3
150	399.0	0.4	1.3	280.2	0.5	1.7	207.1	0.5	2.2	162.5	0.5	2.7	127.5	0.6	3.2	108.6	0.6	3.6	90.5	0.6	4.1	76.1	0.6	4.7	64.6	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Construction

Prior to start of construction, diversions should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process. A diversion should be built according to planned alignment, grade and cross section. Typically, a diversion is constructed with the following activities.

Site Preparation

Determine exact location of any underground utilities (see Appendix C: MS One-Call and 811 Color Coding).

Locate and mark the alignment of the diversion as shown on the plans. Minor adjustments to the grade and alignment may be required to meet site conditions. The alignment should maintain a positive grade toward the outlet and end in a stable outlet or an area that can be stabilized.

Clear the construction area of trees, stumps, brush, sod and other unsuitable material which would interfere with compaction of the ridge.

Disk or scarify the area where the ridge is to be installed before placing the fill.

Clean out and refill with compacted earth fill all ditches, swales or gullies to be crossed.

Apply gravel or hard surface protection at vehicle crossings to prevent rutting.

Install stable outlets prior to construction. Adequate vegetation should be established in the outlet channel. If vegetation cannot be established, use *Erosion Control Blankets* and/or *Rock Outlets* or *Outlet Protection*.

Grading

Excavate, fill and shape the diversion to planned alignment, grade and cross section. The channel should have a positive grade toward the outlet to avoid ponding. Where possible, blend diversion into the surrounding landscape.

Overfill and compact the ridge, allowing for 10% settlement. Fill should be placed in lifts of no more than 6″ to 8″ in depth. Compaction may be achieved by driving wheeled equipment along the ridge as lifts are added. The settled ridge top must be at or above design elevation at all points.

All earth removed and not needed for the practice should be spread or disposed of so that it will not interfere with the functioning of the diversion.

Erosion and Sediment Control

Control sediment along grading limits with sediment control measures.

Leave sufficient area adjacent to the diversion to permit clean-out and regrading.

Immediately after installation, install vegetation treatment or other means to stabilize the diversion in accordance with plans.

Install gravel or hard surface protection at vehicle crossings.

Stabilize diversion outlets in accordance with plans.

Construction Verification

Check finished grades and cross section of diversions to eliminate constrictions to flow. Check all ridges for low spots and stability.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate diversion will not function as intended. Changes in plans will be needed.

Design specifications for seed variety or seeding cannot be met. Substitutions not approved by the design professional could result in erosion and lead to diversion failure.

Seepage is encountered during construction. It may be necessary to install drains.

Maintenance

Inspect weekly and following each storm event for erosion until the diversion is vegetated.

Remove debris and sediment from the channel, and rebuild the ridge to design elevation where needed.

Check diversion outlet for erosion and repair if area becomes unstable. Maintain vegetation with periodic fertilization and mowing to keep vegetation in a vigorous, healthy condition. Mow for weed and brush control during the first year and as needed to prevent brush and tree seedlings from becoming established after the first year of installation.

When the work area has been stabilized, remove temporary diversions, sediment barriers and traps, and repair bare or damaged areas in the vegetation by planting and mulching or sodding.

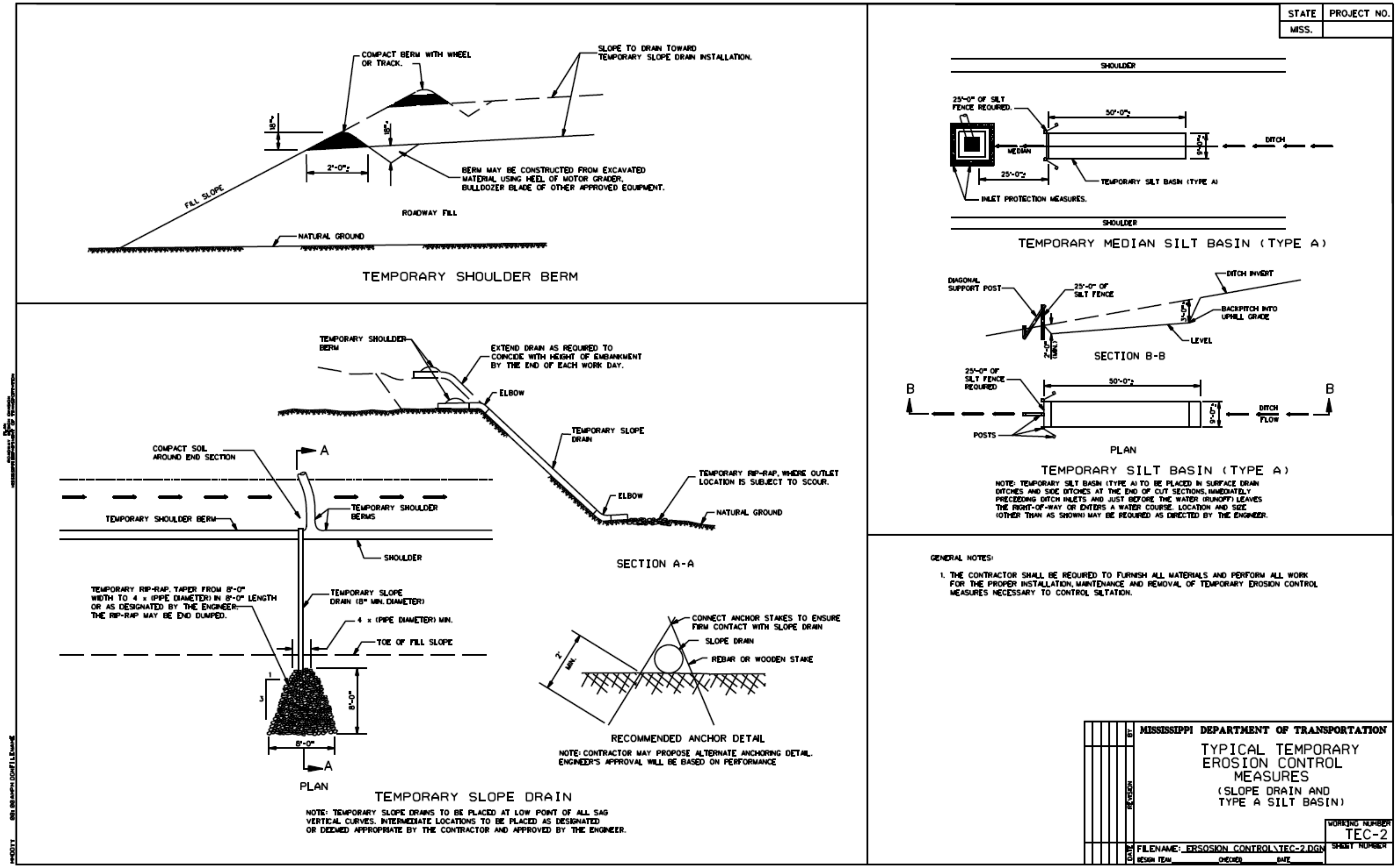
Stabilize all eroded, rutted or disturbed areas as soon as possible with vegetation or synthetic erosion control measures as specified in the design.

References

BMPs from Volume 1

Chapter 4

MDOT Drawing TEC-2


STATE
PROJECT NO.
MISS.
COMPACT BERM WITH WHEEL OR TRACK.
SLOPE TO DRAIN TOWARD TEMPORARY SLOPE DRAIN INSTALLATION.
BERM MAY BE CONSTRUCTED FROM EXCAVATED MATERIAL USING HEEL OF MOTOR GRADER, BULLDOZER BLADE OF OTHER APPROVED EQUIPMENT.
FILL SLOPE
ROADWAY FILL
NATURAL GROUND
TEMPORARY SHOULDER BERM
SHOULDER
25'-0" OF SILT FENCE REQUIRED.
50'-0"±
DITCH
MEDIAN
25'-0"±
TEMPORARY SILT BASIN (TYPE A)
INLET PROTECTION MEASURES.
TEMPORARY MEDIAN SILT BASIN (TYPE A)
DIAGONAL SUPPORT POST
25'-0" OF SILT FENCE
DITCH INVERT
BACKPITCH INTO UPHILL GRADE
LEVEL
SECTION B-B
25'-0" OF SILT FENCE REQUIRED
B
B
DITCH FLOW
POSTS
PLAN
TEMPORARY SILT BASIN (TYPE A)
NOTE: TEMPORARY SILT BASIN (TYPE A) TO BE PLACED IN SURFACE DRAIN DITCHES AND SIDE DITCHES AT THE END OF CUT SECTIONS, IMMEDIATELY PRECEEDING DITCH INLETS AND JUST BEFORE THE WATER (RUNOFF) LEAVES THE RIGHT-OF-WAY OR ENTERS A WATER COURSE. LOCATION AND SIZE (OTHER THAN AS SHOWN) MAY BE REQUIRED AS DIRECTED BY THE ENGINEER.
TEMPORARY SHOULDER BERM
EXTEND DRAIN AS REQUIRED TO COINCIDE WITH HEIGHT OF EMBANKMENT BY THE END OF EACH WORK DAY.
ELBOW
TEMPORARY SLOPE DRAIN
ELBOW
TEMPORARY RIP-RAP, WHERE OUTLET LOCATION IS SUBJECT TO SCOUR.
NATURAL GROUND
SECTION A-A
COMPACT SOIL AROUND END SECTION
A
TEMPORARY SHOULDER BERMS
TEMPORARY SHOULDER BERM
SHOULDER
TEMPORARY RIP-RAP. TAPER FROM 8'-0" WIDTH TO 4 x (PIPE DIAMETER) IN 8'-0" LENGTH OR AS DESIGNATED BY THE ENGINEER. THE RIP-RAP MAY BE END DUMPED.
TEMPORARY SLOPE DRAIN (8" MIN. DIAMETER)
4 x (PIPE DIAMETER) MIN.
TOE OF FILL SLOPE
8'-0"
8'-0"
A
PLAN
TEMPORARY SLOPE DRAIN
NOTE: TEMPORARY SLOPE DRAINS TO BE PLACED AT LOW POINT OF ALL SAG VERTICAL CURVES. INTERMEDIATE LOCATIONS TO BE PLACED AS DESIGNATED OR DEEMED APPROPRIATE BY THE CONTRACTOR AND APPROVED BY THE ENGINEER.
CONNECT ANCHOR STAKES TO ENSURE FIRM CONTACT WITH SLOPE DRAIN
SLOPE DRAIN
REBAR OR WOODEN STAKE
2' MIN.
RECOMMENDED ANCHOR DETAIL
NOTE: CONTRACTOR MAY PROPOSE ALTERNATE ANCHORING DETAIL. ENGINEER'S APPROVAL WILL BE BASED ON PERFORMANCE
GENERAL NOTES:
1. THE CONTRACTOR SHALL BE REQUIRED TO FURNISH ALL MATERIALS AND PERFORM ALL WORK FOR THE PROPER INSTALLATION, MAINTENANCE AND REMOVAL OF TEMPORARY EROSION CONTROL MEASURES NECESSARY TO CONTROL SILTATION.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
TYPICAL TEMPORARY EROSION CONTROL MEASURES
(SLOPE DRAIN AND TYPE A SILT BASIN)
WORKING NUMBER
TEC-2
SHEET NUMBER
FILENAME: ERSOSION CONTROL\TEC-2.DGN

Drop Structure (DS)

Practice Description

A drop structure is an erosion-control structure created by constructing a barrier across a drainageway or installing a permanent manufactured product down a slope. The purpose of a drop structure is to convey concentrated flow storm runoff from the top to the bottom of a slope or to lower water from a grassed swale into an open channel such as an intermittent or perennial stream. This practice applies where other erosion-control measures are insufficient to prevent excessive erosion and off-site sedimentation.

Planning Considerations

This practice applies to the following sites: 1) where earth and vegetation cannot safely handle water at permissible velocities; 2) where excessive grades or over-fall conditions are encountered; and/or 3) where water is to be structurally lowered from one elevation to another. These structures should be planned and installed as a part of an overall surface-water disposal system. This practice does not apply to storm sewers, concrete over-fall structures, in-channel grade-control structures, or road culverts.

Design Criteria and Construction

Design and specifications shall be prepared for each structure on an individual job basis depending on its purpose and site conditions.

Capacity

The minimum design capacity for pipe structures shall be as required to pass the peak runoff expected from a 2-year frequency, 24-hour duration storm. Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.

- Natural Resources Conservation Service (formerly Soil Conservation Service), Technical Release 55, Urban Hydrology for Small Watersheds.

- Other comparable methods – See *Appendix A: Erosion and Stormwater Runoff Calculations* found in the Appendices Volume.

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the pipe structures during the planned life of the structure.

All pipe structures should be designed as island type with an emergency spillway to safely pass storm runoff greater than the structure design storm. The minimum total capacity of the principal and emergency spillways shall be that required to handle the 25-year 24-hour duration storm, or the peak rate of flow from the contributing structure, whichever is greater.

General

The planning and design of antivortex devices, trash racks, and anti-seep collars should be in accordance with the requirements for principal spillway pipe design in the *Sediment Basin Practice*. Outlet protection should be designed according to the *Outlet Protection Practice.*

The crest elevation for the emergency spillway shall be set at the minimum level necessary to ensure full pipe flow of the principal spillway. The top of the settled embankment shall be based on 1 foot of freeboard above the design flow depth in the emergency spillway.

Straight pipe structures should be built in accordance with Figure DS-l.

Pipe drop structures should be built in accordance with Figure DS-2.

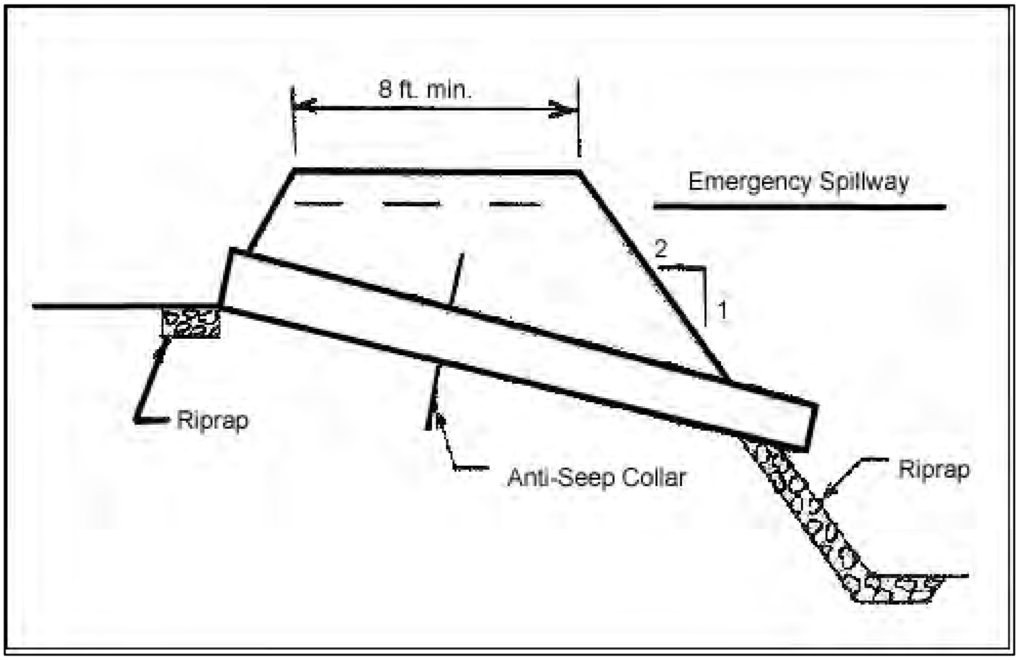


Figure DS-1 Straight Pipe Structure

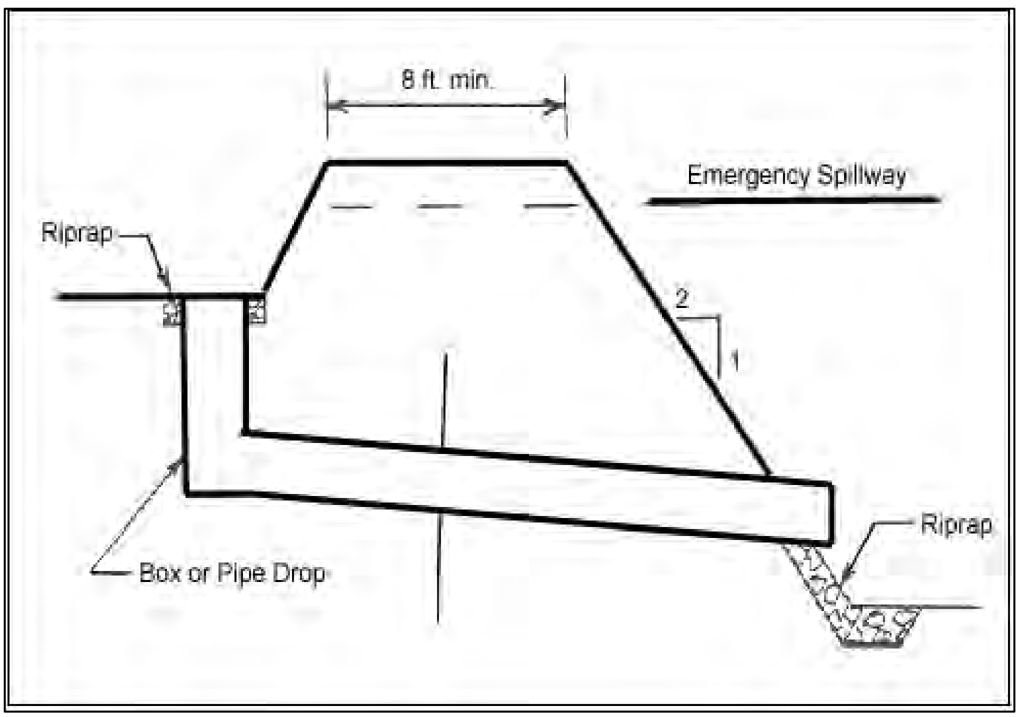


Figure DS-2 Pipe Drop Structure

Construction

Prior to the start of construction, drop structures should be designed by a qualified design professional.

Plans and specifications should be referred to by field personnel throughout the construction process. The drop structure should be built according to planned grades and dimensions.

Note: Construction of an embankment with spillways is the only type of drop structure covered in this edition of the manual.

Consider the following guidance as construction proceeds:

Site Preparation

Locate all utilities at the site to ensure avoidance (See Appendix C: MS One-Call and 811 Color Coding).

Clear, grub, and strip the dam foundation and emergency spillway area, removing all woody vegetation, rocks and other objectionable material. Dispose of trees, limbs, logs, and other debris in designated disposal areas.

Stockpile surface soil for use later during topsoiling.

Clear the sediment pool to facilitate sediment clean-out and dispose of trees, limbs, logs, and other debris in designated disposal areas.

Principal Spillway

Prepare the pipe bedding and situate the spillway barrel (pipe) on a firm, even foundation.

Install anti-seep collars according to the design plan.

Place around the barrel 4″ layers of moist, clayey, workable soil (not pervious material such as sand, gravel or silt), and compact with hand tampers to at least the density of the foundation soil. (Do not raise the pipe from the foundation when compacting under the pipe haunches.)

At the pipe inlet, install *Inlet Protection* according to the design plan.

At the pipe outlet, install *Outlet Protection* according to the design plan (if not specific, use a riprap apron at least 5 feet wide to a stable grade).

Embankment

Scarify the foundation of the dam before placing fill. Use fill from predetermined borrow areas. It should be clean, stable soil free of roots, woody vegetation, rocks and other debris, and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.

Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.

Protect the spillway barrel with 2 feet of fill that has been compacted with hand tampers before traversing over the pipe with equipment.

Compact the fill material in 6″ to 8″ continuous layers over the length of the embankment. One way is by routing construction equipment so that each layer is traversed by at least one wheel of the equipment.

Construct and compact the embankment to an elevation 10% above the design height to allow for settling. The embankment should have a minimum 8-foot top width and 3:1 (Horizontal: Vertical) side slopes, but the design may specify additional width and gentler side slopes.

Emergency Spillway

Construct the spillway at the site located by the qualified design professional according to the plan design (in undisturbed soil around one end of the embankment, and so that any flow will return to the receiving channel without damaging the embankment).

Erosion Control

Minimize the size of all disturbed areas.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Vegetate and stabilize the embankment, the emergency spillway and all disturbed areas immediately after construction.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate drop structure will not function as intended.

Seepage is encountered during construction; it may be necessary to install drains.

Design specifications for fill, pipe, seed variety or seeding dates cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect the drop structure after each storm event until it is completely stabilized with vegetation.

Periodically check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.

References

BMPs from Volume 1

Chapter 4

Grass Swale (GS)

GW

Practice Description

A grass swale is a natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation for the stable conveyance of runoff without causing damage to the channel by erosion. This practice applies to the following sites: 1) where concentrated runoff will cause erosion damage; 2) a vegetative lining provides sufficient stability for the channel as designed; and/or 3) space is available for a relatively large cross section. Typical situations where concentrated-flow areas are addressed with a grass swale include roadside ditches, channels at property boundaries, outlets for diversions and other concentrated-flow areas subject to channel erosion. Grassed swales are generally considered permanent structures but may be used as a temporary measure. Grassed swales as permanent structures are discussed further in Chapter 4 of Volume 2 - *Stormwater Management Manual*.

Planning Considerations

Grass swales should be carefully built to the design cross section, shape, and dimensions specified. Swales are hydraulic structures and as such depend upon the hydraulic parameters to function satisfactorily. Vegetated swales should be well established before large flows are permitted in the channel.

The design of a channel cross section and lining is based primarily upon the volume and velocity of flow expected in the channel. This practice covers grassed swales with low-velocity flows (generally less than 5 ft/sec). Where high velocities are anticipated, lined swales should be used (see *Lined Swale Practice* or *Riprap-lined Swale Practice*). Lined swales should also be used where there is continuous flow in the swale, which would prevent establishment of vegetation within the flow area.

Besides the primary design considerations of capacity and velocity, a number of other important factors should be taken into account when selecting a cross section (Figure GS-1). These factors include land availability, compatibility with land use and surrounding environment, safety, maintenance requirements outlet conditions, etc.

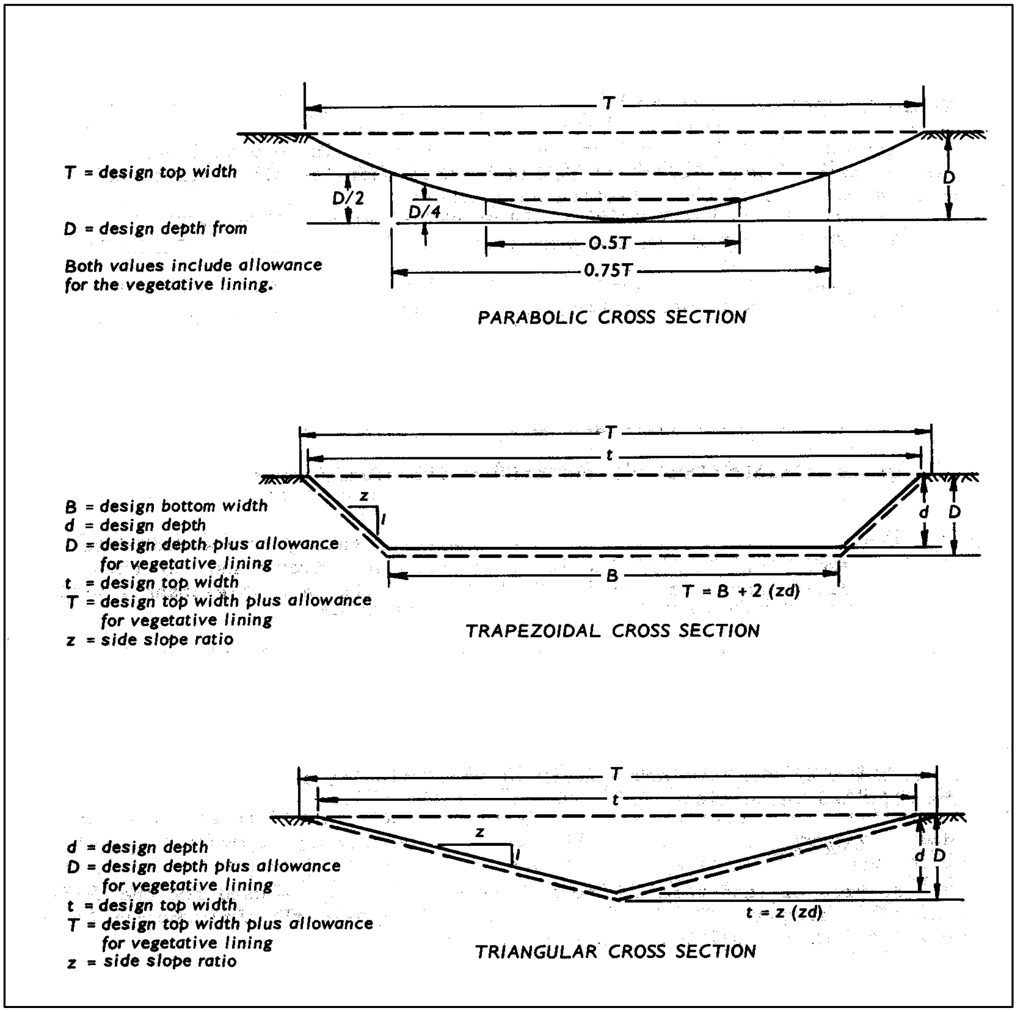


Figure GS-1 Typical Grass Swale Cross Section

Triangular Shaped Ditches

Triangular-shaped ditches are generally used where the quantity of water to be handled is relatively small, such as along roadsides. A triangular grass swale will suffice where velocities in the ditch are low.

Parabolic Channels

Parabolic channels are often used where the quantity of water to be handled is larger and where space is available for a wide, shallow channel with low-velocity flow.

Trapezoidal Channels

Trapezoidal channels are often used where the quantity of water to be carried is large and conditions require that it be carried at a relatively high velocity. Trapezoidal ditches are generally lined with concrete or riprap, but in some cases can be grassed swales, if lined with erosion control blankets (see *Erosion Control Blanket Practice*).

Other Considerations

Outlet conditions for all channels should be considered. Appropriate measures must be taken to dissipate the energy of the flow to prevent scour at the outlet of the swale.

Grass swales should be protected from erosion by concentrated flows. The methods of protecting grass swales would include, but not be limited to, the following:

- Vegetation.
- A combination of biodegradable linings and vegetation.

The type and intensity of the protective linings will determine the design of the grass swale.

If velocities exceed stable velocities, for vegetated swales or vegetation with biodegradable linings, then other linings should be used (see *Lined Swale* or *Riprap-lined Swale Practice*).

The time of the year should be considered when planning grass swales. Grass swales that are seeded to establish vegetation should not be planned for construction during late fall, winter or early spring. Grass swales constructed during mid-summer to early fall may need temporary seeding followed by permanent seeding at the recommended times. The vegetation species should be recommended for the area of the state that it is planned.

Design Criteria

Capacity

Grass swales shall be designed to convey the peak rate of runoff as shown in Table GS-1. Adjustments should be made for release rates from structures and other drainage facilities. Grass swales shall also be designed to comply with local stormwater ordinances. Grass swales should be designed for greater capacity whenever there is danger of flooding or out-of-bank flow cannot be tolerated.

Table GS-1 Design Frequency for Grassed Swale

Grass Swale Type	Typical Area of Protection	24-Hour Design Storm Frequency
Temporary	Construction Areas	2-year
	Building Sites	5-year
Permanent	Agricultural Land	10-year
	Mined Reclamation Area	10-year
	Recreation Areas	10-year
	Isolated Buildings	10-year
	Urban areas, Residential, School, Industrial Areas, etc.	10-year

Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.

- Natural Resources Conservation Service (formerly Soil Conservation Service), Technical Release 55, Urban Hydrology for Small Watersheds.

- Other comparable methods – See Appendix A: Erosion and Stormwater Runoff Calculations found in the Appendices Volume.

Grade of Grass Swale

After selecting a location for the grassed swale that will minimize the impacts to the site and maximize the intended use, the grade in the grass swales should be determined. The grade in feet per 100 feet of length can be determined from a topographic map of the site or from a detailed survey of the planned grassed swale location.

Retardance

The type grass used to vegetate the grassed swale and the degree of maintenance planned for the vegetation determine the retardance of the swale (see Table GS-2).

Generally, the retardance used for the design of grassed swales should be “D” and “C” to produce a stable velocity and adequate capacity to carry the design storm.

Table GS-2 Retardance for Grassed Swales

Retardance	Species	Cover Condition
A	Reed Canarygrass	Excellent stand, tall (average 36″)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36″)
B	Smooth Bromegrass	Good stand, mowed (average 12 to 15″)
	Bermuda Grass	Good stand, tall (average 12″)
	Native Grass Mixture (Little Bluestem, Blue Grama, and other long and short Midwest Grasses)	Good stand, unmowed
	Tall Fescue	Good stand, unmowed (average 18″)
	Lespedeza sericea	Good stand, not woody, tall (average 19″)
	Grass-Legume mixture-Timothy, Smooth Bromegrass, or Orchardgrass	Good stand, uncut (average 20″)
	Reed Canarygrass	Good stand, mowed (average 12 to 15″)
	Tall Fescue, with Bird's Foot Trefoil or Ladino Clover	Good stand, uncut (average 18″)
	Blue Grama	Good stand, uncut (average 13″)
C	Bahiagrass	Good stand, uncut (average 6 to 8″)
	Bermuda Grass	Good stand, mowed (average 6″)
	Redtop	Good stand, headed (15 to 20″)
	Grass-Legume Mixture-Summer (Orchardgrass, Redtop, Italian Ryegrass, and Common Lespedeza)	Good stand, uncut (6 to 8″)
	Centipede grass	Very dense cover (average 6″)
	Kentucky Bluegrass	Good stand, headed (6 to 12″)
D	Bermuda Grass	Good stand, cut to 2.5″ height
	Red Fescue	Good stand, headed (12 to 18″)
	Buffalo Grass	Good stand, uncut (3 to 6″)
	Grass-Legume Mixture-fall, spring (Orchard Grass, Redtop, Italian Ryegrass, and Common Lespedeza)	Good stand, uncut (4 to 5″)
	Lespedeza sericea	After cutting to 2″ height. Very good stand before cutting
E	Bermuda Grass	Good stand, cut to 1.5″ height.
	Bermuda Grass	Burned stubble

Velocities

Classify the soil where the swale is to be constructed into erosion-resistant cohesive (clayey) fine and coarse-grained soils or easily eroded noncohesive silt, clays and sands.

Determine the type of vegetative cover to be established in the swale.

Use the swale grade, cover, and soil erodibility to determine permissible velocity using Table GS-3.

Swale Dimensions

The swale may be triangular shaped, parabolic or trapezoidal, as discussed in the planning considerations of this practice and shown in Figure GS-1.

Using the peak discharge, swale grade, permissible velocity and retardance, the parabolic dimensions can be determined using Table GS-4 (Sheets 1 through 14).

Table GS-3 Permissible Velocities in Grassed Swales

Cover	Slope Range[2]	Permissible Velocity[1] Erosion-Resistant Soils[3] (clayey)	Easily Eroded Soils[4] (sandy)
	percent	ft/sec	ft/sec
Bermuda Grass	<5 5-10 over 10	8 7 6	6 4 3
Bahiagrass **Tall Fescue**	<5 5-10 over 10	7 6 5	5 4 3
Sericea lespedeza **Weeping Lovegrass**	<5[5]	3.5	2.5

[1] Use velocities exceeding (5ft/sec) only where good covers and proper maintenance can be obtained.
[2] Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
[3] Cohesive (clayey) fine-grain soils and coarse-grain soils with cohesive fines with a plasticity index of 10 to 40 (CL, CH, SC, and CG).
[4] Soils that do not meet requirements for erosion-resistant soils.
[5] Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

Design dimensions for triangular-shaped and trapezoidal-shaped swales can be determined using Manning's equation or other accepted engineering designs. (See Appendix A: *Channel Geometry*.)

The design water surface elevation of a channel receiving water from other tributary sources shall be equal to or less than the design water surface elevation of the contributing source. The design water surface elevation of contributing and receiving waters should be the same, whenever practical.

A minimum depth may be necessary to provide adequate outlets for subsurface drains and tributary channels.

Drainage

Polyethylene drainage tubing, tile, or other suitable subsurface drainage measures shall be provided for sites having high water tables or seepage problems.

Freeboard

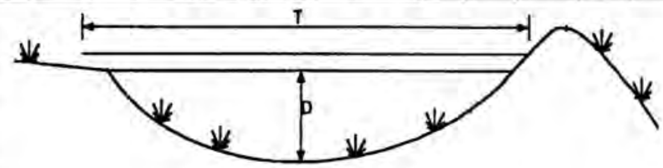
The minimum freeboard is 0.25 foot in depth. Freeboard is not required on grass swales with less than 1% slope and where out-of-bank flow will not be damaging and can be tolerated in the normal operation at the site.

Table GS-4 Parabolic Grass Swale Design Sheet 1 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.25 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15																											
20																											
25	9.3	2.3	1.7																								
30	11.7	2.2	1.8																								
35	14.1	2.1	1.7																								
40	16.3	2.1	1.8																								
45	18.5	2.1	1.8	10.4	2.8	2.3																					
50	20.7	2.1	1.8	12.3	2.6	2.3																					
55	22.9	2.1	1.8	13.8	2.6	2.3																					
60	25.0	2.0	1.8	15.3	2.5	2.3																					
65	27.2	2.0	1.8	16.8	2.5	2.3	10.4	3.4	2.8																		
70	29.3	2.0	1.8	18.2	2.5	2.3	12.1	3.1	2.8																		
75	31.9	2.0	1.7	19.7	2.4	2.3	13.5	3.0	2.8																		
80	34.0	2.0	1.7	21.1	2.4	2.3	14.7	2.9	2.8																		
85	36.1	2.0	1.7	22.5	2.4	2.3	15.8	2.9	2.8																		
90	38.2	2.0	1.7	23.9	2.4	2.3	16.9	2.8	2.8																		
95	40.3	2.0	1.7	25.3	2.4	2.3	18.0	2.8	2.8																		
100	42.4	2.0	1.7	26.7	2.4	2.3	19.1	2.8	2.8																		
105	44.6	2.0	1.7	28.1	2.4	2.3	20.2	2.8	2.8																		
110	46.7	2.0	1.7	29.5	2.4	2.3	21.3	2.8	2.8	12.9	3.8	3.4															
115	48.8	2.0	1.7	30.8	2.4	2.3	22.3	2.8	2.8	14.0	3.7	3.4															
120	50.9	2.0	1.7	32.2	2.4	2.3	23.4	2.8	2.8	15.3	3.5	3.4															
125	53.0	2.0	1.8	33.6	2.4	2.3	24.4	2.8	2.8	16.1	3.5	3.4															
130	55.1	2.0	1.8	35.0	2.4	2.3	25.5	2.8	2.8	16.9	3.4	3.4															
135	57.3	2.0	1.8	36.4	2.4	2.3	26.5	2.7	2.8	17.7	3.4	3.4															
140	59.4	2.0	1.8	38.3	2.4	2.3	27.6	2.7	2.8	18.5	3.4	3.4															
145	61.5	2.0	1.8	39.7	2.4	2.3	28.6	2.7	2.8	19.3	3.3	3.4															
150	63.6	2.0	1.8	41.1	2.4	2.3	29.6	2.7	2.8	20.1	3.3	3.4															



T = Top width, tall vegetation
D = Depth, tall vegetation
V2 = Design velocity, tall vegetation
V1 = Permissible velocity, short vegetation

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 2 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10																											
15	8.4	1.6	1.7																								
20	11.7	1.5	1.7	7.1	2.0	2.2																					
25	14.9	1.5	1.7	9.7	1.8	2.2																					
30	18.0	1.5	1.7	12.0	1.7	2.2																					
35	21.0	1.5	1.7	14.2	1.7	2.2	9.3	2.1	2.7																		
40	24.4	1.5	1.7	16.3	1.7	2.2	10.9	2.0	2.7																		
45	27.4	1.5	1.7	18.5	1.7	2.2	12.5	2.0	2.7																		
50	30.5	1.5	1.7	20.6	1.7	2.2	14.1	1.9	2.7	8.7	2.6	3.3															
55	33.5	1.5	1.7	22.7	1.7	2.2	15.7	1.9	2.7	10.4	2.4	3.3															
60	36.6	1.5	1.7	24.8	1.7	2.2	17.2	1.9	2.7	11.7	2.3	3.3															
65	39.6	1.5	1.7	27.3	1.7	2.2	18.8	1.9	2.7	12.9	2.3	3.3															
70	42.6	1.5	1.7	29.4	1.7	2.2	20.3	1.9	2.7	14.0	2.2	3.3	9.8	2.8	3.8												
75	45.7	1.5	1.7	31.4	1.7	2.2	21.8	1.9	2.7	15.2	2.2	3.3	11.3	2.7	3.8												
80	48.7	1.5	1.7	33.5	1.7	2.2	23.3	1.9	2.7	16.3	2.2	3.3	12.2	2.6	3.8												
85	51.7	1.5	1.7	35.6	1.6	2.2	24.8	1.9	2.7	17.4	2.2	3.3	13.2	2.5	3.8												
90	54.8	1.5	1.7	37.7	1.6	2.2	26.3	1.9	2.7	18.5	2.2	3.3	14.2	2.5	3.8												
95	57.8	1.5	1.7	39.8	1.6	2.2	27.8	1.9	2.7	19.6	2.2	3.3	15.1	2.5	3.8												
100	60.9	1.5	1.7	41.9	1.6	2.2	29.7	1.9	2.7	20.7	2.2	3.3	16.0	2.5	3.8	11.0	3.2	4.3									
105	63.9	1.5	1.7	44.0	1.6	2.2	31.2	1.9	2.7	21.8	2.2	3.3	16.9	2.5	3.8	12.3	3.0	4.3									
110	66.9	1.5	1.7	46.1	1.6	2.2	32.6	1.9	2.7	22.9	2.2	3.3	17.8	2.4	3.8	13.1	2.9	4.3									
115	70.0	1.5	1.7	48.1	1.6	2.2	34.1	1.9	2.7	24.0	2.1	3.3	18.7	2.4	3.8	13.9	2.9	4.3									
120	73.0	1.5	1.7	50.2	1.6	2.2	35.6	1.9	2.7	25.1	2.1	3.3	19.6	2.4	3.8	14.6	2.9	4.3									
125	76.1	1.5	1.7	52.3	1.6	2.2	37.1	1.9	2.7	26.2	2.1	3.3	20.5	2.4	3.8	15.4	2.8	4.3									
130	79.1	1.5	1.7	54.4	1.6	2.2	38.5	1.9	2.7	27.3	2.1	3.3	21.3	2.4	3.8	16.1	2.8	4.3									
135	82.1	1.5	1.7	56.5	1.6	2.2	40.0	1.9	2.7	28.4	2.1	3.3	22.2	2.4	3.8	16.9	2.8	4.3									
140	85.2	1.5	1.7	58.6	1.6	2.2	41.5	1.9	2.7	29.4	2.1	3.3	23.1	2.4	3.8	17.6	2.8	4.3									
145	88.2	1.5	1.7	60.7	1.6	2.2	43.0	1.9	2.7	30.5	2.1	3.3	24.0	2.4	3.8	18.3	2.8	4.3	12.3	3.7	4.9						
150	91.3	1.5	1.7	62.8	1.6	2.2	44.5	1.9	2.7	31.6	2.1	3.3	24.8	2.4	3.8	19.0	2.7	4.3	13.1	3.5	4.9						

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 3 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 0.75 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	7.0	1.3	1.6																								
15	11.0	1.3	1.6	7.1	1.5	2.1																					
20	14.9	1.3	1.6	9.9	1.4	2.1	6.1	1.9	2.6																		
25	18.9	1.2	1.6	12.7	1.4	2.1	8.6	1.6	2.7																		
30	22.7	1.2	1.6	15.3	1.4	2.1	10.6	1.6	2.6	6.7	2.1	3.2															
35	26.5	1.2	1.6	18.0	1.4	2.1	12.6	1.6	2.7	8.7	1.9	3.2															
40	30.2	1.2	1.6	20.6	1.4	2.1	14.5	1.6	2.7	10.3	1.8	3.2															
45	34.0	1.2	1.6	23.5	1.4	2.1	16.4	1.5	2.7	11.8	1.8	3.2	7.8	2.3	3.8												
50	37.8	1.2	1.6	26.1	1.4	2.1	18.3	1.5	2.7	13.2	1.8	3.2	9.5	2.1	3.8												
55	41.5	1.2	1.6	28.7	1.4	2.1	20.2	1.5	2.7	14.7	1.7	3.2	10.7	2.0	3.8												
60	45.3	1.2	1.6	31.3	1.4	2.1	22.1	1.5	2.7	16.1	1.7	3.2	11.8	2.0	3.8												
65	49.1	1.2	1.6	33.9	1.4	2.1	24.3	1.5	2.6	17.6	1.7	3.2	13.0	2.0	3.8	8.5	2.6	4.4									
70	52.9	1.2	1.6	36.5	1.4	2.1	26.2	1.5	2.6	19.0	1.7	3.2	14.1	2.0	3.8	10.0	2.4	4.3									
75	56.6	1.2	1.6	39.1	1.4	2.1	28.0	1.5	2.6	20.4	1.7	3.2	15.2	2.0	3.8	11.0	2.4	4.4									
80	60.4	1.2	1.6	41.7	1.4	2.1	29.9	1.5	2.6	21.8	1.7	3.2	16.3	1.9	3.8	11.9	2.3	4.4									
85	64.2	1.2	1.6	44.3	1.4	2.1	31.8	1.5	2.6	23.2	1.7	3.2	17.4	1.9	3.8	12.8	2.3	4.4	9.1	2.9	4.8						
90	67.9	1.2	1.6	46.9	1.4	2.1	33.6	1.5	2.6	24.6	1.7	3.2	18.5	1.9	3.8	13.7	2.3	4.4	10.3	2.7	4.8						
95	71.7	1.2	1.6	49.5	1.4	2.1	35.5	1.5	2.6	26.0	1.7	3.2	19.6	1.9	3.8	14.6	2.2	4.4	11.4	2.6	4.8						
100	75.5	1.2	1.6	52.1	1.4	2.1	37.3	1.5	2.6	27.8	1.7	3.2	20.7	1.9	3.8	15.4	2.2	4.4	12.2	2.6	4.8						
105	79.3	1.2	1.6	54.7	1.4	2.1	39.2	1.5	2.6	29.1	1.7	3.2	21.8	1.9	3.8	16.3	2.2	4.4	12.9	2.5	4.8						
110	83.0	1.2	1.6	57.3	1.4	2.1	41.1	1.5	2.6	30.5	1.7	3.2	22.8	1.9	3.8	17.2	2.2	4.4	13.7	2.5	4.8						
115	86.8	1.2	1.6	59.9	1.4	2.1	42.9	1.5	2.6	31.9	1.7	3.2	23.9	1.9	3.8	18.0	2.2	4.4	14.4	2.5	4.8	10.5	3.1	5.3			
120	90.6	1.2	1.6	62.5	1.4	2.1	44.8	1.5	2.7	33.3	1.7	3.2	25.0	1.9	3.8	18.9	2.2	4.4	15.2	2.5	4.8	11.4	3.0	5.3			
125	94.3	1.2	1.6	65.1	1.4	2.1	46.7	1.5	2.7	34.7	1.7	3.2	26.0	1.9	3.8	19.7	2.2	4.4	15.9	2.4	4.8	12.4	2.9	5.3			
130	98.1	1.2	1.6	67.7	1.4	2.1	48.5	1.5	2.7	36.0	1.7	3.2	27.1	1.9	3.8	20.5	2.2	4.4	16.6	2.4	4.8	13.0	2.8	5.3			
135	101.9	1.2	1.6	70.3	1.4	2.1	50.4	1.5	2.7	37.4	1.7	3.2	28.2	1.9	3.8	21.4	2.2	4.4	17.3	2.4	4.8	13.7	2.8	5.3			
140	105.7	1.2	1.6	72.9	1.4	2.1	52.2	1.5	2.7	38.8	1.7	3.2	29.3	1.9	3.8	22.2	2.2	4.4	18.0	2.4	4.9	14.3	2.8	5.3			
145	109.4	1.2	1.6	75.5	1.4	2.1	54.1	1.5	2.7	40.2	1.7	3.2	30.8	1.9	3.7	23.1	2.2	4.4	18.7	2.4	4.9	14.9	2.7	5.3			
150	113.2	1.2	1.6	78.1	1.4	2.1	56.0	1.5	2.7	41.6	1.7	3.2	31.9	1.9	3.7	23.9	2.1	4.4	19.4	2.4	4.9	15.5	2.7	5.3			

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 4 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5																											
10	8.2	1.2	1.6	5.2	1.4	2.0																					
15	12.6	1.1	1.6	8.7	1.3	2.1	5.5	1.6	2.6																		
20	17.1	1.1	1.6	11.8	1.2	2.1	8.2	1.4	2.6																		
25	21.4	1.1	1.6	14.9	1.2	2.1	10.5	1.4	2.6	7.3	1.6	3.1															
30	25.7	1.1	1.6	18.0	1.2	2.1	12.8	1.4	2.6	9.1	1.6	3.2															
35	29.9	1.1	1.6	21.2	1.2	2.1	15.0	1.3	2.6	10.9	1.5	3.1	7.8	1.8	3.7												
40	34.2	1.1	1.6	24.3	1.2	2.1	17.3	1.3	2.6	12.6	1.5	3.1	9.2	1.7	3.7												
45	38.5	1.1	1.6	27.3	1.2	2.1	19.5	1.3	2.6	14.3	1.5	3.1	10.6	1.7	3.7	7.2	2.2	4.3									
50	42.7	1.1	1.6	30.3	1.2	2.1	21.9	1.3	2.6	16.0	1.5	3.2	11.9	1.7	3.7	8.8	2.0	4.3									
55	47.0	1.1	1.6	33.3	1.2	2.1	24.1	1.3	2.6	17.7	1.5	3.2	13.3	1.7	3.7	9.9	1.9	4.3									
60	51.3	1.1	1.6	36.3	1.2	2.1	26.3	1.3	2.6	19.3	1.5	3.2	14.6	1.7	3.7	11.0	1.9	4.3									
65	55.5	1.1	1.6	39.4	1.2	2.1	28.5	1.3	2.6	21.0	1.5	3.2	15.9	1.6	3.7	12.1	1.9	4.3	8.0	2.5	4.9						
70	59.8	1.1	1.6	42.4	1.2	2.1	30.7	1.3	2.6	22.7	1.5	3.2	17.1	1.6	3.7	13.2	1.9	4.3	9.5	2.3	4.8						
75	64.1	1.1	1.6	45.4	1.2	2.1	32.9	1.3	2.6	24.6	1.5	3.1	18.5	1.6	3.7	14.2	1.8	4.3	10.4	2.2	4.9						
80	68.3	1.1	1.6	48.4	1.2	2.1	35.0	1.3	2.6	26.2	1.5	3.1	19.8	1.6	3.7	15.2	1.8	4.3	11.3	2.2	4.9						
85	72.6	1.1	1.6	51.5	1.2	2.1	37.2	1.3	2.6	27.9	1.5	3.1	21.0	1.6	3.7	16.3	1.8	4.3	12.1	2.2	4.9	8.8	2.7	5.4			
90	76.9	1.1	1.6	54.5	1.2	2.1	39.4	1.3	2.6	29.5	1.5	3.1	22.3	1.6	3.7	17.3	1.8	4.3	13.0	2.1	4.9	9.8	2.6	5.4			
95	81.1	1.1	1.6	57.5	1.2	2.1	41.6	1.3	2.6	31.1	1.5	3.1	23.6	1.6	3.7	18.3	1.8	4.3	13.8	2.1	4.9	10.9	2.5	5.3			
100	85.4	1.1	1.6	60.5	1.2	2.1	43.8	1.3	2.6	32.7	1.5	3.1	24.9	1.6	3.7	19.3	1.8	4.3	14.6	2.1	4.9	11.6	2.4	5.4			
105	89.7	1.1	1.6	63.6	1.2	2.1	46.0	1.3	2.6	34.4	1.5	3.1	26.5	1.6	3.7	20.3	1.8	4.3	15.4	2.1	4.9	12.4	2.4	5.4	9.7	2.8	5.8
110	94.0	1.1	1.6	66.6	1.2	2.1	48.2	1.3	2.6	36.0	1.5	3.1	27.7	1.6	3.7	21.3	1.8	4.3	16.2	2.1	4.9	13.1	2.4	5.4	10.8	2.6	5.8
115	98.2	1.1	1.6	69.6	1.2	2.1	50.4	1.3	2.6	37.6	1.5	3.1	29.0	1.6	3.7	22.3	1.8	4.3	17.0	2.1	4.9	13.8	2.3	5.4	11.5	2.6	5.8
120	102.5	1.1	1.6	72.6	1.2	2.1	52.5	1.3	2.6	39.3	1.5	3.1	30.2	1.6	3.7	23.3	1.8	4.3	17.9	2.1	4.9	14.5	2.3	5.4	12.2	2.6	5.8
125	106.8	1.1	1.6	75.7	1.2	2.1	54.7	1.3	2.6	40.9	1.5	3.1	31.5	1.6	3.7	24.3	1.8	4.3	18.7	2.1	4.9	15.2	2.3	5.4	12.8	2.5	5.8
130	111.0	1.1	1.6	78.7	1.2	2.1	56.9	1.3	2.6	42.5	1.5	3.1	32.7	1.6	3.7	25.3	1.8	4.3	19.4	2.1	4.9	15.9	2.3	5.4	13.4	2.5	5.8
135	115.3	1.1	1.6	81.7	1.2	2.1	59.1	1.3	2.6	44.2	1.5	3.1	34.0	1.6	3.7	26.3	1.8	4.3	20.2	2.0	4.9	16.6	2.3	5.4	14.1	2.5	5.8
140	119.6	1.1	1.6	84.7	1.2	2.1	61.3	1.3	2.6	45.8	1.5	3.1	35.2	1.6	3.7	27.3	1.8	4.3	21.0	2.0	4.9	17.2	2.3	5.4	14.7	2.5	5.8
145	123.8	1.1	1.6	87.8	1.2	2.1	63.5	1.3	2.6	47.5	1.5	3.1	36.5	1.6	3.7	28.7	1.8	4.3	21.8	2.0	4.9	17.9	2.3	5.4	15.3	2.5	5.8
150	128.1	1.1	1.6	90.8	1.2	2.1	65.7	1.3	2.6	49.1	1.5	3.1	37.8	1.6	3.7	29.7	1.8	4.3	22.6	2.0	4.9	18.6	2.3	5.4	15.9	2.4	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 5 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.25 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	4.1	1.2	1.5																								
10	9.4	1.0	1.5	6.3	1.2	2.0																					
15	14.3	1.0	1.6	9.9	1.1	2.0	6.8	1.3	2.6																		
20	19.4	1.0	1.5	13.4	1.1	2.0	9.5	1.2	2.6	6.7	1.4	3.1															
25	24.2	1.0	1.5	17.0	1.1	2.0	12.1	1.2	2.6	8.8	1.4	3.1	5.9	1.7	3.6												
30	29.0	1.0	1.6	20.4	1.1	2.0	14.6	1.2	2.6	10.7	1.4	3.1	7.8	1.6	3.7												
35	33.8	1.0	1.6	23.8	1.1	2.0	17.1	1.2	2.6	12.7	1.3	3.1	9.4	1.5	3.7	6.5	1.9	4.2									
40	38.6	1.0	1.6	27.1	1.1	2.0	19.8	1.2	2.5	14.6	1.3	3.1	10.9	1.5	3.7	8.1	1.7	4.2									
45	43.5	1.0	1.6	30.5	1.1	2.0	22.3	1.2	2.5	16.5	1.3	3.1	12.5	1.5	3.7	9.4	1.7	4.2									
50	48.3	1.0	1.6	33.9	1.1	2.0	24.8	1.2	2.5	18.3	1.3	3.1	13.9	1.5	3.7	10.6	1.7	4.2	7.7	2.0	4.8						
55	53.1	1.0	1.6	37.3	1.1	2.0	27.2	1.2	2.6	20.5	1.3	3.1	15.4	1.5	3.7	11.8	1.6	4.3	9.0	1.9	4.8						
60	57.9	1.0	1.6	40.7	1.1	2.0	29.7	1.2	2.6	22.3	1.3	3.1	16.9	1.5	3.7	13.0	1.6	4.3	10.1	1.9	4.8						
65	62.8	1.0	1.6	44.1	1.1	2.0	32.2	1.2	2.6	24.2	1.3	3.1	18.3	1.5	3.7	14.2	1.6	4.3	11.1	1.8	4.8	8.0	2.3	5.3			
70	67.6	1.0	1.6	47.5	1.1	2.0	34.6	1.2	2.6	26.0	1.3	3.1	19.8	1.4	3.7	15.4	1.6	4.3	12.0	1.8	4.8	9.3	2.1	5.3			
75	72.4	1.0	1.6	50.8	1.1	2.0	37.1	1.2	2.6	27.9	1.3	3.1	21.2	1.4	3.7	16.5	1.6	4.3	13.0	1.8	4.8	10.1	2.1	5.3			
80	77.2	1.0	1.6	54.2	1.1	2.0	39.6	1.2	2.6	29.7	1.3	3.1	23.0	1.4	3.6	17.7	1.6	4.3	14.0	1.8	4.8	11.0	2.0	5.3			
85	82.1	1.0	1.6	57.6	1.1	2.0	42.0	1.2	2.6	31.6	1.3	3.1	24.4	1.4	3.6	18.8	1.6	4.3	14.9	1.8	4.8	11.8	2.0	5.3			
90	86.9	1.0	1.6	61.0	1.1	2.0	44.5	1.2	2.6	33.5	1.3	3.1	25.8	1.4	3.6	20.0	1.6	4.3	15.9	1.8	4.8	12.6	2.0	5.3	9.1	2.5	5.9
95	91.7	1.0	1.6	64.4	1.1	2.0	47.0	1.2	2.6	35.3	1.3	3.1	27.3	1.4	3.6	21.1	1.6	4.3	16.8	1.8	4.8	13.4	2.0	5.4	10.2	2.4	5.9
100	96.6	1.0	1.6	67.8	1.1	2.0	49.4	1.2	2.6	37.2	1.3	3.1	28.7	1.4	3.6	22.3	1.6	4.3	17.7	1.8	4.8	14.2	2.0	5.4	10.9	2.3	5.9
105	101.4	1.0	1.6	71.2	1.1	2.0	51.9	1.2	2.6	39.0	1.3	3.1	30.1	1.4	3.6	23.4	1.6	4.3	18.7	1.8	4.8	15.0	2.0	5.4	11.6	2.3	5.9
110	106.2	1.0	1.6	74.6	1.1	2.0	54.4	1.2	2.6	40.9	1.3	3.1	31.6	1.4	3.6	24.6	1.6	4.3	19.6	1.7	4.8	15.8	2.0	5.4	12.3	2.3	5.9
115	111.0	1.0	1.6	78.0	1.1	2.0	56.8	1.2	2.6	42.7	1.3	3.1	33.0	1.4	3.6	26.1	1.6	4.2	20.5	1.7	4.8	16.6	1.9	5.4	13.0	2.2	5.9
120	115.9	1.0	1.6	81.3	1.1	2.0	59.3	1.2	2.6	44.6	1.3	3.1	34.4	1.4	3.6	27.2	1.6	4.2	21.5	1.7	4.8	17.3	1.9	5.4	13.6	2.2	5.9
125	120.7	1.0	1.6	84.7	1.1	2.0	61.8	1.2	2.6	46.4	1.3	3.1	35.9	1.4	3.6	28.3	1.6	4.2	22.4	1.7	4.8	18.1	1.9	5.4	14.3	2.2	5.9
130	125.5	1.0	1.6	88.1	1.1	2.0	64.3	1.2	2.6	48.3	1.3	3.1	37.3	1.4	3.7	29.5	1.6	4.2	23.3	1.7	4.8	18.9	1.9	5.4	14.9	2.2	5.9
135	130.3	1.0	1.6	91.5	1.1	2.0	66.7	1.2	2.6	50.2	1.3	3.1	38.7	1.4	3.7	30.6	1.6	4.2	24.2	1.7	4.8	19.6	1.9	5.4	15.6	2.2	5.9
140	135.2	1.0	1.6	94.9	1.1	2.0	69.2	1.2	2.6	52.0	1.3	3.1	40.2	1.4	3.7	31.7	1.6	4.2	25.1	1.7	4.8	20.4	1.9	5.4	16.2	2.2	5.9
145	140.0	1.0	1.6	98.3	1.1	2.0	71.7	1.2	2.6	53.9	1.3	3.1	41.6	1.4	3.7	32.9	1.6	4.2	26.1	1.7	4.8	21.2	1.9	5.4	16.9	2.2	5.9
150	144.8	1.0	1.6	101.7	1.1	2.0	74.1	1.2	2.6	55.7	1.3	3.1	43.0	1.4	3.7	34.0	1.6	4.2	27.0	1.7	4.8	21.9	1.9	5.4	17.5	2.2	5.9

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 6 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.50 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	4.9	1.0	1.5																								
10	10.5	0.9	1.5	7.1	1.1	2.0	4.6	1.3	2.5																		
15	16.0	0.9	1.5	10.9	1.0	2.0	7.8	1.1	2.5	5.3	1.4	3.1															
20	21.3	0.9	1.5	14.7	1.0	2.0	10.6	1.1	2.5	7.7	1.3	3.1	5.1	1.6	3.6												
25	26.6	0.9	1.5	18.6	1.0	2.0	13.4	1.1	2.5	9.9	1.2	3.1	7.3	1.4	3.6												
30	31.9	0.9	1.5	22.3	1.0	2.0	16.2	1.1	2.5	12.0	1.2	3.1	9.0	1.4	3.6	6.6	1.6	4.2									
35	37.3	0.9	1.5	26.0	1.0	2.0	19.1	1.1	2.5	14.1	1.2	3.1	10.7	1.4	3.6	8.1	1.5	4.2									
40	42.6	0.9	1.5	29.7	1.0	2.0	21.8	1.1	2.5	16.2	1.2	3.1	12.4	1.3	3.6	9.5	1.5	4.2	6.9	1.8	4.7						
45	47.9	0.9	1.5	33.4	1.0	2.0	24.5	1.1	2.5	18.3	1.2	3.1	14.0	1.3	3.6	10.8	1.5	4.2	8.3	1.7	4.7						
50	53.2	0.9	1.5	37.1	1.0	2.0	27.3	1.1	2.5	20.6	1.2	3.0	15.7	1.3	3.6	12.1	1.5	4.2	9.4	1.7	4.8						
55	58.5	0.9	1.5	40.8	1.0	2.0	30.0	1.1	2.5	22.7	1.2	3.0	17.3	1.3	3.6	13.4	1.5	4.2	10.5	1.6	4.8	8.1	1.9	5.3			
60	63.8	0.9	1.5	44.5	1.0	2.0	32.7	1.1	2.5	24.7	1.2	3.0	18.9	1.3	3.6	14.7	1.4	4.2	11.6	1.6	4.8	9.1	1.9	5.3			
65	69.2	0.9	1.5	48.2	1.0	2.0	35.4	1.1	2.5	26.8	1.2	3.1	20.8	1.3	3.6	16.0	1.4	4.2	12.7	1.6	4.8	10.0	1.8	5.3			
70	74.5	0.9	1.5	51.9	1.0	2.0	38.2	1.1	2.5	28.8	1.2	3.1	22.4	1.3	3.6	17.3	1.4	4.2	13.7	1.6	4.8	10.9	1.8	5.3	8.2	2.2	5.8
75	79.8	0.9	1.5	55.6	1.0	2.0	40.9	1.1	2.5	30.9	1.2	3.1	23.9	1.3	3.6	18.6	1.4	4.2	14.8	1.6	4.8	11.8	1.8	5.3	9.3	2.1	5.8
80	85.1	0.9	1.5	59.4	1.0	2.0	43.6	1.1	2.5	32.9	1.2	3.1	25.5	1.3	3.6	19.9	1.4	4.2	15.8	1.6	4.8	12.7	1.8	5.3	10.1	2.0	5.9
85	90.4	0.9	1.5	63.1	1.0	2.0	46.3	1.1	2.5	35.0	1.2	3.1	27.1	1.3	3.6	21.2	1.4	4.2	16.9	1.6	4.8	13.6	1.8	5.3	10.9	2.0	5.9
90	95.8	0.9	1.5	66.8	1.0	2.0	49.0	1.1	2.5	37.1	1.2	3.1	28.7	1.3	3.6	22.8	1.4	4.1	17.9	1.6	4.8	14.5	1.8	5.3	11.6	2.0	5.9
95	101.1	0.9	1.5	70.5	1.0	2.0	51.8	1.1	2.5	39.1	1.2	3.1	30.3	1.3	3.6	24.0	1.4	4.2	18.9	1.6	4.8	15.3	1.7	5.3	12.4	2.0	5.9
100	106.4	0.9	1.5	74.2	1.0	2.0	54.5	1.1	2.5	41.2	1.2	3.1	31.9	1.3	3.6	25.3	1.4	4.2	20.0	1.6	4.8	16.2	1.7	5.3	13.1	1.9	5.9
105	111.7	0.9	1.5	77.9	1.0	2.0	57.2	1.1	2.5	43.2	1.2	3.1	33.5	1.3	3.6	26.5	1.4	4.2	21.0	1.6	4.8	17.0	1.7	5.3	13.9	1.9	5.9
110	117.0	0.9	1.5	81.6	1.0	2.0	59.9	1.1	2.5	45.3	1.2	3.1	35.1	1.3	3.6	27.8	1.4	4.2	22.0	1.6	4.8	17.9	1.7	5.3	14.6	1.9	5.9
115	122.4	0.9	1.5	85.3	1.0	2.0	62.6	1.1	2.5	47.3	1.2	3.1	36.7	1.3	3.6	29.1	1.4	4.2	23.1	1.6	4.8	18.8	1.7	5.3	15.3	1.9	5.9
120	127.7	0.9	1.5	89.0	1.0	2.0	65.4	1.1	2.5	49.4	1.2	3.1	38.3	1.3	3.6	30.3	1.4	4.2	24.1	1.6	4.8	19.6	1.7	5.3	16.1	1.9	5.9
125	133.0	0.9	1.5	92.7	1.0	2.0	68.1	1.1	2.5	51.4	1.2	3.1	39.9	1.3	3.6	31.6	1.4	4.2	25.4	1.6	4.8	20.5	1.7	5.3	16.8	1.9	5.9
130	138.3	0.9	1.5	96.4	1.0	2.0	70.8	1.1	2.5	53.5	1.2	3.1	41.4	1.3	3.6	32.8	1.4	4.2	26.4	1.6	4.8	21.3	1.7	5.3	17.5	1.9	5.9
135	143.6	0.9	1.5	100.1	1.0	2.0	73.5	1.1	2.5	55.6	1.2	3.1	43.0	1.3	3.6	34.1	1.4	4.2	27.4	1.6	4.8	22.2	1.7	5.3	18.2	1.9	5.9
140	149.0	0.9	1.5	103.9	1.0	2.0	76.3	1.1	2.5	57.6	1.2	3.1	44.6	1.3	3.6	35.3	1.4	4.2	28.5	1.6	4.8	23.0	1.7	5.3	18.9	1.9	5.9
145	154.3	0.9	1.5	107.6	1.0	2.0	79.0	1.1	2.5	59.7	1.2	3.1	46.2	1.3	3.6	36.6	1.4	4.2	29.5	1.6	4.8	23.8	1.7	5.3	19.7	1.9	5.9
150	159.6	0.9	1.5	111.3	1.0	2.0	81.7	1.1	2.5	61.7	1.2	3.1	47.8	1.3	3.6	37.9	1.4	4.2	30.5	1.6	4.8	24.7	1.7	5.3	20.4	1.9	5.9

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 7 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 1.75 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	5.4	0.9	1.5																								
10	11.4	0.9	1.5	7.7	1.0	2.0	5.4	1.1	2.5																		
15	17.3	0.9	1.5	11.8	1.0	2.0	8.6	1.1	2.5	6.2	1.2	3.0															
20	23.1	0.9	1.5	16.0	0.9	2.0	11.6	1.0	2.5	8.6	1.2	3.0	6.3	1.3	3.6												
25	28.8	0.9	1.5	20.0	0.9	2.0	14.6	1.0	2.5	10.9	1.1	3.0	8.2	1.3	3.6	5.9	1.5	4.1									
30	34.6	0.9	1.5	24.0	0.9	2.0	17.8	1.0	2.5	13.2	1.1	3.0	10.1	1.2	3.6	7.6	1.4	4.2									
35	40.3	0.9	1.5	28.0	0.9	2.0	20.7	1.0	2.5	15.5	1.1	3.0	11.9	1.2	3.6	9.1	1.4	4.2	6.9	1.6	4.7						
40	46.1	0.9	1.5	32.0	0.9	2.0	23.7	1.0	2.5	18.0	1.1	3.0	13.7	1.2	3.6	10.6	1.4	4.2	8.2	1.6	4.7						
45	51.9	0.9	1.5	36.0	0.9	2.0	26.6	1.0	2.5	20.2	1.1	3.0	15.4	1.2	3.6	12.0	1.3	4.2	9.4	1.5	4.7	7.0	1.8	5.3			
50	57.6	0.9	1.5	40.0	0.9	2.0	29.6	1.0	2.5	22.4	1.1	3.0	17.2	1.2	3.6	13.5	1.3	4.1	10.6	1.5	4.7	8.3	1.7	5.3			
55	63.4	0.9	1.5	44.0	0.9	2.0	32.5	1.0	2.5	24.7	1.1	3.0	19.2	1.2	3.6	14.9	1.3	4.1	11.8	1.5	4.7	9.3	1.7	5.3	6.7	2.1	5.8
60	69.1	0.9	1.5	48.0	0.9	2.0	35.5	1.0	2.5	26.9	1.1	3.0	20.9	1.2	3.6	16.3	1.3	4.1	12.9	1.5	4.7	10.3	1.6	5.3	8.1	1.9	5.8
65	74.9	0.9	1.5	52.0	0.9	2.0	38.4	1.0	2.5	29.2	1.1	3.0	22.7	1.2	3.6	17.7	1.3	4.1	14.1	1.5	4.7	11.3	1.6	5.3	9.0	1.9	5.8
70	80.7	0.9	1.5	56.0	0.9	2.0	41.4	1.0	2.5	31.4	1.1	3.0	24.4	1.2	3.6	19.1	1.3	4.1	15.2	1.5	4.7	12.3	1.6	5.3	9.8	1.8	5.8
75	86.4	0.9	1.5	60.0	0.9	2.0	44.3	1.0	2.5	33.6	1.1	3.0	26.1	1.2	3.6	20.5	1.3	4.1	16.4	1.4	4.7	13.2	1.6	5.3	10.7	1.8	5.8
80	92.2	0.9	1.5	63.9	0.9	2.0	47.3	1.0	2.5	35.9	1.1	3.0	27.9	1.2	3.6	22.2	1.3	4.1	17.5	1.4	4.7	14.2	1.6	5.3	11.5	1.8	5.8
85	97.9	0.9	1.5	67.9	0.9	2.0	50.2	1.0	2.5	38.1	1.1	3.0	29.6	1.2	3.6	23.5	1.3	4.1	18.6	1.4	4.7	15.1	1.6	5.3	12.3	1.8	5.8
90	103.7	0.9	1.5	71.9	0.9	2.0	53.2	1.0	2.5	40.3	1.1	3.0	31.4	1.2	3.6	24.9	1.3	4.1	19.8	1.4	4.7	16.1	1.6	5.3	13.1	1.8	5.8
95	109.5	0.9	1.5	75.9	0.9	2.0	56.1	1.0	2.5	42.6	1.1	3.0	33.1	1.2	3.6	26.3	1.3	4.1	20.9	1.4	4.7	17.0	1.6	5.3	13.9	1.7	5.8
100	115.2	0.9	1.5	79.9	0.9	2.0	59.1	1.0	2.5	44.8	1.1	3.0	34.8	1.2	3.6	27.7	1.3	4.1	22.0	1.4	4.7	17.9	1.6	5.3	14.7	1.7	5.8
105	121.0	0.9	1.5	83.9	0.9	2.0	62.0	1.0	2.5	47.1	1.1	3.0	36.6	1.2	3.6	29.0	1.3	4.1	23.4	1.4	4.7	18.9	1.6	5.3	15.5	1.7	5.8
110	126.8	0.9	1.5	87.9	0.9	2.0	65.0	1.0	2.5	49.3	1.1	3.0	38.3	1.2	3.6	30.4	1.3	4.1	24.5	1.4	4.7	19.8	1.6	5.3	16.3	1.7	5.8
115	132.5	0.9	1.5	91.9	0.9	2.0	67.9	1.0	2.5	51.5	1.1	3.0	40.1	1.2	3.6	31.8	1.3	4.1	25.6	1.4	4.7	20.7	1.6	5.3	17.1	1.7	5.9
120	138.3	0.9	1.5	95.9	0.9	2.0	70.9	1.0	2.5	53.8	1.1	3.0	41.8	1.2	3.6	33.2	1.3	4.1	26.8	1.4	4.7	21.7	1.6	5.3	17.9	1.7	5.9
125	144.0	0.9	1.5	99.9	0.9	2.0	73.8	1.0	2.5	56.0	1.1	3.0	43.5	1.2	3.6	34.6	1.3	4.1	27.9	1.4	4.7	22.6	1.6	5.3	18.7	1.7	5.9
130	149.8	0.9	1.5	103.9	0.9	2.0	76.8	1.0	2.5	58.3	1.1	3.0	45.3	1.2	3.6	35.9	1.3	4.1	29.0	1.4	4.7	23.5	1.6	5.3	19.4	1.7	5.9
135	155.6	0.9	1.5	107.9	0.9	2.0	79.7	1.0	2.5	60.5	1.1	3.0	47.0	1.2	3.6	37.3	1.3	4.1	30.1	1.4	4.7	24.5	1.6	5.3	20.2	1.7	5.9
140	161.3	0.9	1.5	111.9	0.9	2.0	82.7	1.0	2.5	62.7	1.1	3.0	48.8	1.2	3.6	38.7	1.3	4.1	31.2	1.4	4.7	25.7	1.6	5.3	21.0	1.7	5.9
145	167.1	0.9	1.5	115.9	0.9	2.0	85.6	1.0	2.5	65.0	1.1	3.0	50.5	1.2	3.6	40.1	1.3	4.1	32.3	1.4	4.7	26.6	1.6	5.3	21.8	1.7	5.9
150	172.8	0.9	1.5	119.9	0.9	2.0	88.6	1.0	2.5	67.2	1.1	3.0	52.2	1.2	3.6	41.5	1.3	4.1	33.4	1.4	4.7	27.5	1.6	5.3	22.6	1.7	5.9

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 8 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 2.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	5.9	0.9	1.5																								
10	12.4	0.8	1.5	8.1	0.9	2.0	5.9	1.0	2.5																		
15	18.5	0.8	1.5	12.3	0.9	2.0	9.3	1.0	2.5	6.8	1.1	3.0	4.7	1.4	3.5												
20	24.7	0.8	1.5	16.7	0.9	2.0	12.5	1.0	2.5	9.4	1.1	3.0	7.0	1.2	3.6	4.7	1.5	4.1									
25	30.8	0.8	1.5	20.8	0.9	2.0	15.9	1.0	2.4	11.8	1.1	3.0	9.0	1.2	3.5	6.8	1.3	4.1									
30	37.0	0.8	1.5	25.0	0.9	2.0	19.0	1.0	2.5	14.3	1.1	3.0	11.0	1.2	3.5	8.5	1.3	4.1	6.4	1.5	4.7						
35	43.2	0.8	1.5	29.1	0.9	2.0	22.2	1.0	2.5	16.9	1.0	3.0	12.9	1.1	3.5	10.1	1.3	4.1	7.8	1.4	4.7						
40	49.3	0.8	1.5	33.3	0.9	2.0	25.3	1.0	2.5	19.3	1.0	3.0	14.8	1.1	3.5	11.6	1.3	4.1	9.1	1.4	4.7	7.1	1.6	5.2			
45	55.5	0.8	1.5	37.4	0.9	2.0	28.5	1.0	2.5	21.7	1.0	3.0	16.7	1.1	3.5	13.1	1.3	4.1	10.4	1.4	4.7	8.2	1.6	5.2			
50	61.7	0.8	1.5	41.6	0.9	2.0	31.7	1.0	2.5	24.1	1.0	3.0	18.8	1.1	3.5	14.7	1.2	4.1	11.7	1.4	4.7	9.3	1.5	5.3	7.1	1.8	5.8
55	67.8	0.8	1.5	45.7	0.9	2.0	34.8	1.0	2.5	26.5	1.0	3.0	20.7	1.1	3.5	16.2	1.2	4.1	12.9	1.4	4.7	10.4	1.5	5.3	8.2	1.7	5.8
60	74.0	0.8	1.5	49.9	0.9	2.0	38.0	1.0	2.5	28.9	1.0	3.0	22.6	1.1	3.5	17.7	1.2	4.1	14.1	1.4	4.7	11.4	1.5	5.3	9.2	1.7	5.8
65	80.2	0.8	1.5	54.0	0.9	2.0	41.1	1.0	2.5	31.4	1.0	3.0	24.5	1.1	3.5	19.5	1.2	4.1	15.4	1.3	4.7	12.4	1.5	5.3	10.1	1.7	5.8
70	86.3	0.8	1.5	58.2	0.9	2.0	44.3	1.0	2.5	33.8	1.0	3.0	26.3	1.1	3.5	21.0	1.2	4.1	16.6	1.3	4.7	13.5	1.5	5.3	11.0	1.6	5.8
75	92.5	0.8	1.5	62.3	0.9	2.0	47.5	1.0	2.5	36.2	1.0	3.0	28.2	1.1	3.5	22.4	1.2	4.1	17.8	1.3	4.7	14.5	1.5	5.3	11.8	1.6	5.8
80	98.7	0.8	1.5	66.5	0.9	2.0	50.6	1.0	2.5	38.6	1.0	3.0	30.1	1.1	3.5	23.9	1.2	4.1	19.0	1.3	4.7	15.5	1.5	5.3	12.7	1.6	5.8
85	104.8	0.8	1.5	70.6	0.9	2.0	53.8	1.0	2.5	41.0	1.0	3.0	32.0	1.1	3.5	25.4	1.2	4.1	20.3	1.3	4.7	16.5	1.5	5.3	13.6	1.6	5.8
90	111.0	0.8	1.5	74.8	0.9	2.0	57.0	1.0	2.5	43.4	1.0	3.0	33.8	1.1	3.5	26.9	1.2	4.1	21.8	1.3	4.6	17.5	1.5	5.3	14.4	1.6	5.8
95	117.2	0.8	1.5	78.9	0.9	2.0	60.1	1.0	2.5	45.8	1.0	3.0	35.7	1.1	3.5	28.4	1.2	4.1	23.0	1.3	4.6	18.6	1.5	5.3	15.3	1.6	5.8
100	123.3	0.8	1.5	83.1	0.9	2.0	63.3	1.0	2.5	48.2	1.0	3.0	37.6	1.1	3.5	29.9	1.2	4.1	24.2	1.3	4.6	19.6	1.5	5.3	16.2	1.6	5.8
105	129.5	0.8	1.5	87.3	0.9	2.0	66.4	1.0	2.5	50.6	1.0	3.0	39.5	1.1	3.5	31.4	1.2	4.1	25.4	1.3	4.6	20.6	1.5	5.3	17.0	1.6	5.8
110	135.7	0.8	1.5	91.4	0.9	2.0	69.6	1.0	2.5	53.0	1.0	3.0	41.3	1.1	3.5	32.9	1.2	4.1	26.6	1.3	4.7	21.6	1.4	5.3	17.9	1.6	5.8
115	141.8	0.8	1.5	95.6	0.9	2.0	72.8	1.0	2.5	55.4	1.0	3.0	43.2	1.1	3.5	34.4	1.2	4.1	27.9	1.3	4.7	22.6	1.4	5.3	18.7	1.6	5.8
120	148.0	0.8	1.5	99.7	0.9	2.0	75.9	1.0	2.5	57.9	1.0	3.0	45.1	1.1	3.5	35.9	1.2	4.1	29.1	1.3	4.7	23.9	1.4	5.2	19.5	1.6	5.8
125	154.1	0.8	1.5	103.9	0.9	2.0	79.1	1.0	2.5	60.3	1.0	3.0	47.0	1.1	3.5	37.4	1.2	4.1	30.3	1.3	4.7	24.8	1.4	5.2	20.4	1.6	5.8
130	160.3	0.8	1.5	108.0	0.9	2.0	82.3	1.0	2.5	62.7	1.0	3.0	48.8	1.1	3.5	38.9	1.2	4.1	31.5	1.3	4.7	25.8	1.4	5.3	21.2	1.6	5.8
135	166.5	0.8	1.5	112.2	0.9	2.0	85.4	1.0	2.5	65.1	1.0	3.0	50.7	1.1	3.5	40.3	1.2	4.1	32.7	1.3	4.7	26.8	1.4	5.3	22.1	1.6	5.8
140	172.6	0.8	1.5	116.3	0.9	2.0	88.6	1.0	2.5	67.5	1.0	3.0	52.6	1.1	3.5	41.8	1.2	4.1	33.9	1.3	4.7	27.8	1.4	5.3	22.9	1.6	5.8
145	178.8	0.8	1.5	120.5	0.9	2.0	91.8	1.0	2.5	69.9	1.0	3.0	54.5	1.1	3.5	43.3	1.2	4.1	35.1	1.3	4.7	28.8	1.4	5.3	23.7	1.6	5.8
150	185.0	0.8	1.5	124.6	0.9	2.0	94.9	1.0	2.5	72.3	1.0	3.0	56.4	1.1	3.5	44.8	1.2	4.1	36.3	1.3	4.7	29.8	1.4	5.3	24.6	1.6	5.8

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 9 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 3.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	7.4	0.7	1.4	4.9	0.8	1.9	3.2	1.0	2.3																		
10	15.1	0.7	1.4	10.2	0.8	1.9	7.6	0.8	2.4	5.7	0.9	2.9	4.0	1.1	3.4												
15	22.6	0.7	1.4	15.6	0.8	1.9	11.5	0.8	2.4	8.8	0.9	2.9	6.7	1.0	3.4	5.1	1.1	4.0									
20	30.1	0.7	1.4	20.7	0.8	1.9	15.5	0.8	2.4	11.8	0.9	2.9	9.2	0.9	3.4	7.2	1.0	4.0	5.5	1.2	4.6						
25	37.6	0.7	1.4	25.9	0.8	1.9	19.4	0.8	2.4	15.0	0.9	2.9	11.6	0.9	3.4	9.2	1.0	4.0	7.2	1.1	4.6	5.6	1.3	5.1			
30	45.1	0.7	1.4	31.1	0.8	1.9	23.3	0.8	2.4	18.0	0.9	2.9	14.0	0.9	3.4	11.1	1.0	4.0	8.9	1.1	4.6	7.1	1.2	5.2	5.3	1.5	5.7
35	52.7	0.7	1.4	36.2	0.8	1.9	27.1	0.8	2.4	21.0	0.9	2.9	16.5	0.9	3.4	13.0	1.0	4.0	10.5	1.1	4.6	8.4	1.2	5.2	6.7	1.4	5.7
40	60.2	0.7	1.4	41.4	0.8	1.9	31.0	0.8	2.4	24.0	0.9	2.9	18.9	0.9	3.4	14.9	1.0	4.0	12.0	1.1	4.6	9.8	1.2	5.2	7.9	1.3	5.7
45	67.7	0.7	1.4	46.6	0.8	1.9	34.9	0.8	2.4	27.0	0.9	2.9	21.2	0.9	3.4	17.0	1.0	4.0	13.6	1.1	4.6	11.1	1.2	5.2	9.1	1.3	5.7
50	75.2	0.7	1.4	51.8	0.8	1.9	38.8	0.8	2.4	29.9	0.9	2.9	23.6	0.9	3.4	18.9	1.0	4.0	15.2	1.1	4.6	12.4	1.2	5.2	10.2	1.3	5.7
55	82.8	0.7	1.4	56.9	0.8	1.9	42.6	0.8	2.4	32.9	0.9	2.9	25.9	0.9	3.4	20.8	1.0	4.0	16.7	1.1	4.6	13.7	1.2	5.2	11.3	1.3	5.7
60	90.3	0.7	1.4	62.1	0.8	1.9	46.5	0.8	2.4	35.9	0.9	2.9	28.3	0.9	3.4	22.7	1.0	4.0	18.5	1.1	4.5	14.9	1.2	5.2	12.4	1.3	5.7
65	97.8	0.7	1.4	67.3	0.8	1.9	50.4	0.8	2.4	38.9	0.9	2.9	30.6	0.9	3.4	24.6	1.0	4.0	20.0	1.1	4.5	16.2	1.2	5.2	13.5	1.3	5.7
70	105.3	0.7	1.4	72.4	0.8	1.9	54.3	0.8	2.4	41.9	0.9	2.9	33.0	0.9	3.4	26.4	1.0	4.0	21.5	1.1	4.5	17.5	1.2	5.2	14.5	1.3	5.7
75	112.8	0.7	1.4	77.6	0.8	1.9	58.1	0.8	2.4	44.9	0.9	2.9	35.3	0.9	3.4	28.3	1.0	4.0	23.1	1.1	4.5	19.1	1.2	5.1	15.6	1.3	5.7
80	120.4	0.7	1.4	82.8	0.8	1.9	62.0	0.8	2.4	47.9	0.9	2.9	37.7	0.9	3.4	30.2	1.0	4.0	24.6	1.1	4.5	20.3	1.2	5.1	16.7	1.3	5.7
85	127.9	0.7	1.4	88.0	0.8	1.9	65.9	0.8	2.4	50.9	0.9	2.9	40.1	0.9	3.4	32.1	1.0	4.0	26.1	1.1	4.5	21.6	1.2	5.1	17.8	1.2	5.7
90	135.4	0.7	1.4	93.1	0.8	1.9	69.8	0.8	2.4	53.9	0.9	2.9	42.4	0.9	3.4	34.0	1.0	4.0	27.7	1.1	4.5	22.9	1.2	5.1	18.9	1.2	5.7
95	142.9	0.7	1.4	98.3	0.8	1.9	73.6	0.8	2.4	56.9	0.9	2.9	44.8	0.9	3.4	35.9	1.0	4.0	29.2	1.1	4.5	24.1	1.2	5.1	20.2	1.2	5.7
100	150.5	0.7	1.4	103.5	0.8	1.9	77.5	0.8	2.4	59.9	0.9	2.9	47.1	0.9	3.4	37.8	1.0	4.0	30.7	1.1	4.5	25.4	1.2	5.1	21.2	1.2	5.7
105	158.0	0.7	1.4	108.7	0.8	1.9	81.4	0.8	2.4	62.8	0.9	2.9	49.5	0.9	3.4	39.6	1.0	4.0	32.3	1.1	4.5	26.7	1.2	5.1	22.3	1.2	5.7
110	165.5	0.7	1.4	113.8	0.8	1.9	85.3	0.8	2.4	65.8	0.9	2.9	51.8	0.9	3.4	41.5	1.0	4.0	33.8	1.1	4.6	27.9	1.2	5.1	23.3	1.2	5.7
115	173.0	0.7	1.4	119.0	0.8	1.9	89.1	0.8	2.4	68.8	0.9	2.9	54.2	0.9	3.4	43.4	1.0	4.0	35.4	1.1	4.6	29.2	1.2	5.1	24.4	1.2	5.7
120	180.5	0.7	1.4	124.2	0.8	1.9	93.0	0.8	2.4	71.8	0.9	2.9	56.5	0.9	3.4	45.3	1.0	4.0	36.9	1.1	4.6	30.5	1.2	5.1	25.5	1.2	5.7
125	188.1	0.7	1.4	129.4	0.8	1.9	96.9	0.8	2.4	74.8	0.9	2.9	58.9	0.9	3.4	47.2	1.0	4.0	38.4	1.1	4.6	31.7	1.2	5.1	26.5	1.2	5.7
130	195.6	0.7	1.4	134.5	0.8	1.9	100.8	0.8	2.4	77.8	0.9	2.9	61.2	0.9	3.4	49.1	1.0	4.0	40.0	1.1	4.6	33.0	1.2	5.1	27.6	1.2	5.7
135	203.1	0.7	1.4	139.7	0.8	1.9	104.6	0.8	2.4	80.8	0.9	2.9	63.6	0.9	3.4	51.0	1.0	4.0	41.5	1.1	4.6	34.3	1.2	5.1	28.6	1.2	5.7
140	210.6	0.7	1.4	144.9	0.8	1.9	108.5	0.8	2.4	83.8	0.9	2.9	66.0	0.9	3.4	52.8	1.0	4.0	43.0	1.1	4.6	35.6	1.2	5.1	29.7	1.2	5.7
145	218.2	0.7	1.4	150.1	0.8	1.9	112.4	0.8	2.4	86.8	0.9	2.9	68.3	0.9	3.4	54.7	1.0	4.0	44.6	1.1	4.6	36.8	1.2	5.1	30.7	1.2	5.7
150	225.7	0.7	1.4	155.2	0.8	1.9	116.3	0.8	2.4	89.8	0.9	2.9	70.7	0.9	3.4	56.6	1.0	4.0	46.1	1.1	4.6	38.1	1.2	5.1	31.8	1.2	5.7

RETARDANCE "D" AND "C"

NOTE: Width and Depth dir sions are in feet; Velocity measurements are in feet per second; includ llowance for freeboarc settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 10 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 4.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	8.5	0.6	1.4	5.9	0.7	1.8	4.1	0.8	2.3																		
10	17.2	0.6	1.4	12.1	0.7	1.8	8.8	0.7	2.3	6.7	0.8	2.8	5.2	0.9	3.3	3.8	1.0	3.9									
15	25.8	0.6	1.4	18.1	0.7	1.8	13.4	0.7	2.3	10.3	0.8	2.8	8.1	0.8	3.4	6.4	0.9	3.9	4.9	1.0	4.5						
20	34.4	0.6	1.4	24.2	0.7	1.8	17.8	0.7	2.3	13.9	0.8	2.8	10.9	0.8	3.4	8.7	0.9	3.9	6.9	1.0	4.5	5.5	1.1	5.0			
25	43.0	0.6	1.4	30.2	0.7	1.9	22.3	0.7	2.3	17.4	0.8	2.8	13.8	0.8	3.3	10.9	0.9	3.9	8.8	1.0	4.5	7.1	1.0	5.1	5.7	1.2	5.6
30	51.6	0.6	1.4	36.3	0.7	1.9	26.7	0.7	2.3	20.8	0.8	2.8	16.5	0.8	3.3	13.2	0.9	3.9	10.7	0.9	4.5	8.7	1.0	5.1	7.1	1.1	5.6
35	60.2	0.6	1.4	42.3	0.7	1.9	31.1	0.7	2.3	24.3	0.8	2.8	19.3	0.8	3.4	15.6	0.9	3.9	12.5	0.9	4.5	10.3	1.0	5.0	8.4	1.1	5.6
40	68.8	0.6	1.4	48.3	0.7	1.9	35.6	0.7	2.3	27.8	0.8	2.8	22.0	0.8	3.4	17.8	0.9	3.9	14.4	0.9	4.5	11.8	1.0	5.0	9.8	1.1	5.7
45	77.4	0.6	1.4	54.4	0.7	1.9	40.0	0.7	2.4	31.2	0.8	2.8	24.8	0.8	3.4	20.0	0.9	3.9	16.4	0.9	4.4	13.3	1.0	5.0	11.1	1.1	5.7
50	86.0	0.6	1.4	60.4	0.7	1.9	44.5	0.7	2.4	34.7	0.8	2.8	27.5	0.8	3.4	22.2	0.9	3.9	18.2	0.9	4.4	14.9	1.0	5.0	12.3	1.1	5.7
55	94.6	0.6	1.4	66.5	0.7	1.9	48.9	0.7	2.4	38.2	0.8	2.8	30.3	0.8	3.4	24.4	0.9	3.9	20.0	0.9	4.4	16.6	1.0	5.0	13.6	1.1	5.7
60	103.2	0.6	1.4	72.5	0.7	1.9	53.4	0.7	2.4	41.7	0.8	2.8	33.0	0.8	3.4	26.6	0.9	3.9	21.8	0.9	4.5	18.1	1.0	5.0	14.9	1.1	5.7
65	111.8	0.6	1.4	78.5	0.7	1.9	57.8	0.7	2.4	45.1	0.8	2.8	35.8	0.8	3.4	28.9	0.9	3.9	23.6	0.9	4.5	19.6	1.0	5.0	16.2	1.1	5.7
70	120.4	0.6	1.4	84.6	0.7	1.9	62.3	0.7	2.4	48.6	0.8	2.8	38.6	0.8	3.4	31.1	0.9	3.9	25.4	0.9	4.5	21.1	1.0	5.0	17.7	1.1	5.6
75	129.0	0.6	1.4	90.6	0.7	1.9	66.7	0.7	2.4	52.1	0.8	2.8	41.3	0.8	3.4	33.3	0.9	3.9	27.2	0.9	4.5	22.6	1.0	5.0	19.0	1.1	5.6
80	137.6	0.6	1.4	96.7	0.7	1.9	71.2	0.7	2.4	55.5	0.8	2.8	44.1	0.8	3.4	35.5	0.9	3.9	29.1	0.9	4.5	24.1	1.0	5.0	20.2	1.1	5.6
85	146.2	0.6	1.4	102.7	0.7	1.9	75.6	0.7	2.4	59.0	0.8	2.8	46.8	0.8	3.4	37.7	0.9	3.9	30.9	0.9	4.5	25.6	1.0	5.0	21.5	1.1	5.6
90	154.8	0.6	1.4	108.7	0.7	1.9	80.0	0.7	2.4	62.5	0.8	2.8	49.6	0.8	3.4	39.9	0.9	3.9	32.7	0.9	4.5	27.1	1.0	5.0	22.8	1.1	5.6
95	163.4	0.6	1.4	114.8	0.7	1.9	84.5	0.7	2.4	65.9	0.8	2.8	52.3	0.8	3.4	42.2	0.9	3.9	34.5	0.9	4.5	28.6	1.0	5.0	24.0	1.1	5.6
100	172.0	0.6	1.4	120.8	0.7	1.9	88.9	0.7	2.4	69.4	0.8	2.8	55.1	0.8	3.4	44.4	0.9	3.9	36.3	0.9	4.5	30.1	1.0	5.0	25.3	1.1	5.6
105	180.6	0.6	1.4	126.9	0.7	1.9	93.4	0.7	2.4	72.9	0.8	2.8	57.8	0.8	3.4	46.6	0.9	3.9	38.1	0.9	4.5	31.6	1.0	5.0	26.5	1.1	5.6
110	189.2	0.6	1.4	132.9	0.7	1.9	97.8	0.7	2.4	76.3	0.8	2.8	60.6	0.8	3.4	48.8	0.9	3.9	39.9	0.9	4.5	33.1	1.0	5.0	27.8	1.1	5.6
115	197.8	0.6	1.4	138.9	0.7	1.9	102.3	0.7	2.4	79.8	0.8	2.8	63.3	0.8	3.4	51.0	0.9	3.9	41.7	0.9	4.5	34.6	1.0	5.0	29.0	1.1	5.6
120	206.4	0.6	1.4	145.0	0.7	1.9	106.7	0.7	2.4	83.3	0.8	2.8	66.1	0.8	3.4	53.3	0.9	3.9	43.6	0.9	4.5	36.1	1.0	5.0	30.2	1.1	5.7
125	215.0	0.6	1.4	151.0	0.7	1.9	111.2	0.7	2.4	86.8	0.8	2.8	68.8	0.8	3.4	55.5	0.9	3.9	45.4	0.9	4.5	37.6	1.0	5.0	31.5	1.1	5.7
130	223.7	0.6	1.4	157.1	0.7	1.9	115.6	0.7	2.4	90.2	0.8	2.8	71.6	0.8	3.4	57.7	0.9	3.9	47.2	0.9	4.5	39.1	1.0	5.0	32.7	1.1	5.7
135	232.3	0.6	1.4	163.1	0.7	1.9	120.1	0.7	2.4	93.7	0.8	2.8	74.3	0.8	3.4	59.9	0.9	3.9	49.0	0.9	4.5	40.6	1.0	5.0	34.0	1.1	5.7
140	240.9	0.6	1.4	169.1	0.7	1.9	124.5	0.7	2.4	97.2	0.8	2.8	77.1	0.8	3.4	62.1	0.9	3.9	50.8	0.9	4.5	42.1	1.0	5.0	35.2	1.1	5.7
145	249.5	0.6	1.4	175.2	0.7	1.9	129.0	0.7	2.4	100.6	0.8	2.8	79.8	0.8	3.4	64.3	0.9	3.9	52.6	0.9	4.5	43.6	1.0	5.0	36.5	1.1	5.7
150	258.1	0.6	1.4	181.2	0.7	1.9	133.4	0.7	2.4	104.1	0.8	2.8	82.6	0.8	3.4	66.6	0.9	3.9	54.4	0.9	4.5	45.1	1.0	5.0	37.8	1.1	5.7

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second; Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 11 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 5.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	9.5	0.6	1.4	6.7	0.6	1.8	4.7	0.7	2.3	3.5	0.8	2.8															
10	19.0	0.6	1.4	13.7	0.6	1.8	9.7	0.7	2.3	7.6	0.7	2.8	6.0	0.8	3.3	4.7	0.8	3.8	3.4	1.0	4.4						
15	28.5	0.6	1.4	20.5	0.6	1.8	14.8	0.7	2.3	11.7	0.7	2.8	9.2	0.7	3.3	7.3	0.8	3.8	5.9	0.9	4.4	4.7	1.0	5.0			
20	38.0	0.6	1.4	27.3	0.6	1.8	19.7	0.7	2.3	15.5	0.7	2.8	12.4	0.7	3.3	9.9	0.8	3.8	8.0	0.9	4.4	6.5	0.9	4.9	5.3	1.0	5.5
25	47.5	0.6	1.4	34.1	0.6	1.8	24.6	0.7	2.3	19.4	0.7	2.8	15.5	0.7	3.3	12.6	0.8	3.8	10.1	0.8	4.4	8.3	0.9	5.0	6.8	1.0	5.6
30	57.0	0.6	1.4	40.9	0.6	1.8	29.5	0.7	2.3	23.3	0.7	2.8	18.6	0.7	3.3	15.1	0.8	3.8	12.2	0.8	4.4	10.1	0.9	5.0	8.3	1.0	5.6
35	66.5	0.6	1.4	47.7	0.6	1.8	34.4	0.7	2.3	27.2	0.7	2.8	21.7	0.7	3.3	17.6	0.8	3.8	14.5	0.8	4.4	11.8	0.9	5.0	9.8	1.0	5.6
40	76.0	0.6	1.4	54.6	0.6	1.8	39.4	0.7	2.3	31.0	0.7	2.8	24.8	0.7	3.3	20.1	0.8	3.8	16.5	0.8	4.4	13.6	0.9	5.0	11.3	1.0	5.5
45	85.5	0.6	1.4	61.4	0.6	1.8	44.3	0.7	2.3	34.9	0.7	2.8	27.9	0.7	3.3	22.6	0.8	3.8	18.6	0.8	4.4	15.5	0.9	4.9	12.8	1.0	5.5
50	95.0	0.6	1.4	68.2	0.6	1.8	49.2	0.7	2.3	38.8	0.7	2.8	31.0	0.7	3.3	25.1	0.8	3.8	20.6	0.8	4.4	17.2	0.9	4.9	14.3	1.0	5.5
55	104.6	0.6	1.4	75.0	0.6	1.8	54.1	0.7	2.3	42.7	0.7	2.8	34.1	0.7	3.3	27.6	0.8	3.8	22.7	0.8	4.4	18.9	0.9	4.9	15.9	0.9	5.5
60	114.1	0.6	1.4	81.8	0.6	1.8	59.0	0.7	2.3	46.6	0.7	2.8	37.2	0.7	3.3	30.1	0.8	3.8	24.7	0.8	4.4	20.6	0.9	4.9	17.3	0.9	5.5
65	123.6	0.6	1.4	88.6	0.6	1.8	63.9	0.7	2.3	50.4	0.7	2.8	40.3	0.7	3.3	32.6	0.8	3.8	26.8	0.8	4.4	22.3	0.9	4.9	18.8	0.9	5.5
70	133.1	0.6	1.4	95.5	0.6	1.8	68.9	0.7	2.3	54.3	0.7	2.8	43.4	0.7	3.3	35.1	0.8	3.8	28.9	0.8	4.4	24.0	0.9	4.9	20.2	0.9	5.5
75	142.6	0.6	1.4	102.3	0.6	1.8	73.8	0.7	2.3	58.2	0.7	2.8	46.5	0.7	3.3	37.7	0.8	3.8	30.9	0.8	4.4	25.7	0.9	4.9	21.6	0.9	5.5
80	152.1	0.6	1.4	109.1	0.6	1.8	78.7	0.7	2.3	62.1	0.7	2.8	49.6	0.7	3.3	40.2	0.8	3.8	33.0	0.8	4.4	27.4	0.9	4.9	23.1	0.9	5.5
85	161.6	0.6	1.4	115.9	0.6	1.8	83.6	0.7	2.3	65.9	0.7	2.8	52.7	0.7	3.3	42.7	0.8	3.8	35.0	0.8	4.4	29.1	0.9	5.0	24.5	0.9	5.5
90	171.1	0.6	1.4	122.7	0.6	1.8	88.5	0.7	2.3	69.8	0.7	2.8	55.8	0.7	3.3	45.2	0.8	3.8	37.1	0.8	4.4	30.9	0.9	5.0	26.0	0.9	5.5
95	180.6	0.6	1.4	129.6	0.6	1.8	93.4	0.7	2.3	73.7	0.7	2.8	58.9	0.7	3.3	47.7	0.8	3.8	39.2	0.8	4.4	32.6	0.9	5.0	27.4	0.9	5.5
100	190.1	0.6	1.4	136.4	0.6	1.8	98.4	0.7	2.3	77.6	0.7	2.8	62.0	0.7	3.3	50.2	0.8	3.8	41.2	0.8	4.4	34.3	0.9	5.0	28.8	0.9	5.5
105	199.6	0.6	1.4	143.2	0.6	1.8	103.3	0.7	2.3	81.5	0.7	2.8	65.1	0.7	3.3	52.7	0.8	3.8	43.3	0.8	4.4	36.0	0.9	5.0	30.3	0.9	5.5
110	209.1	0.6	1.4	150.0	0.6	1.8	108.2	0.7	2.3	85.3	0.7	2.8	68.2	0.7	3.3	55.2	0.8	3.8	45.3	0.8	4.4	37.7	0.9	5.0	31.7	0.9	5.5
115	218.6	0.6	1.4	156.8	0.6	1.8	113.1	0.7	2.3	89.2	0.7	2.8	71.3	0.7	3.3	57.7	0.8	3.8	47.4	0.8	4.4	39.4	0.9	5.0	33.2	0.9	5.5
120	228.1	0.6	1.4	163.6	0.6	1.8	118.0	0.7	2.3	93.1	0.7	2.8	74.3	0.7	3.3	60.2	0.8	3.8	49.5	0.8	4.4	41.1	0.9	5.0	34.6	0.9	5.5
125	237.6	0.6	1.4	170.5	0.6	1.8	123.0	0.7	2.3	97.0	0.7	2.8	77.4	0.7	3.3	62.7	0.8	3.8	51.5	0.8	4.4	42.8	0.9	5.0	36.0	0.9	5.5
130	247.1	0.6	1.4	177.3	0.6	1.8	127.9	0.7	2.3	100.8	0.7	2.8	80.5	0.7	3.3	65.2	0.8	3.8	53.6	0.8	4.4	44.6	0.9	5.0	37.5	0.9	5.5
135	256.6	0.6	1.4	184.1	0.6	1.8	132.8	0.7	2.3	104.7	0.7	2.8	83.6	0.7	3.3	67.8	0.8	3.8	55.6	0.8	4.4	46.3	0.9	5.0	38.9	0.9	5.5
140	266.1	0.6	1.4	190.9	0.6	1.8	137.7	0.7	2.3	108.6	0.7	2.8	86.7	0.7	3.3	70.3	0.8	3.8	57.7	0.8	4.4	48.0	0.9	5.0	40.4	0.9	5.5
145	275.6	0.6	1.4	197.7	0.6	1.8	142.6	0.7	2.3	112.5	0.7	2.8	89.8	0.7	3.3	72.8	0.8	3.8	59.8	0.8	4.4	49.7	0.9	5.0	41.8	0.9	5.5
150	285.1	0.6	1.4	204.6	0.6	1.8	147.5	0.7	2.3	116.4	0.7	2.8	92.9	0.7	3.3	75.3	0.8	3.8	61.8	0.8	4.4	51.4	0.9	5.0	43.2	0.9	5.5

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 12 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 6.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	10.6	0.5	1.3	7.3	0.6	1.8	5.3	0.6	2.3	4.0	0.7	2.8	2.9	0.8	3.2												
10	21.1	0.5	1.3	14.7	0.6	1.8	10.9	0.6	2.3	8.4	0.7	2.8	6.6	0.7	3.2	5.3	0.8	3.8	4.2	0.8	4.3						
15	31.6	0.5	1.3	22.1	0.6	1.8	16.3	0.6	2.3	12.7	0.6	2.7	10.1	0.7	3.3	8.2	0.7	3.8	6.6	0.8	4.3	5.4	0.9	4.9	4.3	1.0	5.5
20	42.1	0.5	1.3	29.5	0.6	1.8	21.7	0.6	2.3	17.0	0.6	2.7	13.6	0.7	3.2	11.1	0.7	3.7	9.0	0.8	4.3	7.4	0.8	4.9	6.1	0.9	5.5
25	52.7	0.5	1.3	36.8	0.6	1.8	27.1	0.6	2.3	21.2	0.6	2.8	17.0	0.7	3.2	13.9	0.7	3.8	11.3	0.8	4.3	9.3	0.8	4.9	7.8	0.9	5.5
30	63.2	0.5	1.3	44.2	0.6	1.8	32.5	0.6	2.3	25.4	0.6	2.8	20.4	0.7	3.2	16.6	0.7	3.8	13.7	0.8	4.3	11.3	0.8	4.9	9.4	0.9	5.5
35	73.7	0.5	1.3	51.6	0.6	1.8	38.0	0.6	2.3	29.7	0.6	2.8	23.8	0.7	3.2	19.4	0.7	3.8	16.0	0.8	4.3	13.4	0.8	4.9	11.1	0.9	5.5
40	84.2	0.5	1.3	58.9	0.6	1.8	43.4	0.6	2.3	33.9	0.6	2.8	27.2	0.7	3.3	22.2	0.7	3.8	18.3	0.8	4.3	15.3	0.8	4.9	12.7	0.9	5.5
45	94.8	0.5	1.3	66.3	0.6	1.8	48.8	0.6	2.3	38.2	0.6	2.8	30.7	0.7	3.3	24.9	0.7	3.8	20.6	0.8	4.3	17.2	0.8	4.9	14.5	0.9	5.4
50	105.3	0.5	1.3	73.6	0.6	1.8	54.2	0.6	2.3	42.4	0.6	2.8	34.1	0.7	3.3	27.7	0.7	3.8	22.8	0.8	4.3	19.1	0.8	4.9	16.1	0.9	5.4
55	115.8	0.5	1.3	81.0	0.6	1.8	59.7	0.6	2.3	46.6	0.6	2.8	37.5	0.7	3.3	30.5	0.7	3.8	25.1	0.8	4.3	21.0	0.8	4.9	17.7	0.9	5.4
60	126.4	0.5	1.3	88.4	0.6	1.8	65.1	0.6	2.3	50.9	0.6	2.8	40.9	0.7	3.3	33.3	0.7	3.8	27.4	0.8	4.3	22.9	0.8	4.9	19.3	0.9	5.4
65	136.9	0.5	1.3	95.7	0.6	1.8	70.5	0.6	2.3	55.1	0.6	2.8	44.3	0.7	3.3	36.0	0.7	3.8	29.7	0.8	4.3	24.8	0.8	4.9	20.9	0.9	5.4
70	147.4	0.5	1.3	103.1	0.6	1.8	75.9	0.6	2.3	59.3	0.6	2.8	47.7	0.7	3.3	38.8	0.7	3.8	32.0	0.8	4.3	26.7	0.8	4.9	22.5	0.9	5.4
75	158.0	0.5	1.3	110.5	0.6	1.8	81.3	0.6	2.3	63.6	0.6	2.8	51.1	0.7	3.3	41.6	0.7	3.8	34.3	0.8	4.3	28.6	0.8	4.9	24.1	0.9	5.4
80	168.5	0.5	1.3	117.8	0.6	1.8	86.8	0.6	2.3	67.8	0.6	2.8	54.5	0.7	3.3	44.3	0.7	3.8	36.5	0.8	4.3	30.5	0.8	4.9	25.7	0.9	5.5
85	179.0	0.5	1.3	125.2	0.6	1.8	92.2	0.6	2.3	72.0	0.6	2.8	57.9	0.7	3.3	47.1	0.7	3.8	38.8	0.8	4.3	32.4	0.8	4.9	27.3	0.9	5.5
90	189.6	0.5	1.3	132.6	0.6	1.8	97.6	0.6	2.3	76.3	0.6	2.8	61.3	0.7	3.3	49.9	0.7	3.8	41.1	0.8	4.3	34.3	0.8	4.9	28.9	0.9	5.5
95	200.1	0.5	1.3	139.9	0.6	1.8	103.0	0.6	2.3	80.5	0.6	2.8	64.7	0.7	3.3	52.6	0.7	3.8	43.4	0.8	4.3	36.2	0.8	4.9	30.5	0.9	5.5
100	210.6	0.5	1.3	147.3	0.6	1.8	108.5	0.6	2.3	84.8	0.6	2.8	68.1	0.7	3.3	55.4	0.7	3.8	45.7	0.8	4.3	38.1	0.8	4.9	32.1	0.9	5.5
105	221.1	0.5	1.3	154.6	0.6	1.8	113.9	0.6	2.3	89.0	0.6	2.8	71.5	0.7	3.3	58.2	0.7	3.8	47.9	0.8	4.3	40.0	0.8	4.9	33.7	0.9	5.5
110	231.7	0.5	1.3	162.0	0.6	1.8	119.3	0.6	2.3	93.2	0.6	2.8	74.9	0.7	3.3	60.9	0.7	3.8	50.2	0.8	4.3	41.9	0.8	4.9	35.3	0.9	5.5
115	242.2	0.5	1.3	169.4	0.6	1.8	124.7	0.6	2.3	97.5	0.6	2.8	78.3	0.7	3.3	63.7	0.7	3.8	52.5	0.8	4.3	43.8	0.8	4.9	36.9	0.9	5.5
120	252.7	0.5	1.3	176.7	0.6	1.8	130.2	0.6	2.3	101.7	0.6	2.8	81.7	0.7	3.3	66.5	0.7	3.8	54.8	0.8	4.3	45.7	0.8	4.9	38.5	0.9	5.5
125	263.3	0.5	1.3	184.1	0.6	1.8	135.6	0.6	2.3	106.0	0.6	2.8	85.1	0.7	3.3	69.3	0.7	3.8	57.1	0.8	4.3	47.6	0.8	4.9	40.1	0.9	5.5
130	273.8	0.5	1.3	191.5	0.6	1.8	141.0	0.6	2.3	110.2	0.6	2.8	88.5	0.7	3.3	72.0	0.7	3.8	59.4	0.8	4.3	49.5	0.8	4.9	41.7	0.9	5.5
135	284.3	0.5	1.3	198.8	0.6	1.8	146.4	0.6	2.3	114.4	0.6	2.8	91.9	0.7	3.3	74.8	0.7	3.8	61.6	0.8	4.3	51.4	0.8	4.9	43.3	0.9	5.5
140	294.9	0.5	1.3	206.2	0.6	1.8	151.8	0.6	2.3	118.7	0.6	2.8	95.3	0.7	3.3	77.6	0.7	3.8	63.9	0.8	4.3	53.3	0.8	4.9	44.9	0.9	5.5
145	305.4	0.5	1.3	213.6	0.6	1.8	157.3	0.6	2.3	122.9	0.6	2.8	98.7	0.7	3.3	80.3	0.7	3.8	66.2	0.8	4.3	55.2	0.8	4.9	46.5	0.9	5.5
150	315.9	0.5	1.3	220.9	0.6	1.8	162.7	0.6	2.3	127.1	0.6	2.8	102.1	0.7	3.3	83.1	0.7	3.8	68.5	0.8	4.3	57.1	0.8	4.9	48.1	0.9	5.5

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second:
Depth "D" does not include allowance for freeboard or settlement.

Table GS-4 Parabolic Grass Swale Design Sheet 13 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH' (D), AND V2 FOR RETARDANCE "C"

Grade 8.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	12.0	0.5	1.3	8.5	0.5	1.7	6.2	0.5	2.2	4.6	0.6	2.7	3.7	0.6	3.2	2.9	0.7	3.6									
10	24.1	0.5	1.3	16.9	0.5	1.7	12.6	0.5	2.2	9.6	0.6	2.7	7.8	0.6	3.2	6.3	0.6	3.7	5.1	0.7	4.2	4.2	0.8	4.8	3.2	0.9	5.3
15	36.1	0.5	1.3	25.3	0.5	1.7	18.9	0.5	2.2	14.4	0.6	2.7	11.8	0.6	3.2	9.7	0.6	3.7	7.9	0.7	4.2	6.5	0.7	4.8	5.4	0.8	5.3
20	48.1	0.5	1.3	33.8	0.5	1.7	25.2	0.5	2.2	19.2	0.6	2.7	15.8	0.6	3.2	12.9	0.6	3.7	10.7	0.7	4.2	8.8	0.7	4.8	7.4	0.8	5.3
25	60.1	0.5	1.3	42.2	0.5	1.7	31.5	0.5	2.2	24.0	0.6	2.7	19.7	0.6	3.2	16.2	0.6	3.7	13.4	0.7	4.2	11.2	0.7	4.7	9.3	0.8	5.3
30	72.1	0.5	1.3	50.6	0.5	1.7	37.8	0.5	2.2	28.8	0.6	2.7	23.6	0.6	3.2	19.4	0.6	3.7	16.1	0.7	4.2	13.5	0.7	4.8	11.3	0.7	5.3
35	84.1	0.5	1.3	59.1	0.5	1.7	44.1	0.5	2.2	33.6	0.6	2.7	27.6	0.6	3.2	22.6	0.6	3.7	18.7	0.7	4.2	15.7	0.7	4.8	13.3	0.7	5.3
40	96.2	0.5	1.3	67.5	0.5	1.7	50.4	0.5	2.2	38.4	0.6	2.7	31.5	0.6	3.2	25.8	0.6	3.7	21.4	0.7	4.2	17.9	0.7	4.8	15.2	0.7	5.3
45	108.2	0.5	1.3	76.0	0.5	1.7	56.7	0.5	2.2	43.2	0.6	2.7	35.4	0.6	3.2	29.0	0.6	3.7	24.1	0.7	4.2	20.2	0.7	4.8	17.1	0.7	5.3
50	120.2	0.5	1.3	84.4	0.5	1.7	63.0	0.5	2.2	48.0	0.6	2.7	39.4	0.6	3.2	32.3	0.6	3.7	26.8	0.7	4.2	22.4	0.7	4.8	19.0	0.7	5.3
55	132.2	0.5	1.3	92.8	0.5	1.7	69.3	0.5	2.2	52.8	0.6	2.7	43.3	0.6	3.2	35.5	0.6	3.7	29.4	0.7	4.2	24.7	0.7	4.8	20.9	0.7	5.3
60	144.2	0.5	1.3	101.3	0.5	1.7	75.6	0.5	2.2	57.6	0.6	2.7	47.2	0.6	3.2	38.7	0.6	3.7	32.1	0.7	4.2	26.9	0.7	4.8	22.8	0.7	5.3
65	156.3	0.5	1.3	109.7	0.5	1.7	81.8	0.5	2.2	62.4	0.6	2.7	51.2	0.6	3.2	41.9	0.6	3.7	34.8	0.7	4.2	29.1	0.7	4.8	24.7	0.7	5.3
70	168.3	0.5	1.3	118.2	0.5	1.7	88.1	0.5	2.2	67.2	0.6	2.7	55.1	0.6	3.2	45.2	0.6	3.7	37.5	0.7	4.2	31.4	0.7	4.8	26.6	0.7	5.3
75	180.3	0.5	1.3	126.6	0.5	1.7	94.4	0.5	2.2	72.0	0.6	2.7	59.0	0.6	3.2	48.4	0.6	3.7	40.1	0.7	4.2	33.6	0.7	4.8	28.5	0.7	5.3
80	192.3	0.5	1.3	135.0	0.5	1.7	100.7	0.5	2.2	76.8	0.6	2.7	63.0	0.6	3.2	51.6	0.6	3.7	42.8	0.7	4.2	35.9	0.7	4.8	30.3	0.7	5.3
85	204.3	0.5	1.3	143.5	0.5	1.7	107.0	0.5	2.2	81.6	0.6	2.7	66.9	0.6	3.2	54.9	0.6	3.7	45.5	0.7	4.2	38.1	0.7	4.8	32.2	0.7	5.3
90	216.4	0.5	1.3	151.9	0.5	1.7	113.3	0.5	2.2	86.4	0.6	2.7	70.8	0.6	3.2	58.1	0.6	3.7	48.1	0.7	4.2	40.3	0.7	4.8	34.1	0.7	5.3
95	228.4	0.5	1.3	160.3	0.5	1.7	119.6	0.5	2.2	91.2	0.6	2.7	74.8	0.6	3.2	61.3	0.6	3.7	50.8	0.7	4.2	42.6	0.7	4.8	36.0	0.7	5.3
100	240.4	0.5	1.3	168.8	0.5	1.7	125.9	0.5	2.2	96.0	0.6	2.7	78.7	0.6	3.2	64.5	0.6	3.7	53.5	0.7	4.2	44.8	0.7	4.8	37.9	0.7	5.3
105	252.4	0.5	1.3	177.2	0.5	1.7	132.2	0.5	2.2	100.8	0.6	2.7	82.6	0.6	3.2	67.8	0.6	3.7	56.2	0.7	4.2	47.1	0.7	4.8	39.8	0.7	5.3
110	264.4	0.5	1.3	185.7	0.5	1.7	138.5	0.5	2.2	105.6	0.6	2.7	86.6	0.6	3.2	71.0	0.6	3.7	58.8	0.7	4.2	49.3	0.7	4.8	41.7	0.7	5.3
115	276.5	0.5	1.3	194.1	0.5	1.7	144.8	0.5	2.2	110.4	0.6	2.7	90.5	0.6	3.2	74.2	0.6	3.7	61.5	0.7	4.2	51.5	0.7	4.8	43.6	0.7	5.3
120	288.5	0.5	1.3	202.5	0.5	1.7	151.1	0.5	2.2	115.2	0.6	2.7	94.4	0.6	3.2	77.4	0.6	3.7	64.2	0.7	4.2	53.8	0.7	4.8	45.5	0.7	5.3
125	300.5	0.5	1.3	211.0	0.5	1.7	157.4	0.5	2.2	120.0	0.6	2.7	98.4	0.6	3.2	80.7	0.6	3.7	66.9	0.7	4.2	56.0	0.7	4.8	47.4	0.7	5.3
130	312.5	0.5	1.3	219.4	0.5	1.7	163.7	0.5	2.2	124.8	0.6	2.7	102.3	0.6	3.2	83.9	0.6	3.7	69.5	0.7	4.2	58.3	0.7	4.8	49.3	0.7	5.3
135	324.5	0.5	1.3	227.9	0.5	1.7	170.0	0.5	2.2	129.6	0.6	2.7	106.2	0.6	3.2	87.1	0.6	3.7	72.2	0.7	4.2	60.5	0.7	4.8	51.2	0.7	5.3
140	336.6	0.5	1.3	236.3	0.5	1.7	176.3	0.5	2.2	134.4	0.6	2.7	110.2	0.6	3.2	90.3	0.6	3.7	74.9	0.7	4.2	62.7	0.7	4.8	53.1	0.7	5.3
145	348.6	0.5	1.3	244.7	0.5	1.7	182.6	0.5	2.2	139.2	0.6	2.7	114.1	0.6	3.2	93.6	0.6	3.7	77.6	0.7	4.2	65.0	0.7	4.8	55.0	0.7	5.3
150	360.6	0.5	1.3	253.2	0.5	1.7	188.9	0.5	2.2	144.0	0.6	2.7	118.0	0.6	3.2	96.8	0.6	3.7	80.2	0.7	4.2	67.2	0.7	4.8	56.9	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second

Depth "D" does not include allowance for freeboard or settlement

Table GS-4 Parabolic Grass Swale Design Sheet 14 of 14

V1 FOR RETARDANCE "D", TOP WIDTH (T), DEPTH (D), AND V2 FOR RETARDANCE "C"

Grade 10.00 Percent

Q CFS	V1=2.0			V1=2.5			V1=3.0			V1=3.5			V1=4.0			V1=4.5			V1=5.0			V1=5.5			V1=6.0		
	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2	T	D	V2
5	13.3	0.4	1.3	9.4	0.5	1.7	6.8	0.5	2.2	5.3	0.5	2.6	4.1	0.6	3.2	3.4	0.6	3.6	2.6	0.7	4.1						
10	26.6	0.4	1.3	18.7	0.5	1.7	13.8	0.5	2.2	10.9	0.5	2.6	8.5	0.6	3.2	7.1	0.6	3.6	5.9	0.6	4.1	4.9	0.7	4.7	4.0	0.7	5.3
15	39.9	0.4	1.3	28.0	0.5	1.7	20.7	0.5	2.2	16.3	0.5	2.6	12.8	0.6	3.2	10.9	0.6	3.6	9.0	0.6	4.1	7.5	0.6	4.7	6.3	0.7	5.2
20	53.2	0.4	1.3	37.4	0.5	1.7	27.6	0.5	2.2	21.7	0.5	2.7	17.0	0.6	3.2	14.5	0.6	3.6	12.1	0.6	4.1	10.2	0.6	4.6	8.5	0.7	5.2
25	66.5	0.4	1.3	46.7	0.5	1.7	34.5	0.5	2.2	27.1	0.5	2.7	21.3	0.6	3.2	18.1	0.6	3.6	15.1	0.6	4.1	12.7	0.6	4.7	10.8	0.7	5.2
30	79.8	0.4	1.3	56.1	0.5	1.7	41.4	0.5	2.2	32.5	0.5	2.7	25.5	0.6	3.2	21.7	0.6	3.6	18.1	0.6	4.1	15.2	0.6	4.7	12.9	0.7	5.2
35	93.1	0.4	1.3	65.4	0.5	1.7	48.3	0.5	2.2	37.9	0.5	2.7	29.8	0.6	3.2	25.3	0.6	3.6	21.1	0.6	4.1	17.8	0.6	4.7	15.1	0.7	5.2
40	106.4	0.4	1.3	74.7	0.5	1.7	55.2	0.5	2.2	43.3	0.5	2.7	34.0	0.6	3.2	29.0	0.6	3.6	24.1	0.6	4.1	20.3	0.6	4.7	17.2	0.7	5.2
45	119.7	0.4	1.3	84.1	0.5	1.7	62.1	0.5	2.2	48.8	0.5	2.7	38.3	0.6	3.2	32.6	0.6	3.6	27.2	0.6	4.1	22.8	0.6	4.7	19.4	0.7	5.2
50	133.0	0.4	1.3	93.4	0.5	1.7	69.0	0.5	2.2	54.2	0.5	2.7	42.5	0.6	3.2	36.2	0.6	3.6	30.2	0.6	4.1	25.4	0.6	4.7	21.5	0.7	5.2
55	146.3	0.4	1.3	102.8	0.5	1.7	75.9	0.5	2.2	59.6	0.5	2.7	46.8	0.6	3.2	39.8	0.6	3.6	33.2	0.6	4.1	27.9	0.6	4.7	23.7	0.7	5.2
60	159.6	0.4	1.3	112.1	0.5	1.7	82.8	0.5	2.2	65.0	0.5	2.7	51.0	0.6	3.2	43.4	0.6	3.6	36.2	0.6	4.1	30.5	0.6	4.7	25.9	0.7	5.2
65	172.9	0.4	1.3	121.4	0.5	1.7	89.7	0.5	2.2	70.4	0.5	2.7	55.3	0.6	3.2	47.1	0.6	3.6	39.2	0.6	4.1	33.0	0.6	4.7	28.0	0.7	5.2
70	186.2	0.4	1.3	130.8	0.5	1.7	96.6	0.5	2.2	75.8	0.5	2.7	59.5	0.6	3.2	50.7	0.6	3.6	42.2	0.6	4.1	35.5	0.6	4.7	30.2	0.7	5.2
75	199.5	0.4	1.3	140.1	0.5	1.7	103.5	0.5	2.2	81.2	0.5	2.7	63.8	0.6	3.2	54.3	0.6	3.6	45.2	0.6	4.1	38.1	0.6	4.7	32.3	0.7	5.2
80	212.8	0.4	1.3	149.5	0.5	1.7	110.5	0.5	2.2	86.7	0.5	2.7	68.0	0.6	3.2	57.9	0.6	3.6	48.3	0.6	4.1	40.6	0.6	4.7	34.5	0.7	5.2
85	226.1	0.4	1.3	158.8	0.5	1.7	117.4	0.5	2.2	92.1	0.5	2.7	72.3	0.6	3.2	61.5	0.6	3.6	51.3	0.6	4.1	43.1	0.6	4.7	36.6	0.7	5.2
90	239.4	0.4	1.3	168.1	0.5	1.7	124.3	0.5	2.2	97.5	0.5	2.7	76.5	0.6	3.2	65.2	0.6	3.6	54.3	0.6	4.1	45.7	0.6	4.7	38.8	0.7	5.2
95	252.7	0.4	1.3	177.5	0.5	1.7	131.2	0.5	2.2	102.9	0.5	2.7	80.8	0.6	3.2	68.8	0.6	3.6	57.3	0.6	4.1	48.2	0.6	4.7	40.9	0.7	5.2
100	266.0	0.4	1.3	186.8	0.5	1.7	138.1	0.5	2.2	108.3	0.5	2.7	85.0	0.6	3.2	72.4	0.6	3.6	60.3	0.6	4.1	50.7	0.6	4.7	43.1	0.7	5.2
105	279.3	0.4	1.3	196.2	0.5	1.7	145.0	0.5	2.2	113.7	0.5	2.7	89.3	0.6	3.2	76.0	0.6	3.6	63.3	0.6	4.1	53.3	0.6	4.7	45.2	0.7	5.2
110	292.6	0.4	1.3	205.5	0.5	1.7	151.9	0.5	2.2	119.2	0.5	2.7	93.5	0.6	3.2	79.6	0.6	3.6	66.4	0.6	4.1	55.8	0.6	4.7	47.4	0.7	5.2
115	305.9	0.4	1.3	214.9	0.5	1.7	158.8	0.5	2.2	124.6	0.5	2.7	97.8	0.6	3.2	83.3	0.6	3.6	69.4	0.6	4.1	58.3	0.6	4.7	49.5	0.7	5.3
120	319.2	0.4	1.3	224.2	0.5	1.7	165.7	0.5	2.2	130.0	0.5	2.7	102.0	0.6	3.2	86.9	0.6	3.6	72.4	0.6	4.1	60.9	0.6	4.7	51.7	0.7	5.3
125	332.5	0.4	1.3	233.5	0.5	1.7	172.6	0.5	2.2	135.4	0.5	2.7	106.3	0.6	3.2	90.5	0.6	3.6	75.4	0.6	4.1	63.4	0.6	4.7	53.8	0.7	5.3
130	345.8	0.4	1.3	242.9	0.5	1.7	179.5	0.5	2.2	140.8	0.5	2.7	110.5	0.6	3.2	94.1	0.6	3.6	78.4	0.6	4.1	66.0	0.6	4.7	56.0	0.7	5.3
135	359.1	0.4	1.3	252.2	0.5	1.7	186.4	0.5	2.2	146.2	0.5	2.7	114.8	0.6	3.2	97.7	0.6	3.6	81.4	0.6	4.1	68.5	0.6	4.7	58.1	0.7	5.3
140	372.4	0.4	1.3	261.6	0.5	1.7	193.3	0.5	2.2	151.7	0.5	2.7	119.0	0.6	3.2	101.3	0.6	3.6	84.4	0.6	4.1	71.0	0.6	4.7	60.3	0.7	5.3
145	385.7	0.4	1.3	270.9	0.5	1.7	200.2	0.5	2.2	157.1	0.5	2.7	123.3	0.6	3.2	105.0	0.6	3.6	87.5	0.6	4.1	73.6	0.6	4.7	62.5	0.7	5.3
150	399.0	0.4	1.3	280.2	0.5	1.7	207.1	0.5	2.2	162.5	0.5	2.7	127.5	0.6	3.2	108.6	0.6	3.6	90.5	0.6	4.1	76.1	0.6	4.7	64.6	0.7	5.3

RETARDANCE "D" AND "C"

NOTE: Width and Depth dimensions are in feet; Velocity measurements are in feet per second;
Depth "D" does not include allowance for freeboard or settlement.

Construction

Prior to start of construction, grass swale channels should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process to ensure that the channel has planned alignment, grade, and cross section.

Scheduling

Schedule construction during a period of relatively low rainfall and runoff events if practical. Consider also the establishment period (planting dates) for the planned species that will be used for long-term vegetative cover.

Site Preparation

Determine exact location of underground utilities. (See Appendix C: MS One-Call and 811 Color Coding.)

Install any structures required to stabilize the swale outlet or to provide drainage along the swale prior to beginning installation of the swale. Refer to design for structures to be installed.

Remove brush, trees, and other debris from the construction area and dispose of properly.

Constructing

Excavate and shape the channel to dimensions shown in the design specifications, removing and properly disposing of excess soil so surface water can enter the channel freely. The typical features of a grass swale are shown in Figure GS-2 and listed below, but may be different in the design for a specific site.

Cross Section: trapezoidal or parabolic.

Side Slopes: 3:1 (Horizontal: Vertical) or flatter for trapezoidal channels.

Outlet: Channel should empty into a stable outlet, sediment traps, or detention/retention basins.

Subsurface Drain: Use in areas with seasonally high water tables or seepage problems.

Topsoil: Provide topsoil as needed to grow grass on areas disturbed by construction.

Protect all concentrated inflow points along the channel with erosion-resistant linings, such as riprap, sod, mulch, erosion control blankets, turf-reinforcement mats or other appropriate practices as specified in the design plan.

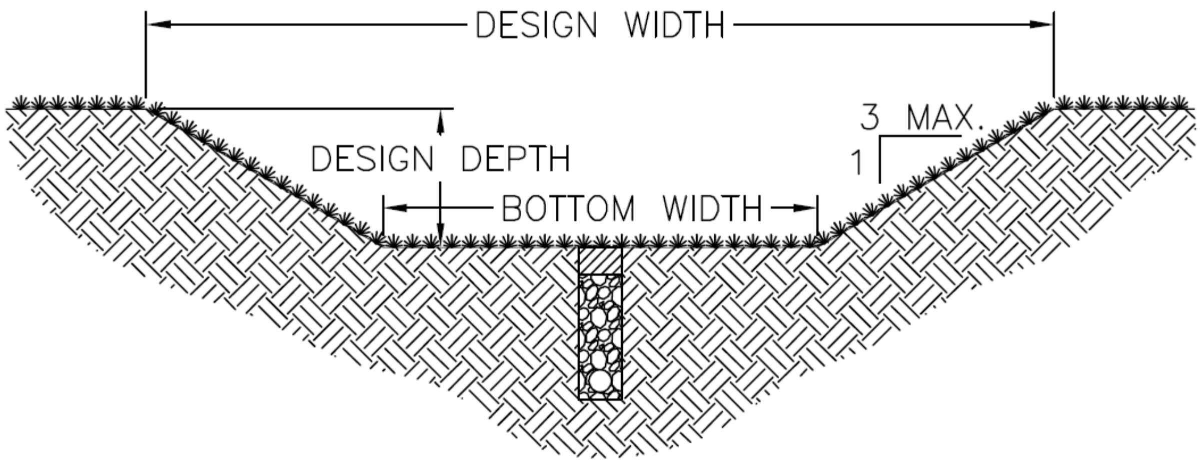


Figure GS-2 Typical Trapezoidal Grass-Lined Channel

Construction Verification

Check finished grade and cross section of channel throughout the length of the watercourse. Verify channel cross sections at several locations to avoid constrictions to flow.

Vegetating

Prepare seedbed; apply lime, fertilizer, and seed or sod in the swale immediately after grading; and protect with erosion control blankets, turf-reinforcement mats, or mulch according to the design plan. If not specified in a plan, select lime, fertilizer, grass variety and mulching components from related practices (*Permanent Seeding* or *Temporary Seeding*, *Erosion Control Blanket* or *Sodding*).

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate practice will not function as intended.

Changes in plan may be needed.

Design specifications for seed variety, seeding dates or erosion control materials cannot be met; substitution may be required.

Erosion occurs in channel before vegetation is fully established.

Erosion occurs at channel outlet before vegetation is fully established.

Sediment is deposited at channel outlet before vegetation is fully established.

Maintenance

Inspect the channel following storm events both during and after grass cover is established; make needed repairs immediately.

Check the channel outlet and road crossings for blockage, ponding, sediment, and bank instability, breaks and eroded areas; remove any blockage; and make repairs immediately to maintain design cross section and grade.

References

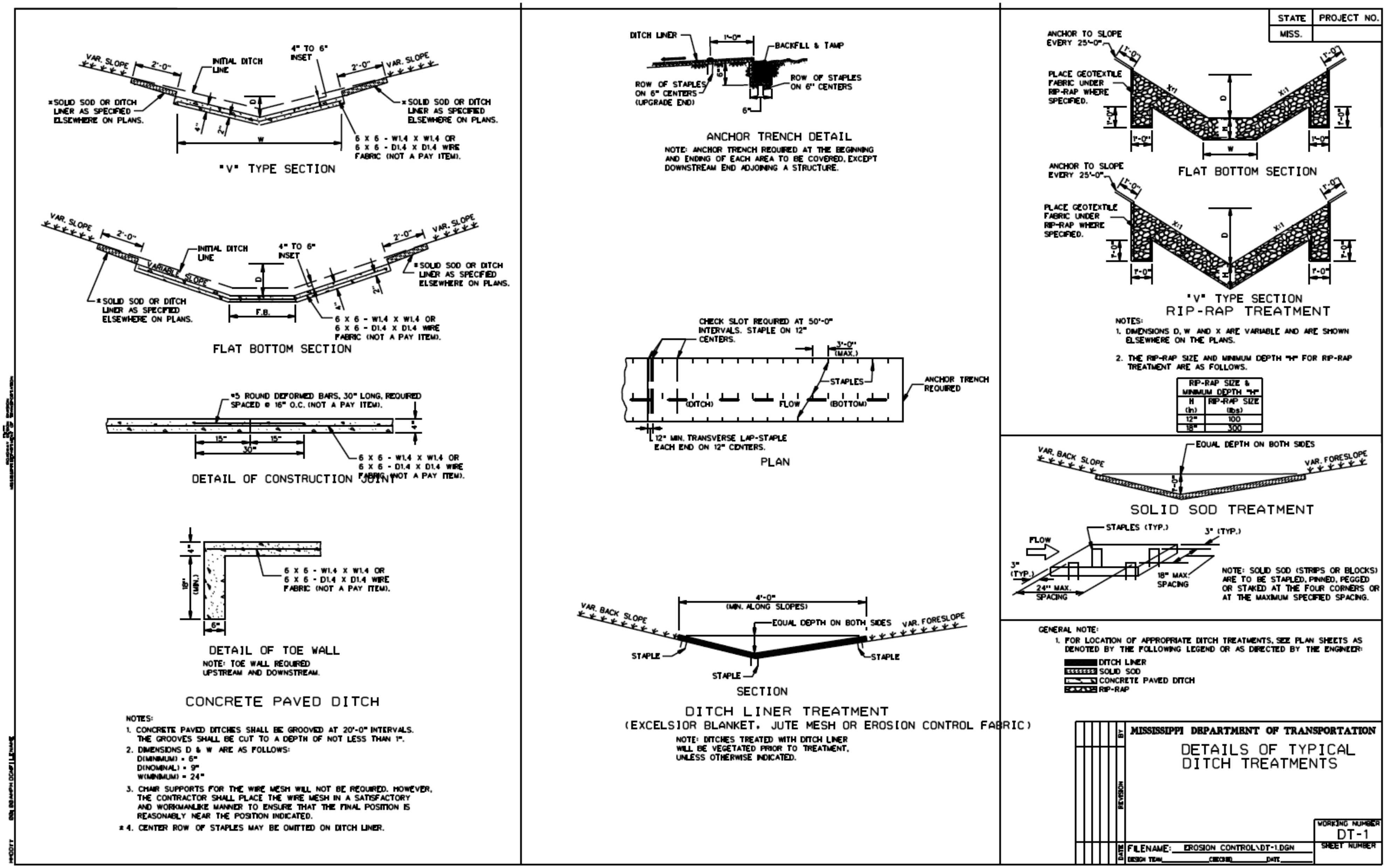
BMPs from Volume 1

Chapter 4

Erosion Control Blanket (ECB)	4-33
Permanent Seeding (PS)	4-53
Sodding (SOD)	4-93
Temporary Seeding (TS)	4-103
Lined Swale (LS)	4-190
Riprap-lined Swale (RS)	4-210

MDOT Drawing DT-1

Details of Typical Ditch Treatments	4-185



"V" TYPE SECTION
FLAT BOTTOM SECTION
DETAIL OF CONSTRUCTION JOINT
DETAIL OF TOE WALL
NOTE: TOE WALL REQUIRED UPSTREAM AND DOWNSTREAM.
CONCRETE PAVED DITCH
NOTES:
1. CONCRETE PAVED DITCHES SHALL BE GROOVED AT 20'-0" INTERVALS. THE GROOVES SHALL BE CUT TO A DEPTH OF NOT LESS THAN 1".
2. DIMENSIONS D & W ARE AS FOLLOWS: D(MINIMUM) = 6" D(NOMINAL) = 9" W(MINIMUM) = 24"
3. CHAIR SUPPORTS FOR THE WIRE MESH WILL NOT BE REQUIRED. HOWEVER, THE CONTRACTOR SHALL PLACE THE WIRE MESH IN A SATISFACTORY AND WORKMANLIKE MANNER TO ENSURE THAT THE FINAL POSITION IS REASONABLY NEAR THE POSITION INDICATED.
* 4. CENTER ROW OF STAPLES MAY BE OMITTED ON DITCH LINER.
ANCHOR TRENCH DETAIL
NOTE: ANCHOR TRENCH REQUIRED AT THE BEGINNING AND ENDING OF EACH AREA TO BE COVERED, EXCEPT DOWNSTREAM END ADJOINING A STRUCTURE.
PLAN
SECTION
DITCH LINER TREATMENT
(EXCELSIOR BLANKET, JUTE MESH OR EROSION CONTROL FABRIC)
NOTE: DITCHES TREATED WITH DITCH LINER WILL BE VEGETATED PRIOR TO TREATMENT, UNLESS OTHERWISE INDICATED.
STATE PROJECT NO.
MISS.
FLAT BOTTOM SECTION
"V" TYPE SECTION
RIP-RAP TREATMENT
NOTES:
1. DIMENSIONS D, W AND X ARE VARIABLE AND ARE SHOWN ELSEWHERE ON THE PLANS.
2. THE RIP-RAP SIZE AND MINIMUM DEPTH "H" FOR RIP-RAP TREATMENT ARE AS FOLLOWS.
RIP-RAP SIZE & MINIMUM DEPTH "H"
H (in) | RIP-RAP SIZE (lbs)
12" | 100
18" | 300
SOLID SOD TREATMENT
NOTE: SOLID SOD (STRIPS OR BLOCKS) ARE TO BE STAPLED, PINNED, PEGGED OR STAKED AT THE FOUR CORNERS OR AT THE MAXIMUM SPECIFIED SPACING.
GENERAL NOTE:
1. FOR LOCATION OF APPROPRIATE DITCH TREATMENTS, SEE PLAN SHEETS AS DENOTED BY THE FOLLOWING LEGEND OR AS DIRECTED BY THE ENGINEER:
DITCH LINER
SOLID SOD
CONCRETE PAVED DITCH
RIP-RAP
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF TYPICAL DITCH TREATMENTS
WORKING NUMBER DT-1
SHEET NUMBER
FILENAME: EROSION CONTROL\DT-1.DGN

Level Spreader (LVS)

Practice Description

A level spreader provides a non-erosive outlet for concentrated runoff (diversions) by dispersing flow uniformly across a stable slope. They are relatively low-cost structures designed to release small volumes of water safely.

Planning Considerations

Level spreaders are designed to be used where sediment-free storm runoff is intercepted and diverted away from graded areas onto undisturbed stabilized areas. This practice applies only in those situations where the spreader can be constructed on undisturbed soil and the area below the level crest is stabilized by natural or pre-established vegetation. The water should not be allowed to re-concentrate after release.

The drainage area for a level spreader should be limited to 5 acres, and the size of the spreader based on design runoff. When the level spreader is used as an outlet for temporary or permanent diversions, runoff containing high sediment loads must be treated in a sediment trapping device before release into a level spreader (see *Sediment Basin Practice*).

Design Criteria

Capacity

The capacity of the spreader crest shall be limited to those drainage areas producing no more than 40 cfs from a 10-year storm.

Length

By estimating the flow, the spreader crest length can be determined from the following table.

Design Flow (CFS)	Minimum Depression Depth (Feet)	Minimum Length (Feet)
0-10	0.5	10
10-20	0.6	20
20-30	0.7	30
30-40	0.8	40

Width

The minimum acceptable width of the depressional area along the level crest shall be 6 feet.

Grade

The grade of the channel for the last 20 feet of the dike or diversion entering the level spreader shall be less than or equal to 1%. The grade of the depression along the level spreader shall be 0%.

Outlet

The release of the stormwater will be over the level crest onto an undisturbed stabilized area. The level crest should be of uniform height and zero grade over the length of the spreader crest.

Setback

Level spreader setbacks should be a minimum of 10 feet from property lines and receiving water features. Sheet flow depth at property lines shall be consistent with pre-development flow.

Construction

Site Preparation

Level spreaders must be constructed on undisturbed soil (not fill material).

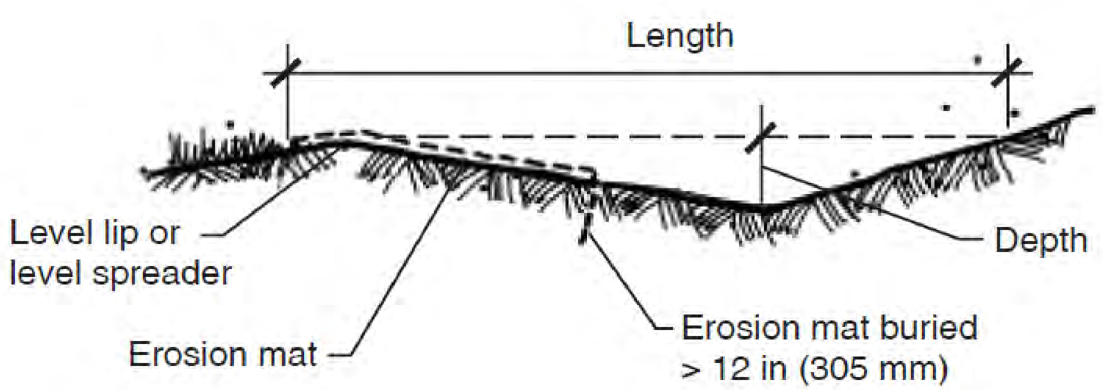


Figure LVS-1 Level Spreader, Sectional View (Source: NRCS)

Level Spreader Crest

The level spreader crest shall be constructed to a uniform height and zero grade over the length of the spreader. For flows of 4 cfs or greater, a rigid crest of non-erodible material shall be used. For flows less than 4 cfs, a vegetated crest may be used. An erosion control blanket should be used with a vegetative crest (see *Erosion Control Blanket Practice* for blanket requirements). The erosion control blanket should be a minimum of 4 feet wide and extend at least 1 foot downstream. Secure the blanket with heavy duty staples and bury the upstream and downstream edges in a trench at least 6 inches deep.

Erosion control blankets should be used for rigid crest level spreaders as well. The erosion control blanket should be entrenched a minimum of 4 inches below existing ground and securely anchored to prevent displacement. An apron of coarse aggregate should be placed along the rigid crest and extended downslope at least 3 feet.

Vegetation

The natural buffer-area vegetation is important to improve infiltration function, protect from rain and wind erosion and enhance aesthetic conditions. The level spreader itself does not need vegetation. The lower buffer area should be protected from disturbance during construction.

Filter Strip

Level spreaders used in conjunction with a filter strip should have a capacity designed based on the filter strip specifics (See *Filter Strip Practice*). The spreader shall run linearly along the entire width of the filter strip to which is discharges. The ends of the spreader should be tied into higher ground to prevent flow around the spreader.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate practice will not function as intended; changes in plan may be needed.

Design specifications cannot be met; substitution may be required. Unapproved substitutions could result in failure of the practice.

Maintenance

Annual inspection is required. Trees and shrubs that have established on the level spreader crest should be removed.

Inspection should occur annually for the presence of debris and sediment buildup on the level spreader.

Regulation inspection, especially after significant rain events (greater than 3-4 inches in 24-hours), should be done to address possible erosion and gully formation.

References

BMPs from Volume 1

Chapter 4

Lined Swale (LS)

LW

PAVED

Practice Description

A lined swale is a constructed channel with a permanent lining designed to carry concentrated runoff to a stable outlet. This practice applies to the following sites: 1) where grass swales are unsuitable because of conditions such as steep channel grades, prolonged flow areas, soils that are too erodible or not suitable to support vegetation or insufficient space and/or 2) where riprap-lined swales are not desired. The purpose of a lined swale is to conduct stormwater runoff without causing erosion problems in the area of channel flow.

The material that provides the permanent lining may be concrete, a specialized type of erosion control blanket, or manufactured concrete products.

Planning Considerations

A lined swale is used to convey concentrated runoff to a stable outlet in situations where a grass swale is inadequate. A lined swale can be lined with concrete, manufactured concrete products, or manufactured erosion-control products. Concrete-lined swales are the only type of lining covered in this practice. The practice *Erosion Control Blanket* should be referenced for criteria on permanent erosion control blankets. Product manufacturers and qualified design professional should be consulted for design requirements for manufactured concrete linings. Concrete-lined swales are generally used in areas where riprap-lined swales are not desired due to aesthetics, safety, or maintenance concerns. Concrete-lined swales allow easy maintenance of surrounding vegetation with normal lawn care equipment. The concrete generally provides a more visually pleasing structure than the riprap linings. Concrete-lined swales are especially desirable in areas accessed by small children.

In areas where stormwater infiltration is a concern, riprap and manufactured products should be considered rather than the concrete lining.

Design Criteria

Capacity

Lined swales should be capable of passing the peak flow expected from a 10-year 24-hour duration storm.

Adjustments should be made for release rates from structures and other drainage facilities. Swales shall also be designed to comply with local stormwater ordinances, and should be designed for greater capacity whenever there is danger of flooding or when out-of-bank flow cannot be tolerated.

Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, Engineering Field Manual for Conservation Practices, Chapter 2, Estimating Runoff.
- Natural Resources Conservation Service (formerly Soil Conservation Service), Technical Release 55, Urban Hydrology for Small Watersheds.
- Other comparable methods – See Appendix A: Erosion and Stormwater Runoff Calculations found in the Appendices Volume.

Slope

This practice applies only to paved flumes that are installed on slopes of 25% or less. Slopes steeper than this should be designed by a qualified design professional.

The slope in feet per 100 feet of length can be determined from a topographic map of the site or from a detailed survey of the planned lined swale location.

Cross Section

With peak flow (capacity) and slope known, the paved flume cross section can be determined by using Figures LS-l – LS-3.

Concrete

Flumes should be constructed of concrete with a minimum 28-day compressive strength of 3,000 psi. Flumes shall have a minimum concrete thickness of 4″.

Cutoff Walls

Cutoff walls shall be constructed at the beginning and end of every flume except where the flume connects with a catch basin or inlet.

Alignment

Keep paved flumes as straight as possible because they often carry supercritical flow velocities.

Inlet Section

The inlet section to the paved flume should be at least 6 feet long and have a bottom width equal to twice the bottom width of the flume itself. The bottom width should transition from twice the flume bottom width to the flume bottom width over the 6-foot length.

Outlet

Outlets of paved flumes shall be protected from erosion. The standard for *Outlet Protection* can be used to provide this protection. A method to dissipate the energy of low flows is to bury the last section of the flume in the ground. This will usually force the development of a “scour hole,” which will stabilize and serve as a plunge basin. For the design of large-capacity flumes, it may be necessary to design a larger energy dissipater at the outlet.

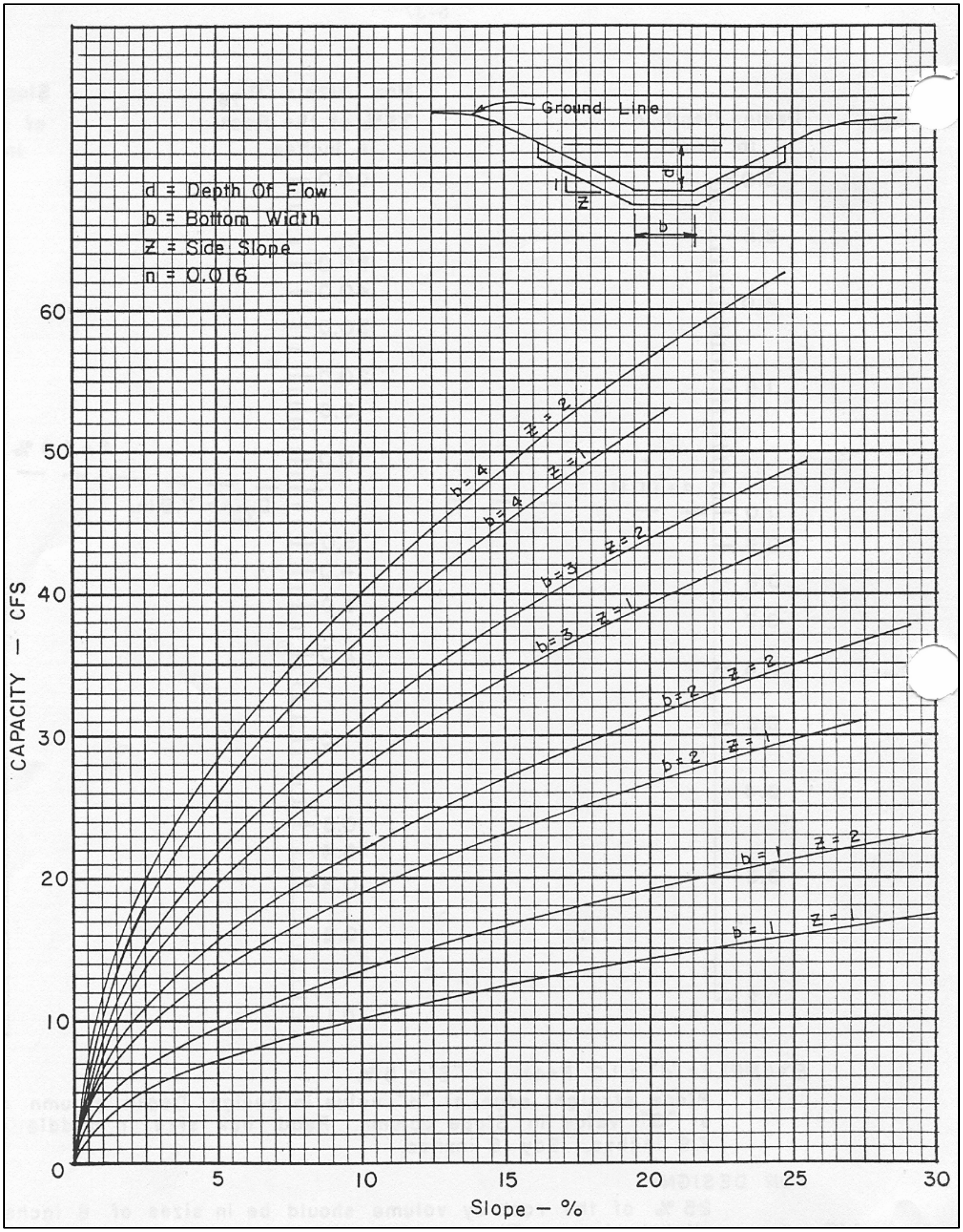


Figure LS-1 Capacity Graph for Concrete Flumes
Depth of Flow = 0.50 Foot

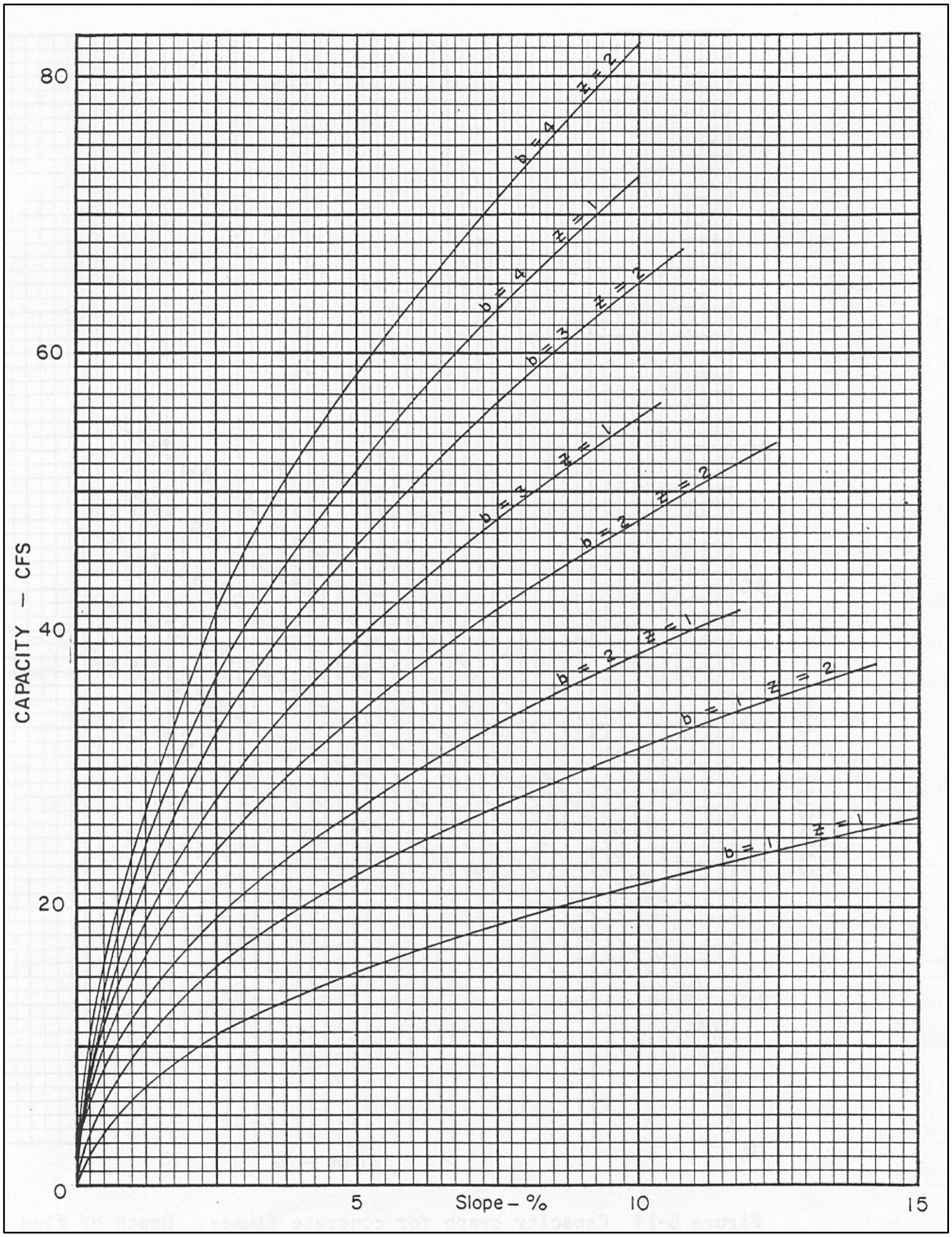


Figure LS-2 Capacity Graph for Concrete Flumes
Depth of Flow = 0.75 Foot

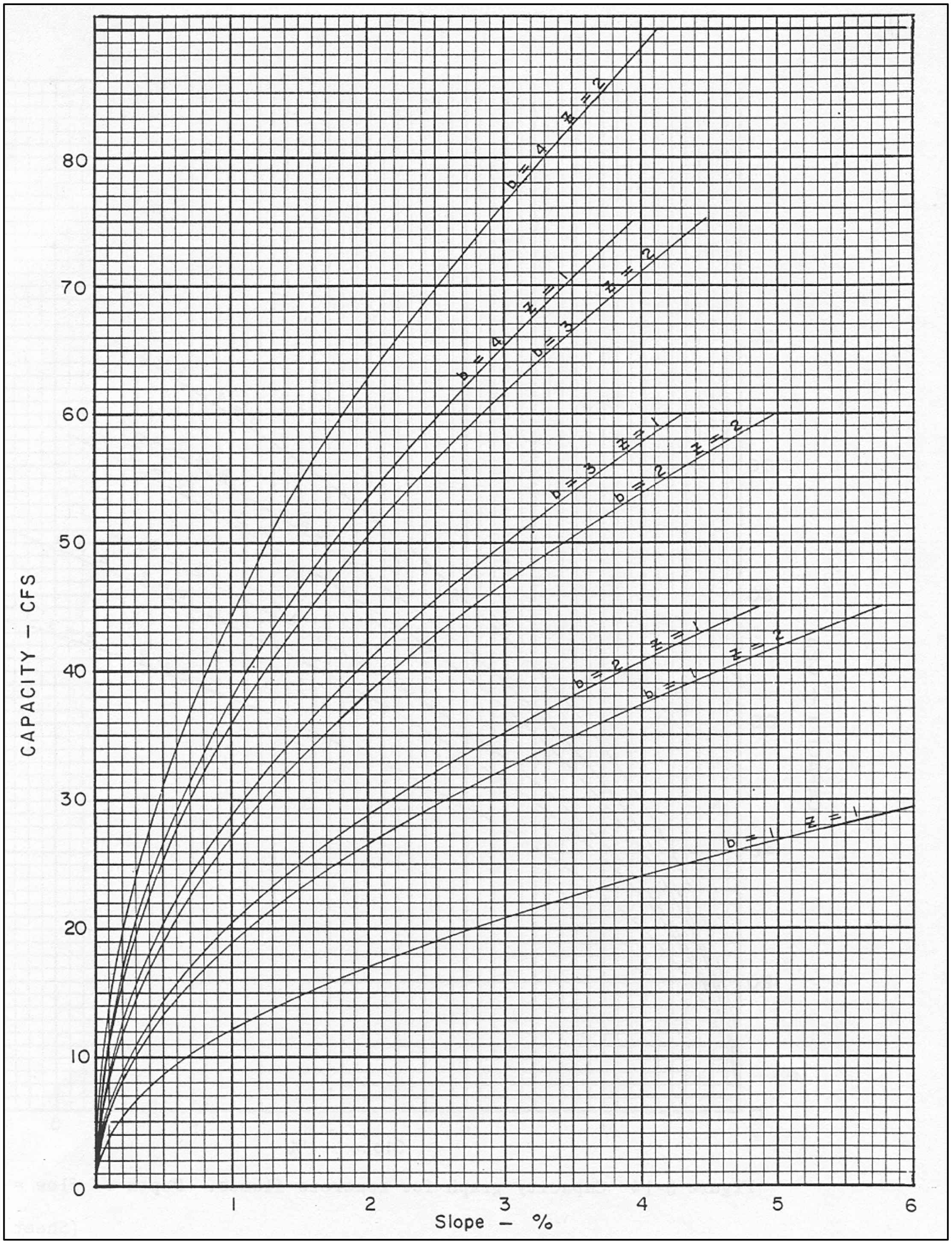


Figure LS-3 Capacity Graph for Concrete Flumes
Depth of Flow = 1.00 Foot

Construction

Prior to start of construction, lined swales should be designed by a qualified design professional, and specifications should be available to field personnel.

Plans and specifications should be referred to by field personnel throughout the construction process.

> *Note: Concrete-lined channel is the only lining method that is covered in this edition of the manual. Numerous permanent erosion control blankets and rock products are available with similar applications, and their unique installation procedures should be obtained from the manufacturer of the product being used. In addition, Riprap-Lined Swale is covered in this manual.*

Site Preparation

Determine exact location of underground utilities (See Appendix C: MS One-Call and 811 Color Coding).

Remove brush, trees, and other debris from the channel and spoil areas, and dispose of properly.

Grade or excavate cross section to the lines and grades shown in design for the concrete subgrade.

Remove soft sections and unsuitable material and replace with suitable material. The subgrade should be thoroughly compacted and shaped to a smooth, uniform surface.

Material Placement

Place forms to meet the specific plan design for the project, and place concrete of the designed mix into the forms according to construction specifications.

Construction and expansion joints should be used where swale length exceeds 10 feet. Construction joints should be spaced at 10-foot intervals and expansion points at intervals not to exceed 20 feet.

The subgrade should be moist at the time the concrete is placed.

Place concrete for the lined channel to the thickness shown on the plans and finish it in a workmanlike manner.

Coat the concrete with an approved curing compound as soon as finish work is complete and the free water has disappeared from the surface.

Provisions should be made to protect the freshly poured concrete from extreme temperatures to ensure proper curing.

Stabilization

Stabilize channel inlet and outlet points according to the design plan.

Stabilize adjacent disturbed areas after construction is completed with a vegetation treatment (see *Permanent Seeding* or *Temporary Seeding Practices*) and mulching. Provide topsoil, lime, and fertilizer as needed to grow grass on areas disturbed by construction. Many design plans specify a row of sod at the edges of the concrete channel.

If not specified in a plan, select lime, fertilizer, variety and mulching components from related practices – *Permanent Seeding* or *Temporary Seeding*, *Mulching, Erosion Control Blankets,* or *Sodding*.

Construction Verification

Check finished grades and cross sections throughout the length of the channel. Verify channel cross-section dimensions at several locations to avoid flow constrictions.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate practice will not function as intended; changes in plan may be needed.

Design specifications cannot be met; substitution may be required. Unapproved substitutions could result in failure of the practice.

Maintenance

Inspect lined channel at regular intervals and after storm events. Check for erosion adjacent to the channel, at inlets and outlets, and underneath the lined channel.

Give special attention to the channel inlet and outlet, and repair eroded areas promptly.

Inspect for erosion in the entire swale, and repair with appropriate vegetative treatment (permanent or temporary seeding and mulching).

References

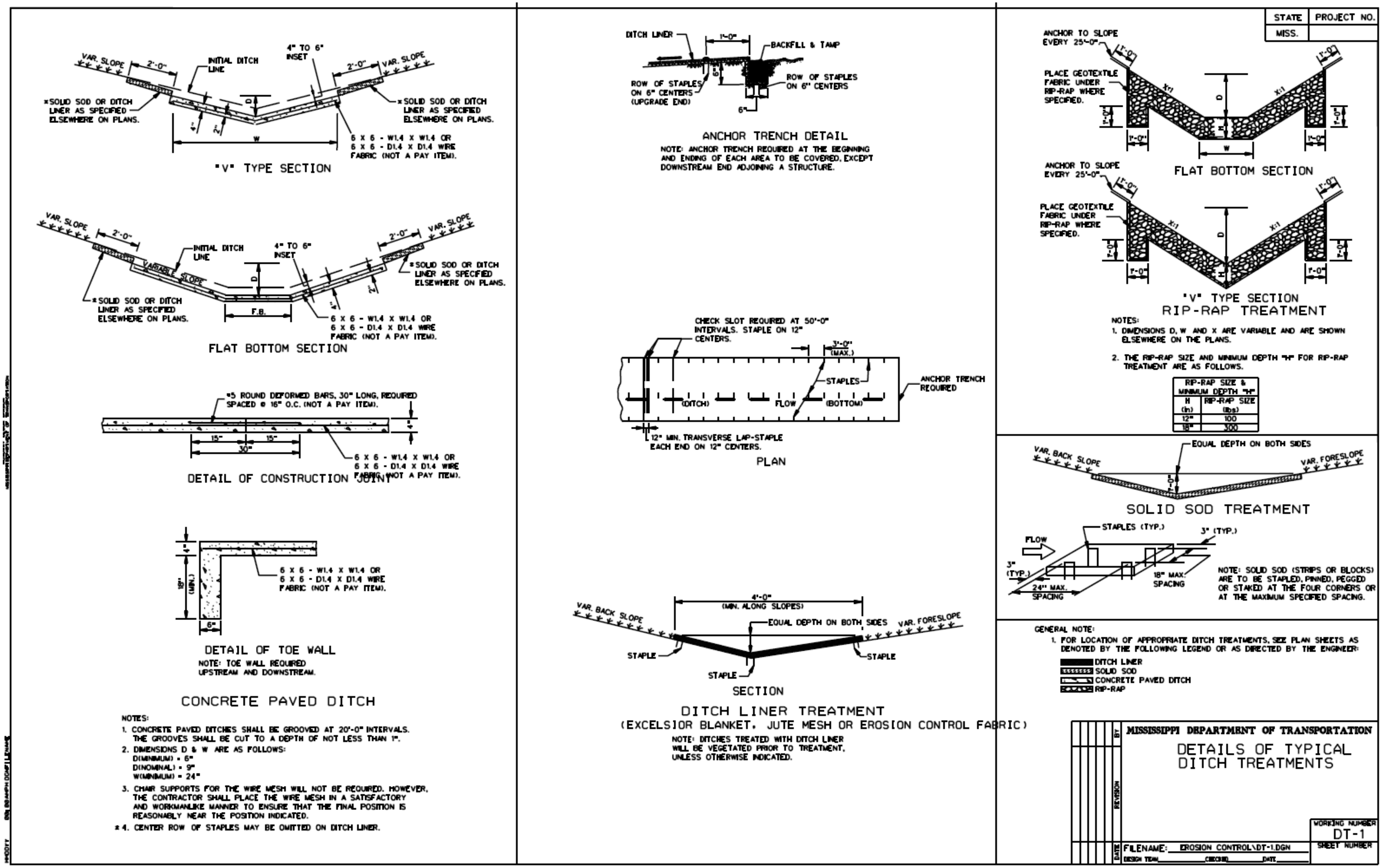
BMPs from Volume 1

Chapter 4

Erosion Control Blanket (ECB)	4-33
Permanent Seeding (PS)	4-53
Sodding (SOD)	4-93
Temporary Seeding (TS)	4-103
Outlet Protection (OP)	4-199

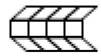
MDOT Drawing DT-1

Details of Typical Ditch Treatments	4-198


STATE
PROJECT NO.
MISS.
VAR. SLOPE
2'-0"
INITIAL DITCH LINE
4" TO 6" INSET
* SOLID SOD OR DITCH LINER AS SPECIFIED ELSEWHERE ON PLANS.
6 X 6 - W1.4 X W1.4 OR 6 X 6 - D1.4 X D1.4 WIRE FABRIC (NOT A PAY ITEM).
"V" TYPE SECTION
VARIABLE SLOPE
F.B.
FLAT BOTTOM SECTION
#5 ROUND DEFORMED BARS, 30" LONG, REQUIRED SPACED @ 16" O.C. (NOT A PAY ITEM).
15"
30"
DETAIL OF CONSTRUCTION JOINT
18" (MIN.)
6"
DETAIL OF TOE WALL
NOTE: TOE WALL REQUIRED UPSTREAM AND DOWNSTREAM.
CONCRETE PAVED DITCH
NOTES:
1. CONCRETE PAVED DITCHES SHALL BE GROOVED AT 20'-0" INTERVALS. THE GROOVES SHALL BE CUT TO A DEPTH OF NOT LESS THAN 1".
2. DIMENSIONS D & W ARE AS FOLLOWS:
D(MINIMUM) = 6"
D(NOMINAL) = 9"
W(MINIMUM) = 24"
3. CHAIR SUPPORTS FOR THE WIRE MESH WILL NOT BE REQUIRED. HOWEVER, THE CONTRACTOR SHALL PLACE THE WIRE MESH IN A SATISFACTORY AND WORKMANLIKE MANNER TO ENSURE THAT THE FINAL POSITION IS REASONABLY NEAR THE POSITION INDICATED.
* 4. CENTER ROW OF STAPLES MAY BE OMITTED ON DITCH LINER.
DITCH LINER
1'-0"
BACKFILL & TAMP
ROW OF STAPLES ON 6" CENTERS (UPGRADE END)
ROW OF STAPLES ON 6" CENTERS
ANCHOR TRENCH DETAIL
NOTE: ANCHOR TRENCH REQUIRED AT THE BEGINNING AND ENDING OF EACH AREA TO BE COVERED, EXCEPT DOWNSTREAM END ADJOINING A STRUCTURE.
CHECK SLOT REQUIRED AT 50'-0" INTERVALS. STAPLE ON 12" CENTERS.
3'-0" (MAX.)
STAPLES
(DITCH)
FLOW
(BOTTOM)
ANCHOR TRENCH REQUIRED
12" MIN. TRANSVERSE LAP-STAPLE EACH END ON 12" CENTERS.
PLAN
VAR. BACK SLOPE
4'-0" (MIN. ALONG SLOPES)
EQUAL DEPTH ON BOTH SIDES
VAR. FORESLOPE
STAPLE
SECTION
DITCH LINER TREATMENT
(EXCELSIOR BLANKET, JUTE MESH OR EROSION CONTROL FABRIC)
NOTE: DITCHES TREATED WITH DITCH LINER WILL BE VEGETATED PRIOR TO TREATMENT, UNLESS OTHERWISE INDICATED.
ANCHOR TO SLOPE EVERY 25'-0"
PLACE GEOTEXTILE FABRIC UNDER RIP-RAP WHERE SPECIFIED.
X:1
1'-0"
FLAT BOTTOM SECTION
"V" TYPE SECTION
RIP-RAP TREATMENT
NOTES:
1. DIMENSIONS D, W AND X ARE VARIABLE AND ARE SHOWN ELSEWHERE ON THE PLANS.
2. THE RIP-RAP SIZE AND MINIMUM DEPTH "H" FOR RIP-RAP TREATMENT ARE AS FOLLOWS.
RIP-RAP SIZE & MINIMUM DEPTH "H"
H (in) | RIP-RAP SIZE (lbs)
12" | 100
18" | 300
VAR. BACK SLOPE
EQUAL DEPTH ON BOTH SIDES
VAR. FORESLOPE
SOLID SOD TREATMENT
STAPLES (TYP.)
3" (TYP.)
FLOW
24" MAX. SPACING
18" MAX. SPACING
NOTE: SOLID SOD (STRIPS OR BLOCKS) ARE TO BE STAPLED, PINNED, PEGGED OR STAKED AT THE FOUR CORNERS OR AT THE MAXIMUM SPECIFIED SPACING.
GENERAL NOTE:
1. FOR LOCATION OF APPROPRIATE DITCH TREATMENTS, SEE PLAN SHEETS AS DENOTED BY THE FOLLOWING LEGEND OR AS DIRECTED BY THE ENGINEER:
DITCH LINER
SOLID SOD
CONCRETE PAVED DITCH
RIP-RAP
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF TYPICAL DITCH TREATMENTS
WORKING NUMBER
DT-1
SHEET NUMBER
FILENAME: EROSION CONTROL\DT-1.DGN
DESIGN TEAM
CHECKED
DATE
REVISION
BY
DATE

Outlet Protection (OP)

 ROCK OUTLET PROTECTION

 PAVED FLUME (OP-4)

Practice Description

This practice is designed to prevent erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy. Outlet protection measures usually consist of a riprap-lined apron, a reinforced concrete flume with concrete baffles, a reinforced concrete box with chambers or baffles, and possibly pre-manufactured products. This practice applies wherever high-velocity discharge must be released on erodible material.

Planning Considerations

The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater that is transported through man-made conveyance systems at design capacity generally reaches a velocity that exceeds the ability of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is required, which will absorb the initial impact of the flow and reduce the flow velocity to a level that will not erode the receiving channel or area of discharge.

The most commonly used structure for outlet protection is an erosion-resistant lined apron. These aprons are generally lined with loose rock riprap, grouted riprap, or concrete. They are constructed at zero grade for a distance that is related to the outlet flow rate and the tailwater level. Criteria for designing these structures are contained in this practice. Several outlet conditions are shown in Figure OP-1. Example design problems for outlet protection are found at the end of this practice.

Where the flow is excessive for the economical use of an apron, excavated stilling basins may be used. Acceptable designs for stilling basins may be found in the following documents available from the U.S. Government Printing Office.

1) Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulics Engineering Circular No.14, U.S. Department of Transportation, Federal Highway Administration.

2) Hydraulic Design of Stilling Basins and Energy Dissipaters, Engineering Monograph No. 25, U.S. Department of Interior-Bureau of Reclamation.

Design Criteria and Construction

Structurally lined aprons at the outlets of pipes and paved channel sections should be designed according to the following criteria:

Pipe Outlets

Capacity

The structurally lined apron should have the capacity to carry the peak stormflow from the 25-year 24-hour frequency storm, or the storm specified in state laws or local ordinances, or the design discharge of the water conveyance structure, whichever is greatest.

Tailwater

The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. Manning's Equation may be found in Appendix A: Erosion and Stormwater Runoff Calculations (available in the Appendices Volume). If the tailwater depth is less than half the diameter of the outlet pipe, it shall be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than half the pipe diameter, it shall be classified as a Maximum Tailwater Condition. Pipes that outlet to flat areas, with no defined channel, may be assumed to have a Minimum Tailwater Condition.

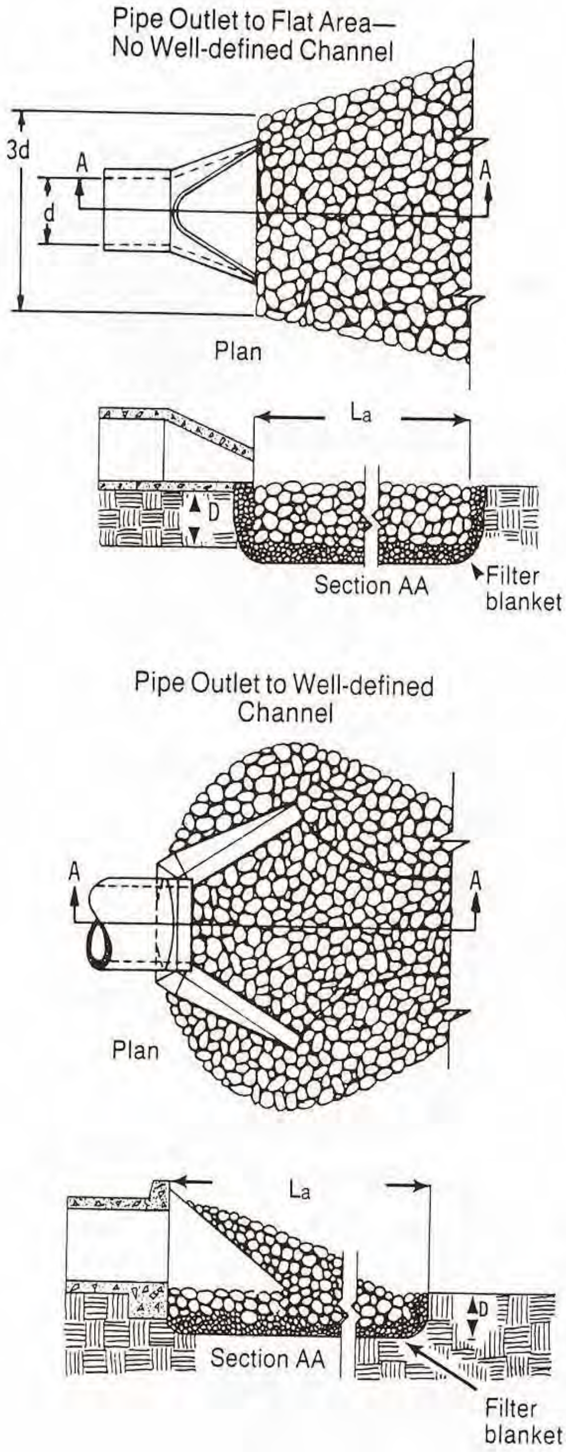
Apron Length

The apron length should be determined from Figure OP-2 or OP-3 according to the tailwater condition.

Apron Thickness

The apron thickness should be determined by the maximum stone size (d_{max}), when the apron is lined with riprap. The maximum stone size shall be 1.5 × d_{50} (median stone size), as determined from Figure OP-2 or OP-3. The apron thickness shall be 1.5 × d_{max}.

When the apron is lined with concrete, the minimum thickness of the concrete shall be 4″.



Notes

1. L_a is the length of the riprap apron.
2. D = 1.5 times the maximum stone diameter but not less than 6".
3. In a well-defined channel extend the apron up the channel banks to an elevation of 6" above the maximum tailwater depth or to the top of the bank, whichever is less.
4. A filter blanket or filter fabric should be installed between the riprap and soil foundation.

Figure OP-1 Pipe Outlet Conditions

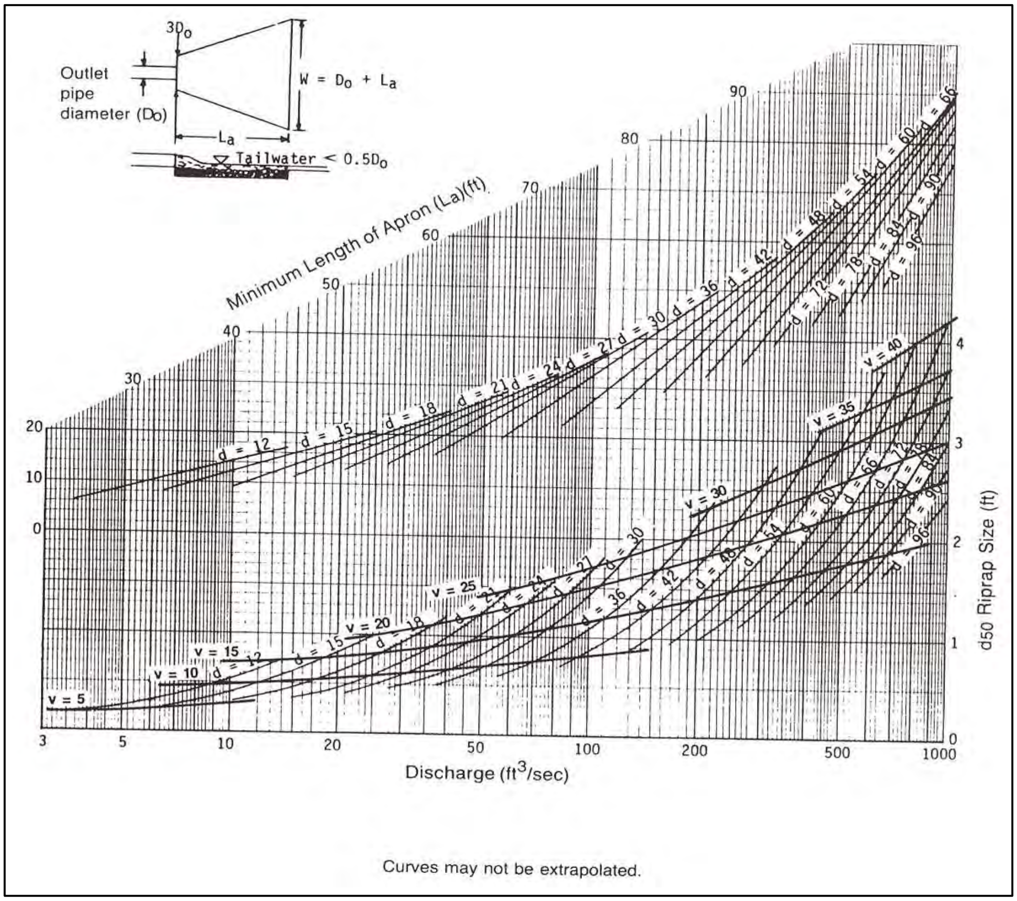


Figure OP-2 Outlet Protection Design for Tailwater <0.5 Diameter

Apron Width

If the pipe discharges directly into a well-defined channel, the apron should extend across the channel bottom and up the channel banks to an elevation 1 foot above the maximum tailwater depth or to the top of the bank, whichever is the least.

If the pipe discharges onto a flat area with no defined channel, the width of the apron should be determined as follows:

- The upstream end of the apron, adjacent to the pipe, should have a width 3 times the diameter of the outlet pipe.
- For a Minimum Tailwater Condition, the downstream end of the apron should have a width equal to the pipe diameter plus the length of the apron obtained from the figures.
- For a Maximum Tailwater Condition, the downstream end shall have a width equal to the pipe diameter plus 0.4 times the length of the apron from Figure OP-2 or OP-3.

Bottom Grade

The apron should be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron shall be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

Side Slope

If the pipe discharges into a well-defined channel, the side slopes of the channel should not be steeper than 2:1 (Horizontal: Vertical).

Alignment

The apron should be located so that there are no bends in the horizontal alignment.

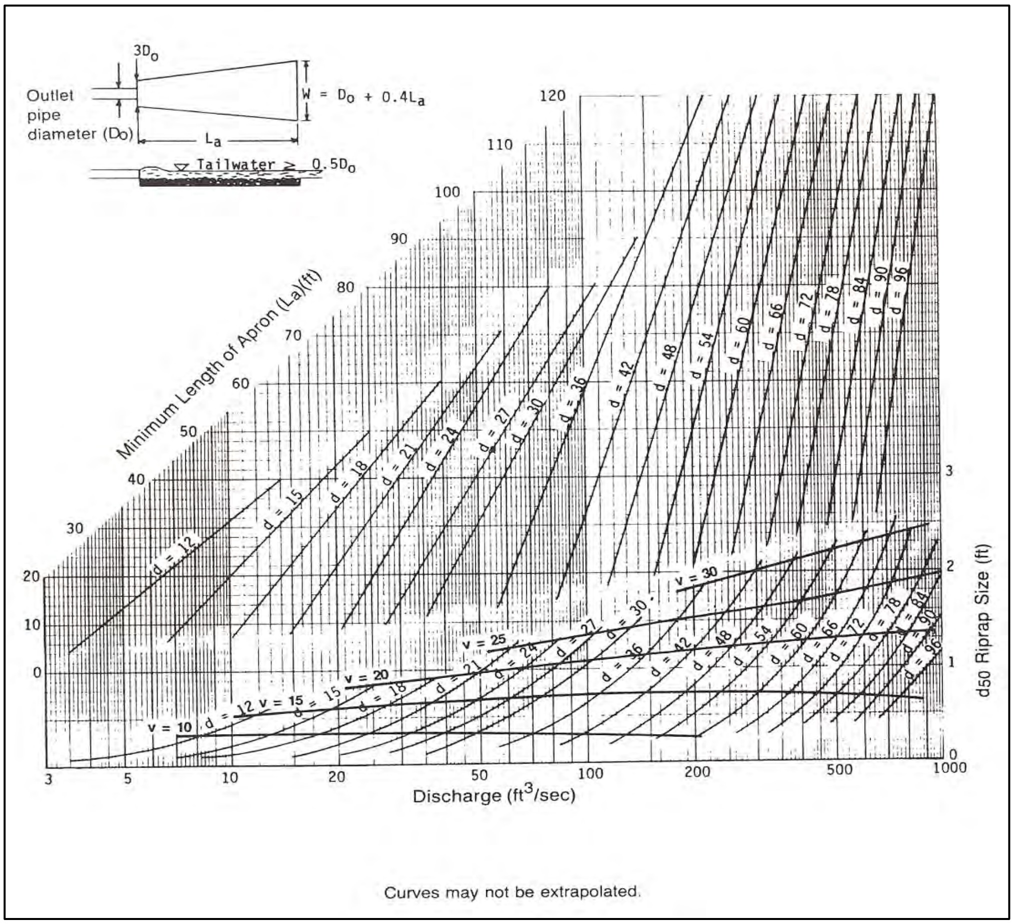


Figure OP-3 Outlet Protection Design for Tailwater ≥0.5 Diameter

Geotextile

When riprap is used to line the apron, geotextile should be used as a separator between the graded stone, the soil subgrade, and the abutments. Geotextile should be placed immediately adjacent to the subgrade without any voids between the fabric and the subgrade. The geotextile will prevent the migration of soil particles from the subgrade into the graded stone. The geotextile shall meet the requirements shown in the table below for Class I geotextile:

Table OP-1 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb)[2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%)[2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. no.40[3]	As specified max. no.40[3]	As specified max. no.40[3]	As specified max. no.40[3]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextiles are required for all other classes.
2 Minimum average roll value (weakest principal direction).
3 U.S. standard sieve size.

Materials

The apron may be lined with loose rock-riprap, grouted riprap, or concrete. The median-sized stone for riprap should be determined from the curves on Figures OP-2 and OP-3 according to the tailwater condition.

After the median stone size is determined, the gradation of rock to be used should be specified using Tables OP-2 and OP-3. Table OP-2 is used to determine the weight of the median stone size (d_{50}). Using this median weight, a gradation can be selected from Table OP-3, which shows commercially available riprap gradations.

Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering; it shall be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

When the apron is lined with concrete, the concrete should have a minimum compressive strength at 28 days of 3000 pounds per square inch. American Concrete Institute guidelines should be used to design concrete structures and reinforcement. As a minimum, the concrete should be reinforced with steel-welded wire fabric.

Construction

Prior to start of construction, the practice should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The structure should conform to the dimensions, grades and alignments shown on the plans and specifications.

Site Preparation

Completely remove stumps, roots, and other debris from the construction area. Fill depressions caused by clearing and grubbing operations with clean, non-organic soil. Grade the site to the lines and grades shown on the plans. Compact any fill required in the subgrade to the density of the surrounding undisturbed material.

If possible, the alignment should be straight throughout its length. If a curve is required, it should be located in the upstream section of the outlet.

Riprap Structures

Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.

Geotextile fabric must meet design requirements and be properly protected from puncturing or tearing during installation. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet with the upstream edge over the downstream edge. If the damage is extensive, replace the entire geotextile fabric.

Riprap may be placed by equipment; however, care should be taken to avoid damaging the filter.

Construct the apron on zero grade with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.

Concrete Structures

Reinforcing steel-welded wire fabric should be placed in strict accordance with the design plans and maintained in the proper position during the pouring of concrete. Concrete should be placed in horizontal layers not exceeding 24″ in thickness, or as specified in the design, and consolidated by mechanical vibrating equipment supplemented by hand-spading, rodding, or tamping.

Concrete should be placed in sturdy wood or metal forms, adequately supported to prevent deformation. Forms should be oiled prior to placement to prevent bonding between concrete and forms.

If possible, concrete should not be placed during inclement weather or periods of temperature extremes. If temperature extremes cannot be avoided, American Concrete Institute guidelines for placement of concrete during such extremes should be consulted.

Concrete should be allowed to cure as required by the plans and specifications.

Typically, the surface should be kept wet during curing by covering it with wet burlap sacks or other means. Design strengths should be confirmed by laboratory tests on representative cylinders made during concrete placement. Form work should not be removed prior to the specified time.

Table OP-2 Size of Riprap Stones

Weight	Mean Spherical Diameter (feet)	**Rectangular Shape** Length	Width, Height (feet)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	5.4	1.8
4000	3.6	6.0	2.0
6000	4.0	6.9	2.3
8000	4.5	7.6	2.5
20000	6.1	10.0	3.3

Table OP-3 Graded Riprap

Class	**Weight (lbs.)**					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

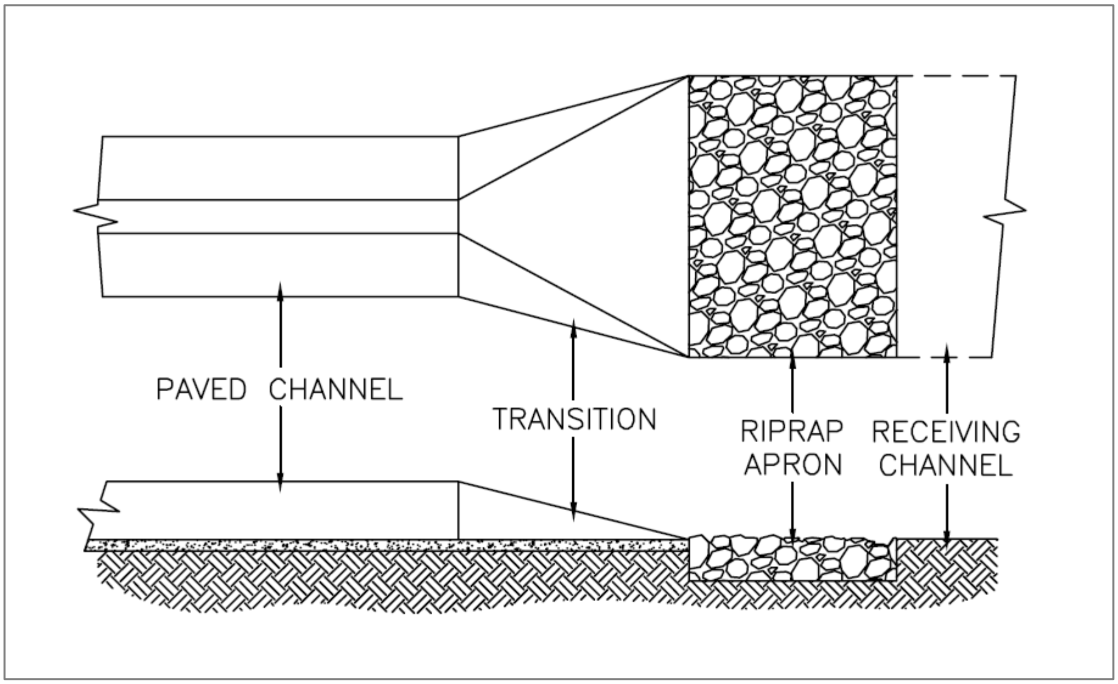


Figure OP-4   Paved Channel Outlet

1) The flow velocity at the outlet of paved channels flowing at design capacity should not exceed the velocity, which will cause erosion and instability in the receiving channel.

2) The end of the paved channel should merge smoothly with the receiving channel section. There should be no overfall at the end of the paved section. Where the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section should be provided. The maximum side divergence of the transition shall be 1 in 3F where

   F = v/gd, and
   F = Froude no.
   v = Velocity at beginning of transition (ft/sec.)
   d = Depth of flow at beginning of transition (feet.)
   g = 32.2 ft/sec.^{2}

3) Bends or curves in the horizontal alignment of the transition are not allowed unless the Froude no. (F) is 0.8 or less, or the section is specifically designed for turbulent flow.

Example Design Problems

Example 1

Given: An 18″ pipe discharges 24 cu. ft/sec at design capacity onto a grassy slope (no defined channel).

Find: The required length, width and median stone size (d_{50}) for a riprap-lined apron.

Solution

Since the pipe discharges onto a grassy slope with no defined channel, a Minimum Tailwater Condition may be assumed.

From Figure OP-2, an apron length (L_a) of 20 feet and a median stone size (d_{50}) of 0.8 foot is determined.

The upstream apron width equals 3 times the pipe diameter: 3 × 1.5 feet = 4.5 feet.

The downstream apron width equals the apron length plus the pipe diameter:
20 feet + 1.5 foot = 21.5 feet.

Example 2

Given: The pipe in example No. 1 discharges into a channel with a triangular cross section, 2 feet deep and 2:1 side slopes. The channel has a 2% slope and an “n” coefficient of 0.045.

Find: The required length, width and the median stone size (d_{50}) for a riprap lining.

Solution

Determine the tailwater depth using Manning’s Equation and the Continuity Equation.

$$Q = 1.49/n \ R^{2/3} S^{1/2} A$$

$$24 = 1.49/n \ [2d/4.47]^{2/3} (0.02)^{1/2} (2d^2)$$

where, d = depth of tailwater
d = 1.74 feet *

*Since d is greater than half the pipe diameter, a Maximum Tailwater Condition exists.

From Figure OP-3, a median stone size (d_{50}) of 0.5 foot and an apron length (L_a) of 41 feet is determined.

The entire channel cross section should be lined, since the maximum tailwater depth is within 1 foot of the top of the channel.

Construction Verification

Check finished structures for conformance with design specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate measure will not function as intended.

Design specifications for riprap, filter fabric, concrete, reinforcing steel, or backfill cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Problems with the structure develop during or after installation.

Maintenance

Inspect riprap outlet structures after heavy rains to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Check concrete structures for cracks and movement. Immediately make all needed repairs to prevent further damage.

References

BMPs from Volume 1

Chapter 4

Grass Swale (GS) 4-162

Riprap-lined Swale (RS)

Practice Description

A riprap-lined swale is a natural or constructed channel with an erosion-resistant rock lining designed to carry concentrated runoff to a stable outlet. This practice applies where grass swales are unsuitable because of conditions such as steep channel grades, prolonged flow areas, or soils that are too erodible or not suitable to support vegetation or insufficient space.

Planning Considerations

Swales should be carefully built to the design cross section, shape, and dimensions. Swales are hydraulic structures and as such depend upon the hydraulic parameters to serve satisfactorily. Swales may be used to

- Serve as outlets for diversions and sediment control basins and stormwater detention basins.
- Convey water collected by road ditches or discharged through culverts.
- Rehabilitate natural draws and gullies carrying concentrations of runoff.

The design of a swale cross section and lining is based primarily upon the volume and velocity of flow expected in the swale. Riprap-lined swales should be used where velocities are in the range of 5 to 10 ft/sec.

Besides the primary design considerations of capacity and velocity, a number of other important factors should be taken into account when selecting a cross section. These factors include land availability, compatibility with land use and surrounding environment, safety, maintenance requirements, and outlet conditions, etc.

Riprap-lined swales are trapezoidal in shape. Trapezoidal swales are often used where the quantity of water to be carried is large and conditions require that it be carried at a relatively high velocity.

Outlet conditions for all swales should be considered. This is particularly important for the transition from the riprap lining to a vegetative lining. Appropriate measures must be taken to dissipate the energy of the flow to prevent scour of the receiving swale.

Design Criteria

Capacity

Lined swales shall be designed to convey the peak rate of runoff from a 10-year 24-hour rainfall event. Adjustments should be made for release rates from structures and other drainage facilities. Swales should also be designed to comply with local stormwater ordinances.

Swales should be designed for greater capacity whenever there is danger of flooding or when out-of-bank flow cannot be tolerated. The maximum capacity of the swale flowing at design depth should be 200 cubic ft/sec.

Peak rates of runoff values used to determine the capacity requirements should be calculated using accepted engineering methods. Some accepted methods are:

- Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.
- Natural Resources Conservation Service (formerly Soil Conservation Service), Technical Release 55, Urban Hydrology for Small Watersheds.
- Other comparable methods – See *Appendix A: Erosion and Stormwater Runoff Calculations* found in the Appendices Volume.

Cross section

The swale cross section should be trapezoidal in shape. The steepest permissible side slope of the swale should be 2:1 (Horizontal: Vertical). A bottom width should be selected based on area available for installation of the swale and available rock sizes. The bottom width will be used in determining stable rock size and flow depth.

Depth

Design flow depth should be determined by the following formula:

$z = [n(q)/1.486(S)^{0.50}]^{3/5}$
S = Bed slope, (ft/ft)
z = Flow depth, (ft)
q = Unit discharge, ($ft^3/s/ft$) (Total discharge ÷ Bottom width)
n = Manning's coefficient of roughness (see formula under velocities)

The design water surface elevation of a swale receiving water from other tributary sources should be equal to or less than the design water surface elevation of the contributing source. The design water surface elevation of contributing and receiving waters should be the same, whenever practical. A minimum depth may be necessary to provide adequate outlets for subsurface drains and tributary swales.

Freeboard

The minimum freeboard is 0.25 foot. Freeboard is not required on swales with less than 1% slope and where out-of-bank flow will not be damaging and can be tolerated from an operational point of view.

Stable Rock Size

Stable rock sizes, for rock-lined swales having gradients between 2 percent and 40 percent should be determined using the following formulas from *Design of Rock Chutes* by Robinson, Rice, and Kadavy.

For swale slopes between 2% and 10%: $d_{50} = [q\,(S)^{1.5}/4.75(10)^{-3}]^{1/1.89}$

For swale slopes between 10% and 40%: $d_{50} = [q\,(S)^{0.58}/3.93(10)^{-2}]^{1/1.89}$

d_{50} = Particle size for which 50 % of the sample is finer, inch
S = Bed slope, ft/ft
q = Unit discharge, $ft^3/s/ft$
(Total discharge ÷ Bottom width)

After the stable median stone size is determined, the gradation of rock to be used should be specified using Tables RS-1 and RS-2. Table RS-1 is used to determine the weight of the median stone size (d_{50}). Using this median weight, a gradation can be selected from Table RS-2, which shows commercially available riprap gradations.

Table RS-1 Size of Riprap Stones

Weight (lbs)	**Mean Spherical Diameter (feet)**	**Rectangular Shape**	
		Length	Width, Height (feet)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	5.4	1.8
4000	3.6	6.0	2.0
6000	4.0	6.9	2.3
8000	4.5	7.6	2.5
20000	6.1	10.0	3.3

Table RS-2 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Velocities

Velocities should be computed by using Manning's Formula with a coefficient of roughness, "n," as follows: $n = 0.047(d_{50} \cdot S)^{0.147}$

Applies on slopes between 2 and 40% with a rock mantle thickness of $2 \times d_{50}$ where:
d_{50} = median rock diameter (inch), S = lined section slope (ft/ft) ($0.02 \leq S \leq 0.4$)

Velocities exceeding critical velocity should be restricted to straight reaches.

Waterways or outlets with velocities exceeding critical velocity should discharge into an outlet protection structure to reduce discharge velocity to less than critical (see *Outlet Protection Practice*).

Lining Thickness

The minimum lining thickness should be equal to the maximum stone size of the specified riprap gradation plus the thickness of any required filter or bedding.

Lining Durability

Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering, and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

Geotextiles

Geotextiles should be used where appropriate as a separator between rock and soil to prevent migration of soil particles from the subgrade, through the lining material. Geotextiles should be Class I material as selected from Table RS-3.

Filters or Bedding

Filters or bedding should be used where needed to prevent piping. Filters should be designed according to the requirements contained in the *Subsurface Drain Practice*. The minimum thickness of a filter or bedding should be 6″.

Table RS-3 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb) [2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [2]	ASTM D 4632	≥50	≥50	≥50	≥50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. no. 40 [3]	As specified max. no. 40 [3]	As specified max. no. 40 [3]	As specified max. no. 40 [3]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextile are required for all other classes.
2 Minimum average roll value (weakest principal direction).
3 U.S. standard sieve size.

Construction

Prior to start of construction, riprap-lined swales should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Site Preparation

Determine exact location of underground utilities (See Appendix C: MS One-Call and 811 Color Coding.)

Remove brush, trees, and other debris from the channel and spoil areas, and dispose of properly.

Grade or excavate cross section to the lines and grades shown in design. Over-excavate to allow for thickness of riprap and filter material. Foundation excavation not deep enough or wide enough may cause riprap to restrict channel flow and result in overflow and erosion. Side slopes are usually 2:1 (Horizontal: Vertical) or flatter.

Foundation Stabilization

Install geotextile fabric or aggregate in the excavated channel as a foundation for the riprap. Anchor fabric in accordance with design specifications. If the fabric is omitted or damaged during stone placement, there may be settlement failure and bank instability.

Installation

As soon as the foundation is prepared, place the riprap to the thickness, depth, and elevations shown in the design specifications. It should be a dense, uniform, and well-graded mass with few voids. Riprap should consist of a well-graded mixture of stone (size and gradation as shown in design specifications) that is hard, angular, and highly chemical, and weather resistant. Larger stone should predominate, with sufficient smaller sizes to fill the voids between the stones. The diameter of the largest stone size should be not greater than 1.5 times the d_{50} size. Minimum thickness of riprap liner should be 1.5 times the maximum stone diameter.

Blend the finished rock surface with the surrounding land surface so there are no overfalls, channel constrictions, or obstructions to flow.

Outlet Stabilization

Stabilize channel inlet and outlet points. Extend riprap as needed.

Stabilize adjacent disturbed areas after construction is completed.

Construction Verification

Check finished grades and cross sections throughout the length of the channel.

Verify channel cross section dimensions at several locations to avoid flow constrictions.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate channel will not function as intended; changes in plan may be needed.

Design specifications for riprap sizing, geotextile fabric or aggregate filter cannot be met; substitution may be required. Unapproved substitutions could result in channel erosion.

Maintenance

Inspect channels at regular intervals and after storm events. Check for rock stability, sediment accumulation, piping, and scour holes throughout the length of the channel.

Look for erosion at inlets and outlets.

When stones have been displaced, remove any debris and replace the stones in such a way as to not restrict the flow of water.

Give special attention to outlets and points where concentrated flow enters the channel and repair eroded areas promptly by extending the riprap as needed.

References

BMPs from Volume 1

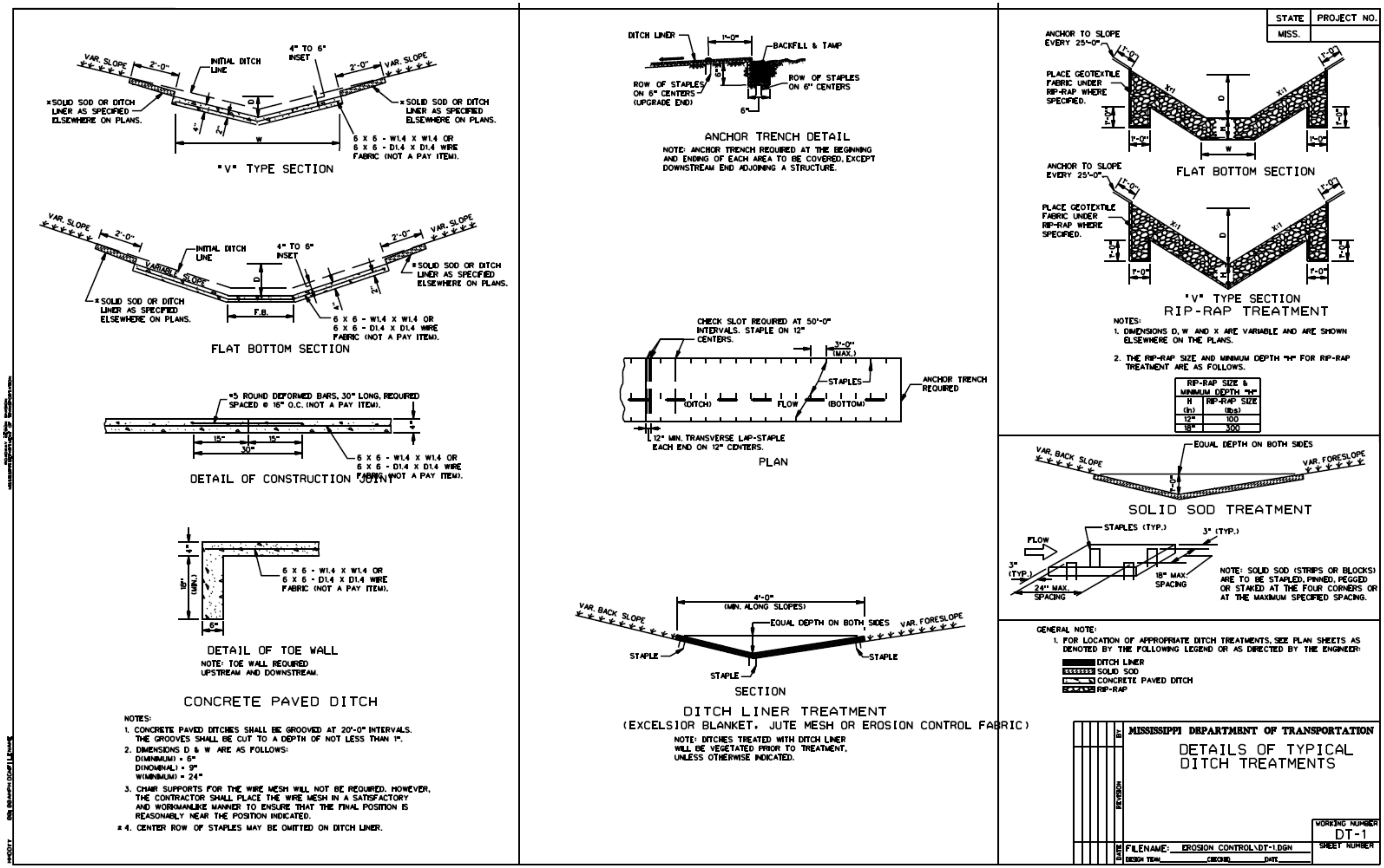
Additional Resources

Natural Resources Conservation Service, National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 2, Estimating Runoff.

Natural Resources Conservation Service (formerly Soil Conservation Service), Technical Release 55, Urban Hydrology for Small Watersheds.

Robinson, K.M., Rice, C.E., and Kadavy, K.C., 1998. Design of Rock Chutes. Am. Soc. Agric. Eng. Trans. 41, 621–626.

MDOT Drawing DT-1



STATE | PROJECT NO.
MISS.
"V" TYPE SECTION
VAR. SLOPE
2'-0"
INITIAL DITCH LINE
4" TO 6" INSET
*SOLID SOD OR DITCH LINER AS SPECIFIED ELSEWHERE ON PLANS.
6 X 6 - W1.4 X W1.4 OR 6 X 6 - D1.4 X D1.4 WIRE FABRIC (NOT A PAY ITEM).
FLAT BOTTOM SECTION
VARIABLE SLOPE
F.B.
#5 ROUND DEFORMED BARS, 30" LONG, REQUIRED SPACED @ 16" O.C. (NOT A PAY ITEM).
DETAIL OF CONSTRUCTION JOINT
DETAIL OF TOE WALL
NOTE: TOE WALL REQUIRED UPSTREAM AND DOWNSTREAM.
CONCRETE PAVED DITCH
NOTES:
1. CONCRETE PAVED DITCHES SHALL BE GROOVED AT 20'-0" INTERVALS. THE GROOVES SHALL BE CUT TO A DEPTH OF NOT LESS THAN 1".
2. DIMENSIONS D & W ARE AS FOLLOWS:
D(MINIMUM) = 6"
D(NOMINAL) = 9"
W(MINIMUM) = 24"
3. CHAIR SUPPORTS FOR THE WIRE MESH WILL NOT BE REQUIRED. HOWEVER, THE CONTRACTOR SHALL PLACE THE WIRE MESH IN A SATISFACTORY AND WORKMANLIKE MANNER TO ENSURE THAT THE FINAL POSITION IS REASONABLY NEAR THE POSITION INDICATED.
* 4. CENTER ROW OF STAPLES MAY BE OMITTED ON DITCH LINER.
DITCH LINER
BACKFILL & TAMP
ROW OF STAPLES ON 6" CENTERS (UPGRADE END)
ROW OF STAPLES ON 6" CENTERS
ANCHOR TRENCH DETAIL
NOTE: ANCHOR TRENCH REQUIRED AT THE BEGINNING AND ENDING OF EACH AREA TO BE COVERED, EXCEPT DOWNSTREAM END ADJOINING A STRUCTURE.
CHECK SLOT REQUIRED AT 50'-0" INTERVALS. STAPLE ON 12" CENTERS.
3'-0" (MAX.)
STAPLES
(DITCH) FLOW (BOTTOM)
ANCHOR TRENCH REQUIRED
12" MIN. TRANSVERSE LAP-STAPLE EACH END ON 12" CENTERS.
PLAN
4'-0" (MIN. ALONG SLOPES)
VAR. BACK SLOPE
EQUAL DEPTH ON BOTH SIDES
VAR. FORESLOPE
STAPLE
SECTION
DITCH LINER TREATMENT
(EXCELSIOR BLANKET, JUTE MESH OR EROSION CONTROL FABRIC)
NOTE: DITCHES TREATED WITH DITCH LINER WILL BE VEGETATED PRIOR TO TREATMENT, UNLESS OTHERWISE INDICATED.
ANCHOR TO SLOPE EVERY 25'-0"
PLACE GEOTEXTILE FABRIC UNDER RIP-RAP WHERE SPECIFIED.
FLAT BOTTOM SECTION
"V" TYPE SECTION
RIP-RAP TREATMENT
NOTES:
1. DIMENSIONS D, W AND X ARE VARIABLE AND ARE SHOWN ELSEWHERE ON THE PLANS.
2. THE RIP-RAP SIZE AND MINIMUM DEPTH "H" FOR RIP-RAP TREATMENT ARE AS FOLLOWS.
RIP-RAP SIZE & MINIMUM DEPTH "H"
H (in) | RIP-RAP SIZE (lbs)
12" | 100
18" | 300
SOLID SOD TREATMENT
STAPLES (TYP.)
3" (TYP.)
FLOW
24" MAX. SPACING
18" MAX. SPACING
NOTE: SOLID SOD (STRIPS OR BLOCKS) ARE TO BE STAPLED, PINNED, PEGGED OR STAKED AT THE FOUR CORNERS OR AT THE MAXIMUM SPECIFIED SPACING.
GENERAL NOTE:
1. FOR LOCATION OF APPROPRIATE DITCH TREATMENTS, SEE PLAN SHEETS AS DENOTED BY THE FOLLOWING LEGEND OR AS DIRECTED BY THE ENGINEER:
DITCH LINER
SOLID SOD
CONCRETE PAVED DITCH
RIP-RAP
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF TYPICAL DITCH TREATMENTS
WORKING NUMBER
DT-1
SHEET NUMBER
FILENAME: EROSION CONTROL\DT-1.DGN

Subsurface Drain (SD)

Practice Description

A subsurface drain is a perforated pipe or continuous layer of porous material installed below the ground surface that intercepts, collects, and carries excessive groundwater to a stable outlet. Subsurface drains by themselves do not provide erosion control. The purpose of a subsurface drain is to improve soil moisture conditions, vegetation growth, and ground stability. Subsurface drains may reduce wet ground from interfering with construction activities. Drains may be constructed using a gravel-filled trench, perforated pipe in gravel bedding, or manufactured drain panel products. This practice applies where groundwater is at or near the ground surface or where adequate drainage cannot be provided for surface runoff.

Planning Considerations

To properly design and install this practice, a detailed site investigation will be required. This investigation should include a site survey to determine the location of the area to be drained, the depth of the area to be drained, the topography of the area to be drained, the outlet of the drain system, and the soils at the site.

When considering use of this practice, the qualified design professional should consider the intended use of the area to be drained. Base flow and interflow of groundwater may increase with installation of this practice due to excess soil water being removed. Groundwater recharge may also be reduced by this practice. Finally, surface runoff may increase due to this practice reducing deep percolation at the site.

All federal, state, and local laws and regulations should be adhered to when planning and installing this practice.

Design Criteria

Layout and Depth

In the absence of site-specific information, a depth of 3 feet and a spacing of 50 feet for drains should be adequate. However, it is recommended that site-specific information be obtained. Typical details of subsurface drain construction can be seen in Figures SD-1 and SD-2. The following guidelines should be followed.

The depth at which the drain is installed will determine how much the water table is lowered. The minimum depth for the drain is 2 feet under normal conditions. The maximum depth is limited by the depth of the impermeable layer and, if a pipe is used in the drain, by the allowable load on the pipe used.

Spacing

The permeability of the soil at the site and the depth of the drain will determine the spacing of the drain.

Multiple Drains

In some cases more than one drain will be needed to achieve the desired results. The first drain should be installed, and additional drains should be added only if seepage or high water table problems continue.

Location

Drains should be located a minimum of 50 feet from any trees to prevent damage to the trees.

Grade

In areas where sedimentation is not likely, the minimum grades should be based on site conditions and a velocity of not less than 0.5 ft/sec. Where a potential for sedimentation exists, a velocity of not less than 1.4 ft/sec should be used to establish the minimum grades if site conditions permit. Otherwise, provisions should be made for prevention of sedimentation by filters or collection and for periodic removal of sediment from installed traps. Steep grades should be avoided.

Gravel Bedding

Typically, 3″ or more of gravel is placed completely around the drain and graded to prevent the infiltration of fine-grained soils into the drain.

Filters and Filter Material

Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The need for a filter will be determined by the characteristics of the surrounding soil material (i.e. permeability), site conditions, and the velocity of flow in the conduit.

A suitable filter should be specified if

- Local experience indicates a need.

- Soil materials surrounding the conduit are dispersed clay, low-plasticity silts, or fine sands (ML or SM with plasticity index less than 7).

- Where deep soil cracking is expected.

- Where the method of installation may result in voids between the conduit and backfill material.

The filter can be geotextile filter fabric, sand, gravel, or sand-gravel combination. If a geotextile is used, it should meet the requirements of the material table found in the *Outlet Protection Practice*. Care should be taken when using geotextile filter fabric since small soil particles can clog the fabric. If a sand-gravel filter is specified, the filter gradation will be based on the gradation of the base material surrounding the conduit within the following limits:

- D_{15} size smaller than 7 times d_{95} size, but not smaller than 0.6 mm.

- D_{15} size larger than 4 times d_{15} size.

- Less than 5% passing No. 200 sieve.

- Maximum size smaller than 1.5″.

D represents the filter material, and d represents the surrounding base material. The number following each letter is the percent of the sample, by weight, that is finer than that size. For example, D_{15} size means that 15 percent of the filter material is finer than that size.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3″ of filter material, except that the top of the conduit and side filter material may be covered by a sheet of plastic or similar impervious material to reduce the quantity of filter material required.

Clean-outs

In long sections of drain and in areas where sedimentation is concerned, clean-outs should be installed in the drain to facilitate removal of sediment deposits.

Outlet and Protection

The outlet must be protected against erosion and undermining of the conduit, entry of tree roots, damaging periods of submergence, and entry of rodents or other animals into the subsurface drain. A continuous section of rigid pipe without open joints or perforations will be used at the outlet end of the line and must discharge above the normal elevation of low flow in the outlet ditch. Corrugated plastic tubing is not suitable for the outlet section.

Materials

Pipe should be perforated, continuous closed-joint pipes of corrugated plastic, concrete, corrugated metal, or bituminous fiber. The pipe should have sufficient strength to withstand the load to be placed on it under the planned installation design.

Manufacturer's recommendations should be followed in designing the pipe to withstand design loads.

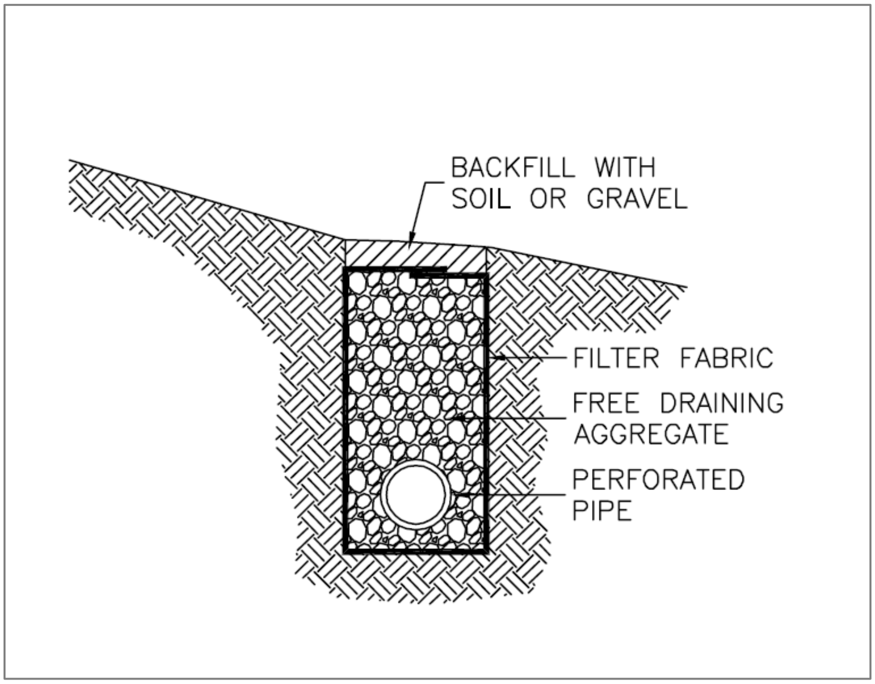


Figure SD-1 Details of Typical Subsurface Drain Construction

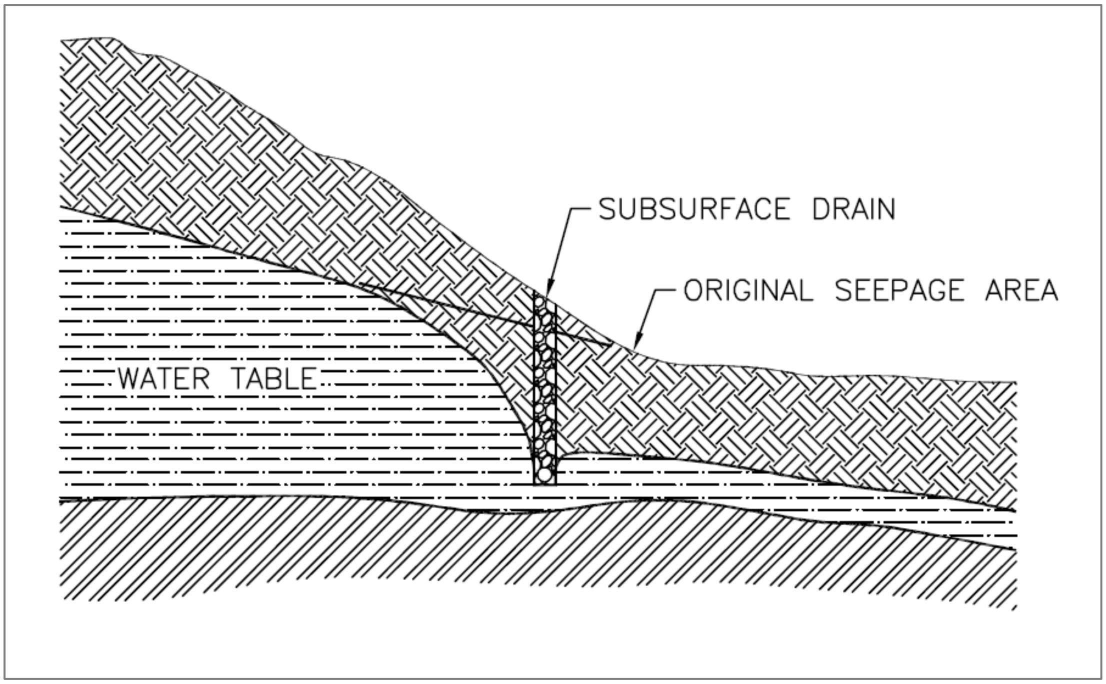


Figure SD-2 Details of Subsurface Drain Construction

Construction

Prior to start of construction, subsurface drains should be designed by a qualified design professional. Materials such as sand, gravel, geotextile filter cloth, and pipe must be properly designed in order for the subsurface drain system to function properly. Plans and specifications should be available to field personnel.

Site Preparation

Determine exact location of underground utilities. At least 3 days prior to construction, request Mississippi One-Call System (1-800-227-6477) to mark all underground utilities within the project area. See Appendix C for more information about utility marking.

Locate and mark the alignment of the drains as shown on the design plans.

Clear installation area of debris and obstacles, such as trees and stumps, that might hinder grading and installation of the subsurface drain.

Trench Excavation

Excavate the trench to the specified depth and grade shown in the design plan. To accommodate the gravel bedding or filter material, excavate the trench to at least 3″ below the design bottom elevation of the pipe (or as shown on the design plans).

Place materials excavated from the trench on the up-gradient side of the trench to prevent water from entering the trench during construction.

Grade the trench to prevent siltation into the drain.

Installation of Drain Pipe, Bedding Material and Geotextile Filter Cloth

Line trench with filter cloth (if specified), providing enough material to overlap over the top of the finished gravel bedding. This helps prevent movement of soil into the gravel.

Spread bedding material specified in the design plan, usually 3″ of gravel, to fill the over-excavated bottom of the trench.

Lay pipe on the design grade and elevation, avoiding reverse grade or low spots, after checking to ensure the pipe meets specifications.

Cap the upper end of each drain with a standard cap made for this purpose or with concrete or other suitable material to prevent soil from entering the open end.

Place bedding material around pipe, on all sides, with the amount shown in the design plan.

Fold filter cloth over the top of the gravel bedding.

Backfill Installation

Backfill immediately after placement of the pipe and bedding. Ensure that the material does not contain rocks or other sharp objects, and place it in the trench in a manner that will not damage or displace the pipe. Overfill the trench slightly to allow for settlement.

Installation of Clean-Out Device

Install clean-outs for maintenance of the subsurface drain in the locations shown on design plan.

Outlet Installation

Construct the outlet of the subsurface drain at the elevation in the design plan. The outlet section of the drain should be at least 10 feet of non-perforated corrugated metal, cast iron, steel, or heavy-duty plastic pipe. Cover at least half of the pipe length with well-compacted soil. Place a suitable animal guard securely over the pipe outlet to keep out rodents.

Stabilization

Keep the settled fill over the pipe outlet slightly higher than the surrounding ground to prevent erosion, rills and gullies.

Stabilize all bare areas of the trench with temporary seeding and mulching unless construction will disturb the area within 13 days.

Safety

Narrow trenches are subject to collapse and can be a safety hazard to persons in the trench. No person should enter a trench without shoring protection or properly sloping the sides of the trench.

Construction Verification

Verify the dimensions during construction with those shown on the plans for location, length, depth, and cross section of trench.

Verify the dimensions and specifications of the aggregate used in the bedding and manufactured materials such as pipe, tile or panel drain.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate subsurface drains will not function as intended or originally designed.

Design specifications for aggregate or manufactured products cannot be met; substitutions may be required. Unapproved substitutions could result in failure of the drain to function as intended.

Pipe is crushed by construction traffic.

Maintenance

Check subsurface drains periodically to ensure that they are free-flowing and not clogged with sediment.

Keep outlet clean and free of debris.

Keep surface inlets open and free of sediment and other debris.

Where drains are crossed by heavy vehicles, check the pipe to ensure that it is not crushed.

References

BMPs from Volume 1

Chapter 4

Outlet Protection (OP)	4-199

Temporary Slope Drain (TSD)

SD

Practice Description

A temporary slope drain is a pipe or other conduit designed to convey concentrated runoff down the face of a cut- or fill-slope without causing erosion. This practice applies wherever concentrated stormwater runoff must be conveyed down a steep slope.

Planning Considerations

There is often a significant lag between the time a cut- or fill-slope is completed and the time a permanent runoff-conveyance system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. This situation also occurs on slope construction that is temporarily delayed before final grade is reached. Temporary slope drains, sometimes called “downdrains,” can provide valuable protection of exposed slopes until permanent runoff-conveyance structures can be installed. See Figure TSD-1 for typical details of a temporary slope drain.

When used in conjunction with diversions, temporary slope drains can be used to convey stormwater from the entire drainage area above a slope to the base of the slope without erosion. It is very important that these temporary structures be installed properly since their failure will often result in severe gully erosion. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be securely staked. Prior approval may be required from local regulatory agencies if the downdrain outlet is tied into an existing storm sewer or in areas where municipal stormwater is regulated.

Design Criteria

Drainage Area

The maximum allowable drainage area per drain is 5 acres.

Flexible Conduit

The downdrain should consist of heavy-duty flexible material designed for this purpose. The diameter of the downdrain should be equal over its entire length. Reinforced hold-down grommets should be spaced at 10-foot (or less) intervals, with the outlet end securely fastened in place. The conduit should extend beyond the toe of the slope.

Downdrains may be sized according to the table TSD-1.

Drains should be designed to convey the peak rate of runoff from a 10-year 24-hour rainfall whenever it is desired to individually design each installation.

Table TSD-1 Flexible Conduit Diameters

Maximum Drainage Area (Acres)	Pipe Diameter (D) (Inches)
0.5	12
1.5	18
2.5	21
3.5	24
5.0	30

Entrance Sections

The entrance to the downdrain (Figures TSD-2 and TSD-3) should consist of a standard flared end-section for metal pipe culverts. All fittings should be watertight.

The toe plate should be a minimum of 8″ deep.

Extension collars should consist of 12″ long corrugated metal pipe. Avoid use of helical pipe. Securing straps should be fabric, metal, or other material well suited to providing a watertight connection. The strap should secure at least one corrugation of the extension collar.

Diversion Design

An earthen diversion should be used to direct stormwater runoff into the slope drain and should be constructed according to the *Diversion Practice*.

The height of the diversion at the centerline of the inlet should be equal to at least the diameter of the pipe (D) plus 12″. Where the dike height is greater than 18″ at the inlet, it should be level for 3 feet each side of the pipe and be sloped at the rate of 3:1 (Horizontal: Vertical) or flatter to transition with the remainder of the dike.

Outlet Protection

The outlet of the downdrain should be protected from erosion as detailed in the *Outlet Protection Practice*.

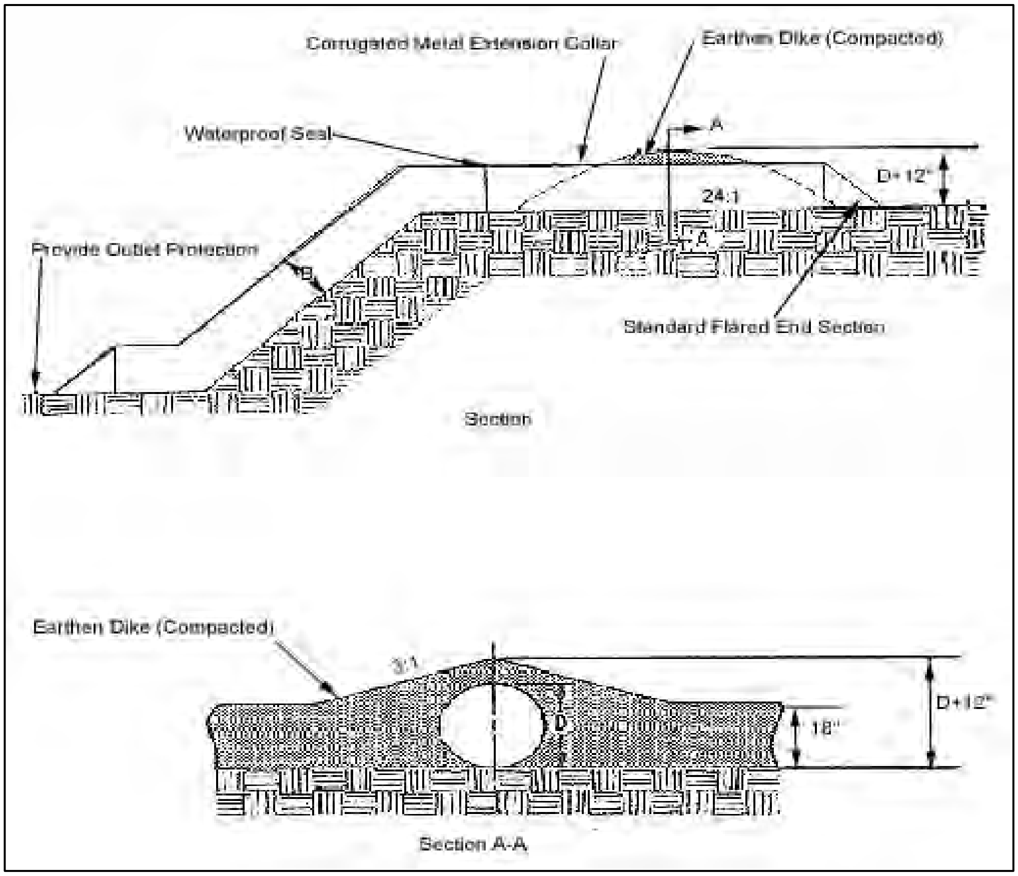


Figure TSD-1 Typical Temporary Slope Drain Detail

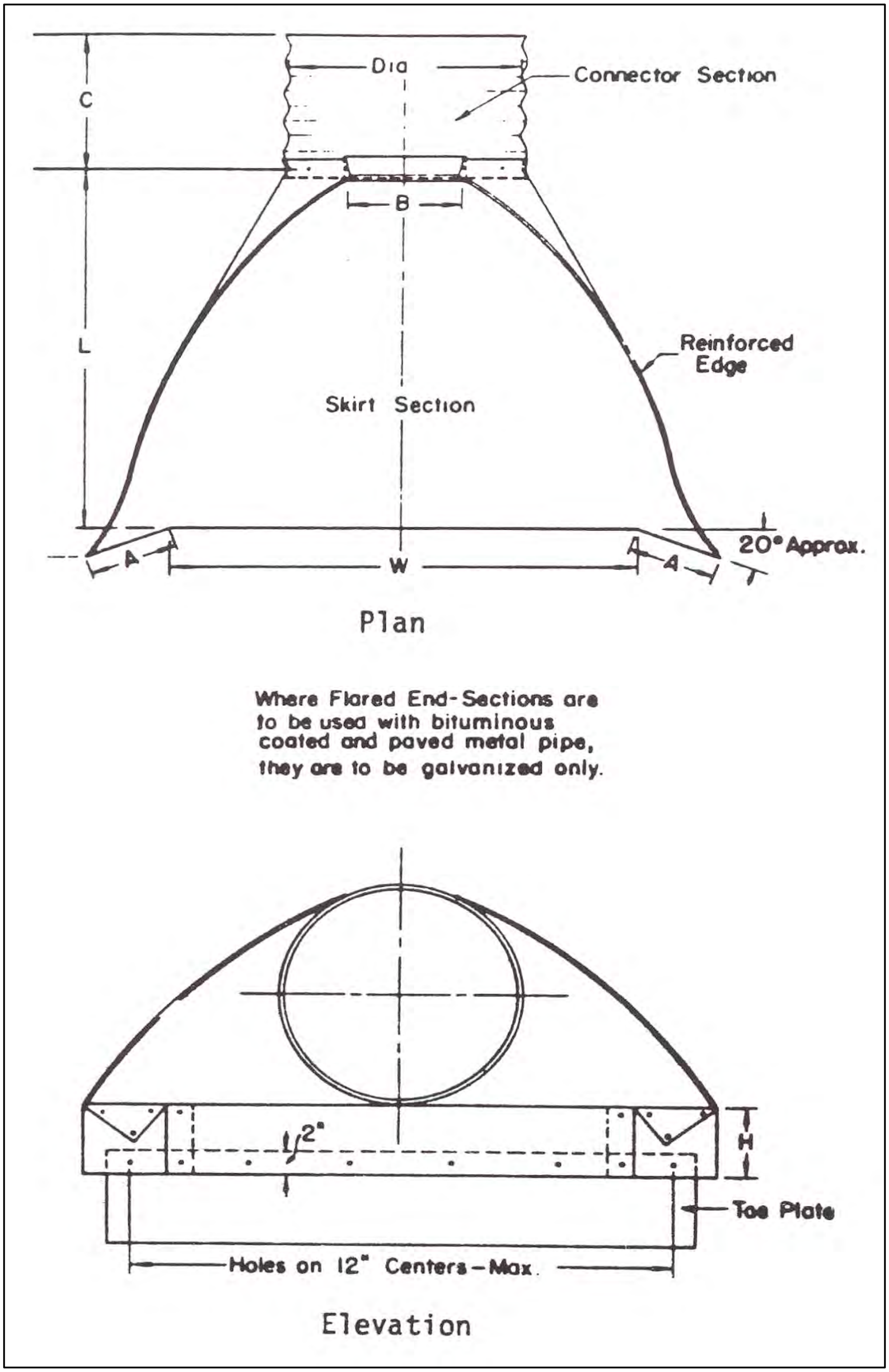
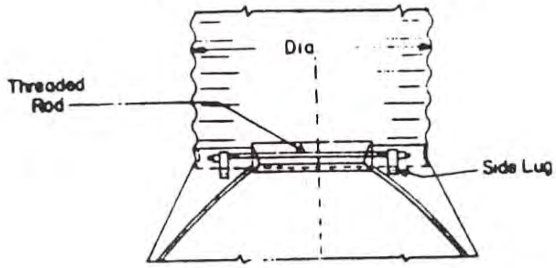


Figure TSD-2 Flared End-Section Detail

Alternate Connection



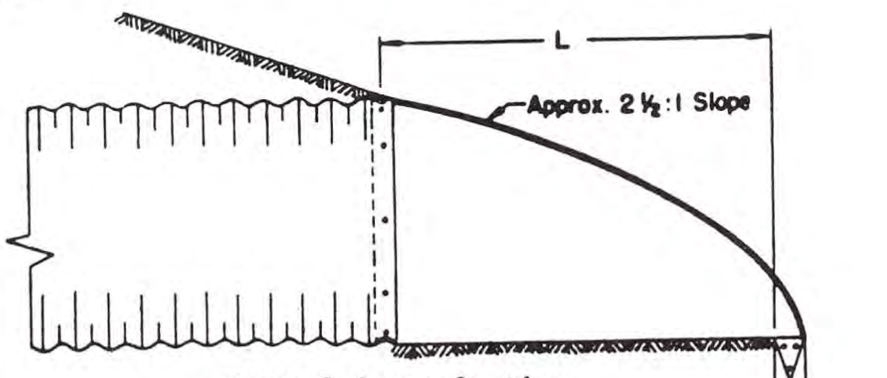
Toe plate, where needed, to be punched to match holes in skirt lip. 3/8" galv. bolts to be furnished. Length of toe plate is W + 10" for 12" to 30" dia. pipe and W + 22" for 36" to 60" dia. pipe.

Skirt Section for 12" to 30" dia. pipe to be made in one piece.

Skirt Section for 36" to 54" dia pipe may be made from two sheets joined by riveting or bolting on center line, 60" may be constructed in 3 pieces.

Connector Section, Corner Plate and Toe Plate to be same sheet thickness as skirt.

End-sections and fittings are to be galvanized steel or aluminum alloy for use with like pipe.



Typical Cross-Section

PIPE DIA	SHEET THICK-NESS	DIMENSIONS					
		A 1" Tol.	B Max.	H 1" Tol.	L 1½" Tol.	W 2" Tol.	C
12"	.064"	6"	6"	6"	21"	24"	24"
15"	.064"	7"	8"	6"	26"	30"	24"
18"	.064"	8"	10"	6"	31"	36"	24"
24"	.064"	10"	13"	6"	41"	48"	24"
30"	.079"	12"	16"	8"	51"	60"	24"
36"	.079"	14"	19"	9"	60"	72"	36"
42"	.109"	16"	22"	11"	69"	84"	36"
48"	.109"	18"	27"	12"	78"	90"	24"
54"	.109"	18"	30"	12"	84"	102"	36"
60"	.109 .138	18"	33"	12"	87"	114"	36"

Figure TSD-3 Flared End-Section Details (continued)

Construction

Prior to start of construction, temporary slope drains should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Site Preparation

Determine exact location of underground utilities (see Appendix C: MS One-Call and 811 Color Coding).

Place temporary slope drain on undisturbed soil or well-compacted fill at locations and elevations shown on the plans.

Grade the diversion channel at the top of the slope toward the temporary slope drain according to the design plan. Provide positive grade in the pipe under the ridge.

Hand tamp the soil under and around the pipe in lifts not to exceed 6″.

Ensure that the fill over the drain pipe at the top of the slope is placed to the dimensions shown on the design plan.

Ensure that all slope drain connections are secure and watertight.

Ensure that all fill material is well compacted. Securely anchor the exposed section of the drain according to the design.

Extend the drain beyond the toe of the slope and adequately protect the outlet from erosion.

Make the settled, compacted diversion ridge no less than 1 foot above the top of the pipe at every point.

Erosion Control

Compaction of earthfill around the pipe in the vicinity of the ridge is extremely important to avoid piping failure and blowouts.

Immediately stabilize all disturbed areas following construction according to the design plan (with vegetation or other appropriate means of protection).

Construction Verification

Verify that materials, elevations, and installation procedures meet design specifications.

Joints should be carefully inspected for separations or looseness.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate temporary slope drains will not function as intended.

Pipe separates or is displaced.

Animals are going into the pipe outlet.

Maintenance

Inspect slope drains and supporting diversions once a week and after every storm event.

Check the inlet for sediment or trash accumulation; clear and restore to proper condition.

Check the fill over the pipe for settlement, cracking or piping holes; repair immediately.

Check for holes where the pipe emerges from the ridge; repair immediately.

Check the conduit for evidence of leaks or inadequate anchoring; repair immediately.

Check the outlet for erosion or sedimentation; clean and repair, or extend if necessary.

Once slopes have been stabilized, remove the temporary diversions and slope drains so that runoff water no longer concentrates but flows uniformly over the protected slope. Stabilize the diversion and slope drain areas.

References

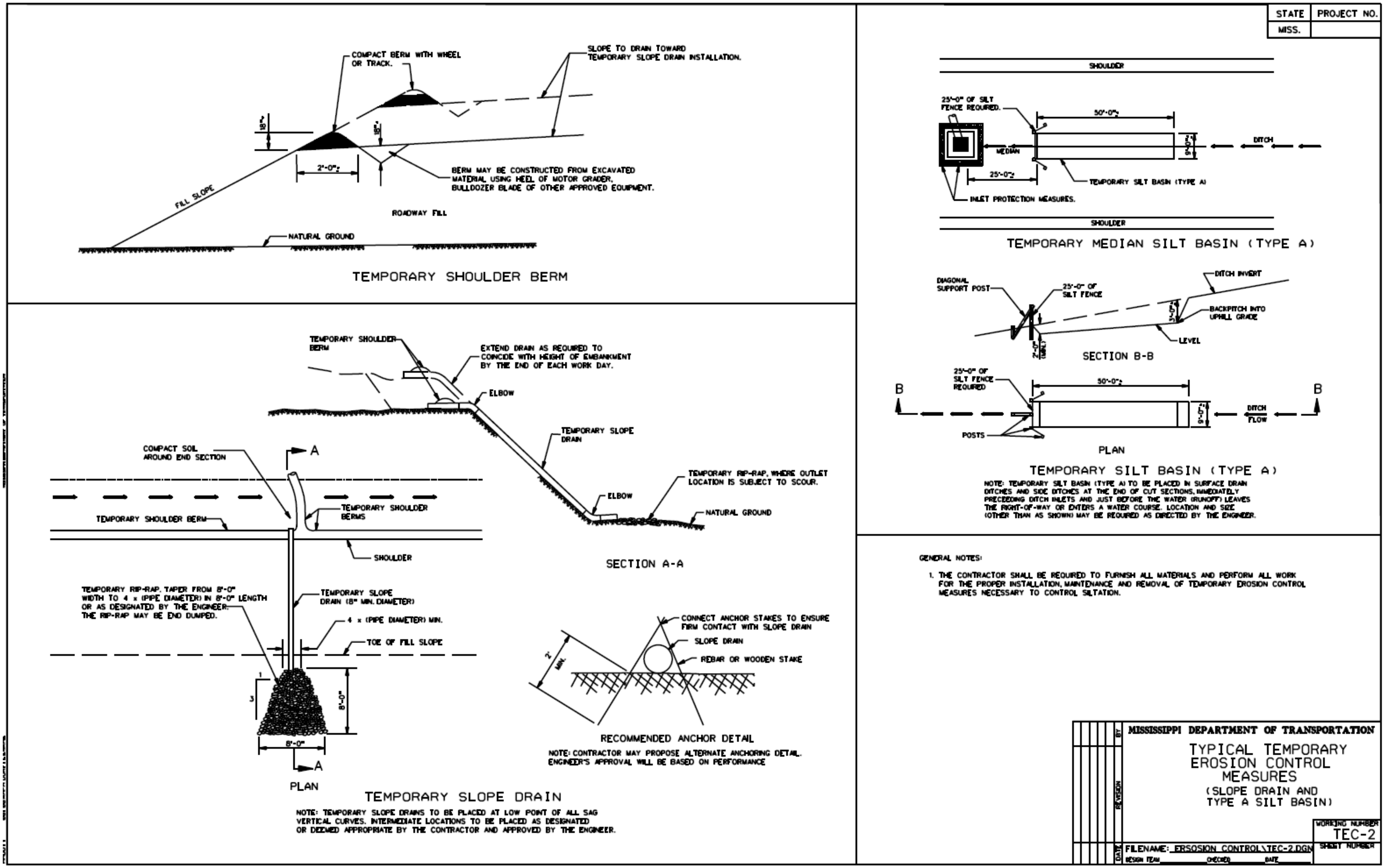
BMPs from Volume 1

Chapter 4

Permanent Seeding (PS)	4-53
Temporary Seeding (TS)	4-103
Diversion (DV)	4-131
Outlet Protection (OP)	4-199

MDOT Drawing TEC-2

Typical Temporary Erosion Control Measures (Slope Drain and Type A Silt Basin)	4-232



STATE
PROJECT NO.
MISS.
COMPACT BERM WITH WHEEL OR TRACK.
SLOPE TO DRAIN TOWARD TEMPORARY SLOPE DRAIN INSTALLATION.
18"±
18"±
2'-0"±
BERM MAY BE CONSTRUCTED FROM EXCAVATED MATERIAL USING HEEL OF MOTOR GRADER, BULLDOZER BLADE OF OTHER APPROVED EQUIPMENT.
FILL SLOPE
ROADWAY FILL
NATURAL GROUND
TEMPORARY SHOULDER BERM
SHOULDER
25'-0" OF SILT FENCE REQUIRED.
50'-0"±
MEDIAN
9'-0"±
DITCH
25'-0"±
TEMPORARY SILT BASIN (TYPE A)
INLET PROTECTION MEASURES.
SHOULDER
TEMPORARY MEDIAN SILT BASIN (TYPE A)
DIAGONAL SUPPORT POST
25'-0" OF SILT FENCE
DITCH INVERT
BACKPITCH INTO UPHILL GRADE
3'-0"±
2'-0" (MIN.)
LEVEL
SECTION B-B
25'-0" OF SILT FENCE REQUIRED
50'-0"±
B
B
9'-0"±
DITCH FLOW
POSTS
PLAN
TEMPORARY SILT BASIN (TYPE A)
NOTE: TEMPORARY SILT BASIN (TYPE A) TO BE PLACED IN SURFACE DRAIN DITCHES AND SIDE DITCHES AT THE END OF CUT SECTIONS, IMMEDIATELY PRECEDING DITCH INLETS AND JUST BEFORE THE WATER (RUNOFF) LEAVES THE RIGHT-OF-WAY OR ENTERS A WATER COURSE. LOCATION AND SIZE (OTHER THAN AS SHOWN) MAY BE REQUIRED AS DIRECTED BY THE ENGINEER.
TEMPORARY SHOULDER BERM
EXTEND DRAIN AS REQUIRED TO CONCIDE WITH HEIGHT OF EMBANKMENT BY THE END OF EACH WORK DAY.
ELBOW
TEMPORARY SLOPE DRAIN
ELBOW
TEMPORARY RIP-RAP, WHERE OUTLET LOCATION IS SUBJECT TO SCOUR.
NATURAL GROUND
SECTION A-A
COMPACT SOIL AROUND END SECTION
A
TEMPORARY SHOULDER BERMS
TEMPORARY SHOULDER BERM
SHOULDER
TEMPORARY RIP-RAP, TAPER FROM 8'-0" WIDTH TO 4 x (PIPE DIAMETER) IN 8'-0" LENGTH OR AS DESIGNATED BY THE ENGINEER. THE RIP-RAP MAY BE END DUMPED.
TEMPORARY SLOPE DRAIN (8" MIN. DIAMETER)
4 x (PIPE DIAMETER) MIN.
TOE OF FILL SLOPE
1
3
8'-0"
8'-0"
A
PLAN
TEMPORARY SLOPE DRAIN
NOTE: TEMPORARY SLOPE DRAINS TO BE PLACED AT LOW POINT OF ALL SAG VERTICAL CURVES. INTERMEDIATE LOCATIONS TO BE PLACED AS DESIGNATED OR DEEMED APPROPRIATE BY THE CONTRACTOR AND APPROVED BY THE ENGINEER.
CONNECT ANCHOR STAKES TO ENSURE FIRM CONTACT WITH SLOPE DRAIN
SLOPE DRAIN
REBAR OR WOODEN STAKE
2' MIN.
RECOMMENDED ANCHOR DETAIL
NOTE: CONTRACTOR MAY PROPOSE ALTERNATE ANCHORING DETAIL. ENGINEER'S APPROVAL WILL BE BASED ON PERFORMANCE
GENERAL NOTES:
1. THE CONTRACTOR SHALL BE REQUIRED TO FURNISH ALL MATERIALS AND PERFORM ALL WORK FOR THE PROPER INSTALLATION, MAINTENANCE AND REMOVAL OF TEMPORARY EROSION CONTROL MEASURES NECESSARY TO CONTROL SILTATION.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
TYPICAL TEMPORARY EROSION CONTROL MEASURES
(SLOPE DRAIN AND TYPE A SILT BASIN)
WORKING NUMBER
TEC-2
SHEET NUMBER
FILENAME: ERSOSION CONTROL\TEC-2.DGN
DESIGN TEAM
CHECKED
DATE
BY
REVISION
DATE

Block and Gravel Inlet Protection (BIP)

Practice Description

Block and gravel inlet protection is a sediment control barrier formed around a storm drain inlet by the use of standard concrete block and gravel. The purpose is to help minimize sediment entering storm drains during construction. This practice applies where use of the storm drain system is necessary during construction and where inlets have a drainage area of 1 acre or less and an approach slope of 1% or less.

Planning Considerations

Storm sewers that are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

This practice is for drainage areas of less than 1 acre. Runoff from large disturbed areas should be routed through a sediment basin (see *Sediment Basin Practice*). This method is for areas where heavy flows are expected and where overflow capacity is necessary to prevent excessive ponding around the structure.

The best way to prevent sediment from entering the storm sewer system is to minimize erosion by leaving as much of the site undisturbed as possible and disturbing the site in small increments, if possible. After disturbance, stabilize the site as quickly as possible to prevent erosion and sediment delivery.

Design Criteria and Construction

Drainage Area

Drainage area should be less than 1 acre per inlet.

Capacity

The design storm for the inlet should be able to enter the inlet without bypass flow.

Approach

The approach to the block and gravel structure should be less than 1%.

Height

The height of the block structure should be 1 to 2 feet.

Side Slopes

Gravel placed around the concrete block structure should have 2:1 (Horizontal: Vertical) side slopes or flatter.

Dewatering

Place a minimum of one block on the bottom row (more as needed) on its side to allow for dewatering the pool.

Site Preparation

Determine exact location of underground utilities (see Appendix C: MS One-Call and 811 Color Coding available in the Appendices Volume).

Clear area of all debris that might hinder excavation and disposal of spoil.

Grade the approach to the inlet uniformly. The top elevation of the structure must be lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure and into the storm drain and not past the structure. Temporary dikes below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose.

Installation of Blocks, Wire Mesh and Gravel

Lay one block on its side in the bottom row on each side of the structure to allow pool drainage. The foundation for the blocks should be excavated at least 2″ below the crest of the storm drain. The bottom row of blocks should be placed against the edge of the storm drain for lateral support and to avoid washouts when overflow occurs. If needed, lateral support may be given to subsequent rows by placing 2″ x 4″ wood studs through block openings.

Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on design needs, by stacking combinations of 4″, 8″ and 12″ wide blocks. The barrier of blocks should be at least 12″ high and no greater than 24″ high.

The top elevation of the structure must be at least 6″ lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure and into the storm drain and not past the structure. Temporary dikes below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose.

Wire mesh should be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Hardware cloth or comparable wire mesh with ½″ openings should be used.

Place stone of the specified gradation around blocks to the lines and dimensions shown on the drawings and smooth to an even grade.

Gravel

Stone should be piled against the wire to the top of the block barrier, as shown in the typical details in Figure BIP-1. Coarse aggregate or similar gradations should be used.

If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned, and replaced.

Erosion Control

Stabilize disturbed areas in accordance with the vegetation plan.

Construction Verification

Check finished grades and dimensions of block and gravel barrier. Check materials for compliance with specifications.

Safety

Provide protection to prevent children from entering the area.

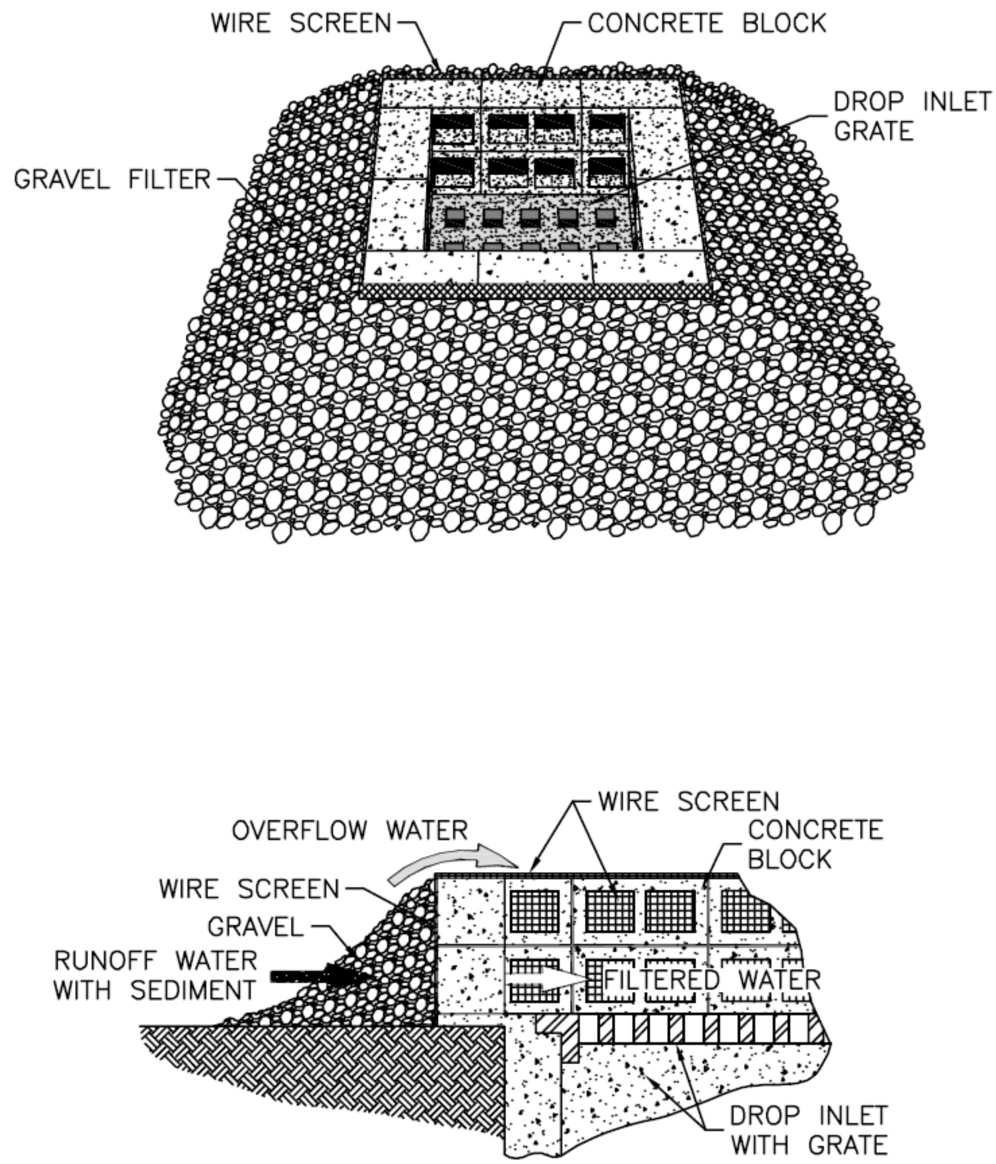


Figure BIP–1 Typical Details of Block and Gravel Inlet Protection

Common Problems

Consult with qualified design professional if the following occurs:

Variations in topography on site indicate block and gravel drop inlet protection will not function as intended; changes in plan may be needed.

Maintenance

Inspect the barrier after each rain and make repairs as needed.

Remove sediment promptly following storms to provide adequate storage volume for subsequent rains and prevent sediment entering the storm drain in subsequent rains.

If the gravel becomes clogged with sediment so that barrier does not drain properly, remove gravel and replace with clean gravel of the specified gradation.

When the contributing drainage area has been adequately stabilized, remove all materials and any sediment, bring the disturbed area to proper grade, and stabilize it with vegetation or other materials shown in the design plan.

References

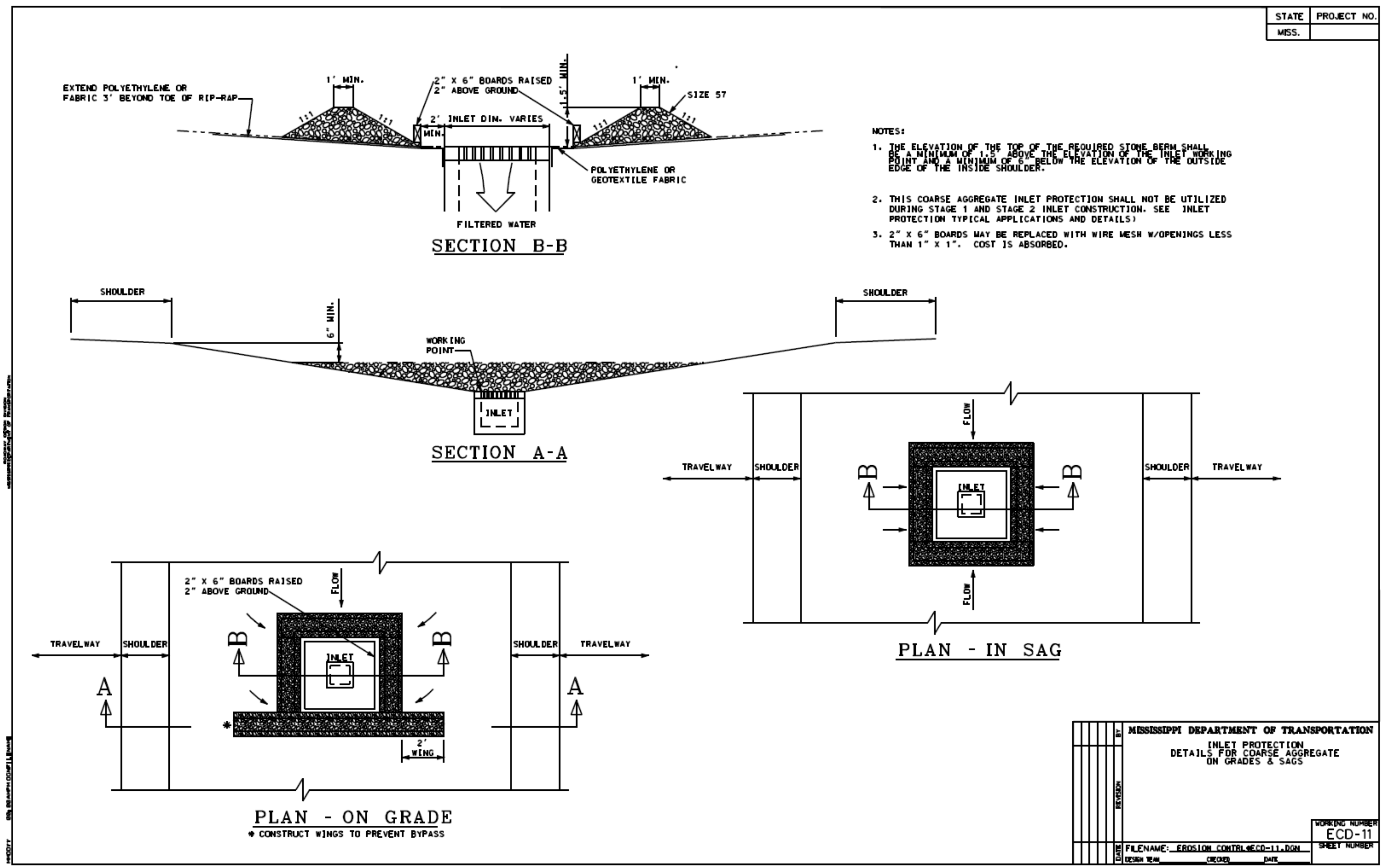
BMPs from Volume 1

Chapter 4

Sediment Basin (SBN) 4-298

MDOT Drawing ECD-1

Inlet Protection Details for Coarse Aggregate on Grades and Sags 4-238


STATE
PROJECT NO.
MISS.
EXTEND POLYETHYLENE OR FABRIC 3' BEYOND TOE OF RIP-RAP
1' MIN.
2" X 6" BOARDS RAISED 2" ABOVE GROUND
1.5' MIN.
1' MIN.
SIZE 57
1:1
2' INLET DIM. VARIES
MIN.
POLYETHYLENE OR GEOTEXTILE FABRIC
FILTERED WATER
SECTION B-B
NOTES:
1. THE ELEVATION OF THE TOP OF THE REQUIRED STONE BERM SHALL BE A MINIMUM OF 1.5' ABOVE THE ELEVATION OF THE INLET WORKING POINT AND A MINIMUM OF 6" BELOW THE ELEVATION OF THE OUTSIDE EDGE OF THE INSIDE SHOULDER.
2. THIS COARSE AGGREGATE INLET PROTECTION SHALL NOT BE UTILIZED DURING STAGE 1 AND STAGE 2 INLET CONSTRUCTION. SEE INLET PROTECTION TYPICAL APPLICATIONS AND DETAILS)
3. 2" X 6" BOARDS MAY BE REPLACED WITH WIRE MESH W/OPENINGS LESS THAN 1" X 1". COST IS ABSORBED.
SHOULDER
6" MIN.
WORKING POINT
INLET
SHOULDER
SECTION A-A
FLOW
TRAVELWAY
SHOULDER
B
INLET
B
SHOULDER
TRAVELWAY
FLOW
PLAN - IN SAG
2" X 6" BOARDS RAISED 2" ABOVE GROUND
FLOW
TRAVELWAY
SHOULDER
B
INLET
B
SHOULDER
TRAVELWAY
A
A
*
2' WING
PLAN - ON GRADE
* CONSTRUCT WINGS TO PREVENT BYPASS
BY
REVISION
DATE
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
INLET PROTECTION
DETAILS FOR COARSE AGGREGATE
ON GRADES & SAGS
WORKING NUMBER
ECD-11
SHEET NUMBER
FILENAME: EROSION CONTRL\ECD-11.DGN
DESIGN TEAM
CHECKED
DATE

Excavated Inlet Protection (EIP)

Practice Description

Excavated inlet protection is a sediment control technique formed around a storm drain inlet by excavating a small area around the inlet to act as a settling pool. The purpose is to help minimize sediment entering storm drains during construction. This practice applies where use of the storm drain system is necessary during construction and where inlets have a drainage area of 1 acre or less.

Planning Considerations

Storm sewers that are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

This practice is for drainage areas of less than 1 acre. Runoff from large disturbed areas should be routed through a sediment basin (see *Sediment Basin Practice*). This method is not recommended for areas where heavy flows are expected as it may overflow the excavated area.

The best way to prevent sediment from entering the storm sewer system is to minimize erosion by leaving as much of the site undisturbed as possible and disturbing the site in small increments, if possible. After disturbance, stabilize the site as quickly as possible to prevent erosion and sediment delivery.

Design Criteria and Construction

Drainage Area

Drainage area should be less than 1 acre per inlet.

Capacity

The trap should be sized to provide a minimum storage of 67 cubic yards for 1 acre of drainage area.

Approach

The approach to the block and gravel structure should be less than 1%.

Depth

The depth of the trap should be no less than 1 foot and no more than 2 feet deep measured from the top of the inlet structure.

Side Slopes

The side slopes of the trap should not exceed 3:1.

Dewatering

Weep holes should be installed to allow for dewatering the pool (Figure EIP-1).

Site Preparation

Determine exact location of underground utilities (see Appendix C: MS One-Call and 811 Color Coding available in the Appendices Volume).

Clear area of all debris that might hinder excavation and disposal of spoil.

Grade the approach to the inlet uniformly. The top elevation of the structure must be lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure and into the storm drain and not past the structure directly into the storm drain. Sediment may be excavated from inside the sediment pool for this purpose.

Erosion Control

Stabilize disturbed areas in accordance with the vegetation plan.

Construction Verification

Check finished grades and dimensions of block and gravel barrier. Check materials for compliance with specifications.

Safety

Provide protection to prevent children from entering the area.

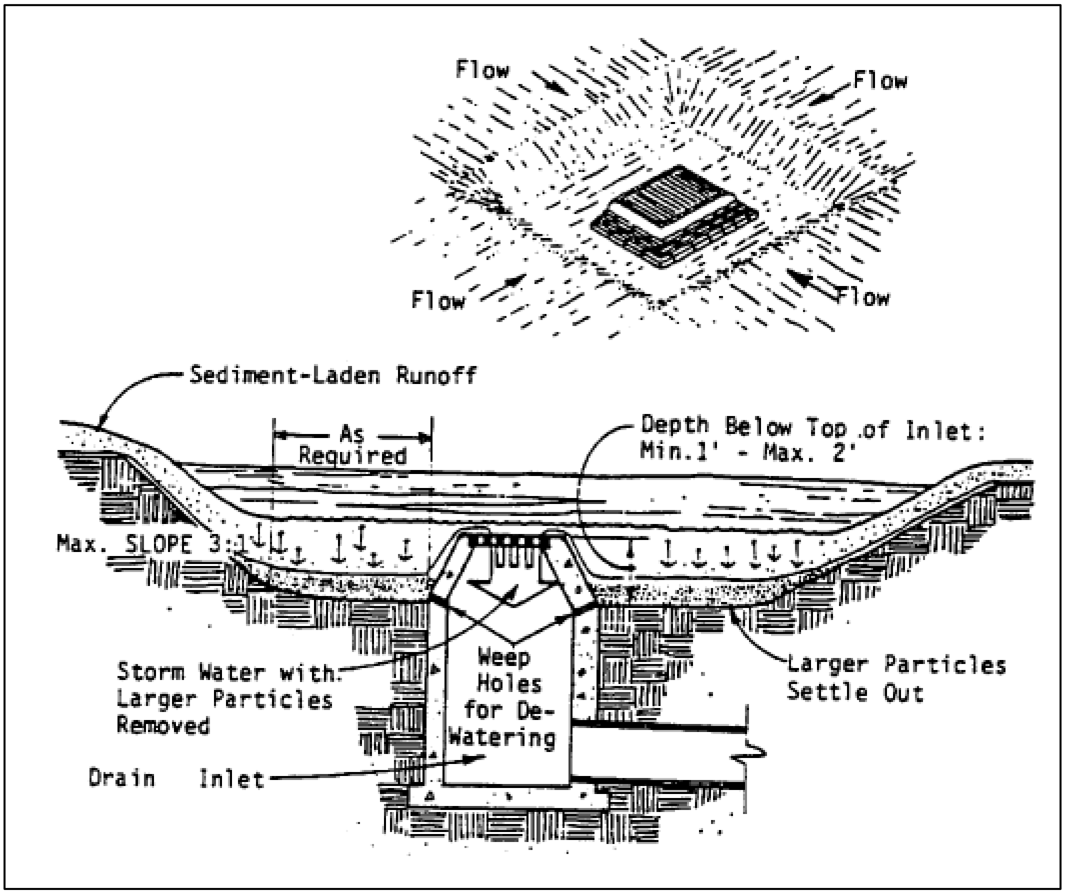


Figure EIP- 1 Excavated Inlet Protection

Common Problems

Consult with qualified design professional if the following occurs:

Storm drains subject to heavy flows may not benefit from excavated inlet protection; changes in plan may be needed.

Maintenance

Inspect the trap after each rain and make repairs as needed.

Remove sediment promptly following storms to provide adequate storage volume for subsequent rains and to prevent sediment entering the storm drain in subsequent rains.

When the contributing drainage area has been adequately stabilized, remove all materials and any sediment, bring the disturbed area to proper grade, and stabilize it with vegetation or other materials shown in the design plan.

References

BMPs from Volume 1

Chapter 4

Sediment Basin (SBN) 4-298

Fabric Drop Inlet Protection (FIP)

Practice Description

Fabric drop inlet protection is a structurally supported geotextile barrier placed around or over a drop inlet to prevent sediment from entering storm drains during construction. This practice applies where early use of the storm drain system is necessary prior to stabilization of the disturbed drainage area. This practice is suitable for inlets with a drainage area of less than 1 acre and a gentle approach slope generally of 1% or less.

Planning Considerations

Storm sewers that are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainage ways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets that discharge directly to waters of the state.

The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source. Sediment is best treated by preventing erosion. Leave as much of the site undisturbed as possible in the total site plan. Clear and disturb the site in small increments, if possible.

Numerous products have been developed to facilitate the capture of suspended soil particles at inlets. The design criteria for performance should be considered when evaluating alternative products. Products that will likely not meet performance goals or that usually fail under storm conditions should not be selected.

Design Criteria and Installation

Prior to start of construction, fabric drop inlet protection structures should be designed by a qualified professional. Plans and specifications should be available to field personnel. (*Note: Premanufactured fabric drop inlet protective structures should be installed and maintained according to the manufacturer's requirements.)*

Drainage Area

Drainage area should be less than 1 acre per inlet.

Sediment Storage

The basin created at the inlet should provide 67 cubic yards per disturbed acre of sediment storage.

Site Preparation

The soil around the drop inlet should be well compacted. The area around the drop inlet should be shaped, if necessary, to store the runoff on an almost level area. If runoff could bypass the protected inlet, a temporary dike should be planned and force the runoff to be trapped by the protective device.

Approach

The approach to the inlet protection practice should generally be less than 1% slope.

Height

The height of the structurally supported geotextile should be at least 1 foot but no more than 2.5 feet. The base of the fabric should be buried with compacted earth fill at least 12 inches into the soil or extend horizontally and be adequately secured with ballast material according to the manufacturer's recommendations. Ensure that the height of the structure when fully ponded does not cause unintentional damage or hazards to adjacent areas.

Structural Frame Installation

The frame (premanufactured or constructed) should provide the internal support necessary to prevent the structure from buckling, the fabric from sagging, or the fabric from being undermined. Frames should be positioned so that water that overtops the device goes directly into the inlet and does not cause erosion between the frame and inlet. Premanufactured frames should be installed according to manufacturer's recommendations.

Fabric Installation

Generally, fabric is installed by one of two methods:

Fabric can be buried vertically in a trench. The trench is excavated at least 12 inches into compacted soil adjacent to the inlet. Support posts are installed securely against the exterior of the drop inlet. Fabric along with wire fence is secured in the bottom of the trench and against the exterior surface of the inlet with stakes no more than 2 feet apart and driven at least 6 inches into the soil. The trench is backfilled with hand-compacted soil to the density equivalent to the surrounding soil. Fence and fabric are secured to the posts and the structure internally supported to meet the structural requirements of the device.

Fabric for pre-manufactured drop inlet protective devices is generally secured with ballast pockets on well-compacted soil around the inlet. Install these according to manufacturer's recommendations

Performance

Either the system of protection for the project or the drop inlet protection that discharges directly to the outfall of the project must be designed to meet the NTU requirements for discharge.

Stabilization

Stabilize all bare areas that drain to the inlet with temporary seeding and mulching unless construction will disturb it within 13 days.

Safety

Protection should be provided to prevent children from entering open-top structures.

Construction Verification

Check finished grades and dimensions of fabric drop inlet protection structures.

Common Problems

Consult with a qualified design professional if any of the following occurs:

Variations in site conditions indicate that the practice will not function as intended; change in plan may be needed.

Sediment not removed from pool resulting in inadequate storage volume for the next storm.

Top of fabric set too high, resulting in flow bypassing the inlet.

Fabric is not adjacent to the inlet exterior surface, resulting in erosion and undercutting of inlet.

Maintenance

Inspect fabric barrier after each rainfall event and make needed repairs immediately.

Remove sediment from the pool area when sediment has reached ½ the fabric height. Take care not to damage or undercut the fabric during the sediment removal.

When the contributing drainage area has been adequately stabilized, remove all materials and unstable sediment and dispose of properly. Fill the disturbed area to the grade of the drop inlet. Stabilize disturbed areas in accordance with the plans.

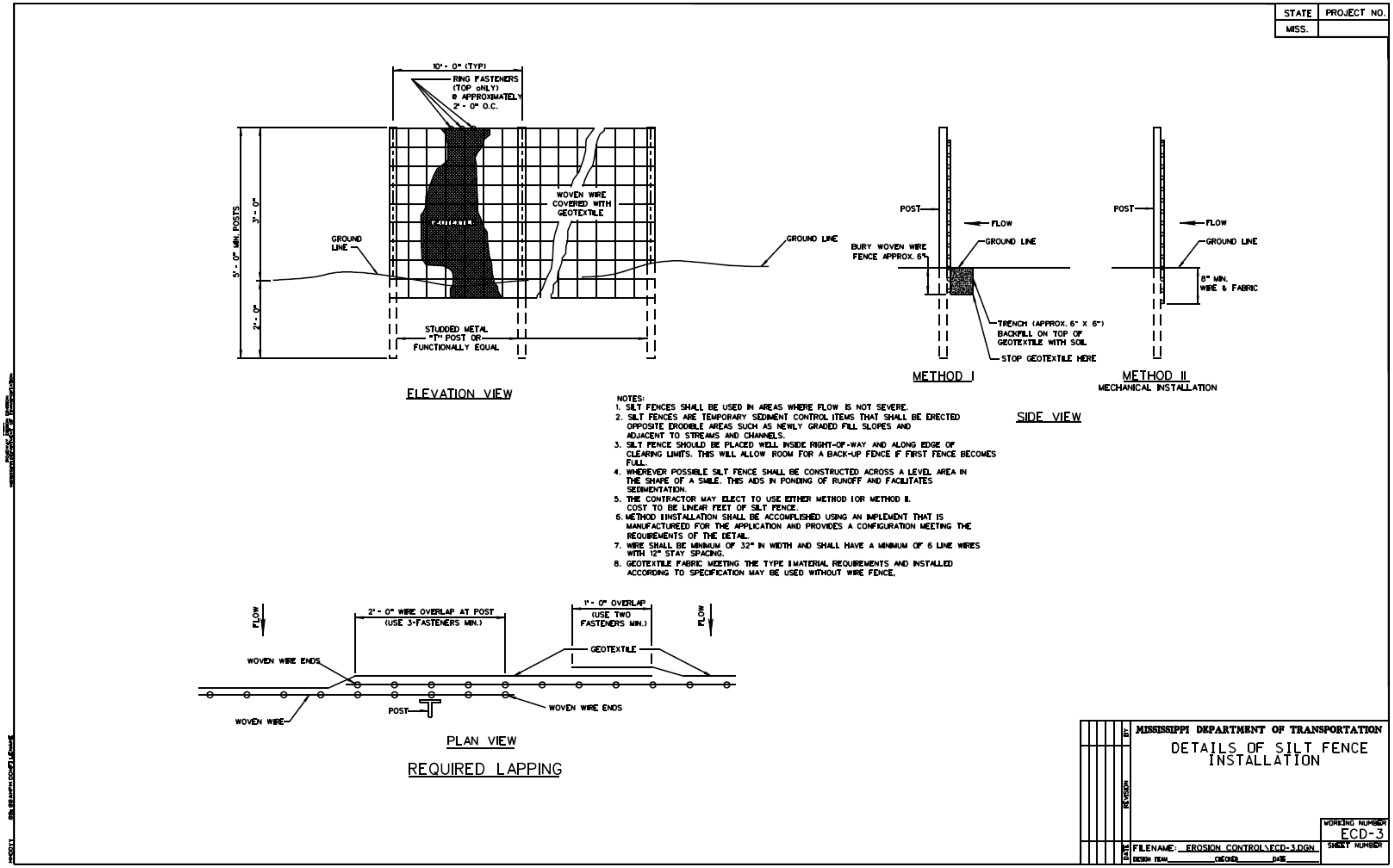
References

BMPs from Volume 1

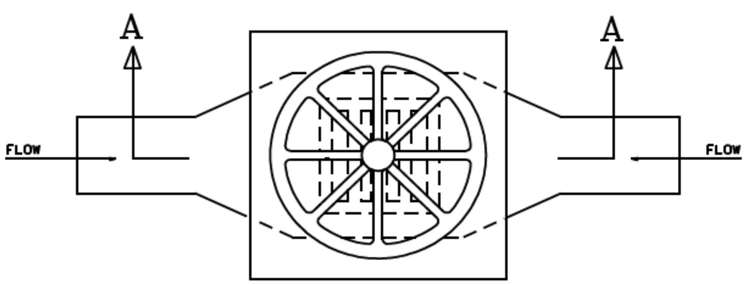
Chapter 4

MDOT Drawing ECD-3

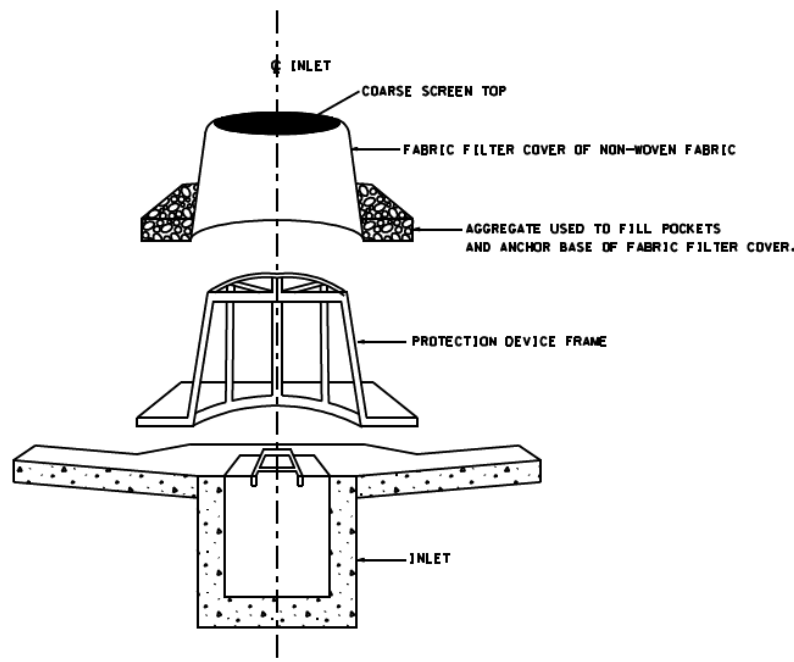
MDOT Drawing ECD-13


STATE
PROJECT NO.
MISS.
10' - 0" (TYP)
RING FASTENERS (TOP ONLY) @ APPROXIMATELY 2' - 0" O.C.
GEOTEXTILE
WOVEN WIRE COVERED WITH GEOTEXTILE
GROUND LINE
5' - 0" MIN. POSTS
3' - 0"
2' - 0"
STUDDED METAL "T" POST OR FUNCTIONALLY EQUAL
ELEVATION VIEW
POST
FLOW
GROUND LINE
BURY WOVEN WIRE FENCE APPROX. 6"
TRENCH (APPROX. 6" X 6") BACKFILL ON TOP OF GEOTEXTILE WITH SOIL
STOP GEOTEXTILE HERE
METHOD I
8" MIN. WIRE & FABRIC
METHOD II
MECHANICAL INSTALLATION
SIDE VIEW
NOTES:
1. SILT FENCES SHALL BE USED IN AREAS WHERE FLOW IS NOT SEVERE.
2. SILT FENCES ARE TEMPORARY SEDIMENT CONTROL ITEMS THAT SHALL BE ERECTED OPPOSITE ERODIBLE AREAS SUCH AS NEWLY GRADED FILL SLOPES AND ADJACENT TO STREAMS AND CHANNELS.
3. SILT FENCE SHOULD BE PLACED WELL INSIDE RIGHT-OF-WAY AND ALONG EDGE OF CLEARING LIMITS. THIS WILL ALLOW ROOM FOR A BACK-UP FENCE IF FIRST FENCE BECOMES FULL.
4. WHEREVER POSSIBLE SILT FENCE SHALL BE CONSTRUCTED ACROSS A LEVEL AREA IN THE SHAPE OF A SMILE. THIS AIDS IN PONDING OF RUNOFF AND FACILITATES SEDIMENTATION.
5. THE CONTRACTOR MAY ELECT TO USE EITHER METHOD I OR METHOD II. COST TO BE LINEAR FEET OF SILT FENCE.
6. METHOD II INSTALLATION SHALL BE ACCOMPLISHED USING AN IMPLEMENT THAT IS MANUFACTUREED FOR THE APPLICATION AND PROVIDES A CONFIGURATION MEETING THE REQUIREMENTS OF THE DETAIL.
7. WIRE SHALL BE MINIMUM OF 32" IN WIDTH AND SHALL HAVE A MINIMUM OF 6 LINE WIRES WITH 12" STAY SPACING.
8. GEOTEXTILE FABRIC MEETING THE TYPE I MATERIAL REQUIREMENTS AND INSTALLED ACCORDING TO SPECIFICATION MAY BE USED WITHOUT WIRE FENCE.
FLOW
2' - 0" WIRE OVERLAP AT POST (USE 3-FASTENERS MIN.)
1' - 0" OVERLAP (USE TWO FASTENERS MIN.)
GEOTEXTILE
WOVEN WIRE ENDS
WOVEN WIRE
POST
PLAN VIEW
REQUIRED LAPPING
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF SILT FENCE INSTALLATION
WORKING NUMBER
ECD-3
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-3.DGN
BY
REVISION
DATE

STATE	PROJECT NO.
MISS.	



PLAN



SECTION "A-A"

NOTES:

1. FRAMES WITH EITHER SQUARE OR CIRCULAR BASES MAY BE USED. SELECTED FRAME BASE SHOULD PROVIDE BEST SEAL AROUND INLET AS DIRECTED BY THE ENGINEER.
2. FILL POCKETS AROUND BASE OF FILTER COVER WITH #57 STONE OR SOIL. STONE IS REQUIRED WHEN ANCHORING THE MANUFACTURED INLET PROTECTION DEVICE OVER PAVED DITCH OR FLUME.
3. USE ONLY DURING STAGE 3 OR STAGE 4 INLET CONSTRUCTION.
4. FOR MEDIAN INLET PROTECTION, THE ELEVATION OF THE COARSE SCREEN TOP SHOULD BE A MINIMUM OF 6" BELOW THE ELEVATION OF THE OUTSIDE EDGE OF THE INSIDE SHOULDER.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

INLET PROTECTION
DETAILS OF MANUFACTURED
INLET PROTECTION DEVICE

WORKING NUMBER: ECD-13

SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-13.DGN

DESIGN TEAM ______ CHECKED ______ DATE ______

Straw Bale Inlet Protection (SBIP)

Practice Description

Straw bale inlet protection is a sediment control barrier formed around a storm drain inlet by the use of standard straw bales. The purpose is to help minimize sediment entering storm drains during construction. This practice applies where use of the storm drain system is necessary during construction and where inlets have a drainage area of 1 acre or less and an approach slope of 1% or less.

Planning Considerations

Storm sewers that are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. In case of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.

This practice is for drainage areas of less than 1 acre. Runoff from large disturbed areas should be routed through a sediment basin. This method is for areas where heavy flows are expected and where overflow capacity is necessary to prevent excessive ponding around the structure.

The best way to prevent sediment from entering the storm sewer system is to minimize erosion by leaving as much of the site undisturbed as possible and disturbing the site in small increments, if possible. After disturbance, stabilize the site as quickly as possible to prevent erosion and sediment delivery.

Design Criteria and Construction

Drainage Area

Drainage area should be less than 1 acre per inlet. The drainage area should be relatively flat (slopes no greater than 5 percent) where sheet or overland flows are typical. The method shall not apply to inlets receiving concentrated flows.

Capacity

The design storm for the inlet should be able to enter the inlet without bypass flow.

Bale Size

Bales should be either wire bound or string-tied with binding oriented around the sides rather than over and under the bales. Bales should be 14″ x 18″ x 36″. Straw wattles can also be used for this practice. A drawing representing straw wattle inlet protection is provided by the MDOT at the end of this practice (MDOT Drawing ECD-12).

Effective Life

Straw and hay bales have a relatively short period of usefulness and should not be used if the project duration is expected to exceed 3 months. Bale placement should result in the twine or cord being on the side and not the bottom of the bale.

Site Preparation

Determine exact location of underground utilities (see Appendix C: MS One-Call and 811 Color Coding available in the Appendices Volume).

Clear area of all debris that might hinder excavation and disposal of spoil.

Installation

Bales should be placed lengthwise in a single row surrounding the inlet with the ends of the adjacent bales pressed together.

If filter fabric is used, it should be entrenched and backfilled. A trench can be excavated around the inlet the width of the bale to a minimum depth of 4″. After the bales are staked, the bales should be backfilled with the excavated soil and compacted against the filter barrier.

Anchors

Two 36″ long (minimum), 2″ x 2″ hardwood stakes should be driven through each bale after the bales are properly entranced. Alternate anchors can be two pieces of No. 4 steel rebar, 36″ long (minimum).

Erosion Control

Stabilize disturbed areas in accordance with vegetation plan. If no vegetation plan exists, consider planting and mulching as part of installation and select planting information from either the *Permanent Seeding* or *Temporary Seeding Practice*. Select mulching information from the *Mulching Practice*.

Construction Verification

Check finished grades and dimensions of the straw bale inlet protection. Check materials for compliance with specifications.

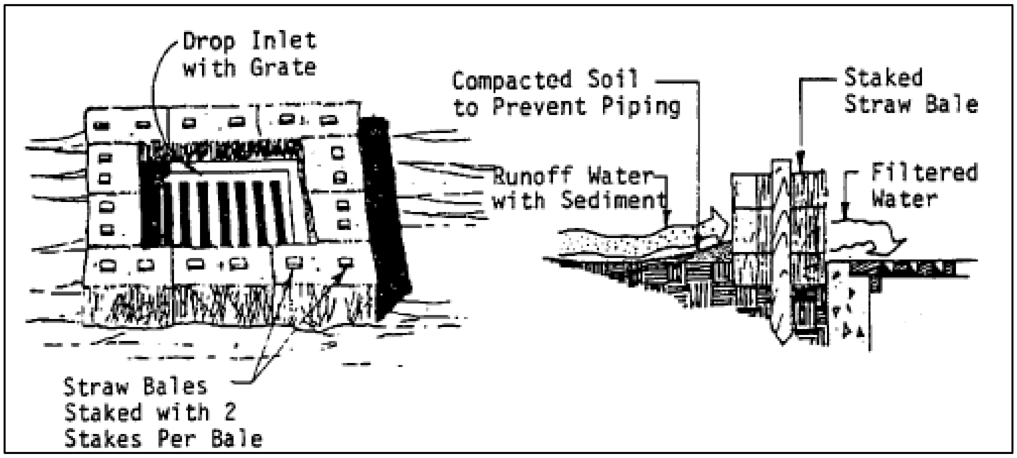


Figure SBIP- 1 Straw Bale Drop Inlet Sediment Filter

Common Problems

Consult with registered design professional if the following occurs:

Variations in topography on site indicate sediment trap will not function as intended; changes in plan may be needed.

Design specifications for materials cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect straw bale barriers after each storm event and remove sediment deposits promptly after it has accumulated to ½ of the original capacity, taking care not to undermine the entrenched bales.

Inspect periodically for deterioration or damage from construction activities. Repair damaged barrier immediately.

After the contributing drainage area has been stabilized, remove all straw bales and sediment, bring the disturbed area to grade, and stabilize it with vegetation or other materials shown in the design plan.

Straw bales may be recycled as mulch.

References

BMPs from Volume 1

MDOT Drawing ECD-10

MDOT Drawing ECD-12

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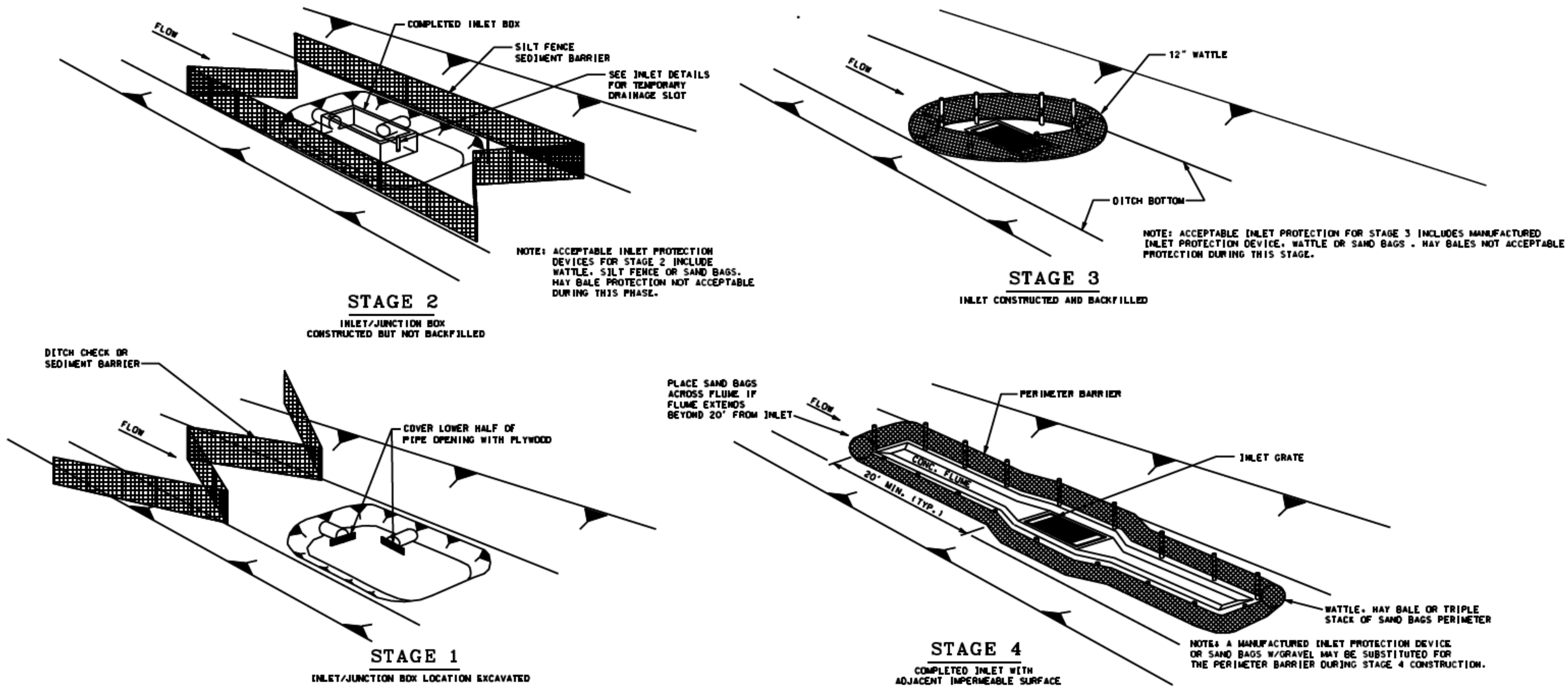


DITCH INLET CONSTRUCTION STAGES

NOTES:

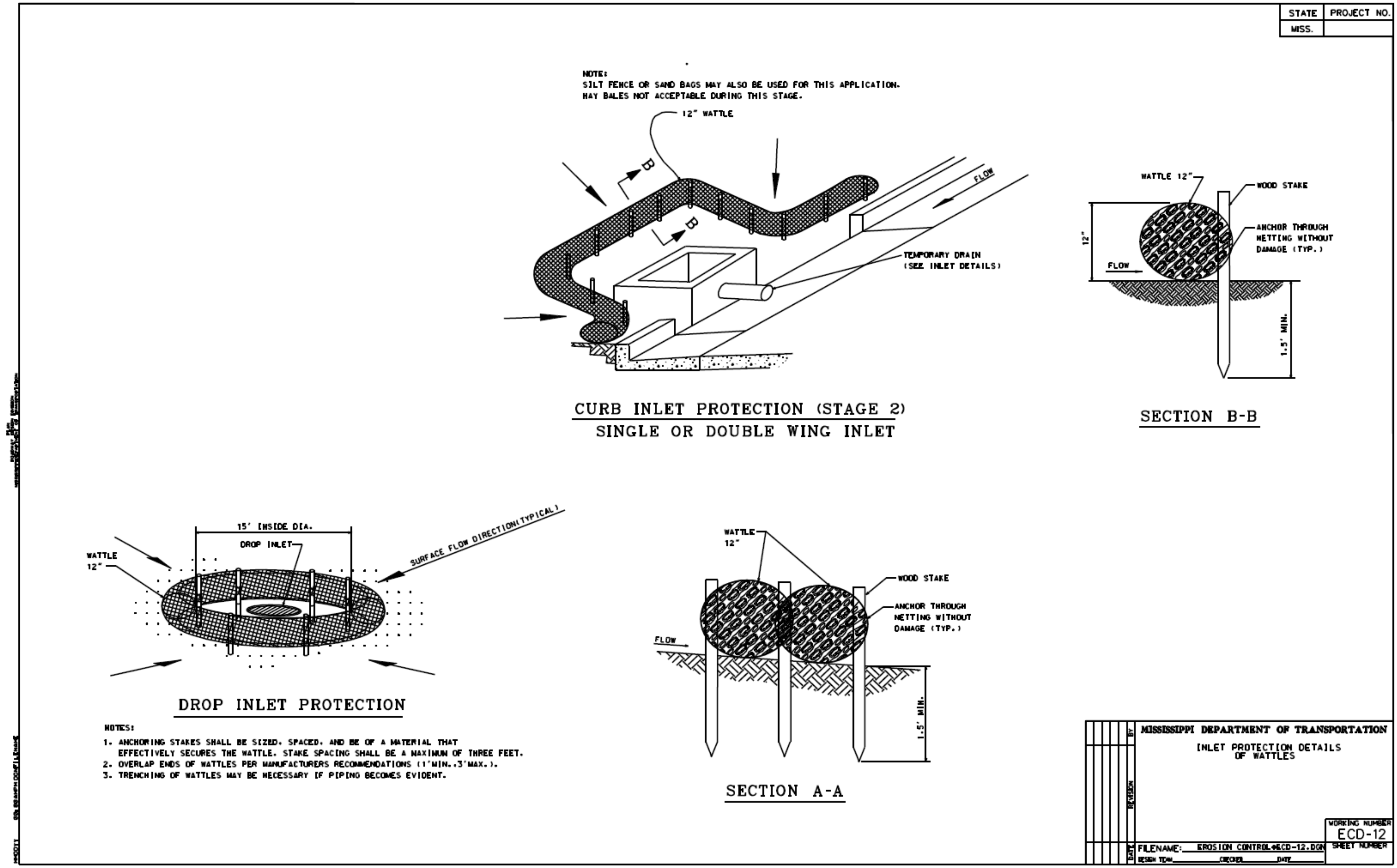
1. FOUNDATION BACKFILL SHOULD BE PLACED IN STAGE 1 IMMEDIATELY AFTER PIPE INSTALLATION. INLET CONSTRUCTION SHOULD COMMENCE AS SOON AS POSSIBLE AND BE CONTINUOUS THROUGH COMPLETION.
2. CONFIGURATIONS MAY BE ADJUSTED WITH APPROVAL OF THE ENGINEER FOR TRAVELWAY SAFETY, WATER FLOW, SOIL OR INSTALLATION CHALLENGES.
3. DURING STAGE 1 AND STAGE 2, SILT FENCE MAY BE REQUIRED UPSLOPE OF THE INLET EXCAVATION AS DIRECTED BY THE ENGINEER.
4. IF SILT FENCING IS INSTALLED AROUND THE INLET EXCAVATION IT SHOULD BE PLACED IN A CONFIGURATION THAT WILL ALLOW INLET CONSTRUCTION.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
INLET PROTECTION
TYPICAL APPLICATIONS AND DETAILS

BY | REVISION | DATE

WORKING NUMBER: ECD-10
SHEET NUMBER

FILENAME: EROSION CONTROL-ECD-10.DGN
DESIGN TEAM ___ CHECKED ___ DATE ___


STATE
PROJECT NO.
MISS.
NOTE:
SILT FENCE OR SAND BAGS MAY ALSO BE USED FOR THIS APPLICATION.
HAY BALES NOT ACCEPTABLE DURING THIS STAGE.
12" WATTLE
B
B
FLOW
TEMPORARY DRAIN
(SEE INLET DETAILS)
CURB INLET PROTECTION (STAGE 2)
SINGLE OR DOUBLE WING INLET
WATTLE 12"
WOOD STAKE
ANCHOR THROUGH NETTING WITHOUT DAMAGE (TYP.)
12"
FLOW
1.5' MIN.
SECTION B-B
15' INSIDE DIA.
DROP INLET
WATTLE 12"
SURFACE FLOW DIRECTION(TYPICAL)
DROP INLET PROTECTION
NOTES:
1. ANCHORING STAKES SHALL BE SIZED, SPACED, AND BE OF A MATERIAL THAT EFFECTIVELY SECURES THE WATTLE. STAKE SPACING SHALL BE A MAXIMUM OF THREE FEET.
2. OVERLAP ENDS OF WATTLES PER MANUFACTURERS RECOMMENDATIONS (1'MIN.,3'MAX.).
3. TRENCHING OF WATTLES MAY BE NECESSARY IF PIPING BECOMES EVIDENT.
WATTLE 12"
WOOD STAKE
ANCHOR THROUGH NETTING WITHOUT DAMAGE (TYP.)
FLOW
1.5' MIN.
SECTION A-A
BY
REVISION
DATE
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
INLET PROTECTION DETAILS OF WATTLES
WORKING NUMBER
ECD-12
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-12.DGN
DESIGN TEAM
CHECKER
DATE

Brush/Fabric Barrier (BFB)

Practice Description

A brush/fabric barrier is a dam-like structure constructed from woody residue and faced with a geotextile fabric to provide a temporary sediment basin. This practice is applicable on sites with a small drainage area where brush and other woody debris are available from a clearing and grubbing operation.

Planning Considerations

This practice is intended to be a temporary sediment basin with a limited life span and applicable only for small drainage areas.

The barrier should be located downslope from areas with potential sheet and rill erosion, with adequate storage volume in front of the barrier, and with no more than 2 acres of drainage area.

Adequate woody material from clearing and grubbing required on the site must be available for the construction of the barrier.

The practice should be located and designed so that adequate storage volume and detention time can be obtained, and failure of the barrier will not result in hazard to the public or damage to work on either on-site or off-site property.

Design Criteria and Construction

Prior to start of construction, a qualified design professional should determine the location and storage for the barrier. Typically, brush/fabric barriers are constructed where materials are readily available and at a location with adequate storage characteristics.

Drainage Area

Brush/fabric barriers should be designed with no more than 2 acres of drainage area. A sediment basin should be considered for larger drainage areas (see *Sediment Basin Practice*).

Structure Life

The design life of the structure should be 1 year or less. The barrier should be removed, and sediment accumulations properly stabilized prior to completion of the construction project.

Sediment Storage

The barrier should be designed to provide 67 cubic yards of sediment storage per acre of disturbed drainage area. Sediment should be removed and properly utilized on-site when half of the sediment storage volume has been filled.

Site Location and Preparation

The site for the barrier should be located so that a basin capable of providing the sediment storage required can be obtained or created. The site for the barrier should be smoothed prior to placement of the brush.

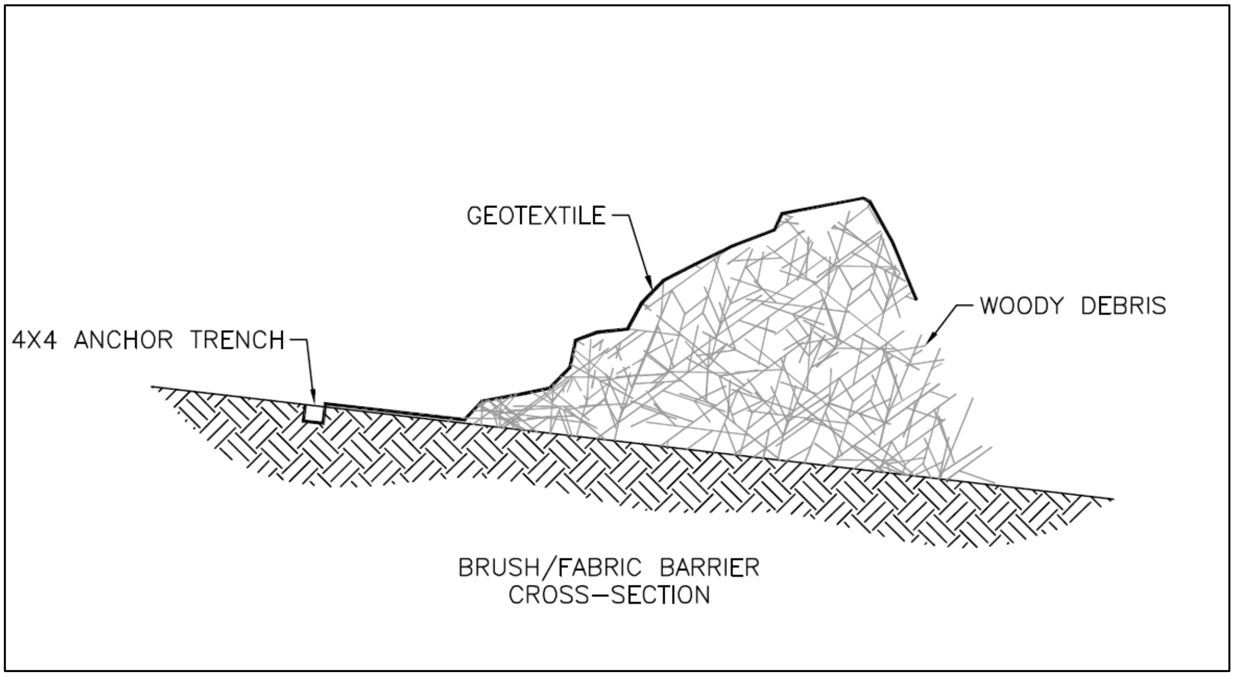


Figure BFB-1 Typical Installation

Materials Installation

Place the cleared and grubbed material in a densely compacted row, mostly on the contour, with each end upturned so that excessive flows will go over the top of the barrier and not around the ends of the barrier. Figure BFB–1 shows the typical installation.

Densely packed material should be placed so that the main stems of the woody debris are aligned with the length of the barrier. Small stems and limbs protruding from the bundle that could damage the fabric should be trimmed.

Generally, the barrier should be at least 3 feet tall, but no more than 6 feet tall. The width of the barrier perpendicular to the direction of flow should be at least 5 feet at its base.

Geotextile filter fabric consistent with the fabric used for silt fencing can be used to cover the face of the barrier. It is best to use wide and long rolls of the fabric so that splicing is minimized or eliminated. The fabric used to face the upstream surface of the brush should be non-woven geotextile equivalent to Class II fabric (see Table BFB-1).

The fabric should be securely buried at the bottom of an excavated trench that is at least 6″ deep in front of the barrier. Prior to backfilling the trench, the fabric should be securely staked at 3-foot centers with minimum 18″ long wooden stakes.

The fabric to be used should be supplied in lengths and widths to minimize vertical splices and eliminate horizontal splices. Avoid longitudinal splices of the fabric. Vertical splices must be securely fastened to each other so that flows will not short-circuit through the splice. The minimum vertical splice overlap should be 3 feet. Vertical splices must be securely fastened to each other so that flows will not short-circuit through the splice.

The top edge of the fabric should be secured so that it will not sag below the designed storage elevation. The upper edge can be anchored with twine fastened to the fabric and secured to stakes behind the barrier.

Table BFB-1 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb) [2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. no. 40 [3]	As specified max. no. 40 [3]	As specified max. no. 40 [3]	As specified max. no. 40 [2]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Heat-bonded or resin-bonded geotextiles may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextile is required for all other classes.
2 Minimum average roll value (weakest principal direction).
3 U.S. standard sieve size.

Construction Verification

Check finished size, elevation, storage, and shape for compliance with standard drawings and materials list. (Check for compliance with specifications if included in contract specifications.)

Common Problems

Consult with a qualified design professional if any of the following occurs:

Variations in topography on-site indicate brush/fabric barrier will not function as intended. Change in design plan will be needed.

There is not adequate cleared, woody material to construct the barrier.

Materials specified in the plan are not available.

Maintenance

Inspect the barrier for short-circuiting of water or flow around the ends of the barrier after each significant rainfall event.

Sediment should be removed if it reaches a depth half of the original fabric height. If the area behind the barrier fills with sediment, there is a greater likelihood that water will flow around the end of the barrier and cause the practice to fail.

Large rainfall events that overtop the structure can result in gully erosion behind the barrier. This should be repaired as needed.

Brush/fabric barriers are temporary structures and should be removed when their useful life has been completed. All accumulated sediment should be properly stabilized. and the area where the barrier was located should be seeded and mulched immediately unless a different treatment is prescribed.

References

BMPs from Volume 1

Chapter 4

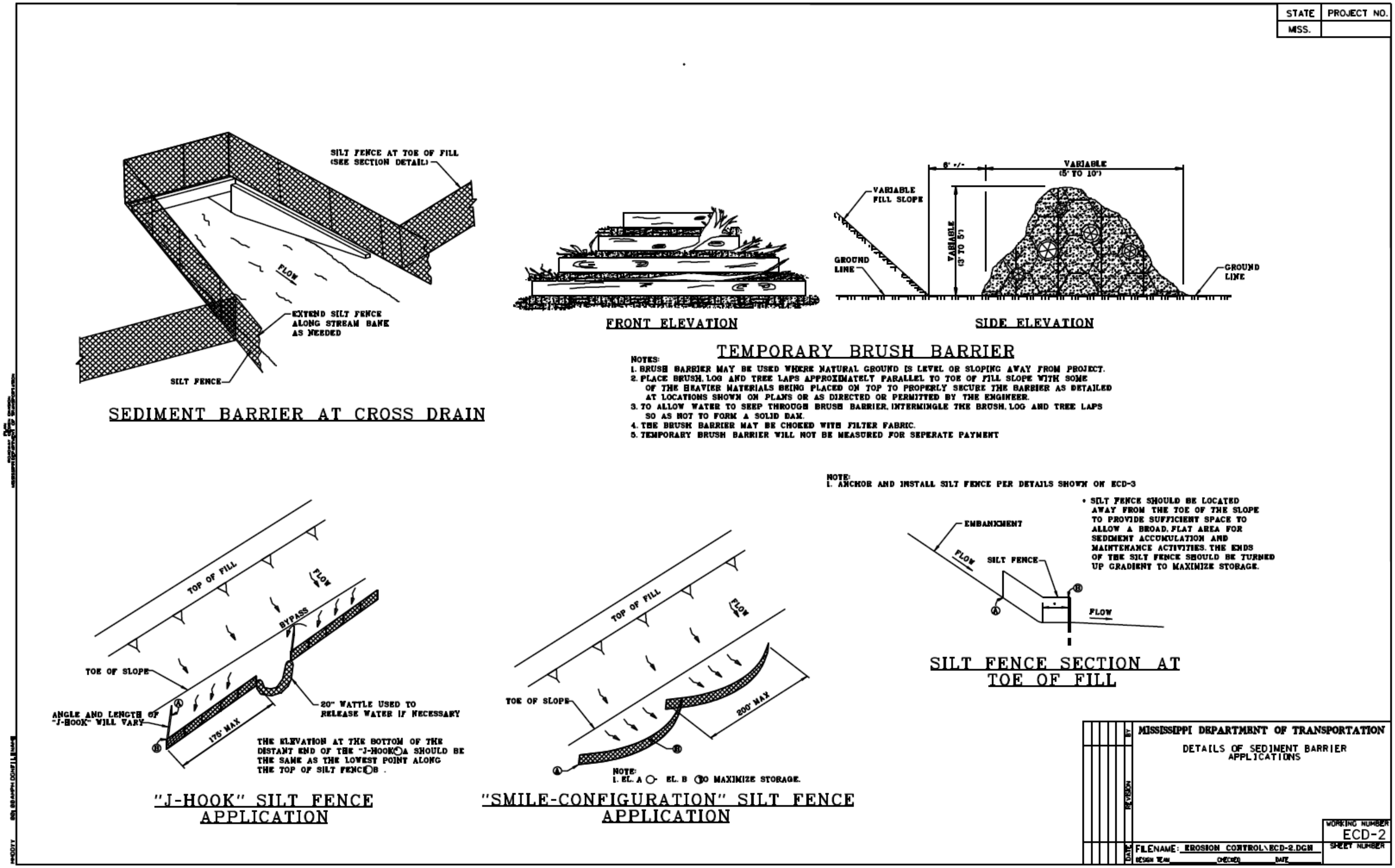
Sediment Basin (SBN) 4-298

MDOT Drawing ECD-2

Details of Sediment Barrier Applications 4-259

MDOT Drawing TEC-1

Typical Temporary Erosion Control Measures 4-260


STATE | PROJECT NO.
MISS.
SILT FENCE AT TOE OF FILL (SEE SECTION DETAIL)
FLOW
EXTEND SILT FENCE ALONG STREAM BANK AS NEEDED
SILT FENCE
SEDIMENT BARRIER AT CROSS DRAIN
FRONT ELEVATION
6' +/-
VARIABLE (5' TO 10')
VARIABLE FILL SLOPE
VARIABLE (3' TO 5')
GROUND LINE
GROUND LINE
SIDE ELEVATION
TEMPORARY BRUSH BARRIER
NOTES:
1. BRUSH BARRIER MAY BE USED WHERE NATURAL GROUND IS LEVEL OR SLOPING AWAY FROM PROJECT.
2. PLACE BRUSH, LOG AND TREE LAPS APPROXIMATELY PARALLEL TO TOE OF FILL SLOPE WITH SOME OF THE HEAVIER MATERIALS BEING PLACED ON TOP TO PROPERLY SECURE THE BARRIER AS DETAILED AT LOCATIONS SHOWN ON PLANS OR AS DIRECTED OR PERMITTED BY THE ENGINEER.
3. TO ALLOW WATER TO SEEP THROUGH BRUSH BARRIER, INTERMINGLE THE BRUSH, LOG AND TREE LAPS SO AS NOT TO FORM A SOLID DAM.
4. THE BRUSH BARRIER MAY BE CHOKED WITH FILTER FABRIC.
5. TEMPORARY BRUSH BARRIER WILL NOT BE MEASURED FOR SEPERATE PAYMENT
NOTE:
1. ANCHOR AND INSTALL SILT FENCE PER DETAILS SHOWN ON ECD-3
• SILT FENCE SHOULD BE LOCATED AWAY FROM THE TOE OF THE SLOPE TO PROVIDE SUFFICIENT SPACE TO ALLOW A BROAD, FLAT AREA FOR SEDIMENT ACCUMULATION AND MAINTENANCE ACTIVITIES. THE ENDS OF THE SILT FENCE SHOULD BE TURNED UP GRADIENT TO MAXIMIZE STORAGE.
EMBANKMENT
FLOW
SILT FENCE
A
B
FLOW
SILT FENCE SECTION AT TOE OF FILL
TOP OF FILL
FLOW
BYPASS
TOE OF SLOPE
ANGLE AND LENGTH OF "J-HOOK" WILL VARY
20" WATTLE USED TO RELEASE WATER IF NECESSARY
175' MAX
THE ELEVATION AT THE BOTTOM OF THE DISTANT END OF THE "J-HOOK" A SHOULD BE THE SAME AS THE LOWEST POINT ALONG THE TOP OF SILT FENCE B .
"J-HOOK" SILT FENCE APPLICATION
TOP OF FILL
FLOW
TOE OF SLOPE
200' MAX
NOTE:
1. EL. A ○ - EL. B ○ TO MAXIMIZE STORAGE.
"SMILE-CONFIGURATION" SILT FENCE APPLICATION
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF SEDIMENT BARRIER APPLICATIONS
WORKING NUMBER
ECD-2
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-2.DGN
DESIGN TEAM CHECKED DATE
BY
REVISION
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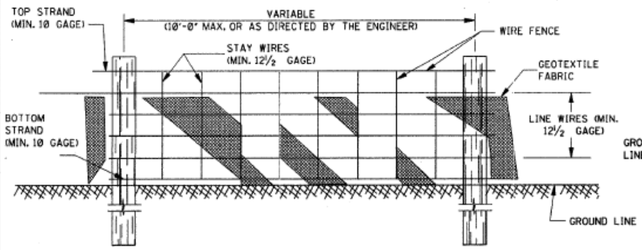
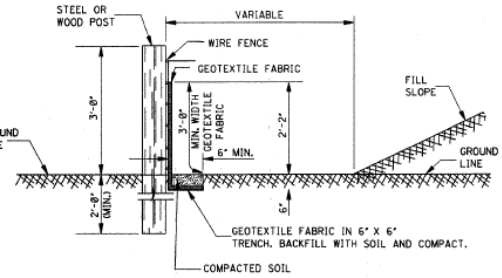


FRONT ELEVATION



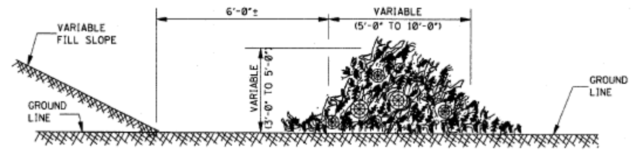
SIDE ELEVATION

TEMPORARY SILT FENCE

NOTES:

1. WIRE SHALL BE MINIMUM OF 32" IN WIDTH AND SHALL HAVE A MINIMUM OF 6 LINE WIRES WITH 12" STAY SPACING.
2. GEOTEXTILE FABRIC SHALL BE A MINIMUM OF 36" IN WIDTH AND SHALL BE FASTENED ADEQUATELY TO THE WIRE AS DIRECTED BY THE ENGINEER.
3. STEEL POST SHALL BE 5'-0" IN HEIGHT AND OF THE SELF-FASTENER ANGLE STEEL TYPE. WOOD POST SHALL BE A MINIMUM OF 5'-0" IN HEIGHT AND 3" OR MORE IN DIAMETER. WIRE FENCE SHALL BE FASTENED TO WOODEN POST WITH NOT LESS THAN 9 GAGE WIRE STAPLES 1" LONG.
4. GEOTEXTILE FABRIC MEETING THE TYPE II MATERIAL REQUIREMENTS AND INSTALLED ACCORDING TO SPECIFICATIONS MAY BE USED WITHOUT WIRE FENCE.

FRONT ELEVATION

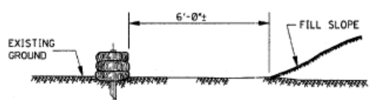


SIDE ELEVATION

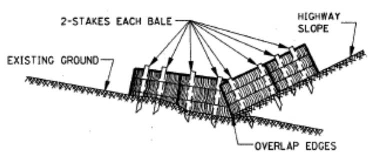
TEMPORARY BRUSH BARRIER

NOTES:

1. BRUSH BARRIER TO BE USED WHERE NATURAL GROUND IS LEVEL OR SLOPING AWAY FROM PROJECT.
2. PLACE BRUSH, LOG AND TREE LAPS APPROXIMATELY PARALLEL TO TOE OF FILL SLOPE WITH SOME OF THE HEAVIER MATERIALS BEING PLACED ON TOP TO PROPERLY SECURE THE BARRIER AS DETAILED AT LOCATIONS SHOWN ON PLANS OR AS DIRECTED BY THE ENGINEER.
3. TO ALLOW WATER TO FLOW THROUGH BRUSH BARRIER, INTERMINGLE THE BRUSH, LOG AND TREE LAPS SO AS NOT TO FORM A SOLID DAM.

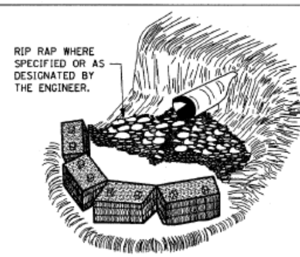


ELEVATION

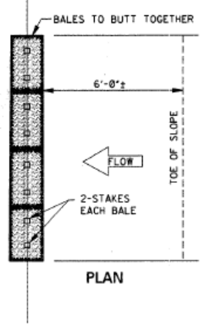


ELEVATION

NOTE: SIMILAR TREATMENT TO BE USED IN DITCHES.

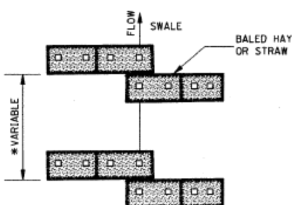


CULVERT

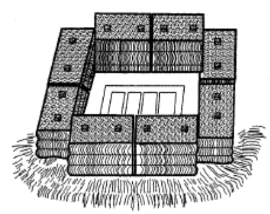


PLAN

FALL OF DITCH (%)	DISTANCE* (ft)
0 - 1	100'
1 - 2	50'
>2	25'



PLAN



DROP INLET

TEMPORARY EROSION CHECKS USING HAY OR STRAW BALES

NOTE: EMBED ALL BALES 3" MINIMUM INTO GROUND AND STAKE (2" X 2" X 36") SECURELY.

GENERAL NOTES:

1. THE CONTRACTOR SHALL BE REQUIRED TO FURNISH ALL MATERIALS AND PERFORM ALL WORK FOR THE PROPER INSTALLATION, MAINTENANCE AND REMOVAL OF TEMPORARY EROSION CONTROL MEASURES NECESSARY TO CONTROL SILTATION.
2. TEMPORARY BRUSH BARRIERS SHALL BE USED AS REQUIRED BUT WILL NOT BE MEASURED FOR SEPARATE PAYMENT.
3. THE USE OF TEMPORARY EROSION CONTROL MEASURES OTHER THAN TEMPORARY BRUSH BARRIERS WILL ONLY BE REQUIRED AND MEASURED FOR SEPARATE PAYMENT WHEN APPROPRIATE PAY ITEM(S) IS INCLUDED IN THE BID SCHEDULE OF THE PROPOSAL.

BY | REVISION | DATE

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN

TYPICAL TEMPORARY EROSION CONTROL MEASURES
(SILT FENCE, HAY BALES & BRUSH BARRIER)

DEPARTMENT OF TRANSPORTATION MISSISSIPPI — ENGLISH

WORKING NUMBER TEC-1

ISSUE DATE: OCTOBER 1, 1998

SHEET NUMBER 142

Filter Strip (FS)

Practice Description

A filter strip is a wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants, and reduce stormwater flow and velocity. Filter strips are similar to grassed swales except that they are designed to intercept overland sheet flow (not channel flow). They cannot treat high-velocity flows. Surface runoff must be evenly distributed across the filter strip. Vegetation may consist of existing cover that is preserved and protected or that is to be planted to establish the strip. Once a channel forms in the filter strip, the filter strip is no longer effective. This practice applies on construction sites and other disturbed areas.

Planning Considerations

Filter strips provide their maximum benefit when established as early as possible after disturbances begin. This concept should receive strong consideration during the scheduling of practices to be installed. In some instances, the existing vegetation may be preserved to serve as a filter strip.

Filter strips should be strategically located on the contour to reduce runoff and increase infiltration. They should be situated downslope from the disturbed site and where runoff-water enters environmentally sensitive areas.

Overland flow entering filter strips should be primarily sheet flow. All concentrated flow should be dispersed prior to entering the filter strip.

Flow length should be based on slope percent and length, predicted amount and particle size distribution of sediment delivered to the filter strip, density and height of the filter strip vegetation, and runoff volume.

The slope of the drainage area above a filter strip should be greater than 1% but less than 10%. The ratio of the drainage area to the filter strip should be less than 50:1.

Existing vegetation may be used if it meets stand density and height requirements and provides for uniform flow through the existing vegetation. The existing vegetation strip must be on a contour to be effective.

Site preparation for filter strips requires that the filter strip be placed on the contour. Variation in placement on the contour should not exceed a 0.5% longitudinal (perpendicular to the flow length) gradient.

All soil amendments should be applied according to a soil test recommendation for the planned vegetation.

The vegetation for filter strips must be permanent herbaceous vegetation of a single species or a mixture of grasses or legumes that have stiff stems and a high stem density near the ground surface. Stem density should be such that the stem spacing does not exceed 1″.

Design Criteria and Construction

Installation (Preservation of Existing Vegetation)

Prior to start of installation, filter strips should be designed by a qualified professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Designate the areas for preserving vegetation on the design plan map.

Indicate in the plan that the designated areas will be fenced or flagged and will not be disturbed. This includes avoiding surface disturbances that affect sheet flow of stormwater runoff and not storing debris from clearing and grubbing, and other construction waste material, in the filter strips during construction.

Installation (Planting)

Site Preparation

If the upper edge of the filter strip does not have a level edge, remove any obstructions and grade the upper edge of the filter strip so that runoff evenly enters the filter strip.

Fill and smooth any rills and gullies that exist over the filter strip area to ensure that overland flow will discharge across the filter strip along a smooth surface.

Seedbed Preparation

Grade and loosen soil to a smooth firm surface to enhance rooting of seedlings and reduce rill erosion. If existing, break up large clods and loosen compacted, hard, or crusted soil surfaces with a disk, ripper, chisel, harrow, or other tillage equipment. Avoid preparing the seedbed under excessively wet conditions.

For broadcast seeding and drilling, tillage should adequately loosen the soil to a depth of at least 6″, alleviate compaction, and smooth and firm the soil for the proper placement of seed.

For no-till drilling, the soil surface does not need to be loosened unless the site has surface compaction. If compaction exists, the area should be chiseled across the slope to a depth of at least 6″.

Applying Soil Amendments

Liming

Follow soil test recommendation. If a soil test is not available, use 2 tons/acre of ground agricultural lime on clayey soils (approximately 90 lbs/1000 ft^2) and 1 ton/acre on sandy soils (approximately 45 lbs/1000 ft^2). (Exception: If the cover is tall fescue and clover, use the 2 tons/acre rate (90 lbs/1000 ft^2) on both clayey and sandy soils.)

Spread the specified amount of lime and incorporate into the top 6″ of soil after applying fertilizer.

Fertilizing

Apply fertilizer at rates specified in the soil test recommendation. In the absence of soil tests, use the following as a guide:

Grass alone: 8-24-24 or equivalent - 400 lbs/acre (9.2 lbs/1000 ft^2). When vegetation has emerged to a stand and is growing, 30 to 40 lbs/acre (0.8 lb/1000 ft^2) of additional nitrogen fertilizer should be applied.

Grass-legume mixture: 8-24-24 or equivalent-400 lbs/acre (9.2 lbs/1000 ft^2). When vegetation has emerged to a stand and is growing, 30 to 40 lbs (0.8 lb/1000 ft^2) of additional nitrogen fertilizer should be applied.

Legume alone: 0-20-20 or equivalent-500 lbs/acre (11.5 lbs/1000 ft^2).

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil test recommendations to local fertilizer dealer for bulk fertilizer blends. This may be more economical than bagged fertilizer.

Incorporate lime and fertilizer to a minimum depth of at least 6″ or more by disking or chiseling on slopes of up to 3:1.

Planting

Plant the species specified in the plan at the rate and depth specified. In the absence of plans and specifications, plant species and seeding rates may be selected by qualified persons using Figure FS-1 and Table FS-1.

Apply seed uniformly using a cyclone seeder, drill seeder, cultipacker seeder, or hydroseeder.

When using a drill seeder, plant grasses and legumes ¼″ to ½″ deep. Calibrate equipment in the field.

When planting by methods other than a drill seeder or hydroseeder, cover seed by raking or by dragging a chain, brush, or mat. Then firm the soil lightly with a roller. Seed can also be covered with hydro-mulched wood fiber and tackifier. Legumes require inoculation with nitrogen-fixing bacterial to ensure good growth. Purchase inoculum specific for the seed and mix with seed prior to planting.

Mulching

Cover 65% to 75% of the surface with the specified mulch materials. Crimp, tack, or tie down straw mulch with netting. Mulching is extremely important for successful seeding (see *Mulching Practice* for more details.)

Construction Verification

Check materials and installation for compliance with specifications during installation of products.

Table FS-1 Commonly Used Plants for Permanent Cover

Species	**Seeding Rates/Ac** PLS[1]	**North** Seeding Dates	**Central**	**South**
Bahia grass,[2] Pensacola	40 lbs	--	Mar 1-July 1	Feb 1-Nov 1
Bermuda grass, Common	10 lbs	Apr 1-July 1	Mar 15-July 15	Mar 1-July 15
Bahia grass, Pensacola **Bermuda grass, Common**	30 lbs 5 lbs	--	Mar 1-July 1	Mar 1-July 15
Bermuda grass, Hybrid (Lawn Types)	Solid sod	Anytime	Anytime	Anytime
Bermuda grass, Hybrid (Lawn Types)	Sprigs 1/sq ft	Mar 1-Aug 1	Mar 1-Aug 1	Feb 15 - Sep 1
Fescue, Tall	40-50 lbs	Sep 1-Nov 1	Sep 1-Nov 1	--
Sericea	40-60 lbs	Mar 15-July 15	Mar 1-July 15	Feb 15 -July 15
Sericea & Common Bermuda grass	40-60 lbs 10 lbs	Mar 15 -July 15	Mar 1-July 15	Feb 15-July 15
Switch grass, Alamo	4 lbs	Apr 1-Jun 15	Mar 15-Jun 15	Mar 15-Jun 15

[1] A late-fall planting of Bahia grass should contain 45 pounds of small grain to provide cover during winter months.

[2] PLS means pure live seed and is used to adjust seeding rates. For example, to plant 10 lbs of a species with germination of 80% and with 10% inert material, 10 PLS = 10 lbs/80% - 10% = 10/0.70 = 14.3 lbs.

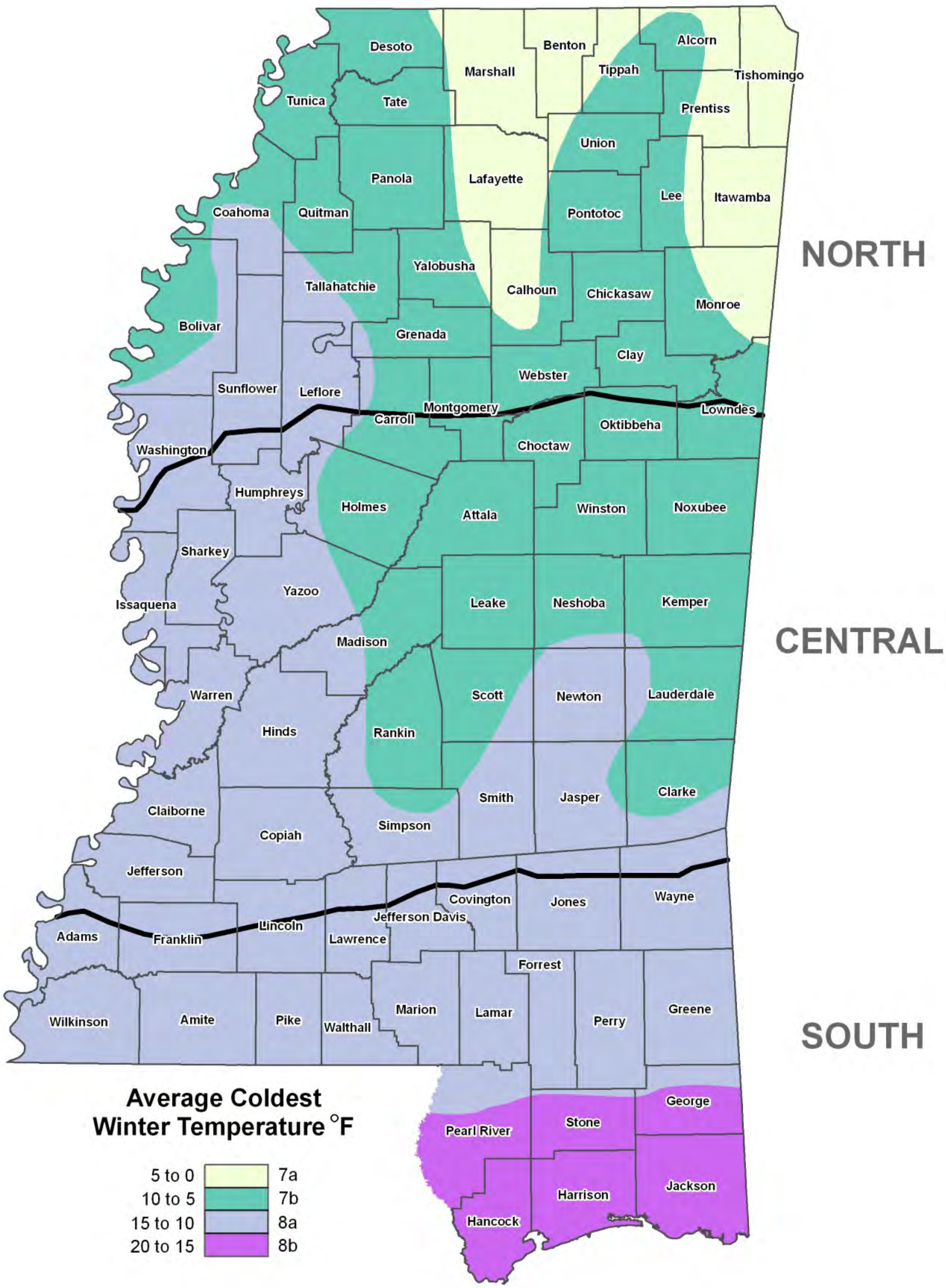


Figure FS-1 Geographical Areas for Species Adaptation and Seeding Dates

Common Problems

Consult with a qualified design professional if any of the following occurs:

Variations in topography on-site indicate filter strip will not function as intended.

Design specifications for seed variety, seeding dates, or mulching cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Seeding at the wrong time of the year results in an inadequate stand. Reseed according to specifications of a qualified professional.

Inadequate mulching results in an inadequate stand, bare spots, or eroded areas; prepare seedbed, reseed, cover seed evenly, and tack or tie down mulch, especially on slopes, ridges, and in channels (see recommendations under *Maintenance*).

Maintenance

Erosion

Check for eroded channels in the filter strip after every storm event until the vegetation is well established. Eroded areas should be repaired by filling and/or smoothing and by reapplication of lime, fertilizer, seed, and mulch. It is particularly important that the surface is smooth and promotes sheet flow of storm runoff.

Generally, a stand of vegetation cannot be determined to be fully established until vegetative cover has been maintained for at least 1 year after planting.

Reseeding

Inspect seeding monthly for stand survival and vigor.

If stand is inadequate, identify the cause of failure—choice of plant materials, lime and fertilizer quantities, poor seedbed preparation, or weather—and take corrective action. If vegetation fails to grow, have the soil tested to determine whether pH is in the correct range or if nutrient deficiency is a problem.

Stand conditions, particularly percent coverage, will determine the extent of remedial actions such as seedbed preparation and reseeding. A qualified professional should be consulted to advise on remedial actions. Consider drill seeding if enough residue exists.

Fertilizing

Establishment may require refertilizing the stand in the second growing season. Follow soil test recommendations or the specifications provided for establishment.

Mowing

Mow vegetation to prevent woody plants from invading.

Certain species can be weakened by mowing regimes that significantly reduce their food reserves stored for the next growing season. Fescue should not be mowed closer than 4″ during the summer. Sericea should not be mowed closer than 4″ during the growing season, and it should not be mowed at all between late summer and frost. Bermuda grass and Bahia grass are tolerant of most mowing regimes and can be mowed often and close, if so desired, during their growing season.

References

Volume 1

Floating Turbidity Barrier (FB)

— FTB — FTB —

Practice Definition

A floating turbidity barrier consists of geotextile material (curtain) with floats on the top, weights on the bottom, and an anchorage system that minimizes sediment transport from a disturbed area that is adjacent to or within a body of water. The barrier provides sedimentation and turbidity protection for a watercourse from up-slope land-disturbance activities where conventional erosion and sediment controls cannot be used or need supplemental sediment control, or from dredging or filling operations within a watercourse. The practice can be used in non-tidal and tidal watercourses where intrusion into the watercourse by construction activities has been permitted and subsequent sediment movement is unavoidable.

Planning Considerations

Soil loss into a watercourse results in long-term suspension of sediment. In time, the suspended sediment may travel long distances and affect widespread areas. A turbidity barrier is designed to deflect and contain sediment within a limited area and provide enough residence time so that soil particles will fall out of suspension and not travel to other areas.

Turbidity barrier types must be selected based on the flow conditions within the waterbody, whether it is a flowing channel, lake, pond, or a tidal watercourse. The specifications contained within this practice pertain to minimal- and moderate-flow conditions where the velocity of flow may reach 5 ft/sec (or a current of approximately 3-knots). For situations where there are greater flow velocities or currents, a qualified design professional and the product manufacturer should be consulted.

Consideration must also be given to the direction of water movement in channel-flow situations. Turbidity barriers are not designed to act as water impoundment dams and cannot be expected to stop the flow of a significant volume of water. They are designed and installed to trap sediment; not to halt the movement of water itself. In most situations, turbidity barriers should not be installed across channel flows. There is an exception to this rule. This occurs when there is a danger of creating a sediment buildup in the middle of a watercourse, thereby blocking access or creating a sediment bar. Curtains have been used effectively in large areas of moving water by forming a very long-sided, sharp “V” to deflect clean water around a work site, confining a large part of the sediment-laden water to the work area inside the “V” and directing much of the sediment toward the shoreline. Care must be taken, however, not to install the curtain perpendicular to the water current.

In tidal or moving water conditions, provisions must be made to allow the volume of water contained within the barrier to change. Since the bottom of the barrier is weighted and external anchors are frequently added, the volume of water contained within the curtain will be much greater at high tide versus low tide, and measures must be taken to prevent the curtain from submerging. In addition to allowing slack in the curtain to rise and fall, water must be allowed to flow through the curtain if the curtain is to remain in roughly the same place and maintain the same shape. Normally, this is achieved by constructing part of the curtain from a heavy, woven filter fabric. The fabric allows the water to pass through the curtain, but retains the sediment particles. Consideration should be given to the volume of water that must pass through the fabric and the sediment particle size when specifying fabric permeability.

Sediment, which has been deflected and settled out by the curtain, may be removed if so directed by the on-site inspector or the permitting agency. However, consideration must be given to the probable outcome of the procedure, which may create more of a sediment problem by re-suspension of particles and accidental dumping of the material by the equipment involved. It is, therefore, recommended that the soil particles trapped by a turbidity curtain be removed only if there has been a significant change in the original contours of the affected area in the watercourse. Regardless of the decision made, soil particles should always be allowed to settle for a minimum of 6-12 hours before removal by equipment or before removal of a turbidity curtain.

It is imperative that all measures in the erosion-control plan be used to keep sediment out of the watercourse. However, when proximity to the watercourse makes successfully mitigating sediment loss impossible, the use of the turbidity curtain during land disturbance is essential. Under no circumstances should permitted land-disturbing activities create violations of water quality standards.

Design Criteria and Construction

Floating turbidity barriers are normally classified into three types:

- Type I (see Figure FB-1) is used in protected areas where there is no current and the area is sheltered from wind and waves.

- Type II (see Figure FB-1) is used in areas where there may be small to moderate current (up to 2 knots or 3.5 ft/sec) and/or wind and wave action can affect the curtain.

- Type III (see Figure FB-2) is used in areas where considerable current (up to 3 knots or 5 ft/sec) may be present, where tidal action may be present, and/or where the curtain is potentially subject to wind and wave action.

Turbidity curtains should extend the entire depth of the watercourse whenever the watercourse in question is not subject to tidal action and/or significant wind and wave forces. This prevents sediment-laden water from escaping under the barrier, scouring, and re-suspending additional sediments.

In tidal and/or wind- and wave-action situations, the curtain should never be so long as to touch the bottom. A minimum 1-foot gap should exist between the weighted, lower end of the skirt and the bottom at “mean” low water. Movement of the lower skirt over the bottom due to tidal reverses or wind and wave action on the flotation system may fan and stir sediments already settled out.

In tidal and/or wind- and wave-action situations, it is seldom practical to extend a turbidity curtain depth lower than 10 to 12 feet below the surface, even in deep water. Curtains that are installed deeper than this will be subjected to very large loads with consequent strain on curtain materials and the mooring system. In addition, a curtain installed in such a manner can "billow up" toward the surface under the pressure of the moving water, which will result in an effective depth that is significantly less than the skirt depth.

Turbidity curtains should be located parallel to the direction of flow of a moving body of water. Turbidity curtains should not be placed across the main flow of a significant body of moving water.

When sizing the length of the floating curtain, allow an additional 10-20% variance in the straight-line measurements. This will allow for measuring errors, make installation easier and reduce stress from potential wave action during high winds.

An attempt should be made to avoid an excessive number of joints in the curtain. A minimum continuous span of 50 feet between joints is a good “rule of thumb.”

For stability reasons, a maximum span of 100 feet between anchor or stake locations is also a good rule to follow.

The ends of the curtain, both floating upper and weighted lower, should extend well up onto the shoreline, especially if high water conditions are expected. The ends should be secured firmly to the shoreline to fully enclose the area where sediment may enter the water.

When there is a specific need to extend the curtain to the bottom of the watercourse in tidal or moving water conditions, a heavy, woven, pervious filter fabric may be substituted for the normally recommended impervious geotextile. This creates a “flow-through” medium, which significantly reduces the pressure on the curtain and will help to keep it in the same relative location and shape during the rise and fall of tidal waters.

Typical installation layouts of turbidity curtains can be seen in Figure FB-3. The number and spacing of external anchors will vary depending on current velocities and potential wind and wave action. Manufacturer’s recommendations should be followed.

In navigable waters, additional permits may be required from the U.S. Army Corps of Engineers or other regulatory agencies if the barrier creates an obstruction to navigation.

Site Preparation

If a floating turbidity barrier is specified in the erosion and sediment control plan, it should be installed before any land-disturbing activities. Shoreline anchor points should be located according to the plans.

Materials and Installation Requirements

Barriers should be a bright color (yellow or “international” orange) that will attract the attention of nearby boaters. The curtain fabric must meet the minimum requirements noted in Table FB-1.

When installing Type I barrier in the calm water of lakes or ponds, it is usually sufficient to merely set the curtain end stakes or anchor points (using anchor buoys if bottom anchors are employed); then, tow the curtain in the furled condition out and attach it to these stakes or anchor points. Following this, any additional stakes or buoyed anchors required to maintain the desired location of the curtain may be set, and these anchor points made fast to the curtain. Only then, the furling lines should be cut to let the curtain skirt drop.

When installing Type II or III barriers in rivers or in other moving water, it is important to set all the curtain anchor points. Care must be taken to ensure that anchor points are of sufficient holding power to retain the curtain under the expected current conditions, before putting the furled curtain into the water. Anchor buoys should be employed on all anchors to prevent the current from submerging the flotation at the anchor points. If the moving water into which the curtain is being installed is tidal and will subject the curtain to currents in both directions as the tide changes, it is important to provide anchors on both sides of the curtain for two reasons:

- Curtain movement will be minimized during tidal current reversals.
- The curtain will not overrun the anchors, pulling them out when the tide reverses.

When the anchors are secure, the furled curtain should be secured to the upstream anchor point and then sequentially attached to each next downstream anchor point until the entire curtain is in position. At this point, and before unfurling, the “lay” of the curtain should be assessed and any necessary adjustments made to the anchors. Finally, when the location is ascertained to be as desired, the furling lines should be cut to allow the skirt to drop.

The anchoring line attached to the flotation device on the downstream side will provide support for the curtain. Attaching the anchors to the bottom of the curtain could cause premature failure of the curtain due to the stresses imparted on the middle section of the curtain.

Seams in the fabric should be either vulcanized welded or sewn, and should develop the full strength of the fabric.

Flotation devices should be flexible, buoyant units contained in an individual flotation sleeve or collar attached to the curtain. Buoyancy provided by the flotation units should be sufficient to support the weight of the curtain and maintain a freeboard of at least 3″ above the water surface level.

Load lines must be fabricated into the bottom of all floating turbidity curtains. Type II and Type III curtains must have load lines also fabricated into the top of the fabric. The top load line should consist of woven webbing or vinyl-sheathed steel cable and should have break strength in excess of 10,000 pounds (5 t). The supplemental (bottom) load line should consist of a chain incorporated into the bottom hem of the curtain of sufficient weight to serve as ballast to hold the curtain in a vertical position. Additional anchorage should be provided as necessary. The load lines should have suitable connecting devices that develop the full breaking strength for connecting to load lines in adjacent sections. (See Figures FB-1 and FB-2 which portray this orientation.)

Table FB-1 Curtain Fabric Material Requirements for Floating Turbidity Barriers

Characteristic Test Method	16 Oz Nominal Laminated	18 Oz Laminated	22 Oz Coated	Geotextile Filter
Construction	Vinyl Laminate On 1300 Denier 9 X 9 Scrim	Vinyl Laminate On1300 Denier 9 X 9 Scrim	Vinyl Coated On Woven 6 Oz Polyester Base	Woven Polypropylene
Weight ASTM D-751-95 Sec 16	Nominal 16 Oz/Sq Yd 376 Gr/Sq M	18 Oz/Sq Yd 423 Gr/Sq M	22 Oz/Sq Yd 517 Gr/Sq M	7.5 Oz/Sq Yd 176 Gr/Sq M
Adhesion ASTM D-751-95 Sec 43.1.2	15 Lb/In 14 Dan/5 Cm	15 Lb/In 14 Dan/5 Cm	14 Lb/In 13 Dan/5 Cm	Not Applicable
Tensile Strength ASTM D-751-95 Sec 12	324 X 271 Lb/In 308 X 258 Dan/5 Cm	397 X 373 Lb/In 378 X 363 Dan/5 Cm	500 X 400 Lb/In 476 X 389 Dan / 5 Cm	350 X 250 Lb/ In 333 X 230 Dan / 5 Cm
Tear Strength ASTM D-751-95 Sec 29	76 X 104 Lb/In 72 X 99 Dan/5 Cm	96 X 86 Lb/In 91 X 82 Dan/5 CM	132 X 143 Lb/In 126 X 136 Dan / 5 Cm	95 X 55 Lb/In 90 X 52 Dan / 5 Cm
Hydrostatic ASTM D-751-95 Sec 34.2	385 Lb/Sq In 2674 kPa	385 Lb/Sq In 674 kPa	881 Lb/Sq In 6118 kPa	Not Applicable

External anchors may consist of 2″ x 4″ or 2½″ minimum-diameter wooden stakes, or 1.33 pounds/linear foot steel posts when Type I installation is used. When Type II or Type III installations are used, bottom anchors should be used.

Bottom anchors must be sufficient to hold the curtain in the same position relative to the bottom of the watercourse without interfering with the action of the curtain. The anchor may dig into the bottom (grappling hook, plow, or fluke-type) or may be weighted (mushroom type), and should be attached to a floating anchor buoy via an anchor line. The anchor line would then run from the buoy to the top load line of the curtain. When used with Type III installations, these lines must contain enough slack to allow the buoy and curtain to float freely with tidal changes without pulling the buoy or curtain down and must be checked regularly to make sure they do not become entangled with debris. As previously noted, anchor spacing will vary with current velocity and expected wind and wave action. Manufacturer's recommendations should be followed. See orientation of external anchors and anchor buoys for tidal installation in Figure FB-2.

Installing two parallel curtains, separated at regular intervals by 10-foot-long wooden boards or lengths of pipe can increase the effectiveness of the barrier.

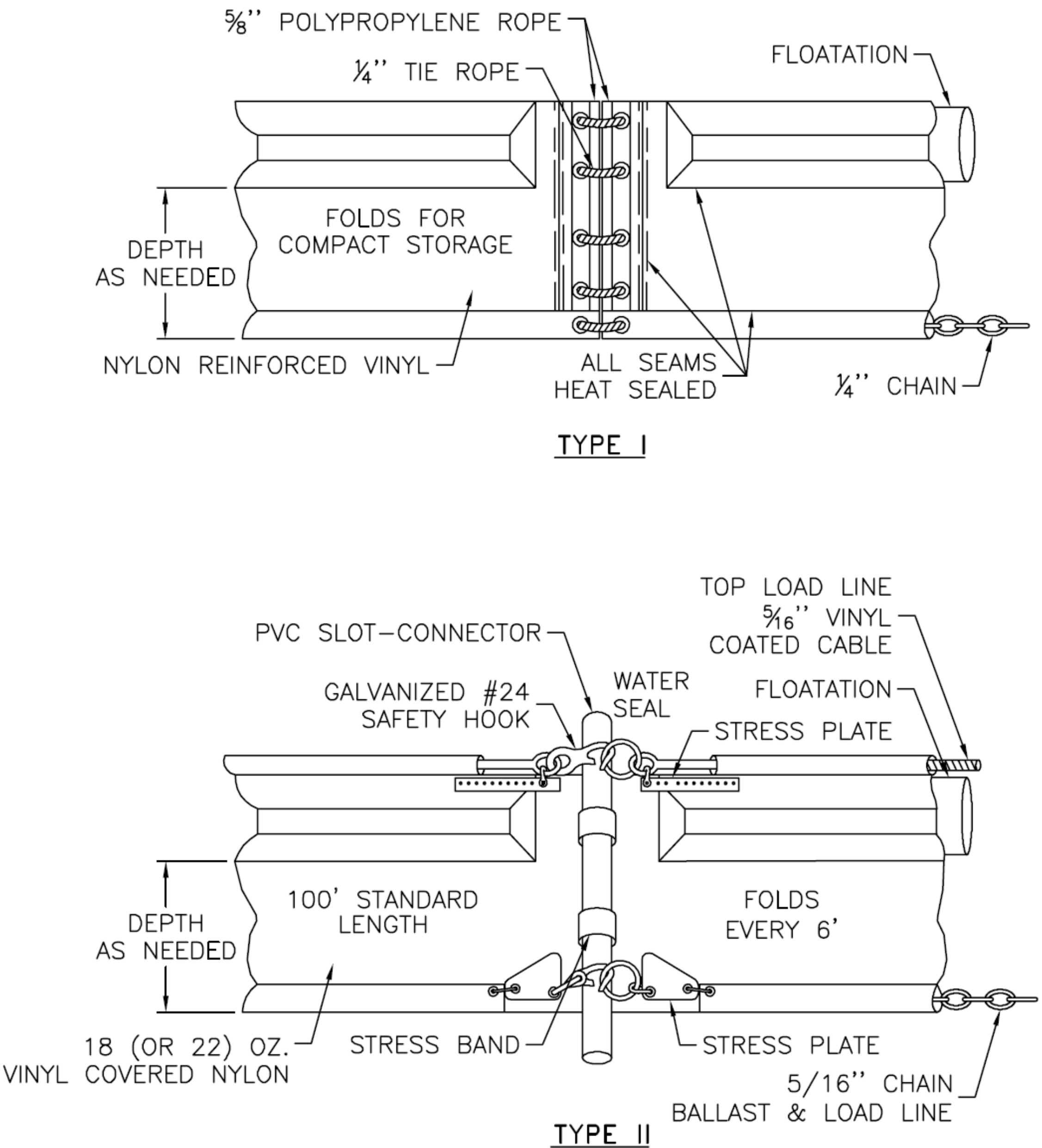


Figure FB-1 Type I and II Floating Turbidity Barriers

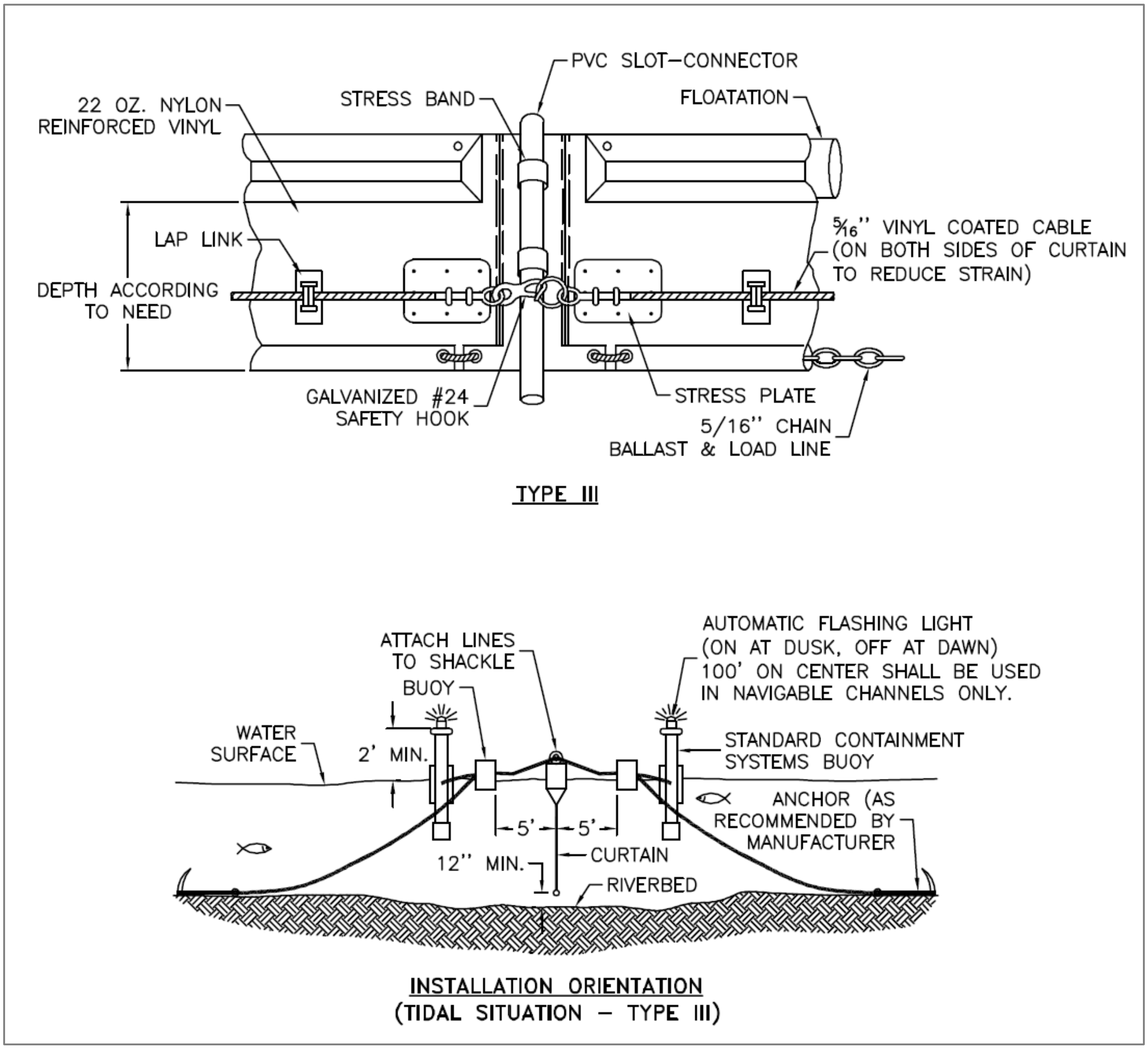


Figure FB-2 Type III Floating Turbidity Barrier

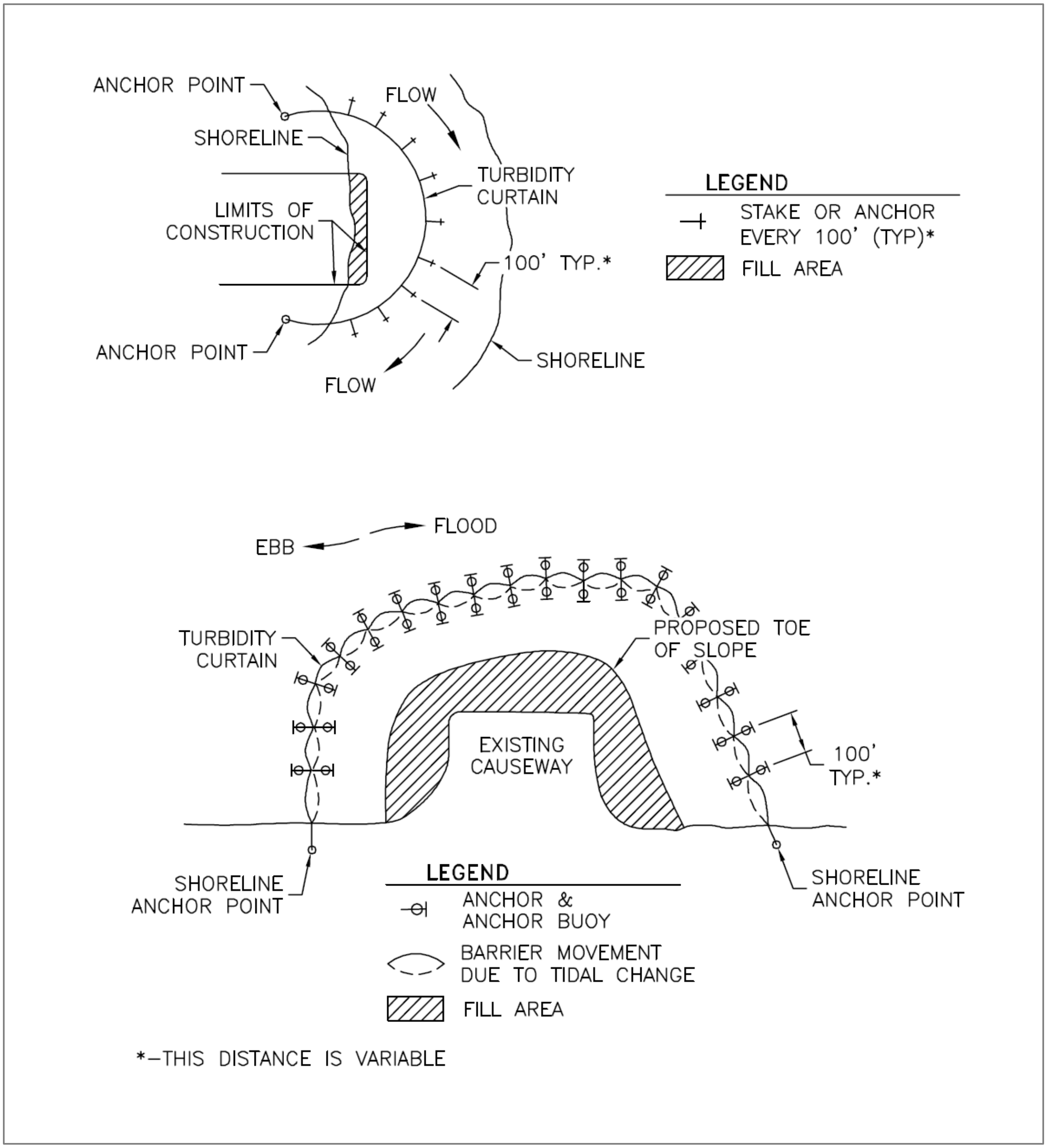


Figure FB-3 Typical Installation Layouts

Construction Verification

Check the type of floating turbidity barrier, installation location, and the installation and anchorage procedures for compliance with the standard drawings and materials list. (Check for compliance with specifications if included in contract specifications.)

Removal

Care should be taken to protect the skirt from damage as the turbidity curtain is dragged from the water.

The site selected to bring the curtain ashore should be free of sharp rocks, broken cement, debris, etc., so as to minimize damage when hauling the curtain over the area.

If the curtain has a deep skirt, it can be further protected by running a small boat along its length with a crew installing furling lines before attempting to remove the curtain from the water.

Common Problems

Consult with a qualified design professional if any of the following occurs:

Variations in topography on site indicate that a floating turbidity barrier will not function as intended. Change in plan will be needed.

The specified anchorage system will not function as planned.

Turbid water is escaping from the barrier enclosure.

Materials specified in the plan are not available.

Maintenance

The floating turbidity barrier should be maintained for the duration of the project to ensure the continuous protection of the watercourse. Anchors, anchor lines, and buoys must be regularly checked to remove debris.

If repairs to the geotextile fabric become necessary, normally, repair kits are available from the manufacturer. Follow the manufacturer's instructions to ensure the adequacy of the repair.

When the curtain is no longer required as determined by the responsible individual, the curtain and related components should be removed in such a manner as to minimize turbidity. If required by the contract or the responsible individual, sediment should be removed and the original depth (or plan elevation) restored before removing the curtain. Remaining sediment should be sufficiently settled before removing the curtain. Any spoils should be taken to an upland area and stabilized.

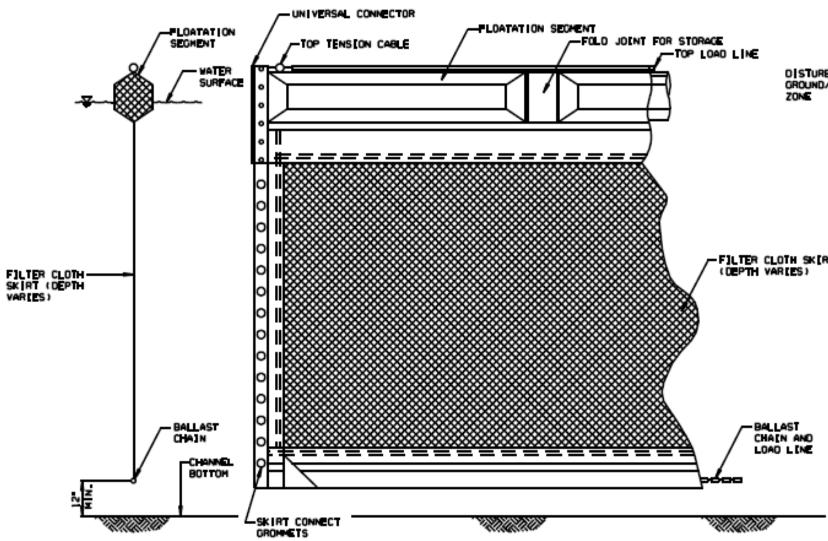
References

MDOT Drawing ECD-19

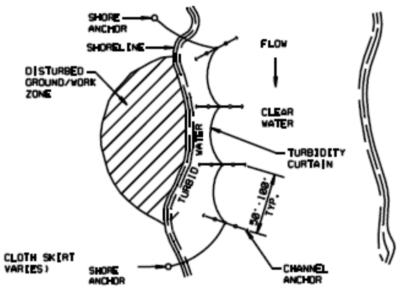
Floating Turbidity Curtain 4-277

STATE	PROJECT NO.
MISS.	

FLOATING TURBIDITY CURTAIN

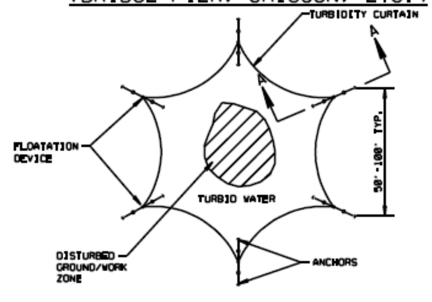


TYPICAL ANCHORING PLAN FOR SHORELINE/RIVER EDGE WORK



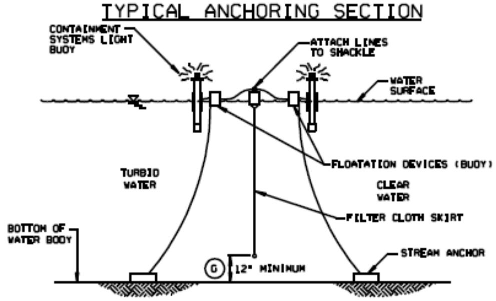
PLAN VIEW

TYPICAL ANCHORING PLAN FOR MID CHANNEL WORK (BRIDGE PIER, CAISSON, ETC.)



PLAN VIEW

TYPICAL ANCHORING SECTION



SECTION A-A

AUTOMATIC FLASHING LIGHT BUOY (ON AT DUSK-OFF AT DAWN) 100' ON CENTER SHALL BE USED IN NAVIGABLE CHANNELS ONLY

EROSION CONTROL PLAN LEGEND: FLOATING TURBIDITY CURTAIN

FLOATING TURBIDITY CURTAIN GENERAL NOTES

(A) FLOATING TURBIDITY CURTAINS (ALSO KNOWN AS TURBIDITY BARRIERS OR SILT CURTAINS) CREATE A BARRIER TO PREVENT TURBID WATER FROM ENTERING CLEAR WATER. FLOATING TURBIDITY CURTAINS SHOULD BE USED TO ISOLATE ACTIVE CONSTRUCTION AREAS WITHIN OR ADJACENT TO A BODY OF WATER TO MINIMIZE THE MIGRATION OF SILT LADEN WATER OUT OF THE CONSTRUCTION ZONE.

(B) TURBIDITY CURTAINS SHALL NOT BE INSTALLED PERPENDICULAR ACROSS THE MAIN FLOW OF A SIGNIFICANT BODY OF MOVING WATER.

(C) FLOATING TURBIDITY CURTAINS SHALL NO BE USED WHERE THE ANTICIPATED FLOW VELOCITIES WILL EXCEED 5 FT/SEC.

(D) TURBIDITY CURTAINS SHALL BE ANCHORED TO PREVENT DRIFT SHOREWARD OR DOWNSTREAM. ANCHORAGE SHALL BE INSTALLED ON BOTH SHORE AND STREAM SIDE. CURTAINS SHALL BE INSTALLED AS CLOSE TO PROJECT SITE AS POSSIBLE. BARRIERS SHOULD BE A BRIGHT COLOR (YELLOW OR "INTERNATIONAL" ORANGE ARE RECOMMENDED) THAT WILL ATTRACT THE ATTENTION OF NEARBY BOATERS.

(E) SHORE ANCHORS SHALL CONSIST OF A POST WITH DEADMAN OR APPROVED EQUAL. STREAM ANCHORS SHALL BE OF SUFFICIENT SIZE TO STABILIZE THE BARRIER WITH NUMBER AND SPACING DEPENDENT ON WATERWAY VELOCITIES AND MANUFACTURER'S RECOMMENDATIONS.

(F) IN SHALLOW WATER (2 FEET OF DEPTH OR LESS) A TURBIDITY CURTAIN MAY BE INSTALLED ON STAKES DRIVEN INTO THE BED OF THE WATER BODY.

(G) FABRIC SECTIONS SHALL BE CONNECTED END TO END WITH MINIMUM •' DIAMETER POLYPROPYLENE ROPE. FABRIC SHALL BE SEAMED TOGETHER IN A MANNER THAT RETAINS THE OVERALL TENSILE STRENGTH.

(H) DESIGN OF CURTAIN AND ANCHORAGE SHALL BE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS. FILTER CLOTH SKIRT SHOULD BE ABLE TO WITHSTAND THE FORCES IMPARTED ON IT DUE TO THE EXPECTED WIND VELOCITY OR STREAM VELOCITY. FABRIC SHALL BE MADE OF A NON-DETERIORATING MATERIAL, SUCH AS PLASTIC OR NYLON, WHICH WILL ALLOW WATER TO PASS THROUGH WHILE STILL RETAINING SEDIMENT.

(I) THE TURBIDITY CURTAIN AND ADJACENT WORK AREAS SHALL NOT BE DISTURBED 12 HOURS PRIOR TO REMOVAL FROM WATER BODY. MAINTENANCE SHALL BE PERFORMED AS NEEDED. CONTRACTOR SHALL REMOVE THE CURTAIN AT COMPLETION OF WORK IN A MANNER THAT WILL PREVENT SILTATION OF THE WATERWAY. DURING REMOVAL, EXTREME CARE SHOULD BE TAKEN NOT TO DISTURB ANY SEDIMENT DEPOSITS.

(J) MAINTAIN 12" MINIMUM GAP BETWEEN SKIRT BOTTOM AND CHANNEL BOTTOM TO PREVENT ACCUMULATED SEDIMENT FROM PULLING TOP OF CURTAIN BELOW WATER SURFACE.

(K) IN WIND OR WAVE ACTION SITUATIONS, THE MAXIMUM DEPTH OF THE CURTAIN SHALL BE 12 FEET.

(L) CONCENTRATED FLOWS SHALL NOT DISCHARGE BEYOND FLOATING TURBIDITY CURTAIN. CURTAINS ARE NOT TO BE INSTALLED ACROSS FLOWING BODY OF WATER.

(M) WHEN INSTALLED IN A NAVIGABLE WATERWAY, BUOYS SHOULD BE LIT ACCORDING TO REGULATORY AGENCY STANDARDS.

(N) WHEN ESTIMATING THE LENGTH OF TURBIDITY CURTAIN, ALLOW 10 TO 20 PERCENT VARIANCE IN STRAIGHT LINE MEASUREMENT.

(O) PAYMENT FOR FLOATING TURBIDITY CURTAIN SHALL INCLUDE ALL MATERIAL AND LABOR NECESSARY FOR CONSTRUCTION, MAINTENANCE, AND REMOVAL OF TURBIDITY CURTAINS

(P) ONLY FLOATING TURBIDITY CURTAINS LISTED ON THE APPROVED PRODUCTS LIST MAY BE USED.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

FLOATING TURBIDITY CURTAIN

WORKING NUMBER: ECD-19

SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-19.DGN

DESIGN TEAM ______ CHECKED ______ DATE ______

Rock Filter Dam (RD)

CD

Practice Description

A rock filter dam is a stone embankment designed to help capture sediment in natural or constructed drainageways on construction sites. This practice can also be used as a forebay to a sediment basin to help capture coarser particles of sediment. It is usually located so that it intercepts runoff (primarily from disturbed areas), is accessible for periodic sediment removal, and does not interfere with construction activities

Planning Considerations

Rock filter dams are used across drainageways to help remove coarser sediment particles and reduce off-site sediment delivery. Since rock filter dams are installed in flowing water, all local, state and federal laws and regulations must be followed during the design and construction process.

Dams should be designed so that impounded water behind the structures will not encroach on adjoining property owners or on other sediment- and erosion-control measures that outlet into the impoundment area.

Dams should be located so that the basin intercepts runoff (primarily from disturbed areas) and has adequate storage, and so that the basin can be accessed for sediment removal. Dams should also be located, as much as possible, in areas that do not interfere with construction activities.

Rock filter dams are not permanent structures. The design life of the structure is 3 years or less.

Design Criteria and Construction

Drainage Area

The drainage area above the dam should not exceed 10 acres.

Dam Height

The height of dam will be limited by the channel bank height or 8 feet, whichever is less. The dam height should also not exceed the elevation of the upstream property line. Water will bypass over the top of the dam, and the back slope of the rock dam should be designed to be stable.

Spillway Capacity

The top of the dam should be designed to handle the peak runoff from a 10-year, 24-hour design storm with a maximum flow depth of 1 foot and freeboard of 1 foot. Therefore, the center portion of the dam should be at least 2 feet lower than the outer edges at the abutment (see Figure RD-1).

Dam Top Width

The minimum top width should be 6 feet (see Figure RD-2).

Dam Side Slopes

Side slopes should be 3:1 (horizontal: vertical) or flatter on the back slope and 2.5:1 (horizontal: vertical) or flatter on the front slope.

Outlet Protection

The downstream toe of the dam should be protected from erosion by placing a riprap apron at the toe. The apron should be placed on a zero grade with a riprap thickness of 1.5 feet. The apron should have a length equal to the height of the dam as a minimum (and longer, if needed) to protect the toe of the dam.

Location

The dam should be located as close to the source of sediment as possible so that it will not cause water to back up onto adjoining property.

Basin Requirements

The basin behind the dam should provide a surface area that maximizes the sediment trapping efficiency. The basin should have a sediment storage capacity of 67 cubic yards per acre of drainage area.

Riprap Requirements

Stone for riprap should consist of field stone or rough, unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering, and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

The minimum median stone size should be 9″. The gradation of rock to be used should be specified using Tables RD-1 and RD-2. Table RD-1 is used to determine the weight of the median stone size (d_{50}). Using this median weight, a gradation can be selected from Table RD-2, which shows the commercially available riprap gradations as classified by the Mississippi Department of Transportation.

The dam should be faced with 1 foot of smaller stone (½″ to ¾″ gravel) on the upstream side to increase efficiency for trapping coarser particles.

Table RD-1 Size of Riprap Stones

Weight	Mean Spherical Diameter (ft)	Rectangular Shape Length	Width, Height (ft)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	5.4	1.8
4000	3.6	6.0	2.0
6000	4.0	6.9	2.3
8000	4.5	7.6	2.5
20000	6.1	10.0	3.3

Table RD-2 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Geotextiles

Geotextiles should be used as a separator between the graded stone, the soil base, and the abutments. Class I geotextile, as specified in Table RD-3 below, should be used. Geotextile should be placed immediately adjacent to the subgrade with no voids between the fabric and the subgrade.

Table RD-3 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [1]
Tensile strength (lb)[2]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%)[2]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. no. 40[3]	As specified max. no. 40[3]	As specified max. no. 40[3]	As specified max. no. 40[3]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

[1] Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextile are required for all other classes.

[2] Minimum average roll value (weakest principal direction).

[3] U.S. standard sieve size.

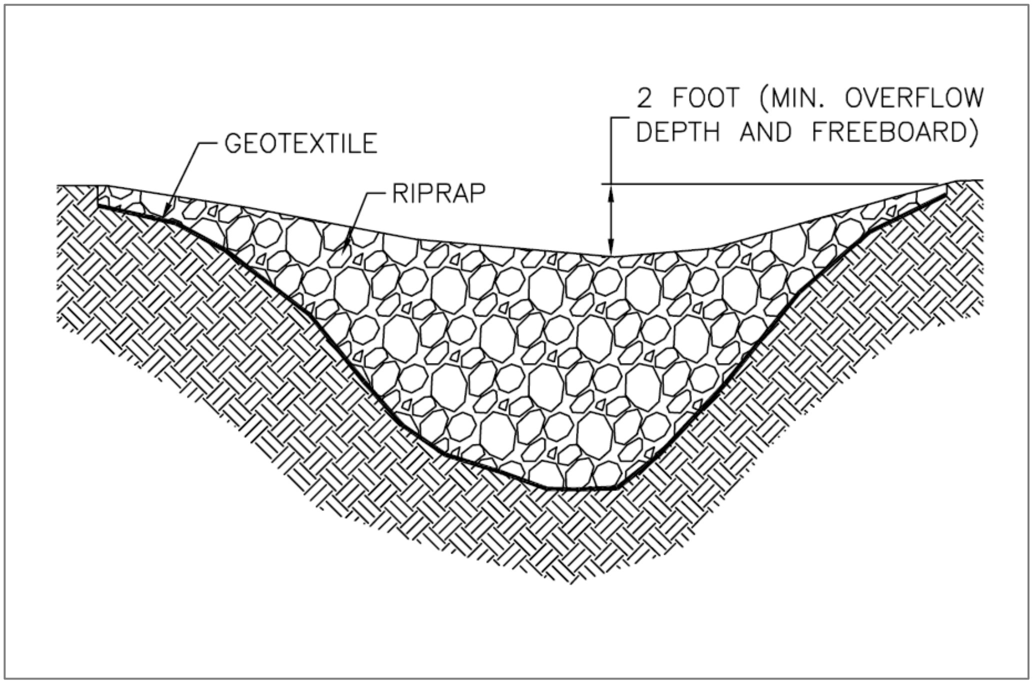


Figure RD-1 Typical Front View of Rock Filter Dam

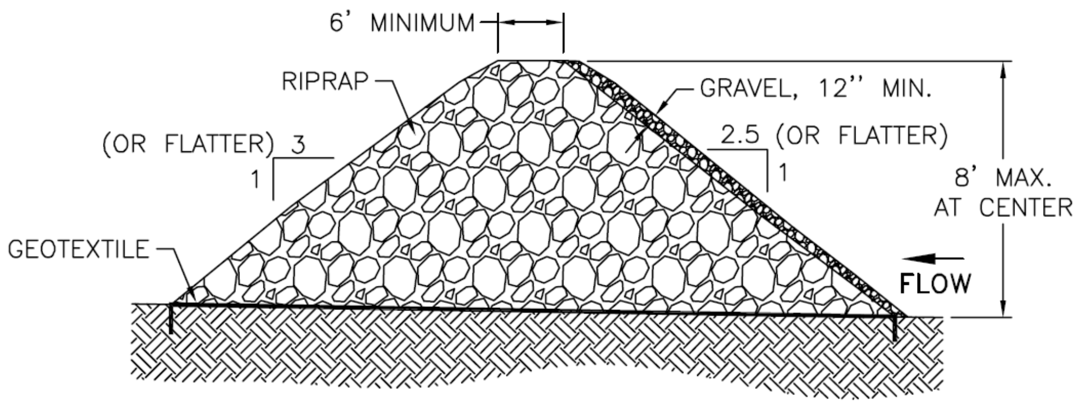


Figure RD-2 Typical Section of Rock Filter Dam

Construction

Prior to start of construction, rock filter dams should be designed by a qualified design professional. The rock filter dam plan should include details on dam height, dam top width, dam side slopes, and rock size(s). Plans and specifications should be referred to by field personnel throughout the construction process.

Site Preparation

Determine exact location of underground utilities, and avoid construction over and under utilities.

Clear and grub the area under the dam, removing and properly disposing of all root material, brush, and other debris.

Divert runoff from undisturbed areas away from the rock dam and basin area. Smooth the dam foundation.

If specified, cover the foundation with geotextile fabric, making sure the upstream strips overlap the downstream strips at least 1 foot and the upslope end is embedded into the foundation at least 1 foot.

Rock Placement

Construct the dam by placing well-graded, hard, angular, durable rock of the specified size over the foundation to planned dimensions and securely embed into both channel banks.

Once the dam is in place, clear the sediment basin area and dispose of the cleared material.

Set a marker stake to indicate the clean-out elevation (i.e., point at which the basin is 50% full of sediment).

Erosion and Sediment Control

Stabilize all disturbed areas with either *Temporary* or *Permanent Seeding.*

Construction Verification

Check materials and finished elevations of the rock filter dam for compliance with specifications.

Common Problems

Consult with a qualified design professional if any of the following occurs:

Variations in topography on site indicate rock filter dam will not function as intended; changes in plan may be needed.

Materials specified in the plan are not available.

Maintenance

Inspect the rock dam and basin after each storm event.

Check the dam for rock displacement and the abutments for erosion and repair immediately when repair is needed. If rock size appears too small or embankment slope is too steep, replace stone with larger size or reduce slope.

Check the drainageway at toe of dam for erosion. If erosion is occurring, a repair involving geotextile fabric (including another toe-in) and additional rock are probably needed to establish a stable outlet.

Remove sediment from the pond reservoir area when it accumulates to ½ the design volume. If the basin does not drain between storms because the filter stone (small gravel) on the upstream face has become clogged, the clogged filter stone should be replaced with clean stone.

Once the construction site is permanently stabilized, remove the structure and any unstable sediment. Smooth the basin site to blend with the surrounding area and stabilize. Sediment should be placed in designated disposal areas and stabilized.

References

BMPs from Volume 1

Chapter 4

Mulching (MU)	4-48
Permanent Seeding (PS)	4-53
Temporary Seeding (TS)	4-103

Sediment Barrier (SB)

Practice Description

Silt fencing is a temporary sediment barrier used across a landscape to reduce the quantity of sediment that is moving farther downslope. Commonly used barriers include silt fence (a geotextile fabric that is trenched into the ground and attached to supporting posts) or hay bales trenched into the ground. Other barrier materials include sand bags, brush piles, and various man-made materials and devices that can be used in a similar manner as silt fence and hay bales.

This practice applies where sheet and rill erosion occurs on small disturbed areas. Barriers intercept runoff from upslope to form ponds that temporarily store runoff and allow sediment to settle out of the water and stay on the construction site.

Planning Considerations

Sediment barriers may be used on developing sites. They should be installed on the contour so that flow will not concentrate and cause bypassing by runoff going around the end of the barrier or overtopping because of lack of storage capacity.

The most commonly used sediment barriers are silt fences, manufactured sediment logs (several names other than "logs" are used), and hay bales. Silt fences and manufactured sediment logs are preferable to hay bales because they are more likely to be installed correctly. The design and installation of a hay bale sediment barrier is the same as for *Straw Bale Sediment Traps*. Manufactured sediment logs should be installed according to manufacturer's recommendations.

The silt fence is the only sediment barrier covered in this manual.

The success of silt fences depends on a proper installation that causes the fence to develop maximum efficiency of sediment trapping. Silt fences should be carefully installed to meet the intended purpose.

A silt fence is specifically designed to retain sediment transported by sheet flow from disturbed areas, while allowing water to pass through the fence. Silt fences should be installed to be stable under the flows expected from the site. Silt fences should not be installed across streams, ditches, waterways, or other concentrated flow areas.

Silt fences are composed of woven geotextile supported between steel or wooden posts. Silt fences are commercially available with geotextile attached to the post, and can be rolled out and installed by driving the post into the ground. This type of silt fence is simple to install, but more expensive than some other installations. Silt fences must be trenched in at the bottom to prevent runoff from undermining the fence and developing rills under the fence. Locations with high runoff flows or velocities should use wire reinforcement.

Design Criteria

Silt fence installations are normally limited to situations in which only sheet- or overland-flow is expected because they normally cannot pass the volumes of water generated by channel flows. Silt fences are normally constructed of synthetic fabric (woven geotextile), and the life is expected to be the duration of most construction projects. Silt fence fabric should conform to the requirements of Table SB-1.

The drainage area behind the silt fence should not exceed ¼ acre per 100 linear feet of silt fence for non-reinforced fence and ½ acre per 100 linear feet of wire-reinforced fence. When all runoff from the drainage area is to be stored behind the fence (i.e. no stormwater disposal system is in place), the maximum slope length behind the fence should not exceed the value shown in Table SB-2.

Type A Silt Fence

The Type A fence is 36″ wide with wire reinforcement and is used on sites needing the highest degree of protection by a silt fence. The wire reinforcement is necessary because the Type A silt fence is used for the highest flow situations and has almost 3 times the flow rate as the Type B silt fence. Type A silt fence should be used where runoff flows or velocities are particularly high or where slopes exceed a vertical height of 10 feet.

Provide a riprap splash pad or other outlet protection device for any point where flow may overtop the sediment fence. Ensure that the maximum height of the fence at a protected, reinforced outlet does not exceed 1 foot and that support post spacing does not exceed 4 feet.

This silt fence should be installed as shown in Figure SB-1. Materials for posts and fasteners are shown in Tables SB-3 and SB-4. Details for overlap of the silt fence and fastener placement are shown in Figure SB-4.

Table SB-1 Specifications for Silt Fence

Specifications	Type A	Type B	Type C
Tensile Strength (Lbs. Min.)[1] (ASTM D-4632)	Warp – 260 Fill – 100	Warp – 120 Fill – 100	Warp – 120 Fill – 100
Elongation (% Max.) (ASTM D-4632)	40	40	40
AOS (Apparent Opening Size) (Max. Sieve Size) (ASTM D-4751)	No. 30	No. 30	No. 30
Flow Rate (Gal/Min/Sq. Ft.) (GDT-87)	70	25	25
Ultraviolet Stability[2] (ASTM D-4632 after 300 hours weathering in accordance with ASTM D-4355)	80	80	80
Bursting Strength (PSI Min.) (ASTM D-3786 Diaphragm Bursting Strength Tester)	175	175	175
Minimum Fabric Width (Inches)	36	36	22

[1] Minimum roll average of five specimens.
[2] Percent of required initial minimum tensile strength.

Table SB-2 Slope Limitations for Silt Fence

Land Slope (Percent)	Maximum Slope Length Above Fence (Feet)
<2	100
2 to 5	75
5 to 10	50
10 to 20*	25
>20	15

*In areas where the slope is greater than 10%, a flat area length of 10 feet between the toe of the slope to the fence should be provided.

Type B Silt Fence

This 36″ wide filter fabric should be used on developments where the life of the project is greater than or equal to 6 months.

This silt fence should be installed as shown in Figure SB-2. Materials for posts and fasteners are shown in Tables SB-3 and SB-4. Details for overlap of the silt fence and fastener placement are shown in Figure SB-4.

Type C Silt Fence

Though only 22″ wide, this filter fabric allows the same flow rate as Type B silt fence. Type C silt fence should be limited to use on relatively minor projects, such as residential home sites or small commercial developments where permanent stabilization will be achieved in less than 6 months.

This silt fence should be installed as shown in Figure SB-3. Materials for posts and fasteners are shown in Tables SB-3 and SB-4. Details for overlap of the silt fence and fastener placement are shown in Figure SB-4.

Table SB-3 Post Size for Silt Fence

	Minimum Length	**Type of Post**	**Size of Post**
Type A	4’	Steel	1.3 lb./ft. min.
Type B	4’	Soft Wood Oak Steel	3″ diameter or 2 X 4 1.5″ X 1.5″ 1.3 lb./ft. min.
Type C	3’	Soft Wood Oak Steel	2″ diameter or 2 X 2 1″ X 1″ 0.75 lb./ft. min.

Table SB-4 Wood Post Fasteners for Silt Fence

	Gauge	**Crown**	**Legs**	**Staples/Post**
Wire Staples	17 min.	¾″ wide	½″ long	5 min.
	Gauge	Length	Button Heads	Nail/Post
Nails	14 min.	1″	¾″ long	4 min.

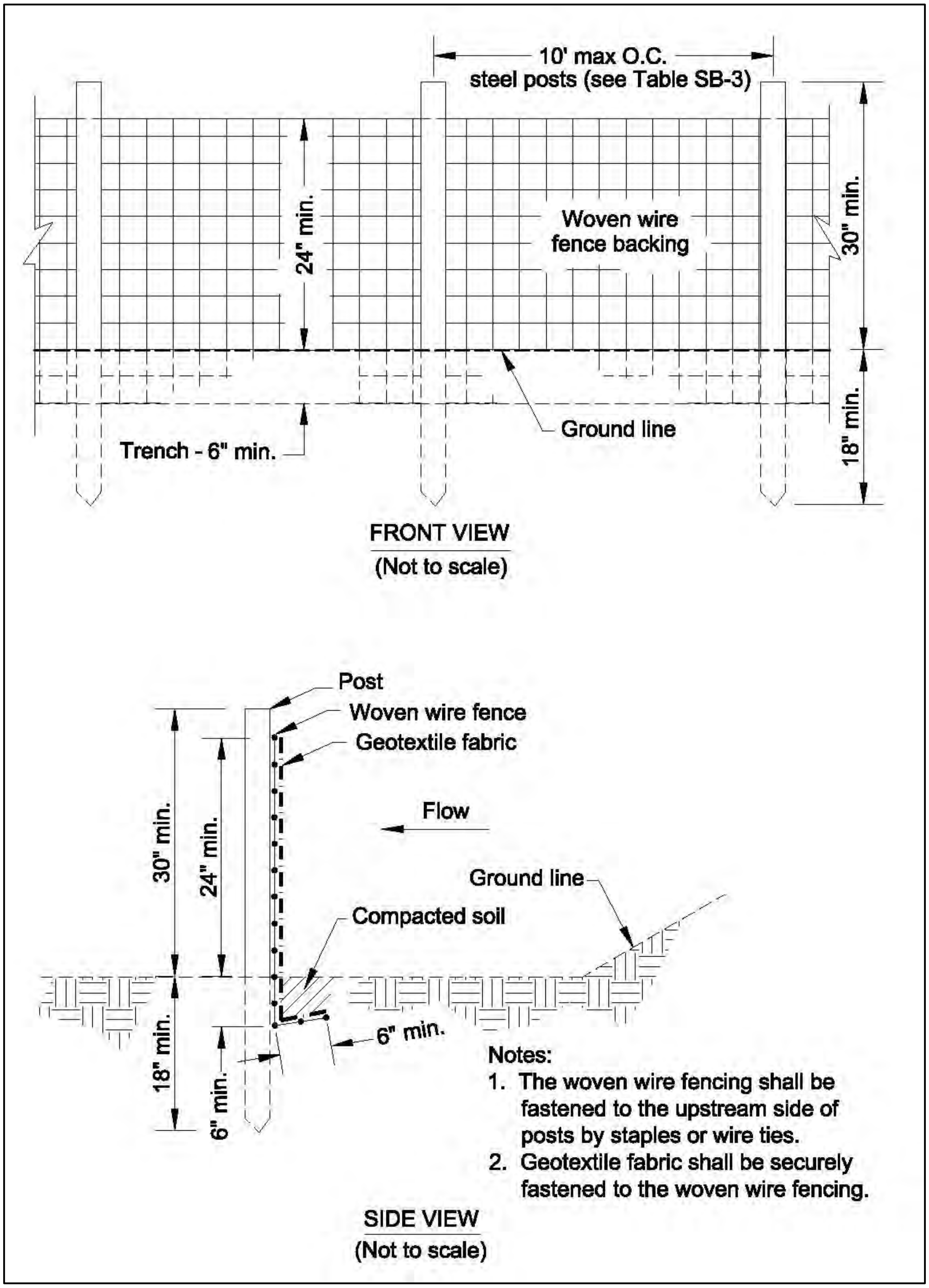


Figure SB-1 Silt Fence-Type A

(1) For fabric material requirements see Table SB-1
(2) For post material requirements see Tables SB-3 and SB-4

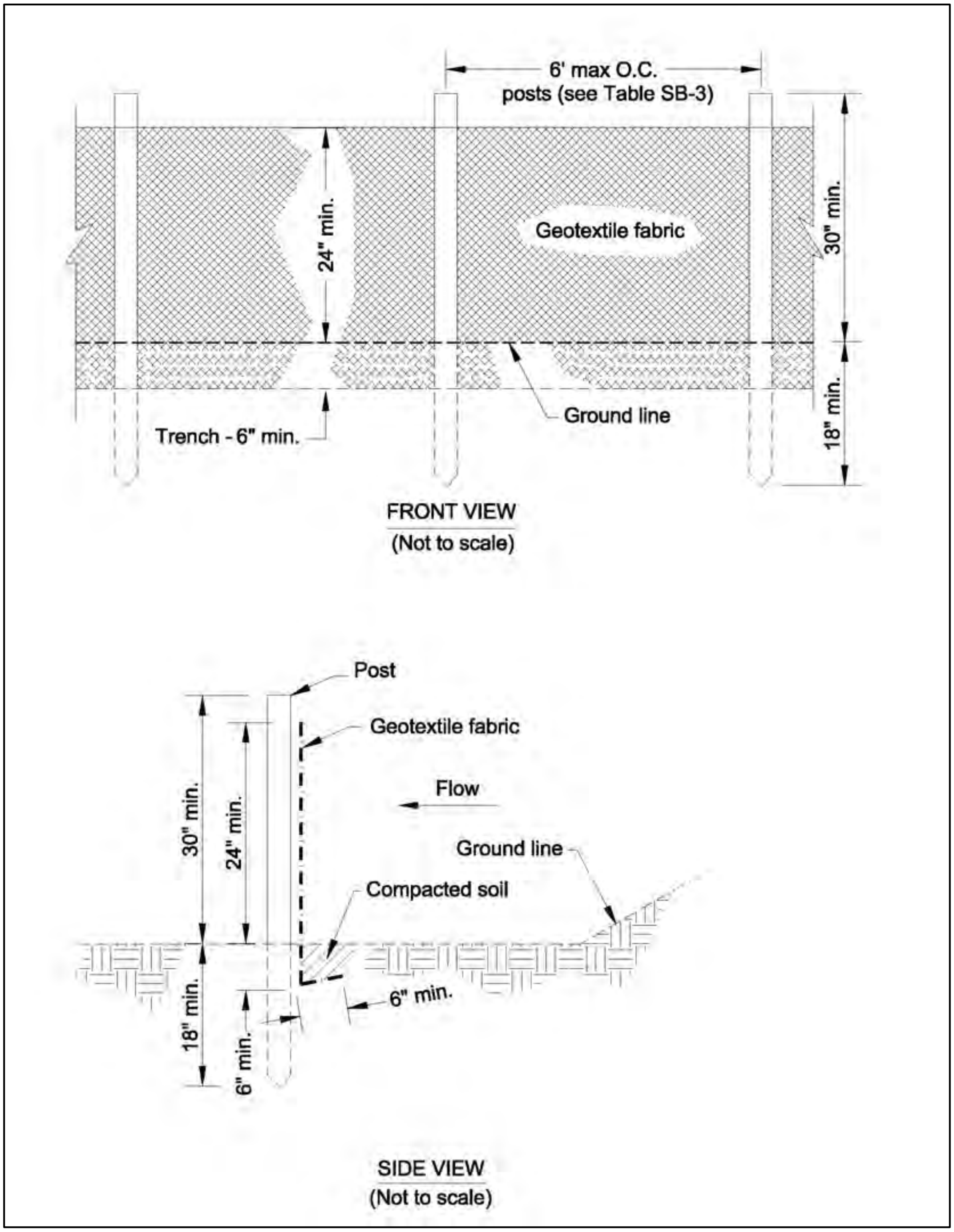


Figure SB-2 Silt Fence - Type B

(1) For fabric material requirements see Table SB-1
(2) For post material requirements see Tables SB-3 and SB-4

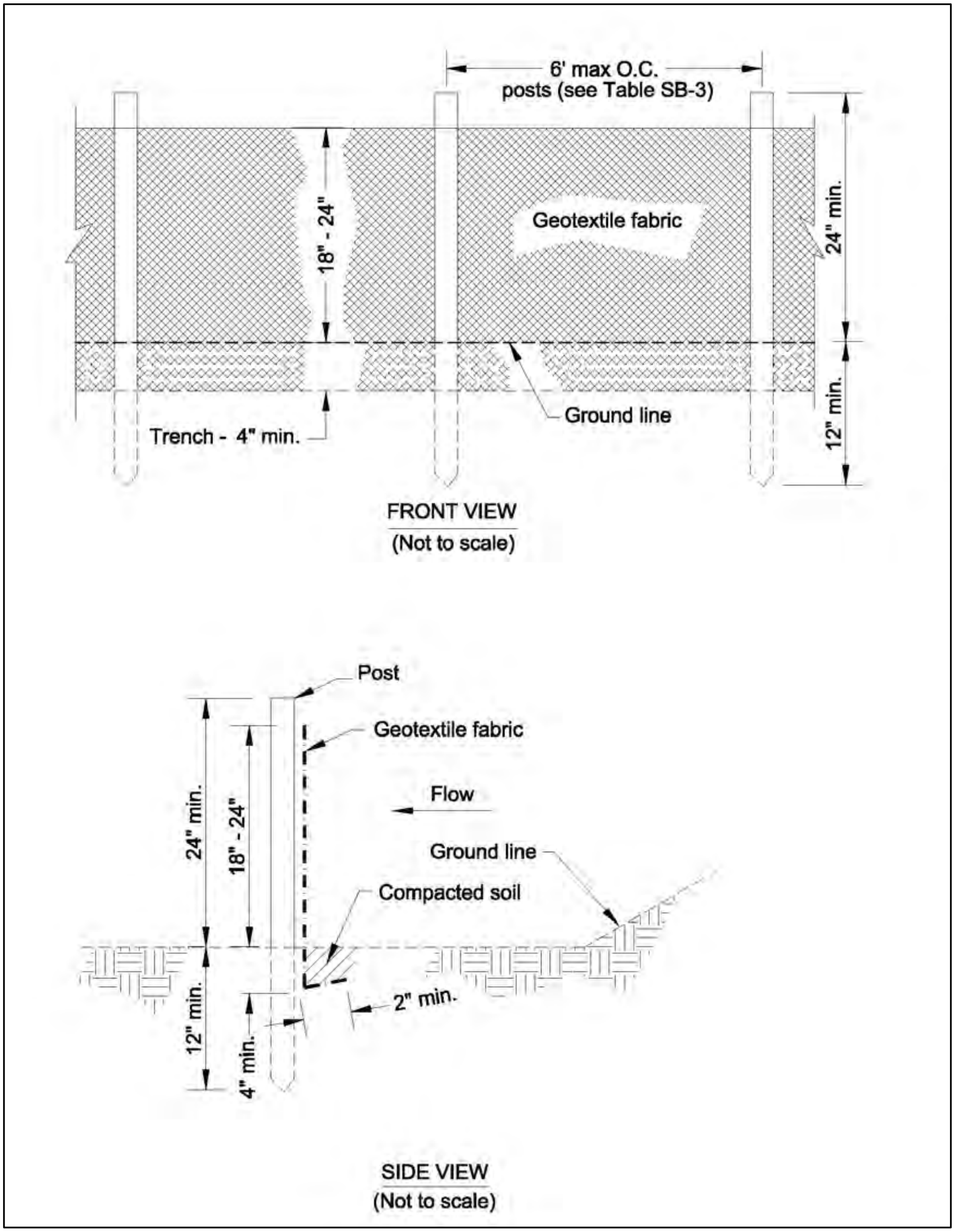
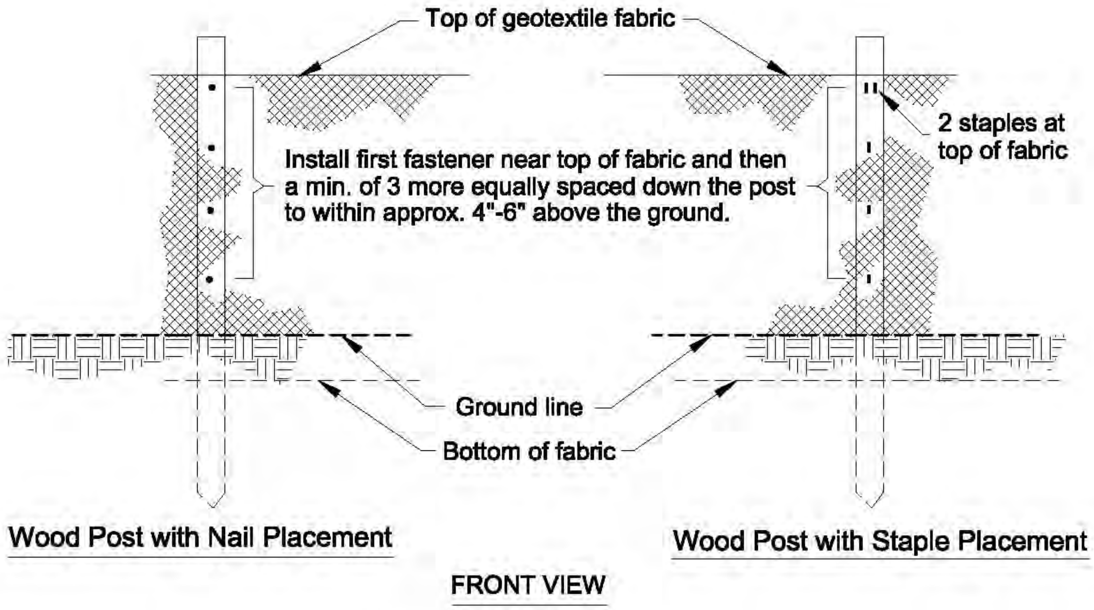
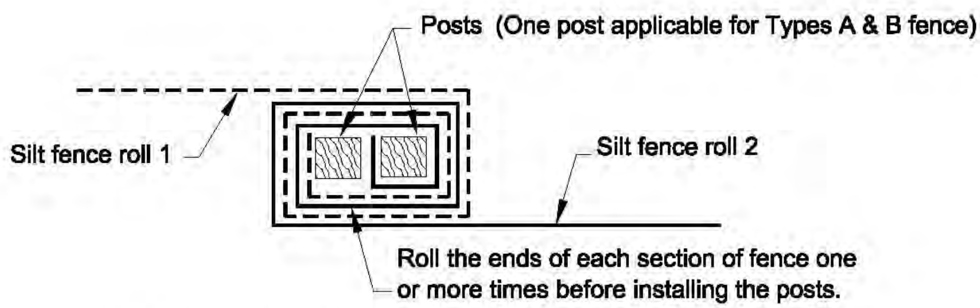


Figure SB-3 Silt Fence – Type C

(1) For fabric material requirements see Table SB-1
(2) For post material requirements see Tables SB-3 and SB-4



FASTENERS FOR SILT FENCES
(Not to scale)



ROLL JOINT FOR JOINING TWO ADJACENT SILT FENCE SECTIONS
(Not to scale)

Figure SB-4 Silt Fence Installation Details

Construction

Prior to start of construction, sediment barriers should be designed by a qualified professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Note: Silt fence is the only barrier installation being covered in this handbook.

Site Preparation

Determine exact location of underground utilities so that locations for digging or placement of stakes can be selected where utilities will not be damaged.

Smooth the construction zone to provide a broad, nearly level area for the fence. The area should be wide enough throughout the length of the fence to provide storage of runoff and sediment behind the fence.

Silt Fence Installation

Silt fence should be installed on the contour, so that runoff can be intercepted as sheet flow; ends should be flared uphill to provide temporary storage of water. Silt fence should be placed so that runoff from disturbed areas must pass through the fence. Silt fence should not be placed across concentrated flow areas such as channels or waterways. When placed near the toe of a slope, the fence should be installed far enough from the slope toe to provide a broad, flat area for adequate storage capacity for sediment. Dig a trench at least 6″ deep along the fence alignment as shown in Figures SB-1 and SB-2 for Types A & B fences. Type C fences require only a 4″ deep trench as shown in Figure SB-3. **Please note that installation with a silt fence installation machine may permit different depths if performance is equal.**

Drive posts at least 18″ into the ground on the downslope side of the trench. Space posts a maximum of 10 feet if fence is supported by woven wire, or 6 feet if high-strength fabric and no support fence is used.

Fasten support wire fence to upslope side of posts, extending 6″ into the trench, as shown in the appropriate figure for the type fence (see Figure SB-1, SB-2 or SB-3).

Attach a continuous length of fabric to the upslope side of fence posts. Minimize the number of joints and, when necessary to join rolls, they should be joined by rolling the ends together using the “roll joint” method illustrated in Figure SB-4. Avoid joints at low points in the fence line.

For Types A and B silt fence, place the bottom 12″ of fabric in the 6″ deep (minimum) trench, lapping toward the upslope side. For Type C fabric, place the bottom 6″ in the 4″ deep (minimum) trench lapping toward the upslope side.

Backfill the trench with compacted earth or gravel as shown in Figures SB-1 – SB-3.

Provide good access in areas of heavy sedimentation for cleanout and maintenance.

Erosion Control

Stabilize disturbed areas in accordance with the vegetation plan. If no vegetation plan exists, consider planting and mulching as a part of barrier installation, and select planting information from the appropriate planting practice (*Permanent Seeding* or T*emporary Seeding*). Select mulching information from the *Mulching Practice*.

Construction Verification

Check finished grades and dimensions of the sediment fence. Check materials for compliance with specifications.

Common Problems

Consult with a qualified design professional if any of the following occurs:

Variations in topography on site indicate sediment fence will not function as intended, or alignment is not on contour, or fence crosses concentrated flow areas; changes in plan may be needed.

Design specifications for filter fabric, support posts, support fence, gravel, or riprap cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Drainage area appears to exceed ¼ acre for 100 feet of non-reinforced silt fence and ½ acre for 100 feet for reinforced fence. Additional sediment-control BMPs may be required.

Maintenance

Inspect sediment fences at least once a week and after each significant rain event.

Make required repairs immediately.

Should the fabric of silt fence collapse, tear, decompose, or become ineffective, replace it promptly.

Remove sediment deposits when they reach a depth of 15″ or ½ the height of the fence as installed, to provide adequate storage volume for the next rain event and to reduce pressure on the fence.

After the contributing drainage area has been properly stabilized, remove all barrier materials and unstable sediment deposits, bring the area to grade, and stabilize it with vegetation.

References

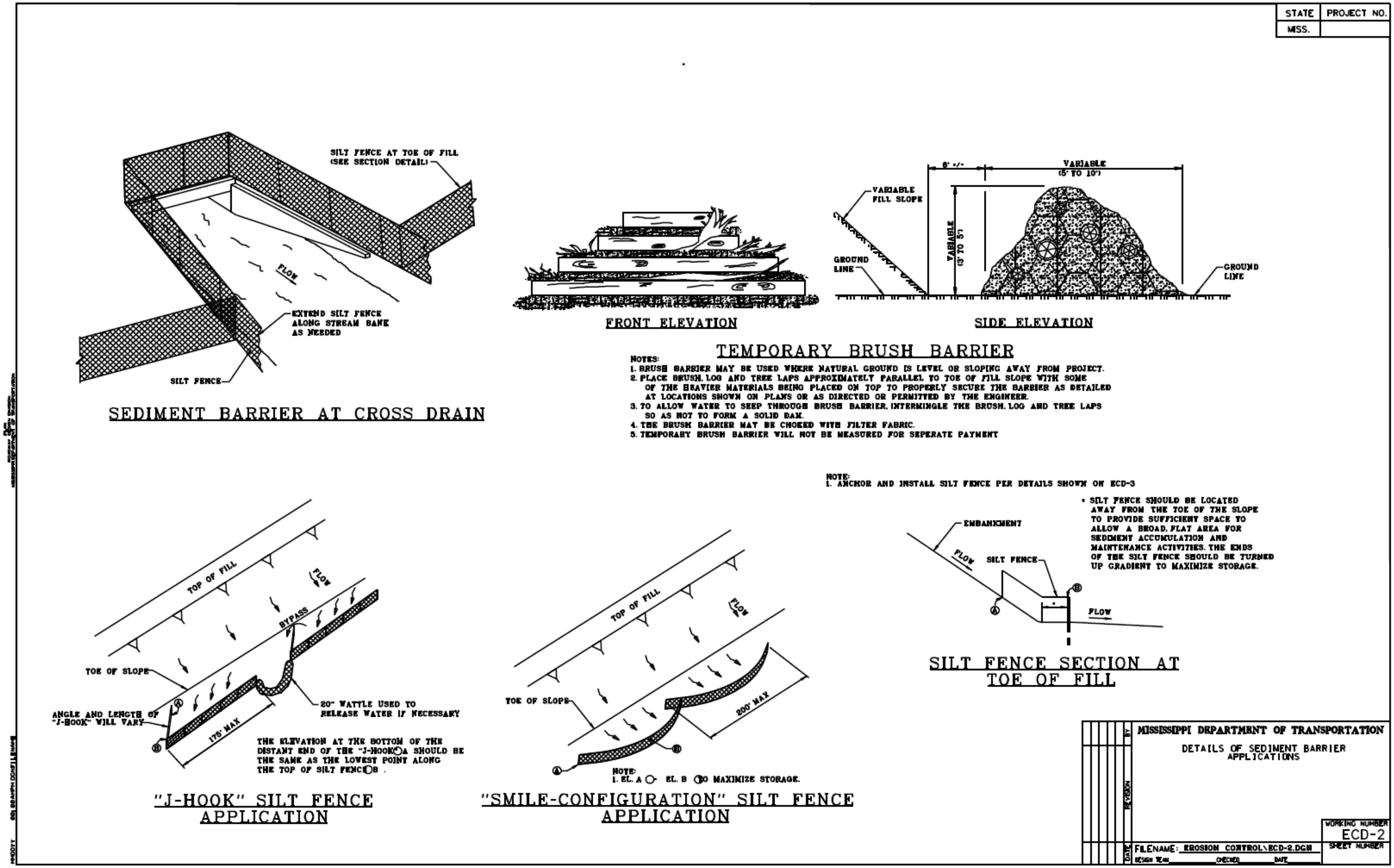
BMPs from Volume I

Chapter 4

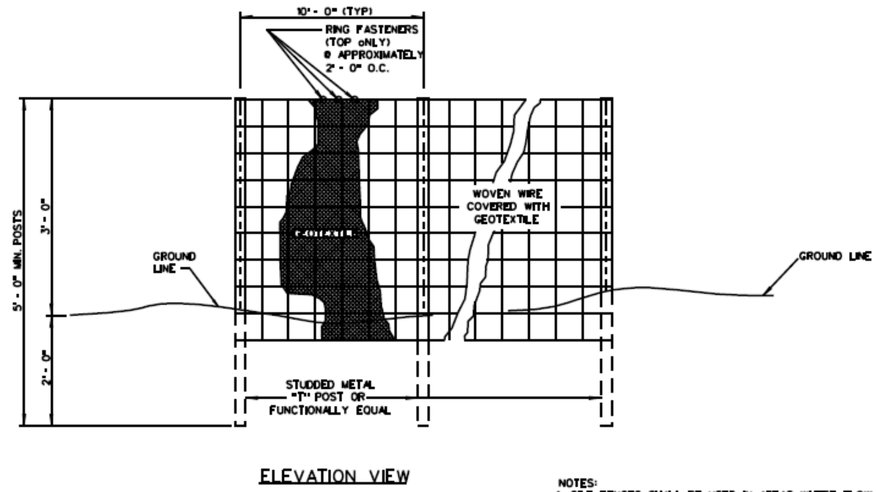
MDOT Drawing ECD-2

MDOT Drawing ECD-3

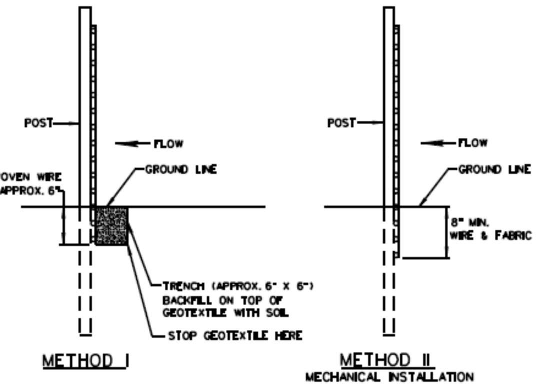
MDOT Drawing SSF-1


STATE
PROJECT NO.
MISS.
SILT FENCE AT TOE OF FILL (SEE SECTION DETAIL)
FLOW
EXTEND SILT FENCE ALONG STREAM BANK AS NEEDED
SILT FENCE
SEDIMENT BARRIER AT CROSS DRAIN
FRONT ELEVATION
6' +/-
VARIABLE (5' TO 10')
VARIABLE FILL SLOPE
VARIABLE (3' TO 5')
GROUND LINE
GROUND LINE
SIDE ELEVATION
TEMPORARY BRUSH BARRIER
NOTES:
1. BRUSH BARRIER MAY BE USED WHERE NATURAL GROUND IS LEVEL OR SLOPING AWAY FROM PROJECT.
2. PLACE BRUSH, LOG AND TREE LAPS APPROXIMATELY PARALLEL TO TOE OF FILL SLOPE WITH SOME OF THE HEAVIER MATERIALS BEING PLACED ON TOP TO PROPERLY SECURE THE BARRIER AS DETAILED AT LOCATIONS SHOWN ON PLANS OR AS DIRECTED OR PERMITTED BY THE ENGINEER.
3. TO ALLOW WATER TO SEEP THROUGH BRUSH BARRIER, INTERMINGLE THE BRUSH, LOG AND TREE LAPS SO AS NOT TO FORM A SOLID DAM.
4. THE BRUSH BARRIER MAY BE CHOKED WITH FILTER FABRIC.
5. TEMPORARY BRUSH BARRIER WILL NOT BE MEASURED FOR SEPERATE PAYMENT
NOTE:
1. ANCHOR AND INSTALL SILT FENCE PER DETAILS SHOWN ON ECD-3
• SILT FENCE SHOULD BE LOCATED AWAY FROM THE TOE OF THE SLOPE TO PROVIDE SUFFICIENT SPACE TO ALLOW A BROAD, FLAT AREA FOR SEDIMENT ACCUMULATION AND MAINTENANCE ACTIVITIES. THE ENDS OF THE SILT FENCE SHOULD BE TURNED UP GRADIENT TO MAXIMIZE STORAGE.
EMBANKMENT
FLOW
SILT FENCE
FLOW
SILT FENCE SECTION AT TOE OF FILL
TOP OF FILL
FLOW
BYPASS
TOE OF SLOPE
ANGLE AND LENGTH OF "J-HOOK" WILL VARY
175' MAX
20" WATTLE USED TO RELEASE WATER IF NECESSARY
THE ELEVATION AT THE BOTTOM OF THE DISTANT END OF THE "J-HOOK" A SHOULD BE THE SAME AS THE LOWEST POINT ALONG THE TOP OF SILT FENCE B .
"J-HOOK" SILT FENCE APPLICATION
TOP OF FILL
FLOW
TOE OF SLOPE
200' MAX
NOTE:
1. EL. A - EL. B TO MAXIMIZE STORAGE.
"SMILE-CONFIGURATION" SILT FENCE APPLICATION
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
DETAILS OF SEDIMENT BARRIER APPLICATIONS
WORKING NUMBER
ECD-2
SHEET NUMBER
FILENAME: EROSION CONTROL\ECD-2.DGN
DESIGN TEAM
CHECKED
DATE
REVISION
DATE
BY

STATE	PROJECT NO.
MISS.	



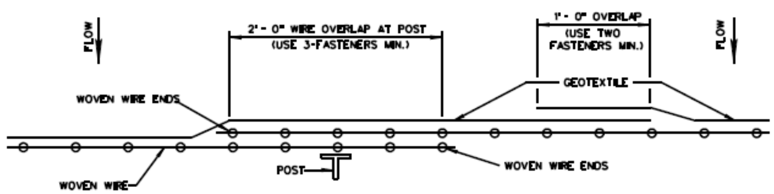
ELEVATION VIEW



SIDE VIEW

NOTES:

1. SILT FENCES SHALL BE USED IN AREAS WHERE FLOW IS NOT SEVERE.
2. SILT FENCES ARE TEMPORARY SEDIMENT CONTROL ITEMS THAT SHALL BE ERECTED OPPOSITE ERODIBLE AREAS SUCH AS NEWLY GRADED FILL SLOPES AND ADJACENT TO STREAMS AND CHANNELS.
3. SILT FENCE SHOULD BE PLACED WELL INSIDE RIGHT-OF-WAY AND ALONG EDGE OF CLEARING LIMITS. THIS WILL ALLOW ROOM FOR A BACK-UP FENCE IF FIRST FENCE BECOMES FULL.
4. WHEREVER POSSIBLE SILT FENCE SHALL BE CONSTRUCTED ACROSS A LEVEL AREA IN THE SHAPE OF A SMILE. THIS AIDS IN PONDING OF RUNOFF AND FACILITATES SEDIMENTATION.
5. THE CONTRACTOR MAY ELECT TO USE EITHER METHOD I OR METHOD II. COST TO BE LINEAR FEET OF SILT FENCE.
6. METHOD II INSTALLATION SHALL BE ACCOMPLISHED USING AN IMPLEMENT THAT IS MANUFACTUREED FOR THE APPLICATION AND PROVIDES A CONFIGURATION MEETING THE REQUIREMENTS OF THE DETAIL.
7. WIRE SHALL BE MINIMUM OF 32" IN WIDTH AND SHALL HAVE A MINIMUM OF 6 LINE WIRES WITH 12" STAY SPACING.
8. GEOTEXTILE FABRIC MEETING THE TYPE I MATERIAL REQUIREMENTS AND INSTALLED ACCORDING TO SPECIFICATION MAY BE USED WITHOUT WIRE FENCE.



PLAN VIEW

REQUIRED LAPPING

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

DETAILS OF SILT FENCE INSTALLATION

WORKING NUMBER ECD-3

SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-3.DGN

DESIGN TEAM ______ CHECKED ______ DATE ______

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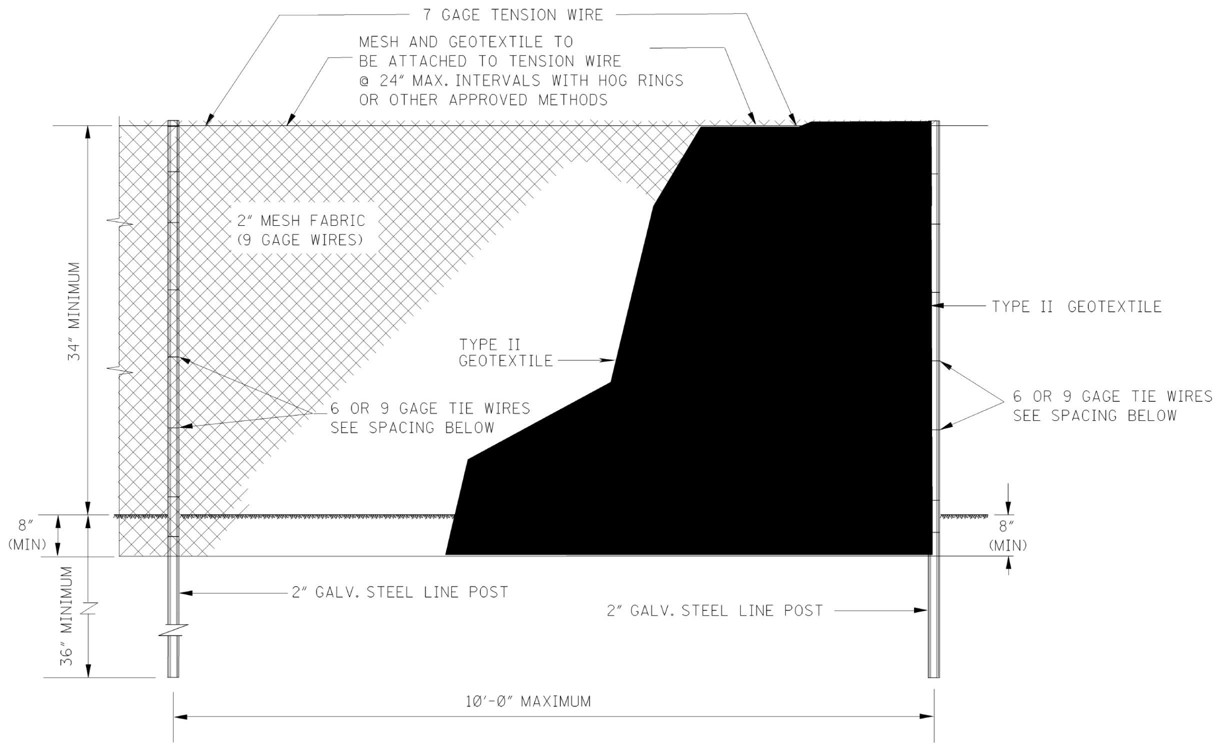
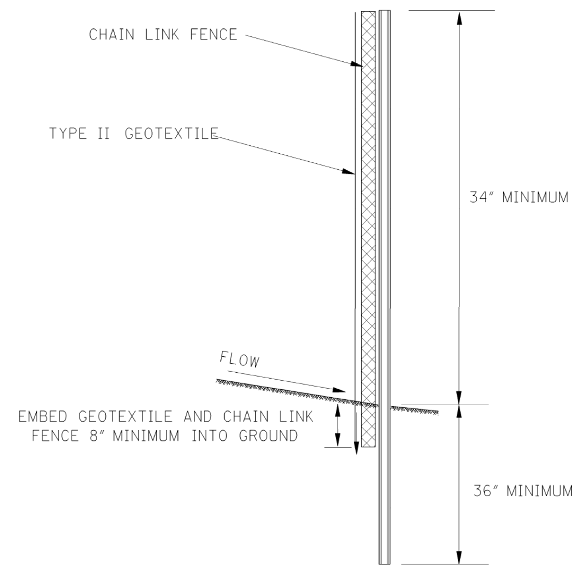
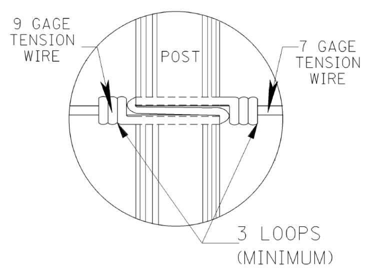






TENSION WIRE TIE DETAILS

6 OR 9 GAGE TIE WIRE SPACING	
TOTAL TEST LOAD (lbs)	TIE WIRE SPACING (C-C)
518	12"
475-517	11"
430-474	10"
387-429	9"
344-386	8"
301-343	7"
258-300	6"

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

SUPER SILT FENCE

BY REVISION DATE

WORKING NUMBER SSF-1

SHEET NUMBER

FILENAME: SSF-1.DGN

DESIGN TEAM ________ CHECKED ________ DATE ________

MISSISSIPPI DEPARTMENT OF TRANSPORTATION ROADWAY DESIGN DIVISION

11/17/2010 7:54 AM SSF-1.DGN

Sediment Basin (SBN)

Practice Description

A sediment basin is an earthen embankment suitably located to capture runoff, with an emergency spillway lined to prevent spillway erosion, interior porous baffles to reduce turbulence and evenly distribute flows, and equipped with a floating skimmer for dewatering. Sediment basins are designed to provide an area for runoff to pool and settle out a portion of the sediment. Old technology utilized a perforated riser for dewatering, which allowed water to leave the basin from all depths. One way to improve the sediment capture rate is to have an outlet that dewaters the basin from the top of the water column where the water is cleanest. A skimmer is probably the most common method to dewater a sediment basin from the surface. The basic concept is that the skimmer does not dewater the basin as fast as runoff enters it but, instead, allows the basin to fill and then slowly drain over multiple days. This process has two effects. First, the sediment in the runoff has more time to settle out prior to discharge. Second, a pool of water forms early in a storm event, which increases sedimentation rates in the basin and reduces turbidity. Many of the storms will produce more volume than the typical sediment basin capacity and flow rates in excess of the skimmer capability, resulting in flow over the emergency spillway. This water is also coming from the top of the water column and has thereby been "treated" to remove sediment as much as possible (adapted from *Soil Facts: Dewatering Sediment Basins Using Surface Outlets*, N. C. State University, Soil Science Department).

Planning Considerations

Sediment basins are needed where drainage areas are too large for other sediment-control practices.

Select locations for basins during initial site evaluation. Locate basin so that sudden failure should not cause loss of life or serious property damage. Install sediment basins before any site grading takes place within the drainage area.

Select sediment basin sites to capture sediment from all areas that are not treated adequately by other sediment-control measures. Always consider access for cleanout and disposal of the trapped sediment. Locations where a pond can be formed by constructing a low dam across a natural swale are generally preferred to sites that require excavation. Where practical, divert sediment-free runoff away from the basin.

Because the emergency spillway is actually used relatively frequently, it is generally stabilized using geotextile and riprap that can withstand the expected flows without erosive velocities. The spillway should be placed as far from the inlet of the basin as possible to maximize sedimentation before discharge. The spillway should be located in natural ground (not over the embankment) to the greatest extent possible.

As discussed in the *Chemical Stabilization Practice,* the proper introduction of polyacrylamides (PAM) into the turbid runoff water at the inlet of the basin and/or at the first baffle should be considered to help polish the discharge from the basin for decreasing the turbidity. See the *Flocculants and Polymers Practice*.

Where heavy loads of coarse sediment are expected, a forebay or sump area prior to the basin should be considered for capture of heavier particles.

Baffles

Porous baffles effectively spread the flow across the entire width of a sediment basin, or trap and cause increased deposition within the basin. Water flows through the baffle material, but is slowed sufficiently to back up the flow, causing it to spread across the entire width of the baffle (Figure SBN-1). Spreading the flow in this manner utilizes the full cross section of the basin and reduces turbulence, which shortens the time required for sediment to be deposited.

The installation of baffles should be similar to a silt fence (Figure SBN-2) utilizing posts and wire backing. The most proven material for a baffle is 700-900 g/m^2 coir erosion blanket (Figure SBN-3). Other materials proven by research to be equivalent in this application may be used. A support wire or rope across the top will help prevent excessive sagging if the material is attached to it with appropriate ties. Another option is to use a sawhorse type of support with the legs stabilized with rebar inserted into the basin floor. These structures work well and can be prefabricated off-site and quickly installed.

Baffles need to be installed correctly to fully provide their benefits. Refer to Figure SBN-2 and the following key points:

- The baffle material needs to be secured at the bottom and sides by staking, trenching, or securing horizontally to the bottom. Flow should not be allowed under the baffle.

- Most of the sediment will accumulate in the first bay, so this should be readily accessible for maintenance.

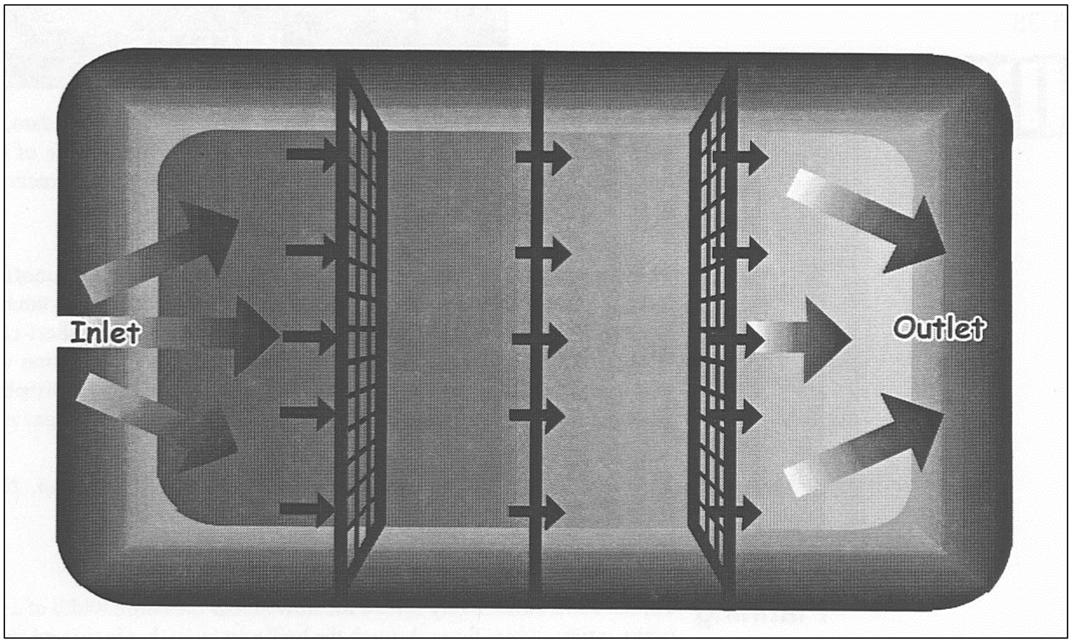


Figure SBN-1 Porous baffle in a sediment basin
(from North Carolina Erosion and Sediment Control Planning and Design Manual)

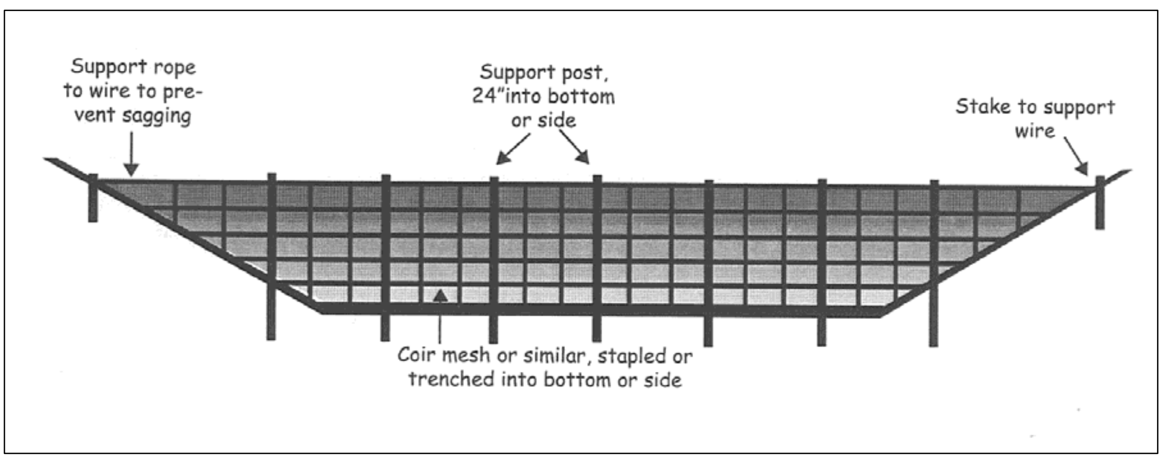


Figure SBN-2 Cross section of a porous baffle in a sediment basin
(Note: there is no weir because the water flows through the baffle material)
(from North Carolina Erosion and Sediment Control Planning and Design Manual)

Figure SBN-3 Example of porous baffle made of 700 g/m^2 coir erosion blanket as viewed from the inlet

Skimmer Option

A skimmer is a sediment basin dewatering-control device that withdraws water from the basin's water surface, thus removing the highest quality water for delivery to the uncontrolled environment. A skimmer is shown in Figure SBN-4. By properly sizing the skimmer's control orifice, the skimmer can be made to dewater a design hydrologic event in a prescribed period.

The costs of using a skimmer system are similar, or occasionally less, than a conventional rock outlet or perforated riser. However, the basin is more efficient in removing sediment when a skimmer is used. Another advantage of the skimmer is that it can be reused on future projects. Skimmers are generally maintenance free, but may require occasional maintenance to remove debris from the orifice.

A skimmer must dewater the basin from the top of the water surface. The rate of dewatering must be controlled. A dewatering time of 48 to 120 hours (2 to 5 days) is required for the basin to function properly.

Perforated Riser

The perforated risers are a common dewatering device in basins that will be retained for stormwater detention post-construction. These devices dewater the basin quickly by drawing water from the entire water column.

Flashboard Riser Option

A flashboard riser forces the basin to fill to a given level before the water tops the riser and is then drained. As with the skimmer option, removing water from the top improves sediment capture, as the top of the water column is often where the least amount of sediment resides. The benefit of the flashboard riser is that water level can be controlled by removed (or adding) "stop logs" to adjust the water level.

Flashboard Riser (Source: NRCS)

Solid Riser Option

A solid riser option is another that is commonly used when the sediment basin will be used for post-construction stormwater control. A solid riser manages stormwater by forcing water to drain over the top of the riser pipe. The disadvantage to the solid riser option is that the only way to fully dewater the basin (for sediment removal) is through a pump system.

Design Criteria and Construction

Summary:	**Temporary Sediment Trap**
Emergency Spillway:	Trapezoidal spillway with non-erosive lining. 10-year, 24-hour rainfall event
Maximum Drainage Area:	10 acres
Minimum Volume:	3,600 cubic feet per acre of drainage area
Minimum L/W Ratio:	2:1
Minimum Depth:	2 feet
Dewatering Mechanism:	Skimmer(s) attached at bottom of barrel pipe
Dewatering Time:	2 – 5 days
Baffles Required:	3

Compliance with Laws and Regulations

Design and construction should comply with state and local laws, ordinances, rules, and regulations.

Design Basin Life

Structures intended for more than 3 years of use should be designed as permanent structures. Procedures outlined in this section do not apply to permanent structures. See *Volume 2: Stormwater Runoff Management* for permanent stormwater control methods.

Dam Height

Maximum height should be 10 feet, measured from the designed (settled) top elevation of the dam to the lowest point of the original ground surface.

Basin Locations

Select areas that

- Are not intermittent or perennial streams;
- Allow a maximum amount of construction runoff to be brought into the structure;
- Provide capacity for storage of sediment from as much of the planned disturbed area as practical;
- Exclude runoff from undisturbed areas where practical;
- Provide access for sediment removal throughout the life of the project; and
- Interfere minimally with construction activities.

Basin Shape

Ensure that the flow-length to basin-width ratio is 2:1 or larger to improve trapping efficiency. Length is measured at the elevation associated with the minimum storage volume. Generally, the bottom of the basin should be level to ensure that the baffles function properly. The area between the inlet and first baffle (forebay) can be designed with reverse grade to improve the trapping efficiency.

Storage Volume

Ensure that the sediment-storage volume of the basin is at least 3,600 cubic feet per acre for the area draining into the basin. Volume is measured below the emergency spillway crest. Remove sediment from the basin when approximately one-half of the storage volume has been filled.

Baffles

Space the baffles to create equal zones of volume within the basin.

The top of the baffle should be the same elevation as the maximum water depth flowing through the emergency spillway.

Baffles should be designed to go up the sides of the basin banks so water does not flow around the baffles. Most of the sediment will be captured in the inlet zone. Smaller particle size sediments are captured in the latter cells.

The design life of the fabric can be up to 3 years, but it may need to be replaced more often if damaged or clogged.

Spillway Capacity

The emergency spillway system must carry the peak runoff from the 10-year 24-hour storm with a minimum 1 foot of freeboard (distance between the surface of the water with the spillway flowing full and the top of the embankment). Base runoff computations on the most severe soil cover conditions expected in the drainage area during the effective life of the structure.

Sediment Cleanout Elevation

Determine the elevation at which the invert of the basin would be half-full. This elevation should also be marked in the field with a permanent stake set at this ground elevation (not the top of the stake).

Basin Dewatering

Basin dewatering discussion will be limited to the skimmer options. Additional dewatering options are discussed in "Planning Considerations" (earlier in this practice). The basin should be provided with a surface outlet. A floating skimmer should be attached to a Schedule 40 PVC barrel pipe of the same diameter as the skimmer arm. The skimmer apparatus will control the rate of dewatering. The skimmer should be sized to dewater the basin in 48 to 120 hours (2–5 days). The barrel pipe should be located under the embankment with at least one anti-seep collar at the center of the embankment projecting a minimum of 1.5 ft in all directions from the pipe. The barrel-pipe outlet must be stable and not cause erosion.

Skimmer Orifice Diameter

Faircloth Skimmer Selection Procedure

The skimmer performance charts (Table SBN-1) are recommended for use in selecting Faircloth Skimmers for use in dewatering sediment control basins. Always verify performance with the manufacturer's information.

Required input data:
Basin volume = ________ ft^3
Desired dewatering time = ________ days

Procedure:

1. First use the basin volume (ft^3) and the desired dewatering time (days) and determine the required skimmer outflow rate in cubic feet per day (ft^3/d) from the following equation

$$Q = \frac{V}{t_d}$$

2. Scan the skimmer performance charts (Table SBN-1) and select the (a) skimmer size and (b) the skimmer orifice diameter (in inches) if desired.

Table SBN-1 Faircloth Skimmer Selection Charts

1.5-inch skimmer (H = 0.125 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	2,079
1.0	809
0.5	193

2-inch skimmer (H = 0.167 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	5,429
1.0	924
0.5	231

2.5-inch skimmer (H = 0.167 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	9,548
1.0	1,039
0.5	250

3-inch skimmer (H = 0.25 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	10,588
1.5	2,541
1.0	1,136
0.5	289

4-inch skimmer (H = 0.333 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	16,863
2.5	8,181
2.0	5,236
1.5	2,945
1.0	1,309
0.5	327

5-inch skimmer (H = 0.333 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	26,276
3.5	16,035
3.0	11,781
2.5	8,181
2.0	5,236
1.5	3,715
1.0	1,309
0.5	327

6-inch skimmer (H = 0.417 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	44,371
4.5	29,645
4.0	23,427
3.5	17,941
3.0	13,186
2.5	9,144
2.0	5,852
1.5	3,292
1.0	1,463
0.5	366

8-inch skimmer (H = 0.5 ft)

Orifice (in.)	Outflow Rate (ft^3/d)
None	127,416
5.5	48,510
5.0	40,098
4.5	32,475
4.0	25,660
3.5	19,654
3.0	14,438
2.5	10,029
2.0	6,410
1.5	3,619
1.0	1,598
0.5	404

Example: Select a skimmer that will dewater a 20,000-ft^3 sediment basin in 3 days.

Solution: First, compute the required outflow rate as

$$Q = \frac{V}{t_d} = \frac{20000\,ft^3}{3d} = 6670\,ft^3/d$$

Now, go the Selection Charts (Table SBN-1) and select an appropriate skimmer. If the 2-inch skimmer with no orifice is chosen, the outflow rate will be 5,429 ft^3/d, which will require about 3.5 days to dewater the basin. An alternative might be to use a 4-inch skimmer with a 2.5-inch-diameter orifice, which will have an outflow rate of 8,181 ft^3/d and dewater the basin in about 2.5 days.

Example: A More Precise Alternative: Each skimmer comes with a plastic plug that can be drilled forming a hole that will limit the skimmer's outflow to any desired rate. Thus, for a specific skimmer, the orifice that will dewater a basin in a more precisely chosen time can be determined. The flow through an orifice can be computed as

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

where C is the orifice coefficient (usually taken to be 0.6), A is the orifice cross-sectional area in ft^2, g is the acceleration of gravity (32.2 ft/sec^2), and H is the driving head on the orifice center in feet. The orifice equation can be simplified to yield the orifice flow in gpm using the diameter, D (in inches), and the head, in feet, as

$$Q = 12D^2\sqrt{H} \ .$$

Or, the orifice flow in ft^3/d using the diameter, D (in inches), and the head, in feet, as

$$Q = 2310D^2\sqrt{H} \ .$$

If we solve the orifice equation for the orifice diameter using the desired outflow rate (6670 ft^3/d) and the head driving water through the skimmer (0.333 ft for a 4-inch skimmer) as

$$D = \sqrt{\frac{Q}{2310\sqrt{H}}} = \sqrt{\frac{6670}{2310\sqrt{0.333}}} = 2.24 inches$$

We see that if the plastic plug were drilled to a diameter of 2.24 inches and placed in a 4-inch skimmer, the dewater rate would be 6,670 ft^3/d and the 20,000-ft^3 basin would dewater in 3 days.

Outlet Protection

Provide outlet protection to ensure erosion does not occur at the pipe outlet.

Basin Emergency Spillway

The emergency spillway should carry the peak runoff from a 10-year storm. The spillway should have a minimum 10-foot bottom width, 0.5-foot flow depth, and 1-foot freeboard above the design water surface.

Construct the entire flow area of the spillway in undisturbed soil to the greatest extent possible. The cross section should be trapezoidal, with side slopes 3:1 (horizontal: vertical) or flatter for grass spillways (Figure SBN-5) and 2:1 (horizontal: vertical) for riprap. Select vegetated lining to meet flow requirements and site conditions.

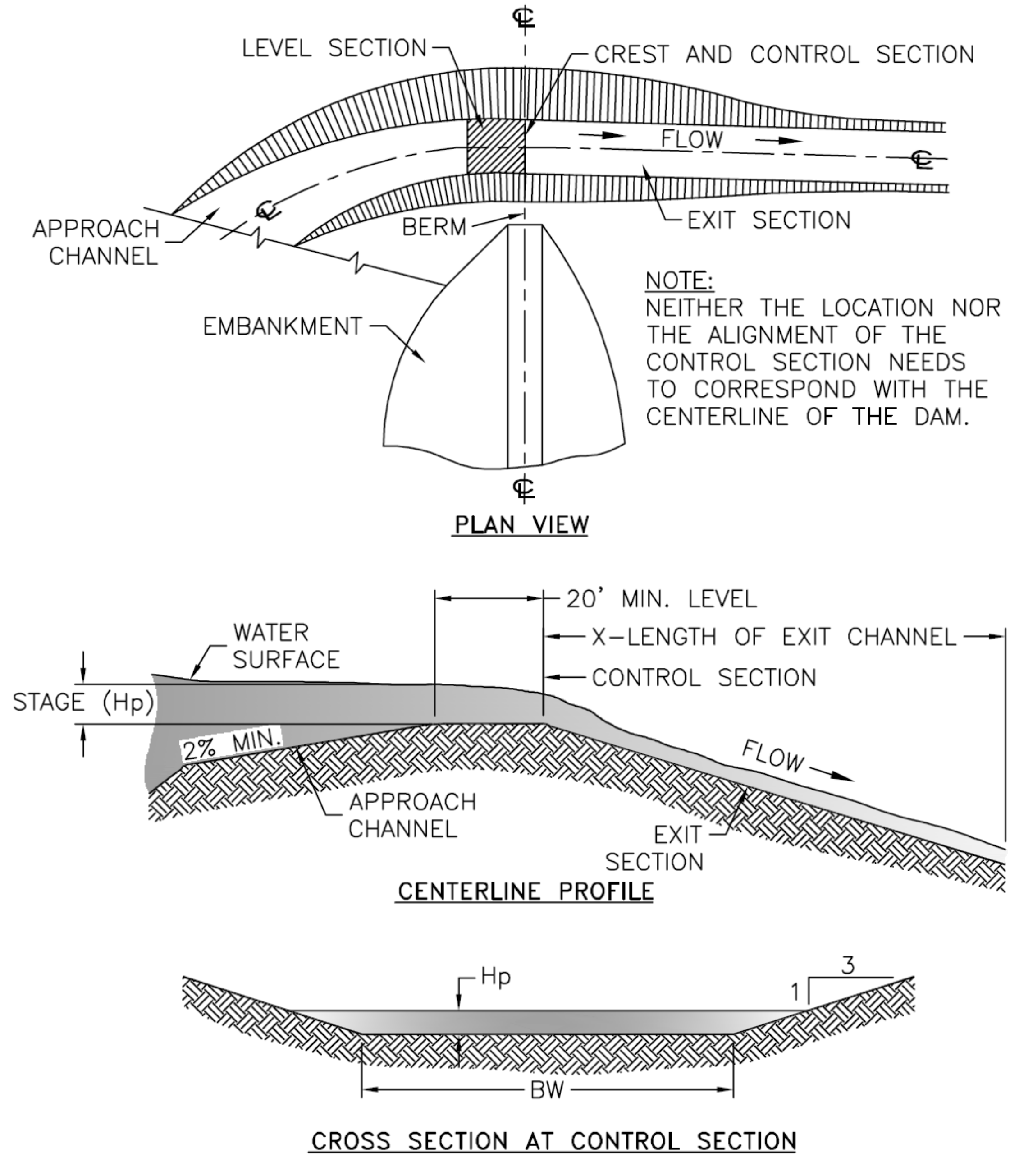


Figure SBN-5 Excavated grass spillway views

Inlet Section

Ensure that the approach section has a slope toward the impoundment area of not less than 2% and is flared at its entrance, gradually reducing to the design width of the control section. The inlet portion of the spillway may be curved to improve alignment.

The Control Section

The control section of the spillway should be level and straight and at least 20 feet long for grass spillways and 10 feet for riprap. Determine the width and depth for the required capacity and site conditions. Wide, shallow spillways are preferred because they reduce outlet velocities.

The Outlet Section

The outlet section of the spillway should be straight, aligned, and sloped to ensure supercritical flow with exit velocities not exceeding values acceptable for site conditions.

Outlet Velocity

Ensure that the velocity of flow from the basin is nonerosive for existing site conditions. It may be necessary to stabilize the downstream areas or the receiving channels.

Embankment

Embankments should not exceed 10 feet in height, measured at the center line from the original ground surface to the designed (settled) top elevation of the embankment. Keep a minimum of 1 foot between the designed (settled) top of the dam and the design water level in the emergency spillway. Additional freeboard may be added to the embankment height, which allows flow through a designated bypass location. Construct embankments with a minimum top width of 8 feet and side slopes of 2.5:1 (horizontal: vertical) or flatter.

There should be a cutoff trench in stable soil material under the dam at the centerline. The trench should be at least 2 feet deep with 1.5:1 (horizontal: vertical) side slopes, and sufficiently wide (at least 8 feet) to allow compaction by machine.

Embankment material should be a stable mineral soil, free of roots, woody vegetation, rocks, or other objectionable materials, with adequate moisture for compaction. Place fill in 9-inch layers through the length of dam and compact by routing construction hauling equipment over it. Maintain moisture and compaction requirements according to the plans and specifications. Hauling or compaction equipment must traverse each layer so that the entire surface has been compacted by at least one pass of the equipment wheels or tracks.

Excavation

Where sediment pools are formed or enlarged by excavation, keep side slopes at 2:1 (horizontal: vertical) or flatter for safety.

Erosion Protection

Minimize the area disturbed during construction. Divert surface water from disturbed areas. When possible, delay clearing the sediment impoundment area until the dam is in place. Keep the remaining temporary pool area undisturbed. Stabilize the spillway, embankment, and all disturbed areas with permanent vegetation. The basin bottom should also be established to a vegetative cover as this promotes sediment deposition.

Trap Efficiency

Improve sediment basin trapping efficiency by employing the following considerations in the basin design:

- Surface area—In the design of the settling pond, allow the largest surface area possible. The shallower the pool, the better.
- Length—Maximize the length-to-width ratio of the basin to provide the longest flow path possible.
- Baffles—Provide a minimum of three porous baffles to evenly distribute flow across the basin and reduce turbulence.
- Inlets—Area between the sediment inlets and the basin bottom should be stabilized by geotextile material, riprap with geotextile, a pipe drop, or other similar methods (Figure SBN-6 shows the area with rocks). Inlets to basin should be located the greatest possible distance away from the spillway.
- Dewatering—Allow the maximum reasonable detention period before the basin is completely dewatered (at least 48 hours).
- Inflow rate—Reduce the inflow velocity to nonerosive rates, and divert all sediment-free runoff.
- Establish permanent vegetation in the bottom and side slopes of the basin.
- Introduce the appropriate PAM material either at the turbulent entrance of the runoff water into the basin and/or apply to the first baffle. Apply the PAM according to manufacturer's recommendations.

Safety

Avoid steep side slopes. Fence basins properly and mark them with warning signs if trespassing is likely. Follow all state and local safety requirements.

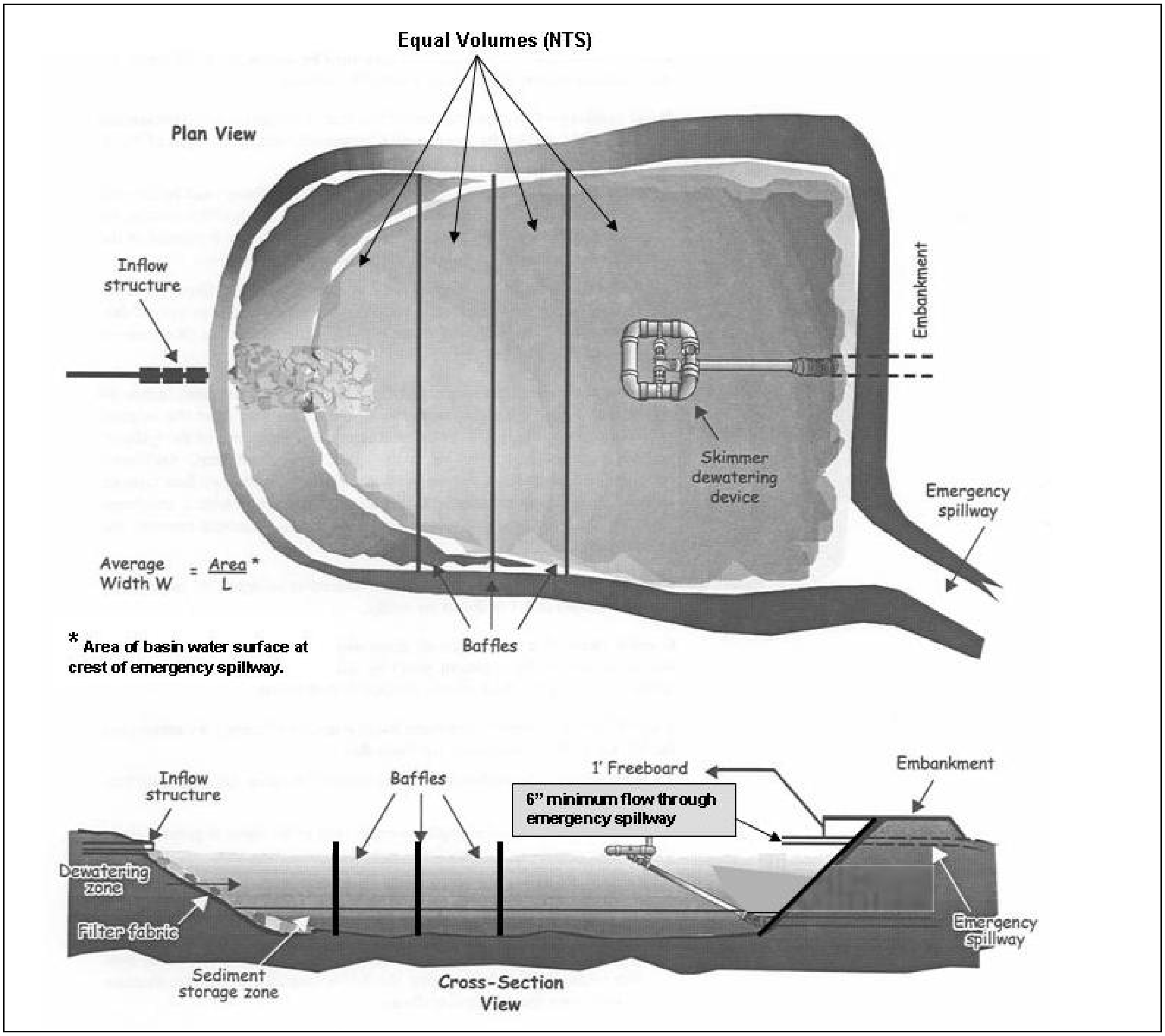


Figure SBN-6 Example of a sediment basin with a skimmer outlet and emergency spillway
(modified from Pennsylvania Erosion and Sediment Control Manual, March 2000)

Design Procedure

Step 1. Determine peak flow, Q_{10}, for the basin drainage area utilizing the NRCS runoff curve number method (see *Appendix A: Erosion and Stormwater Runoff Calculations*).

Step 2. Determine any site limitations for the sediment pool elevation, emergency spillway, or top of the dam.

Step 3. Determine basin volumes:

- Compute minimum volume required (3,600 ft^3/acre of drainage area).
- Specify sediment cleanout level to be clearly marked (one-half the design volume). Specify that the basin area is to be cleared after the dam is built.

Step 4. Determine area of basin, shape of basin, and baffles:

- Check length/width ratio (should be 2:1 or larger).
- Ensure the bottom of the basin is level.
- Design and locate a minimum of three coir baffles. The baffle spacing should produce equal volumes of storage within the basin when the basin is full. The top elevation of the baffles will be set in Step 7.

Step 5. Size the skimmer, skimmer orifice, and barrel pipe.

Use Table SBN-1 or the precise alternative design to size the orifice. Generally, a Schedule 40 PVC barrel pipe the same size as the skimmer arm is used under the embankment.

Step 6. Design the anti-seep collar.

Ensure that anti-seep collar is no closer than 2 feet from a pipe joint and as close to the center of the embankment as possible. Collar must project at least 1.5 feet from the pipe and be watertight.

Step 7. Determine the emergency spillway dimensions.

Size the spillway bottom width and flow depth to handle the Q_{10} peak flow. Tables SBN 2 and SBN-3 can be used for the design process for grassed emergency spillways. Use appropriate design procedures for spillways with other surfaces. Set top of baffles at the elevation of the designed maximum flow depth of the emergency spillway.

Step 8. Spillway approach section.

Adjust the spillway alignment so that the control section and outlet section are straight. The entrance width should be 1.5 times the width of the control section with a smooth transition to the width of the control section. The approach channel should slope toward the reservoir no less than 2%.

Step 9. Spillway control section.

- Locate the control section in natural ground to the greatest extent possible.
- Keep a level area to extend at least 20 feet (grass) or 10 feet (riprap) upstream from the outlet end of the control section to ensure a straight alignment.
- Side slopes should be 3:1 (grass) or 2:1 (riprap).

Step 10. Design spillway exit section.

- Spillway exit should align with the control section and have the same bottom width and side slopes.
- Slope should be sufficient to maintain supercritical flow, but make sure it does not create erosive velocities for site conditions. (Stay within slope ranges in appropriate design tables.)
- Extend the exit channel to a point where the water may be released without damage.

Step 11. Size the embankment.

- Set the design elevation of the top of the dam a minimum of 1 foot above the water surface for the design flow in the emergency spillway.
- Constructed height should be 10% greater than the design to allow for settlement.
- Set side slopes 2.5:1 or flatter.
- Determine depth of cutoff trench from site borings. It should extend to a stable, tight soil layer (a minimum of 2 ft deep).
- Select borrow site remembering that the spillway cut may provide a significant amount of fill.

Step 12. Erosion control

- Select surface-stabilization measures to control erosion.
- Select groundcover for emergency spillway to provide protection for design flow velocity and site conditions. Riprap stone over geotextile fabric may be required in erodible soils or when the spillway is not in undisturbed soils.
- Establish all disturbed areas, including the basin bottom and side slopes, to vegetation.

Step 13. Safety.

- Construct a fence and install warning signs as needed.

Table SBN-2 Design Table for Vegetated Spillways Excavated in Erosion-Resistant Soils
(side slopes 3 horizontal: 1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Table Use:

Given: Discharge, Q_{10} = 87 cfs, Spillway slope (exit section) = 4%.

Find: Bottom Width and Stage in Spillway.

Procedure: Using a discharge of 90 cfs, note that the spillway (exit section) slope falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width of 32 ft, to minimize velocity. Stage in the spillway is 1.14 ft.

Note: Computations are based on: Roughness coefficient, n = 0.40, and a maximum velocity of 5.50 ft per sec.

Table SBN-3 Design Table for Vegetated Spillways Excavated in Very Erodible Soils (side slopes 3 horizontal: 1 vertical)

Discharge Q CFS	Slope Range		Bottom Width Feet	Stage Feet
	Minimum Percent	Maximum Percent		
10	3.5	4.7	8	.68
15	3.4	4.4	12	.69
	3.4	5.9	16	.60
20	3.3	3.3	12	.80
	3.3	4.1	16	.70
	3.5	5.3	20	.62
25	3.3	3.3	16	.79
	3.3	4.0	20	.70
	3.5	4.9	24	.64
30	3.3	3.3	20	.78
	3.3	4.0	24	.71
	3.4	4.7	28	.65
	3.4	5.5	32	.61
35	3.2	3.2	24	.77
	3.3	3.9	28	.71
	3.5	4.6	32	.66
	3.5	5.2	36	.62
40	3.3	3.3	28	.76
	3.4	3.8	32	.71
	3.4	4.4	36	.67
	3.4	5.0	40	.64
45	3.3	3.3	32	.76
	3.4	3.8	36	.71
	3.4	4.3	40	.67
	3.4	4.8	44	.64
50	3.3	3.3	36	.75
	3.3	3.8	40	.71
	3.3	4.3	44	.68
60	3.2	3.2	44	.75
	3.2	3.7	48	.72
70	3.3	3.3	52	.75
80	3.1	3.1	56	.78

Example of Table Use:

Given: Discharge, Q_{10} = 38 cfs, Spillway slope (exit section) = 4%.

Find: Bottom Width and Stage in Spillway.

Procedure: Using a discharge of 40 cfs, note that the spillway (exit section) slope falls within slope ranges corresponding to bottom widths of 36 and 40 ft. Use bottom width of 40 ft, to minimize velocity. Stage in the spillway is 0.64 ft.

Note: Computations are based on: Roughness coefficient, n = 0.40 and a maximum velocity of 3.50 ft per sec.

Construction

Prior to the start of construction, sediment basins should be designed by a qualified design professional.

Plans and specifications should be referred to by field personnel throughout the construction process. The sediment basin should be built according to planned grades and dimensions. Follow all federal, state and local requirements on impoundments.

Consider the following guidance as construction proceeds.

Site Preparation

Locate all utilities at the site to ensure avoidance.

Clear, grub, and strip the dam foundation and emergency spillway area, removing all woody vegetation, rocks, and other objectionable material. Dispose of trees, limbs, logs, and other debris in designated disposal areas.

Stockpile surface soil for use later during topsoiling.

Delay clearing the pool area until the dam is complete and then remove brush, trees, and other objectionable materials to facilitate sediment cleanout.

Keyway Trench

Excavate the keyway trench along the centerline of the planned embankment to a depth determined by the qualified design professional (at least 2 feet). The trench bottom elevation should extend up both abutments to the riser crest elevation and should have a bottom width of at least 8 feet and side slopes no steeper than 1.5:1 (horizontal: vertical). Compaction requirements will be the same as those for the embankment.

Skimmer

Prevent the skimming device from settling into the mud by excavating a shallow pit under the skimmer or providing a low support under the skimmer of stone or timber (Figure SBN-1).

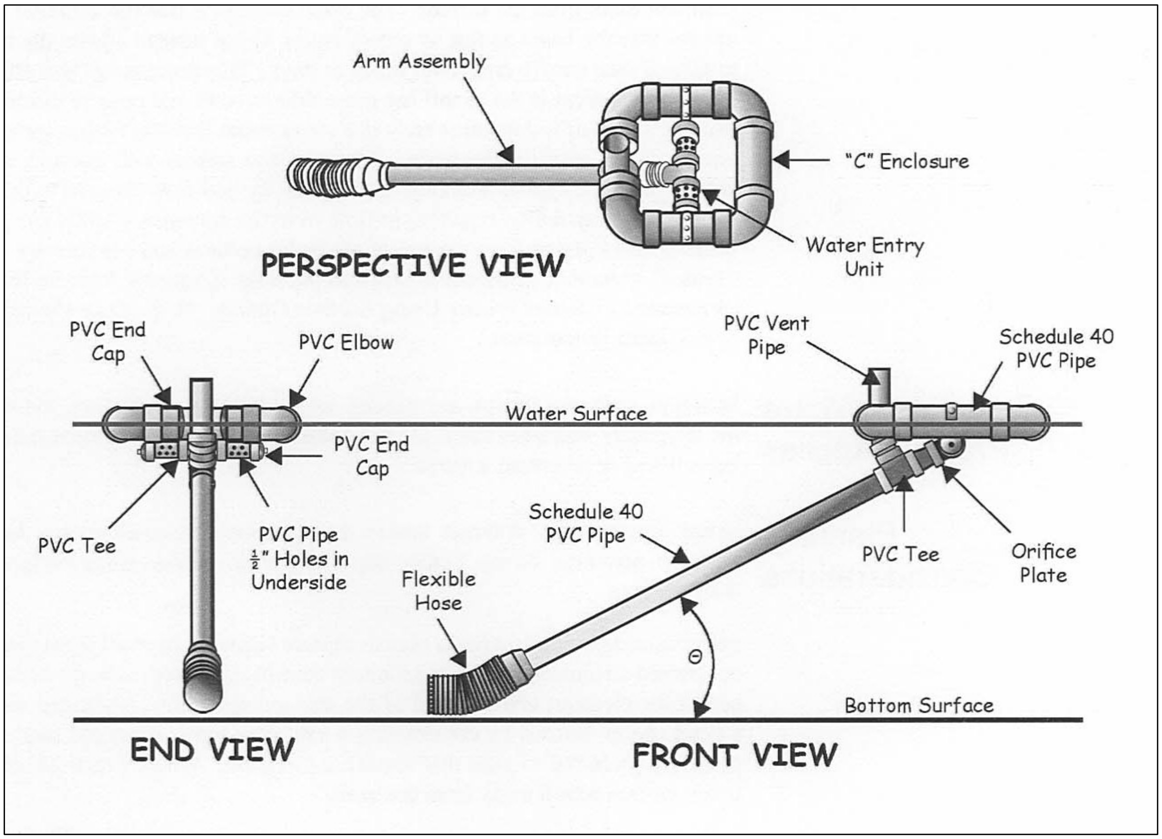


Figure SBN-1 Schematic of a skimmer (Source: Pennsylvania Erosion and Sediment Pollution Control Manual, March 2000)

Place the barrel pipe (typically the same size as the skimmer arm) on a firm, smooth foundation of impervious soil. Do not use pervious material such as sand, gravel, or crushed stone as backfill around the pipe. Place the fill material around the pipe in 4-inch layers and manually compact it under and around the pipe to at least the same density as the adjacent embankment. Care must be taken not to raise the pipe from the firm contact with its foundation when compacting under the pipe haunches.

Construct the anti-seep collar(s), if shown on the plans.

Place a minimum depth of 2 feet of compacted backfill over the pipe before crossing it with construction equipment. In no case should the pipe conduit be installed by cutting a trench through the dam after the embankment is complete.

Assemble the skimmer following the manufacturer's instructions, or as designed.

Lay the assembled skimmer on the bottom of the basin with the flexible joint at the inlet of the barrel pipe. Attach the flexible joint to the barrel pipe and position the skimmer over the excavated pit or support. Be sure to attach a rope to the skimmer and anchor it to the side of the basin. This will be used to pull the skimmer to the side for maintenance.

Install outlet protection as specified.

Embankment

Scarify the foundation of the dam before placing fill.

Use fill from predetermined borrow areas. It should be clean, stable soil free of roots, woody vegetation, rocks, and other debris; and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.

Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.

Place the fill material in 6″ to 9″ continuous uncompacted layers over the length of the dam. Fill should then be compacted to a 4″ to 6″ thick continuous layer (for example, routing construction equipment over the dam so that each layer is traversed by at least four passes of the equipment).

Protect the spillway barrel with 2 feet of fill that has been compacted with hand tampers before traversing over the pipe with equipment.

Construct and compact the dam to an elevation 10% above the design height to allow for settling. The embankment should have a minimum 8-foot top width and 2.5:1 side slopes, but the design may specify additional width and gentler side slopes.

Place a reference stake at the sediment clean-out elevation shown on the plans (50% of design storage volume).

Emergency Spillway

Construct the spillway at the site located by a qualified design professional according to the plan design (in undisturbed soil around one end of the embankment, and so that any flow will return to the receiving channel without damaging the embankment).

Basin and Baffles

Ensure the basin has a length-to-width ratio of at least 2:1 or more as specified. Grade the basin so that the bottom is level front-to-back and side-to-side. Discharge water into the basin in a manner to prevent erosion. Use diversions with outlet protection to divert sediment-laden water to the upper end of the pool area to improve basin trap efficiency.

Install porous coir baffles as specified to ensure water does not flow under or around the baffles (Figure SBN-2).

Install posts or sawhorses across the width of the sediment trap.

Steel posts should be driven to a depth of 24 inches, spaced a maximum of 4 feet apart, and installed up the sides of the basin as well. The top of the fabric should be at least the height of the required storage volume elevation.

Install at least three rows of baffles between the inlet and outlet discharge point and at the locations specified in the plans.

When using posts, add a support wire or rope across the top to prevent sagging.

Wrap porous coir material (700–900 g/m^2) over a sawhorse or the top wire. Hammer rebar into the sawhorse legs for anchoring. Attach fabric to a rope and a support structure with zip ties, wire, or staples.

The bottom and sides of the fabric should be anchored in a trench or pinned with 8-inch erosion-control matting staples.

Do not splice the fabric, but use a continuous piece across the basin.

Figure SBN-2 Example of porous baffle made of 700-g/m^2 coir erosion blanket as viewed from the inlet (Source: North Carolina Erosion and Sediment Control Planning and Design Manual)

Erosion Control

Minimize the size of all disturbed areas.

Divert runoff from undisturbed areas away from the basin.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Divert sediment-laden water to the upper end of the sediment pool to improve trap effectiveness.

Vegetate and stabilize the embankment, the emergency spillway, and all disturbed areas including the basin bottom and side slopes.

Safety

Because sediment basins that impound water are hazardous, the following precautions should be taken:

- Fence the area and post warning signs if trespassing is likely.

- Ensure that the basin does not exceed design heights.

Construction Verification

Check the finished grades and configurations for all earthworks. Check elevations and dimensions of all pipes and structures.

Common Problems

Consult with a registered design professional if any of the following occurs:

Variations in topography on-site indicate sediment basin will not function as intended.

Seepage is encountered during construction; it may be necessary to install drains.

Design specifications for fill, pipe, seed variety, or seeding dates cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect the sediment basin at least weekly and after each significant storm event (½ inch or greater).

Remove and properly dispose of sediment when it accumulates to ½ the design volume.

Remove trash and other debris from the skimmer, emergency spillway, and pool area.

Periodically check the embankment, emergency spillway, and outlet for erosion damage, piping, settling, seepage, or slumping along the toe or around the barrel and repair immediately.

Remove the basin after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water, removing the sediment to a designated disposal area, and smoothing the site to blend with the surrounding area; then stabilize.

References

Volume 1

Chapter 2

Vegetation for Erosion and Sediment Control 2-10

Chapter 4

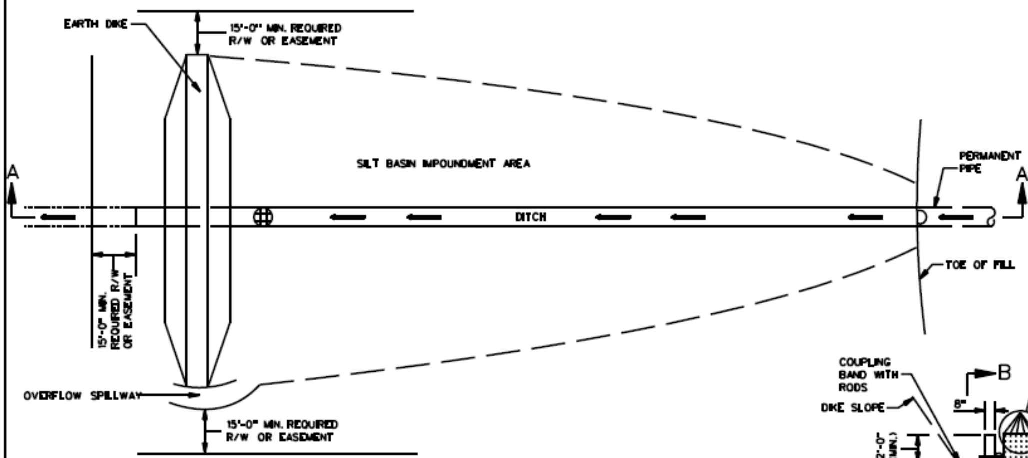
Permanent Seeding (PS) 4-53

Flocculants and Polymers (FLC) 4-328

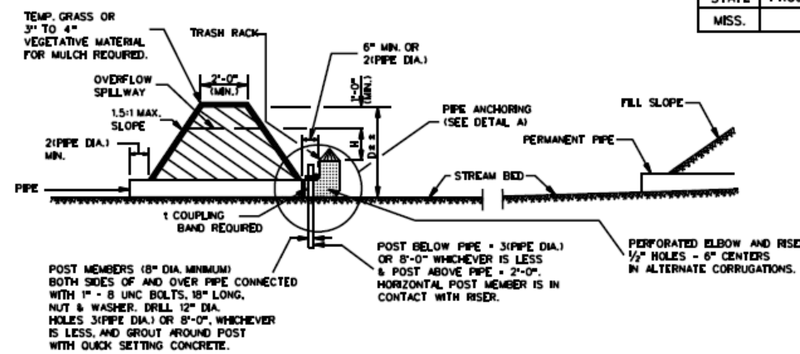
MDOT Drawing TEC-3

Appendix G (Available in Appendices Volume)

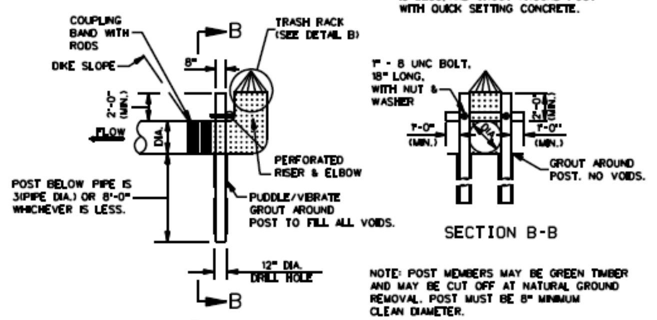
STATE	PROJECT NO.
MISS.	



PLAN

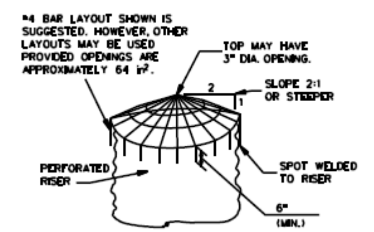


SECTION A-A

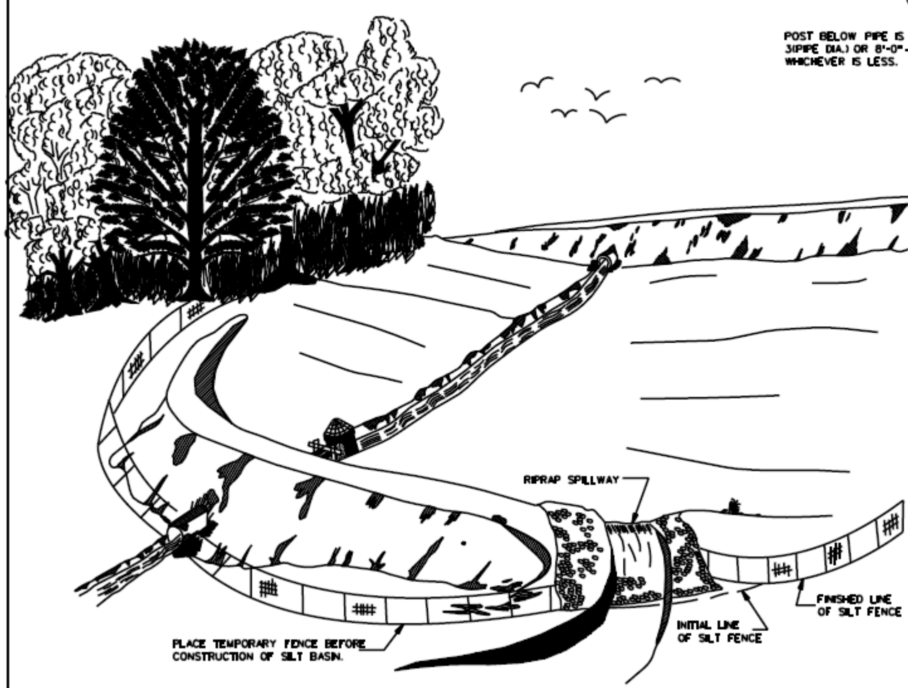


DETAIL A

PIPE ANCHORAGE



DETAIL B
TRASH RACK INSTALLATION



TEMPORARY SILT BASIN (TYPE B)

GENERAL NOTES:

1. PROVIDE OVERFLOW SPILLWAY IN NATURAL GROUND AT A MINIMUM OF 1'-0" BELOW TOP OF DIKE. CROSS-SECTIONAL AREA OF SPILLWAY IS EQUAL TO 1.5 TIMES THE AREA OF THE OUTLET PIPE MINIMUM. RIPRAP SHALL BE REQUIRED AT THE SPILLWAY. AFTER THE PURPOSE OF THE SILT BASIN HAS BEEN SERVED, THE DIKE AND RIPRAP MAY REMAIN IN PLACE AT THE DISCRETION OF THE ENGINEER, BUT THE DRAIN PIPE WITH RISER SHALL BE REMOVED AND THE NEWLY DISTURBED AREA REVEGETATED.
2. BASIN AND DIKE DIMENSIONS DO NOT REQUIRE CONSTRUCTION TO NEAT LINES.
3. THE SILT BASIN MAY BE CONSTRUCTED IN ANY SHAPE WITH THE DIKE EXTENDING ALONG ONE OR MORE SIDES AS LONG AS THE LENGTH MEASURED IN THE DIRECTION OF FLOW IS APPROXIMATELY TWICE THE WIDTH AND THE IMPOUNDMENT AREA AND DEPTH AT LEAST AS LARGE AS INDICATED.
4. MINIMUM DIMENSIONS FOR SILT BASIN (TYPE B) ARE AS FOLLOWS:

MIN. DIMENSIONS OF SILT BASIN (TYPE B)				† COUPLING BAND	
PIPE	** D (ft-in)	H (ft-in)	* AREA (ft²)	LENGTH (in)	COUPLING RODS/SIDE
15"	4'-0"	1'-0"	310	12"	2 & 2
18"	5'-0"	1'-0"	550	12"	2 & 2
24"	5'-0"	1'-0"	1100	12"	2 & 2
30"	6'-0"	1'-6"	1850	24"	3 & 3
36"	6'-0"	1'-6"	2800	24"	3 & 3
42"	7'-0"	2'-0"	4200	24"	3 & 3
48"	8'-0"	2'-0"	6200	24"	3 & 3

NOTES:
* 1. IMPOUNDMENT SURFACE AREAS ARE MEASURED AT ELEVATION OF TOP OF ELBOW RISER.
** 2. RISER REQUIRED WHERE MINIMUM "D" DIMENSION IS EXCEEDED. LENGTH OF RISER IS EQUAL TO THE AMOUNT THAT MINIMUM "D" DIMENSION IS EXCEEDED.
† 3. COUPLING RODS TO BE ½" DIAMETER MINIMUM WITH LUGS.

5. IN SELECTING BASIN SIZE, CONSIDERATION MUST BE GIVEN TO THE AREA DISCHARGING INTO THE BASIN OTHER THAN THAT WHICH COMES THROUGH THE PIPE UNDER THE ROADWAY. THIS WILL AT TIMES NECESSITATE A LARGER BASIN AND OUTLET PIPE SECTION.
6. THE DIKE SHALL BE CONSTRUCTED OF A MATERIAL SUITABLE FOR ROADWAY EMBANKMENT.
7. SILT BASIN (TYPE B) REQUIRED AT LOCATION(S) INDICATED ON PLANS.
8. THE CONTRACTOR SHALL BE REQUIRED TO FURNISH ALL MATERIALS AND PERFORM ALL WORK FOR THE PROPER INSTALLATION, MAINTENANCE AND REMOVAL OF TEMPORARY EROSION CONTROL MEASURES NECESSARY TO CONTROL SILTATION.
9. THE USE OF THE TEMPORARY EROSION CONTROL MEASURE SHOWN ON THIS SHEET WILL ONLY BE REQUIRED AND MEASURED FOR SEPARATE PAYMENT WHEN AN APPROPRIATE PAY ITEM IS INCLUDED IN THE BID SCHEDULE OF THE PROPOSAL.
10. RIPRAP AND TEMPORARY SILT FENCE, USED IN CONJUNCTION WITH TYPE B SILT BASINS AS SHOWN BY THE DETAILS ON THIS SHEET, WILL NOT BE MEASURED FOR SEPARATE PAYMENT. THEIR COST SHALL BE INCLUDED IN THE PRICE BID FOR TYPE B SILT BASIN.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN

BY / REVISION / DATE

TYPICAL TEMPORARY EROSION CONTROL MEASURES
(TYPE B SILT BASIN)

ENGLISH

WORKING NUMBER: TEC-3

SHEET NUMBER: 144

ISSUE DATE: OCTOBER 1, 1998

Straw Bale Sediment Trap (SST)

Practice Description

A straw bale sediment trap is a temporary catch basin consisting of a row or more of entrenched and anchored straw bales. The purpose is to intercept and detain small amounts of sediment to prevent sediment from leaving the construction site. This practice applies within disturbed areas with small drainage basins.

Planning Considerations

In certain situations, straw bales can be used as an alternative to silt fence for trapping sediment. The practice should be used to trap sediment only for a short duration from small drainage areas. Straw bales' comparatively low flow rate should be considered before choosing to use this practice. Ponding above the bales can occur rapidly due to the low flow rate. Overtopping and bypass of the bales can cause significant damage to the site. Additional measures should be used if turbidity leaving the site served by this practice is an issue.

Design Criteria and Construction

Drainage Area

For disturbed areas subject to sheet erosion the drainage area should be restricted to ¼ acre per 100 feet of barrier. The slope length behind the barrier should be restricted according to Table SST-1.

If used in minor swales, the swale should be relatively flat in grade (3 percent or less) and the drainage area should be limited to 1 acre.

Table SST-1 Criteria for Straw or Hay Bale Placement

Land Slope (Percent)	Maximum Slope Length Above Bale (Feet)
<2	75
2 to 5	50
5 to 10	35
10 to 20	20
>20	10

Bale Size

Bales should be 14″ x 18″ x 36″.

Anchors

Two 36″ long (minimum) 2″ x 2″ hardwood stakes should be driven through each bale after the bales are properly entrenched. Alternate anchors can be two pieces of No. 4 steel rebar, 36″ long (minimum). See Figures SST-1 and SST-2 for details on proper installation of straw bales.

Effective Life

Straw and hay bales have a relatively short period of usefulness and should not be used if the project duration is expected to exceed 3 months. Bale placement should result in the twine or cord being on the side and not the bottom of the bale.

Location

This practice should be used on nearly level ground and be placed at least 10 feet from the toe of any slope. The barrier should follow the land contour. The practice should never be used in live streams or in swales where there is a possibility of washout. The practice should also not be used in areas where rock or hard surfaces prevent the full and uniform anchoring of the bales.

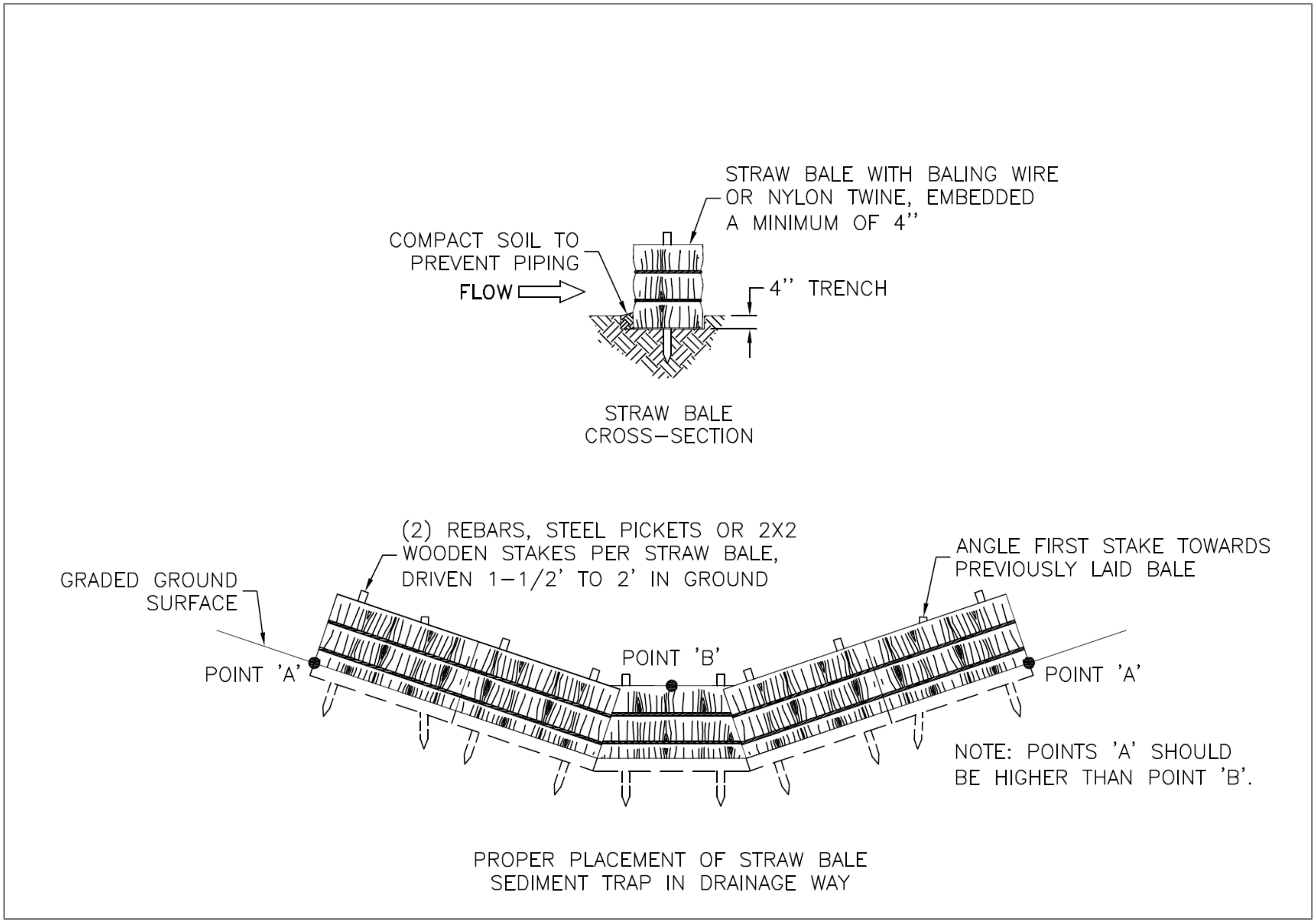
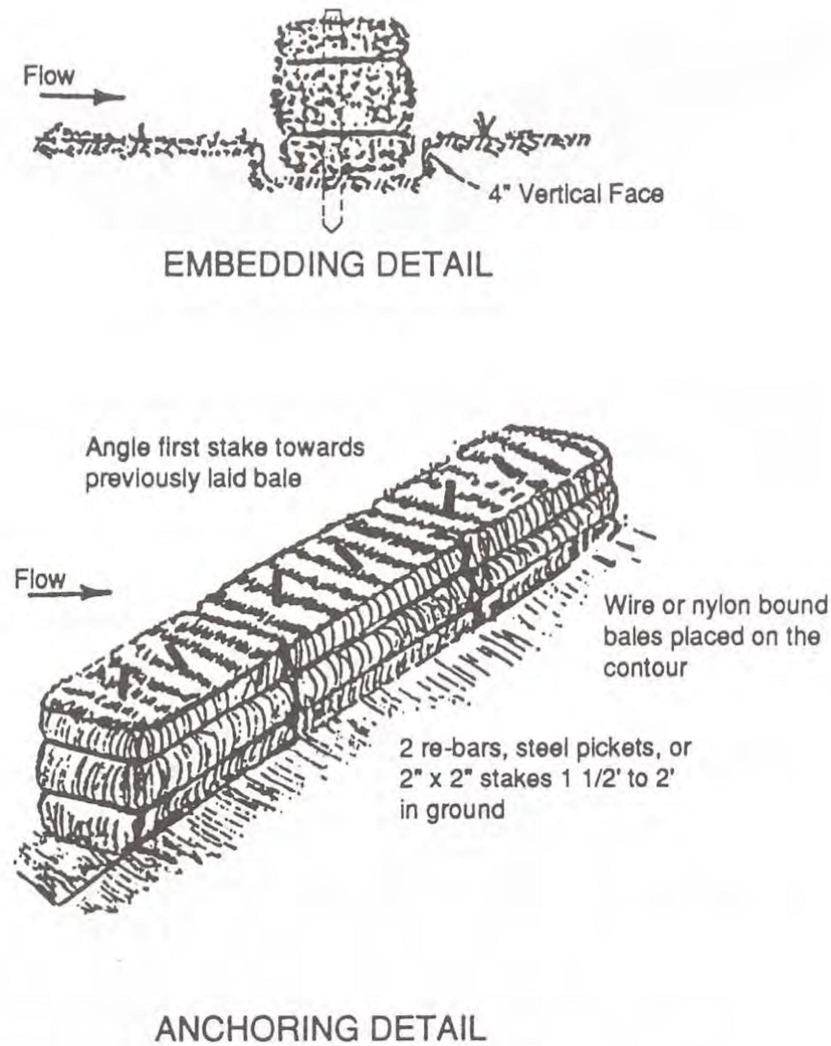


Figure SST-1 Placement of Straw Bale



NOTE:

- Anchor and embed into soil to prevent washout or water working under barrier
- Repair or replacement must be made promptly as needed

Figure SST-2 Anchoring Technique for Straw Bales

Construction

Prior to start of construction, straw bale sediment traps should be designed by a qualified professional. Plans and specifications should be referred to by field personnel throughout the construction process. The straw bale sediment trap should be built according to planned grades and dimensions.

Site Preparation

Determine exact location of underground utilities so that locations for digging or placement of stakes can be selected where utilities will not be damaged.

Smooth the construction zone to provide a broad, nearly level area for the row of bales. The area should be wide enough to provide storage of runoff and sediment behind the straw bales.

To facilitate maintenance, provide good access for cleanout of sediment during maintenance period.

Installation of Straw Bale

Excavate a trench to the dimensions shown on the drawings. The trench should be long enough that the end bales are somewhat upslope of the sediment pool to ensure that excess flows go over the bales and not around the bales.

Place each bale end-to-end in the trench so the bindings are oriented around the sides rather than top and bottom.

Anchor the bales by driving two 36″ long 2″ x 2″ hardwood stakes through each bale at least 18″ into the ground. Drive the first stake toward the previously laid bale to force the bales together.

Wedge loose straw into any gaps between the bales to slow the movement of sediment-laden water.

Anchor the bales in place according to the details shown on the drawings. If specific details are not shown, backfill and compact the excavated soil against the bales to ground level on the downslope side and to 4″ above ground level on the upslope side.

Erosion Control

Stabilize disturbed areas in accordance with the vegetation plan. If no vegetation plan exists, consider planting and mulching as part of the installation and select planting information from either the *Permanent Seeding* or *Temporary Seeding Practice*. Select mulching information from the *Mulching Practice*.

Construction Verification

Check finished grades and dimensions of the straw bale sediment trap. Check materials for compliance with specifications.

Common Problems

Consult with a registered design professional if any of the following occurs:

Variations in topography on site indicate sediment trap will not function as intended; changes in plan may be needed.

Design specifications for materials cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect straw bale barriers after each storm event and remove sediment deposits promptly after it has accumulated to ½ of the original capacity, taking care not to undermine the entrenched bales.

Inspect periodically for deterioration or damage from construction activities. Repair damaged barrier immediately.

After the contributing drainage area has been stabilized, remove all straw bales and sediment, bring the disturbed area to grade, and stabilize it with vegetation or other materials shown in the design plan.

Straw bales may be recycled as mulch.

References

BMPs from Volume 1

Chapter 4

Mulching (MU)	4-48
Permanent Seeding (PS)	4-53
Temporary Seeding	4-103

Flocculants and Polymers (FLC)

Practice Description

Flocculants are used to promote clumping in sediment-laden water. Flocculants can be used in chemical stabilization of soils on steep slopes as is discussed in the *Chemical Stabilization Practice*. This section discusses the use of flocculants in conjunction with pumped construction site stormwater systems. Flocculant is dissolved into sediment retention basin inflows via a rainfall-activated system. The flocculant causes individual particles to be destabilized (i.e. neutralizing electrical charges that cause particles to repel each other), accelerating the coagulation and settlement of particles out of the water column. Flocculant types include polyacrylamides (PAM), gypsum, and alum. Anionic PAM is a negatively charged long-chained molecule that consists of acrylamide and acrylate units. It is available as a crystalline powder, an emulsion, or a solid block or log (McLaughin, 2007). Anionic PAM used for turbidity reduction should contain less than 0.5 percent free acrylamide due to the suspected carcinogenic effect of acrylamide. Gypsum, a natural mineral composed of calcium sulfate and water, is often used in water and wastewater treatment processes. Alum is an aluminum sulfate material that can also be used for water clarification.

Planning Considerations

When utilizing flocculants to aid in sediment removal, the following criteria are required by the MDEQ: 1) only anionic polyacrylamide (PAM) polymer; 2) polymer shall contain less than 0.05% free acrylamide; 3) polymer shall be non-toxic to fish and other aquatic organisms, and; 4) polymer shall be selected for site-specific soil conditions (i.e. jar test). For polymer system treatment of turbidity, the following criteria are required at a minimum: 1) polymer shall be introduced through turbulent mixing into the stormwater upstream of sedimentation BMPs; 2) sedimentation basin shall be constructed in accordance with the criteria specified in ACT 5, T-5 (2)(A) of the Large Construction General Permit (see *Appendix B*); and 3) polymer shall be applied in accordance with manufacturer's instructions, and there shall be no discharge of undissolved polymer, clumps of polymer, and/or unsettled flocculant material.

Design Criteria and Construction

PAM Screening Method

Because of the varied type of soils across the state, there is no one type of PAM that is applicable to all. At this time, the only way to determine the most effective type (or types, if the site is large) of PAM is to do a jar test. Most PAM retailers will perform this test.

1. Obtain a clear container (approximately 16 oz).
2. Fill with tap water.
3. Add a small amount of PAM (a "pinch").
4. Add a teaspoon of soil from the site.
5. Shake for 10-20 seconds or until the water begins to clear, then allow to settle.
6. Repeat for several PAM products, and then select the product that clears the water the most quickly.

Pumped Injection

Pumped injection is an effective treatment route because the concentrations of PAM used can be controlled and the reaction between PAM particles and suspended solids is faster than a solid PAM dosing technique. This setup includes a turbid water source, a PAM dosing pump, and a silting basin to treat turbidity.

A pumped injection system consists of a PAM solution pump and a PAM reservoir. An electric pump is often used to inject the PAM solution, preferably a peristaltic pump with variable speeds. The PAM pump hose can be connected into the intake hose to ensure proper dosing and mixing. A sample configuration is provided as Figure FLC-1.

Dosage Rate

The recommended dosage rate of PAM is 1–5 milligrams per liter or parts per million. Rates can be adjusted based on the results of a jar test.

Baffles

A porous baffle of coir netting is recommended to catch the floating flocs created by the flocculation reaction. The preferred weight for sediment basins is 900 grams per square meter. The flocculation of turbid water may cause sediment baffles to become clogged faster than systems without flocculant use and may require more frequent replacements.

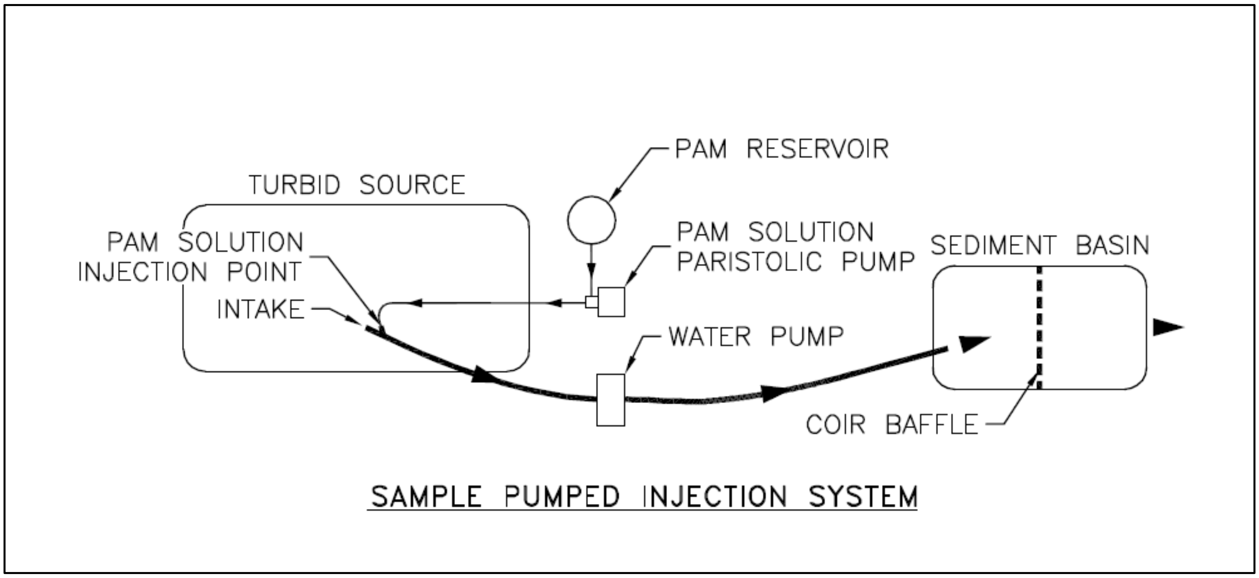


Figure FLC-1 Sample Pumped Injection System

PAM-Treated Channel

This practice uses solid PAM crystalline powder with a jute or coir-lined channel. The turbid water is pumped into the channel and mixes with the solid PAM as it travels toward a sediment basin. This method is also effective when used with fiber check dams (wattles).

The PAM power should only be applied when no water is in the channel. Some wetting of the erosion-control fabric may be required to stabilize the PAM powder. If PAM powder is added directly to the water flow, it will simply settle out and will not be effectively mixed.

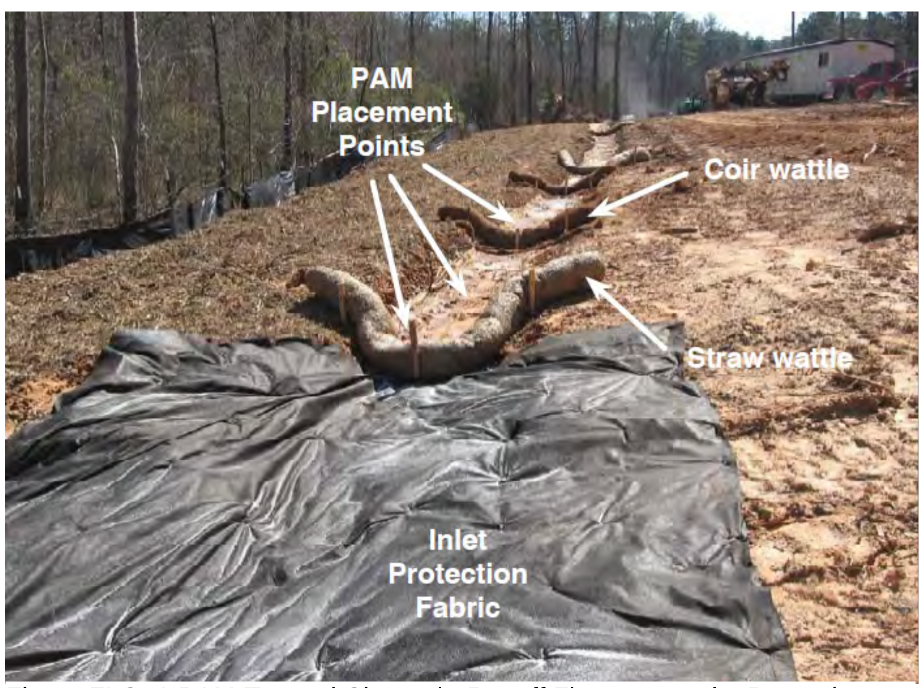


Figure FLC- 1 PAM-Treated Channel - Runoff Flows over Inlet Protection Fabric into Sediment Basin (Source: North Carolina State University)

Treatment Approach

Flocculant use should be installed as a treatment-train approach. Turbid water should be contained on-site, treated with flocculant, and then stored in a sediment basin until solid particles have settled out.

Coagulants

Coagulants such as gypsum and alum can be used to reduce turbidity as well, with approval of MDEQ. These materials can be spread by hand into the water after each storm. The suggested dosage rate is 20–30 pounds per 1,000 cubic feet of water, spread over the surface.

Monitoring

Monitoring is currently voluntary, the results of which will not be required to be documented and/or reported. There are currently no active numeric effluent limitations for construction stormwater discharges. Numeric effluent limitations are expected to be established by the EPA for the next permitting cycle. While these monitoring activities are currently optional, they are still helpful in determining the effectiveness of turbidity reduction procedures. The following monitoring procedures were taken from the Mississippi Large Construction General Permit recommendations found in Act 9: Optional Monitoring (see *Appendix B* for full permit document):

1. Monitor the turbidity of each storm water discharge from actively disturbed areas of the project site for each work day the discharge occurs. Actively disturbed areas are those portions of the project site that have undergone soil disturbing activities (i.e., clearing, grading, filling, excavating, etc.) and have not been stabilized.
    a) Monitoring should be conducted for each point of storm water discharge from the project site. For the purpose of this permit, a discharge point means any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, or container from which storm water and/or pollutants are, or may be, discharged.
    b) Diffuse storm water, such as non-channelized flow that infiltrates into a vegetated area, and does not then discharge to surface waters, would not generally require monitoring.

2. Due to the unique characteristics of linear projects, portions may have suspended construction activity and have undergone temporary or final stabilization [see Definitions] while other portions of the same project may have active construction activities. Therefore, in recognition of these unique regulatory circumstances, only those areas that have active construction activities will require numeric turbidity monitoring. Those areas that have been completed and stabilized will not require turbidity monitoring.

3. Sampling:
    a) A minimum of three (3) samples per work day, per discharge, should be used to calculate a daily average turbidity value. Samples should be collected so as to be representative of the nature of the discharge over its duration. For example,

- (i) Collect first sample within the first hour of discharge or within the first hour of the work day.
- (ii) Collect second sample in the middle of discharge or the middle of the work day.
- (iii) Collect last sample at the end of discharge or at the end of the work day.
- (iv) Continue sampling at the start of the next work day if there continues to be a discharge (until discharge ends or end of the work day). These data should be used to calculate a separate daily average.

b) Monitoring samples should be collected at the nearest accessible point after final treatment, but prior to mixing with the receiving water body.
- (i) Due to the unique characteristics of linear projects, there may be multiple discharge points spaced over a wide geographic area. Therefore, MDEQ will allow representative discharge sampling. For example, representative sampling at certain discharge locations may be representative of the discharge characteristics of other locations within the same sub-watershed. For multiple outfalls that discharge substantially identical effluents, the owner or operator may sample one (or more) of the outfalls and report that data as representative of the other outfalls. At a minimum, at least one discharge point per sub-watershed must be monitored and the same or similar controls must be implemented on the different discharge points.
- (ii) Representative sampling of non-linear projects may be allowed on a case-by-case basis.

c) Monitoring may be accomplished via portable turbidity meters or fixed automated sampling/meter stations.
- (i) Monitoring should be based on grab samples for portable meters.
- (ii) Automated samplers should be programmed to yield a minimum of three (3) representative readings per discharge, per day.
- (iii) Daily turbidity averages should be the average of all monitoring results collected on the day of discharge for the respective discharge point(s). For example, if there were five (5) turbidity readings in a given day, then the average turbidity for that day would be the average of all five (5) readings.

d) Grab samples should be collected according to the following methodology to ensure that each sample is representative of the flow conditions and other characteristics of the discharge.
- (i) Collect samples from the horizontal and vertical center of the storm water outfall channel(s) or other sources of concentrated flow.
- (ii) Avoid stirring the bottom sediments in the storm water channel in which samples are taken by not walking through the areas of storm water flow or disturbing the sediment with the sampling device.
- (iii) Hold sampling container so that the opening faces the upstream direction of the storm water channel in which samples are taken.
- (iv) Avoid overfilling sample container.

e) Monitoring should be conducted for any discharge that occurs during the normal working hours of the project site.

4. Turbidity Meters:
   a) Turbidity meters should meet the following design criteria:
      (i) Accuracy within +/- 5% of measurement,
      (ii) Minimum upper range of 1000 NTU,
      (iii) Able to be calibrated by operator, and
      (iv) Operating temperature range be at least 32 to 122 degrees.
   b) Turbidity meters should be operated, calibrated and maintained according to the meter manufacturer's instructions.

Construction Verification

Check finished grades and dimensions of the sediment basin. Check materials for compliance with specifications.

Common Problems

Consult with a registered design professional if any of the following occurs:

Pumped injection systems are not reducing turbidity in sediment basin. Check PAM reservoir and dosage rates.

A thick gel forms in PAM-treated channel. Application rates are too high – only a thin coating of PAM powder is need.

Maintenance

Regular inspections of PAM reservoir are required to maintain adequate supply.

Inspect power source and piping for potential failures.

Coir baffles may require regular replacement when using flocculants; inspect frequently for clogged baffles.

In PAM-treated channels, inspect channel lining often and replace when needed.

References

BMPs from Volume 1

Chapter 4

Chemical Stabilization (CHS) 4-25

Introduction to Stream Protection Practices

Disturbing the natural process of streams and associated wetlands must be avoided whenever possible. The following provides information regarding federal regulations protecting wetlands and streams and should be reviewed before beginning construction projects adjacent to or within stream channels.

Wetlands

Wetlands are defined by 33CFR328 as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Ecologically, wetlands provide a number of valuable functions, including habitat and foraging opportunities for many species of animals. From a water quality perspective, wetlands provide attenuation of floodwaters, processing of nutrients, and infiltration of stormwater, all of which improve the water quality of the respective watershed.

Stream Channels

Stream channel morphology and adjacent wetland areas play an important role in water quality, flood attenuation, sediment retention, wildlife and aquatic habitat and species, and endangered and threatened species. Stream channelization causes water flowing through the straightened section to move more rapidly and can lead to further erosion problems downstream of the channelized area. Channelization often necessitates the removal of vegetation along the streambanks and placement of fill within wetland areas. The removal of overhanging vegetation in the bends and pools of a stream can reduce the habitat for fish by decreasing feeding and spawning habitat. Restoring these areas after stream channel construction is important to prevent water quality impairment, improve flood control, and restore fish and wildlife habitat.

Stormwater

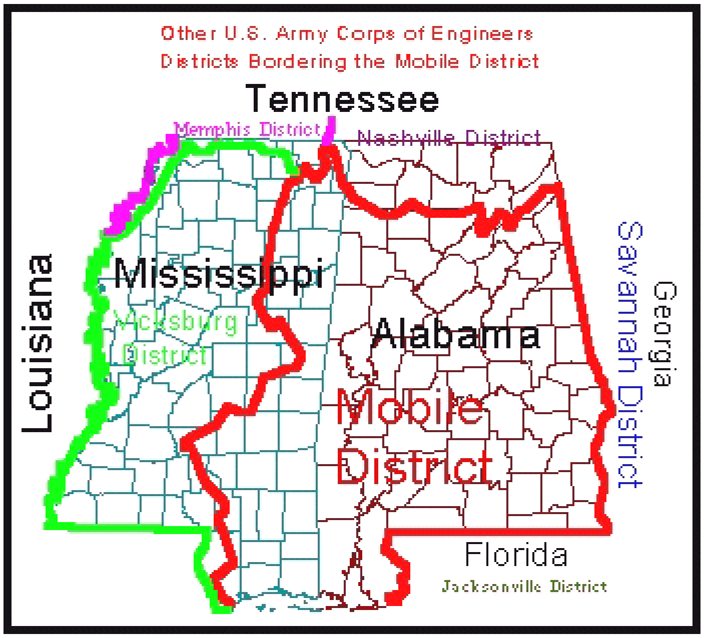
It should be noted that Region 4 of the EPA has established that "the Region will express objections to Section 404 permit applications that propose to construct control structures in waters of the United States for the express purposes of impounding waters to provide storm water treatment or conveyance in lieu of implementation of the required upland controls." However, the Region 4 EPA has stated that "In the case where circumstances preclude the use of upland controls, Region 4 will consider an exceptional case exists." The views of the EPA on in-stream treatment should be carefully considered during the site planning process, as permit authorization will likely be a long process including the satisfaction of the 404(b)(1) guidelines. Upland controls should always be considered first.

Clean Water Act

Section 404 of the Clean Water Act provides regulation of activities affecting waters of the United States. Activities requiring authorization from the U.S. Army Corps of Engineers include the following:

- Construction of piers, marinas, ramps, and cable or pipeline crossings;
- Dredging and excavation in or adjacent to waters of the United States;
- Fill for residential, commercial or recreational developments;
- Construction of revetments, groins, breakwaters, levees, dams, dikes and weirs; and
- Placement of riprap (for channel stabilization)

The U.S. Army Corps of Engineers issues two types of Section 404 permits applicable to the construction industry, General Permits and Individual Permits. It is advisable that you contact the U.S. Army Corps of Engineers District of the proposed project and the MDEQ before site planning to determine if permits are required.



The Section 404 authorization process requires that the developer has taken steps to avoid wetland impacts, minimized the potential impacts on wetlands, and provided compensatory mitigation for any remaining unavoidable impacts. For projects in the Mississippi Coastal Zone (Hancock, Harrison, and Jackson counties) the Mississippi Department of Marine Resources (DMR) acts as the lead regulatory agency, and permit applications are submitted to the DMR Bureau of Wetland Permitting for review. Projects outside of the Mississippi Coastal Zone will submit permit applications to the nearest U.S. Army Corps of Engineers District office.

Section 401 of the Clean Water Act, through the EPA, gives the MDEQ the authority to prohibit an activity, including a construction project, if it can impact water quality or have other unacceptable environmental consequences. Projects which require a 404 permit will also require a 401 Water Quality Certification from the MDEQ.

References

Appendix B: State and Federal Regulations, Permits and Applications

Appendix J: Local Information

U.S. Army Corps of Engineers District Offices:

U.S. Army Corps of Engineers, Mobile District
Attention: CESAM-OP-S
P.O. Box 2288
Mobile, AL 36628-00001
Phone: 334-690-2658
FAX: 334-690-2660

U.S. Army Corps of Engineers, Vicksburg District
Attention: CEMVK-OD-F
4155 Clay Street
Vicksburg, MS 39183-3435
Phone: 601-631-5276
FAX: 601-631-5459

U.S. Army Corps of Engineers, Memphis District
Attention: CEMVM-CO-GR
Clifford Davis Federal Building
Room B-202
Memphis, TN 38103-1894
Phone: 901-544-3471
FAX: 901-544-3266

U.S. Army Corps of Engineers, Nashville District
Attention: CELRN-CO-F
3701 Bell Road
Nashville, TN 37214-2660
Phone: 615-369-7500
FAX: 615-369-7501

Buffer Zone (BZ)

BZ

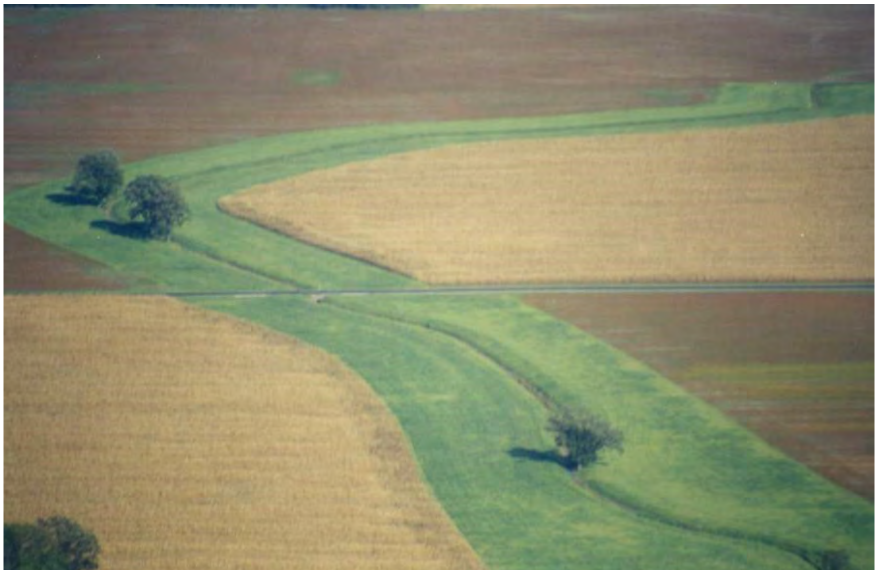


Figure BZ-1 Buffer Zone in Agricultural Area

Practice Description

A buffer zone is a strip of plants adjacent to land-disturbing sites or bordering streams, lakes, and wetlands that provides streambank stability, reduces scour erosion, reduces storm runoff velocities, and filters sediment in stormwater. This practice applies on construction sites and other disturbed areas that can support vegetation and can be particularly effective on floodplains, next to wetlands, along streambanks, and on steep, unstable slopes.

Planning Considerations

Streams, wetlands, and other waters of United States must be avoided as much as possible in all construction and earth-moving activities. (See the *Introduction to Stream Protection Practice* for more information on the regulations protecting streams, wetlands, and other waters of the United States.)

The width and plant composition of a buffer zone will determine its effectiveness.

There is no ideal width and plant community for buffer zones. A buffer zone 150 feet wide with desirable vegetation is required by the MDEQ to provide significant protection of a perennial stream, water body or wetland. Adjustments can be made to account for the purpose(s) of the buffer and landscape characteristics.

Three zones are typically recognized in the buffer area. If planned to be 45 to 55 feet wide, the recommended width and plant categories are described in the following listings:

Zone 1: The first 15 to 20 feet nearest the stream. Cover is close growing trees (commonly 6 to 10 feet apart).
Zone 2: The next 10 to 15 feet. Cover is trees or trees and shrubs.
Zone 3: The remaining buffer area. Cover is grass or dense groundcover.

Note: All widths are for one side of the stream only and are measured from top of streambank.

Existing vegetation should be considered for retention, especially hardwoods that are in Zones 1 and 2.

Buffer Zone 3 may be established with a grass planting or with close-growing groundcover that will provide dense cover to filter sediment. Where topography accommodates sheet flow from the adjacent landscape, Zone 3 should be retained or developed as a filter strip.

Necessary site preparation and planting for establishing new buffers should be done at a time and manner to ensure survival and growth of selected species.

Buffer zones may become part of the overall landscape of the project.

The layout and density of the buffer should complement natural features and mimic natural riparian forests.

Design Criteria and Construction

Preservation

Evaluate vegetation and landscape features in a proposed buffer zone to determine the potential for the existing plant community to maintain streambank stability, prevent sheet, rill and scour erosion, reduce stormwater velocities, and filter sediment.

Dedicate a vegetated zone to effectively minimize streambank and shoreline erosion, prevent sheet, rill and scour erosion in the buffer zone, and remove sediment from sheet flow from the disturbed area. Initially, estimate a width of 50 feet adjacent to the stream (each side), water body or wetland. Adjust the width to account for slope of the land adjacent to the stream and the purposes of the buffer. If the buffer is planned to trap sediment in sheet flow, the width should be increased 2 feet for every 1% slope measured along a line perpendicular to the streambank and immediately downslope of the disturbed area.

Installation (Plantings)

To determine the width and zone requirements for buffer zone plantings, MDEQ recommends the buffer zone should extend 150 feet from the waterway to be protected. The MDEQ will review cases where the 150-foot buffer zone cannot be achieved. See *Preservation of Vegetation* for more information on width and zone requirements.

Site Preparation

Plan appropriate site preparation to provide a suitable planting medium for grass, or for trees and shrubs.

Plan to install sediment- and erosion-control measures such as a silt fence and diversions if zones are graded before seedbed preparation.

If significant compaction exists, plan for chiseling or subsoiling.

For Zone 3 plantings, clear area of clods, rocks, etc., that would interfere with seedbed preparation; smooth the area, to encourage sheet flow, before the soil amendments are applied and firm the soil after the soil amendments are applied. Follow guidelines in the *Filter Strip Practice* if Zone 3 is to be used to filter sheet flow from the adjacent construction area.

Soil Amendments (Lime and Fertilizer)

Plan soil amendments using design criteria for the appropriate category (see *Permanent Seeding; Tree Planting on Disturbed Areas;* and *Shrub, Vine and Groundcover Planting Practices*). Incorporate amendments to a depth of 4″ to 6″ with a disc or chisel plow.

In the absence of a plan or soil test recommendations, apply agricultural limestone at the rate of 2 tons per acre (90 lbs per ft^2) and 10-10-10 fertilizer at the rate of 1000 lbs per acre (25 lbs per 1000 ft^2). Apply ground agricultural limestone unless a soil test shows pH of 6.0 or greater. Incorporate amendments to a depth of 4″ to 6″ with a disc or chisel plow.

Planting Desired Vegetation

Plan the vegetation for buffer zones using design criteria given in the *Permanent Seeding, Tree Planting on Disturbed Areas*, and/or *Shrub, Vine and Groundcover Planting Practices*. No invasive species shall be used. If trees are planted, at least two hardwood species should be used.

Mulching

Spread mulch according to guidelines in the *Mulching Practice*.

Common Problems

Consult with a qualified design professional if any of the following occur:

Soil compaction can prevent adequate plant growth. Compaction should be addressed during site preparation.

Design specifications for plants (variety, seeding/planting dates) and mulch cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Problems that require remedial actions:

Erosion, washout and poor plant establishment – repair eroded surface, reseed, reapply mulch and anchor.

Mulch is lost to wind or stormwater runoff – reapply mulch and anchor.

Maintenance

Replant trees, grass, shrubs or vines where needed to maintain adequate cover for erosion control. Maintain grass plantings with periodic applications of fertilizer and mowing.

References

BMPs from Volume 1

Chapter 4

BMPs from Volume 2

Chapter 4

Riparian/Forested Buffer

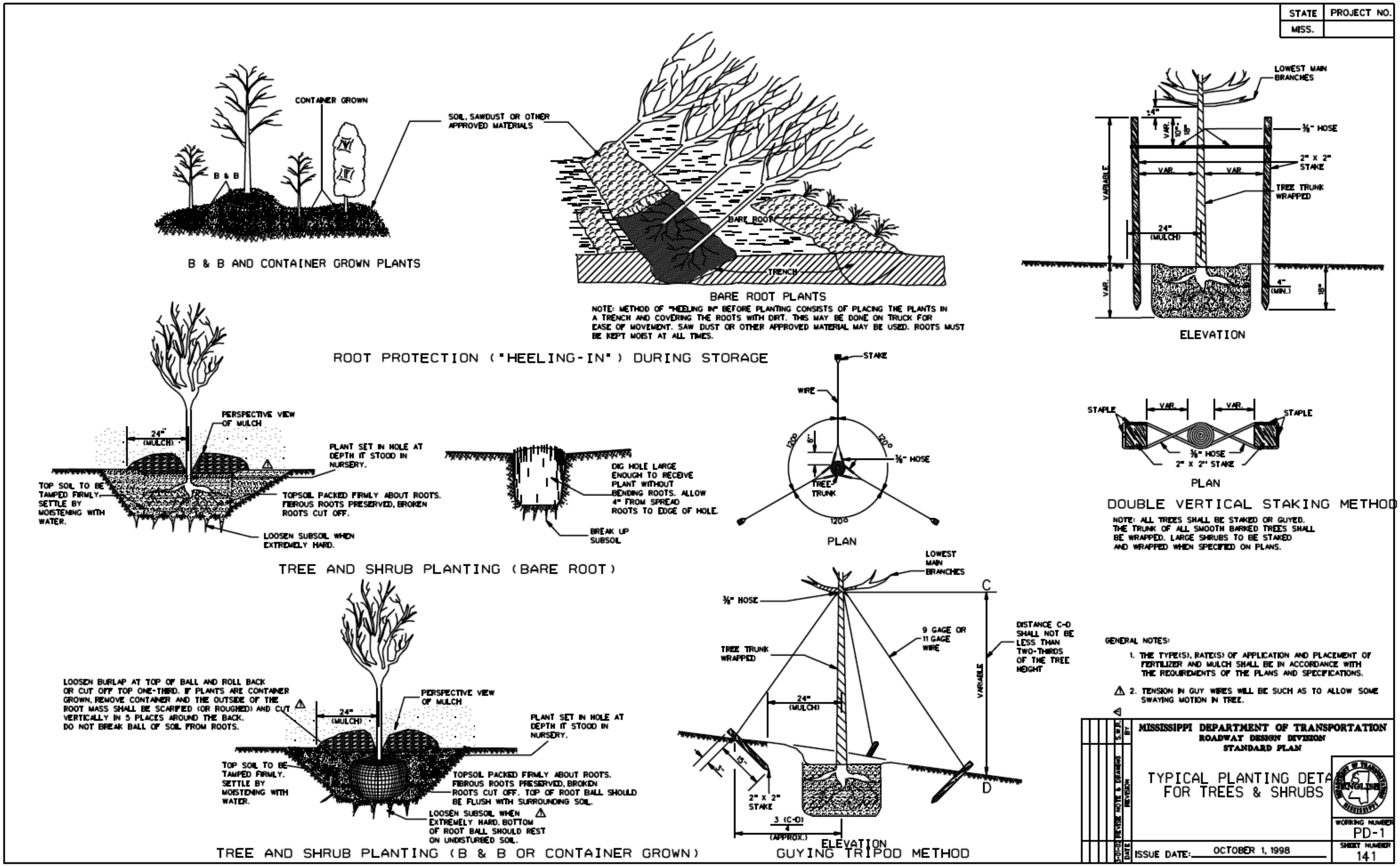
MDOT Drawing PD-1

Additional Resources

Allen, H.H., and Fischenich, J.C. (1999) "Coir geotextile roll and wetland plants for streambank erosion control," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-04), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fischenich, C. (1999). "Irrigation systems for establishing riparian vegetation," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-12), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fisher, R.A., and Fischenich, J.C. (2000). "Design recommendations for riparian corridors and vegetated buffer strips," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.


STATE
PROJECT NO.
MISS.
CONTAINER GROWN
B & B
SOIL, SAWDUST OR OTHER APPROVED MATERIALS
B & B AND CONTAINER GROWN PLANTS
BARE ROOT
TRENCH
BARE ROOT PLANTS
NOTE: METHOD OF "HEELING IN" BEFORE PLANTING CONSISTS OF PLACING THE PLANTS IN A TRENCH AND COVERING THE ROOTS WITH DIRT. THIS MAY BE DONE ON TRUCK FOR EASE OF MOVEMENT. SAW DUST OR OTHER APPROVED MATERIAL MAY BE USED. ROOTS MUST BE KEPT MOIST AT ALL TIMES.
ROOT PROTECTION ("HEELING-IN") DURING STORAGE
LOWEST MAIN BRANCHES
3/8" HOSE
2" X 2" STAKE
TREE TRUNK WRAPPED
VAR.
VARIABLE
24" (MULCH)
4" (MIN.)
18"
ELEVATION
PERSPECTIVE VIEW OF MULCH
24" (MULCH)
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY. SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF.
LOOSEN SUBSOIL WHEN EXTREMELY HARD.
DIG HOLE LARGE ENOUGH TO RECEIVE PLANT WITHOUT BENDING ROOTS. ALLOW 4" FROM SPREAD ROOTS TO EDGE OF HOLE.
BREAK UP SUBSOIL
TREE AND SHRUB PLANTING (BARE ROOT)
STAKE
WIRE
120°
3/8" HOSE
TREE TRUNK
PLAN
STAPLE
3/8" HOSE
2" X 2" STAKE
PLAN
DOUBLE VERTICAL STAKING METHOD
NOTE: ALL TREES SHALL BE STAKED OR GUYED. THE TRUNK OF ALL SMOOTH BARKED TREES SHALL BE WRAPPED. LARGE SHRUBS TO BE STAKED AND WRAPPED WHEN SPECIFIED ON PLANS.
LOWEST MAIN BRANCHES
C
3/8" HOSE
9 GAGE OR 11 GAGE WIRE
TREE TRUNK WRAPPED
DISTANCE C-D SHALL NOT BE LESS THAN TWO-THIRDS OF THE TREE HEIGHT
VARIABLE
24" (MULCH)
D
15"
2" X 2" STAKE
3/4 (C-D) (APPROX.)
ELEVATION
GUYING TRIPOD METHOD
LOOSEN BURLAP AT TOP OF BALL AND ROLL BACK OR CUT OFF TOP ONE-THIRD. IF PLANTS ARE CONTAINER GROWN, REMOVE CONTAINER AND THE OUTSIDE OF THE ROOT MASS SHALL BE SCARIFIED (OR ROUGHED) AND CUT VERTICALLY IN 5 PLACES AROUND THE BACK. DO NOT BREAK BALL OF SOIL FROM ROOTS.
PERSPECTIVE VIEW OF MULCH
24" (MULCH)
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY. SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF. TOP OF ROOT BALL SHOULD BE FLUSH WITH SURROUNDING SOIL.
LOOSEN SUBSOIL WHEN EXTREMELY HARD. BOTTOM OF ROOT BALL SHOULD REST ON UNDISTURBED SOIL.
TREE AND SHRUB PLANTING (B & B OR CONTAINER GROWN)
GENERAL NOTES:
1. THE TYPE(S), RATE(S) OF APPLICATION AND PLACEMENT OF FERTILIZER AND MULCH SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE PLANS AND SPECIFICATIONS.
2. TENSION IN GUY WIRES WILL BE SUCH AS TO ALLOW SOME SWAYING MOTION IN TREE.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN
TYPICAL PLANTING DETAILS FOR TREES & SHRUBS
ENGLISH
WORKING NUMBER
PD-1
SHEET NUMBER
141
ISSUE DATE: OCTOBER 1, 1998

Channel Stabilization (CS)

Practice Description

Channel stabilization is stabilizing a channel, either natural or artificial, in which water flows with a free surface. The purpose of this practice is to establish a non-erosive channel. This practice applies to the stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Methods of channel stabilization include rock riprap lining, concrete lining, grade stabilization structures, and bioengineered treatments, i.e., combinations of structural and vegetative materials. Vegetative-based structural reinforcements are preferred, especially in cases with fisheries resources and/or water quality issues.

Note: The design of open-channel conveyance structures other than Grass Swale is beyond the scope of this edition of the Mississippi Erosion and Sediment Control Manual, Volume 1, and should be done by a qualified design professional and should meet applicable state, federal, and local regulatory requirements.

Planning Considerations

This practice applies to the improvement or stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Channels with drainage greater than 1 square mile will be designed with appropriate criteria. In all cases, channel stabilization design should be done by a qualified design professional experienced in hydrology and hydraulics.

An adequate outlet for the channel must be available for discharge by gravity flow. Construction or other improvements to the channel should not adversely affect the environmental integrity of the area and must not cause significant erosion upstream or flooding and/or sediment deposition downstream.

The alignment and design of channels and stabilization structures shall give careful consideration to the preservation of valuable fish and wildlife habitat and trees of significant value for aesthetic purposes.

Where construction will adversely affect significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include in-stream structures such as pools, riffles, and woody structures, or streamside measures such as trees, shrubs, and other features that enhance wildlife habitat.

Due to the varied nature of these considerations, an interdisciplinary team consisting of engineers, soil bioengineers, hydrologists, and fishery biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream, the team should consider performing a geomorphic analysis of the stream. All local, state and federal laws, especially laws relating to 404 permits, should be followed during the design and construction process.

Design Criteria and Construction

Prior to the start of construction, channel stabilization should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Consider the following guidance as construction proceeds.

Realignment

The realignment of channels should be kept to an absolute minimum. Where realignment is unavoidable, the realigned channel should be designed to have a stable grade considering the soil type, vegetation, and new channel length.

Channel Capacity

The design capacity of open channels and stabilization structures should be determined by procedures applicable to the purposes to be served.

Hydraulic Requirements

Manning’s formula should be used to determine velocities in channels. The “n” values for use in this formula should be estimated using currently accepted guides along with knowledge and experience regarding the conditions. Acceptable guides can be found in hydrology textbooks.

Channel Cross Section

The required channel cross section of new or realigned channels is determined by the design capacity, the bed and bank materials, vegetation, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains and tributary channels. To enhance fisheries and wildlife, consider a channel cross section configuration that will ensure concentrated and unobstructed flow during periods of low flow, but one that incorporates bioengineered treatments with adequate habitat features to ensure refugia, etc., for fish and wildlife.

Drop Structure

Drop structures are used to reduce or prevent excessive erosion by reduction of velocities in the watercourse or by providing structures that can withstand and reduce the higher velocities. They may be constructed of concrete, rock, masonry, steel, aluminum or non-toxic treated wood.

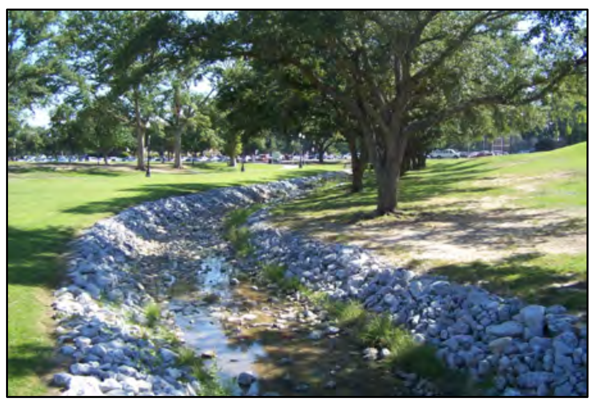
These structures are constructed where the capability of earth and vegetative measures is exceeded in the safe handling of water at permissible velocities, where excessive grades or overall conditions are encountered, or where water is to be lowered structurally from one elevation to another. These structures should generally be planned and installed along with or as part of other erosion-control practices. The structures must be designed hydraulically to adequately carry the channel discharge and structurally to withstand loadings imposed by the site conditions, but must allow fish to traverse if the stream has fish inhabitation. Therefore, a fisheries biologist should be consulted before the design is finalized and the structure installed.

Channel Stability

All channel construction, improvement and modification should be in accord with a design expected to result in a stable channel that can be maintained.

Characteristics of a stable channel are:

- It neither aggrades nor degrades beyond tolerable limits.
- The channel banks do not erode to the extent that the channel cross section is changed appreciably.



- Excessive sediment bars do not develop.
- Excessive erosion does not occur around culverts, bridges or elsewhere.
- Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.
- The determination of channel stability considers “bankfull” flow.
- Bankfull flow is defined as the flow in the channel which creates a water surface that is at or near normal ground elevation for a significant length of a channel reach. Excessive channel depth created by cutting through high ground, such as might result from realignment of the channel, should not be considered in determinations of bankfull flow.

The design for channels in natural materials shall be considered stable if the check velocity is less than the allowable velocities shown in Table CS-l. The check velocity is defined as the lesser of the bankfull velocity or the 10-year frequency peak discharge velocity.

Table CS-1 Allowable Velocities for Various Soil Textures

Soil Texture	**Allowable Velocity (ft/sec.)**
Sand and Sandy Loam (noncolloidal)	2.5
Silt Loam (also high lime clay)	3.0
Sandy Clay Loam	3.5
Clay Loam	4.0
Stiff Clay, Fine Gravel, Graded Loam to Gravel	5.0
Graded Silt to Cobbles (colloidal)	5.5
Shale, Hardpan and Coarse Gravel	6.0

Scheduling

Installation scheduling should be phased according to the following considerations. Hard structures such as rock and other inert materials could be installed during a period not suitable for vegetative establishment whereas vegetation could be planted during the appropriate time for more assurance of its survival. For instance, vegetation would be better established in the late winter/early spring after hard structures have been installed or concurrent with hard structure installation, depending on the design plan. Hard structures could be installed during a construction season prior to vegetative establishment with the vegetation being installed the following spring. For vegetation on high banks (those areas used for the adjoining *Streambank Protection*), schedule that installation during a planting period tailored for optimum survival of the plant species used. In addition, use local weather forecasts to avoid installation activities during rain events that can potentially create abnormal flows and flooding.

Site Preparation

Follow all local, state and federal government regulations on stream modifications.

Determine exact location of all underground activities.

Remove trees, brush, stumps and other objectionable materials according to the design plan. Where possible, vegetation will be left standing and stumps will not be removed.

Spoil material resulting from clearing and grubbing should be disposed of according to the design plan.

The foundation for structures should be cleared of all undesirable materials prior to the installation of the structures.

Channel Linings and Structural Measures

Where channel velocities exceed safe velocities for bare soil, channel linings of rock, concrete, or other durable material may be needed. Grade stabilization structures may also be needed.

Total channel linings covering the entire cross section of the stream are discouraged if the stream is inhabited by fisheries and other biota. Alternatively, a bioengineered stream is preferred that incorporates a zoned approach, such as a rocked toe and then vegetative treatments on the mid- and upper-banks. For more information, please review “Appendix B–Bioengineering for Streambank Erosion Control, Guidelines” of *The WES Stream Investigation and Streambank Stabilization Handbook* referenced at the end of this section. Total covering of ditches with channel linings may be appropriate if they are used solely for drainage and erosion control.

One or more of the following methods can be used to stabilize channels or portions of channels given the above considerations, i.e., whether a stream or a ditch.

Rock Riprap Lining

Rock riprap should be designed to resist displacement when the channel is flowing at the bankfull discharge or the 10-year 24-hour frequency discharge, whichever is the lesser. Rock riprap lining should not be used when channel velocities exceed 10 feet per second unless a detailed engineering analysis is performed using appropriate guidelines.

Use Figure CS-1 to determine the stable basic stone weight (d_{100}). Using the d_{100} size as a d_{90}, select a commercially available riprap gradation as classified by the Mississippi Department of Transportation, from Table CS-2.

Dumped and machine-placed riprap should be installed on slopes flatter than 2 horizontal to 1 vertical. Where riprap is placed by hand, the slopes may be steeper. Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering, and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

A filter blanket should be placed between the riprap and base material, if needed. A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. A filter blanket should be considered where soils have a high piping potential and/or there is significant seepage of groundwater from the bed or banks.

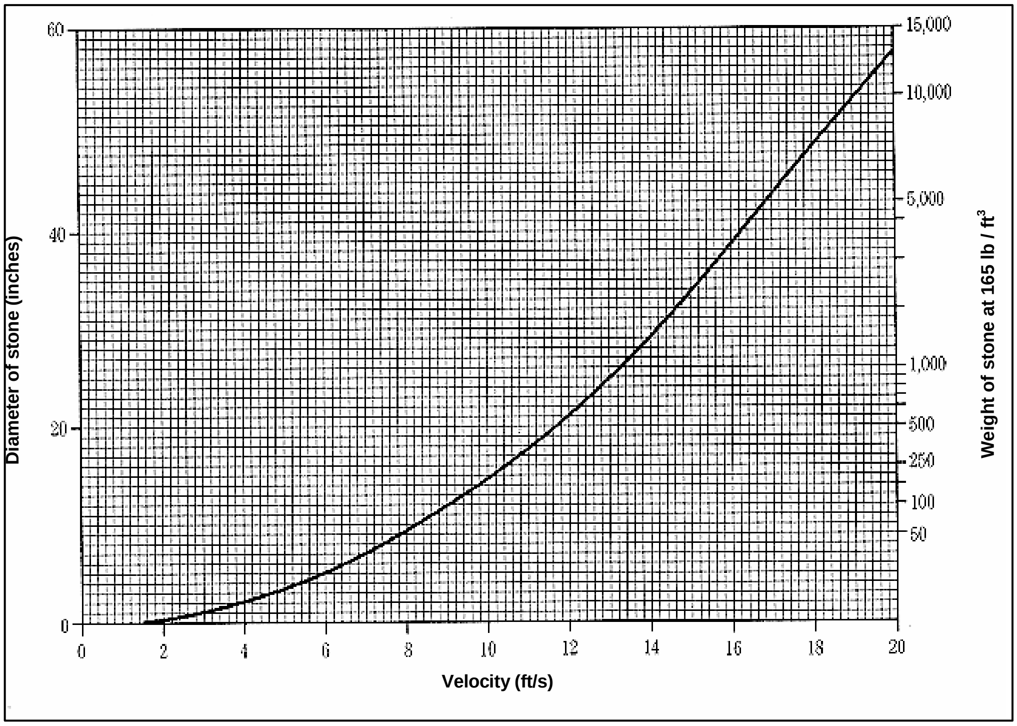


Figure CS-1 Ishbash Curve

Procedure

1) Determine the design velocity.
2) Use design velocity and Figure CS-1 to determine d_{100} rock size.
3) Use d_{100} from Figure CS-1 as d_{90} to select rock gradation from Table CS-2.

Table CS-2 Commercially Available Riprap Gradations

Class	**Weight (lbs.)**					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

A filter blanket can be of two general forms: a gravel layer or a geotextile filter cloth. Gravel filter blankets are to be designed in accordance with the criteria below.

Gravel Filter Blanket

The following relationships must exist:

$$\frac{d_{15}\,\text{filter}}{d_{85}\,\text{base}} < 5 < \frac{d_{15}\,\text{filter}}{d_{15}\,\text{base}} < 40$$

$$\frac{d_{50}\,\text{filter}}{d_{50}\,\text{base}} < 40$$

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6″ thick.

Geotextile Filter Cloth

Geotextile filter cloth may be used in place of or in conjunction with gravel filters. Geotextile will meet the requirements of Class I geotextile as shown in Table CS-4.

Filter blankets should always be provided where seepage from underground sources threatens the stability of the riprap.

Rock Riprap Lining Installation

Where excavation is required, channels will be excavated from one side, leaving vegetation on the opposite side.

Excavation should be at the locations and grades shown on the drawings.

Spoil material resulting from channel excavation should be disposed of according to the design plan.

If required by the plans, place geotextile fabric or a granular filter as a bedding material for the riprap. Install riprap of the specified gradation to the lines and grades shown in the design plan. Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan.

Riprap may be placed by equipment. Care should be taken to avoid punching or tearing of the filter cloth during placement of rock. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet so that the upstream piece of fabric lies on top of the downstream piece of fabric. If the damage is extensive, replace the entire filter cloth.

Installation usually includes some bank shaping. If bank shaping is included, follow details in the design plan and refer to the construction guidelines in *Streambank Protection Practice.*

Concrete Lining

Concrete linings should be designed according to currently accepted guides for structural and hydraulic adequacy. They must be designed to carry the required discharge and to withstand the loading imposed by site conditions. Concrete linings are generally used when velocities exceed 10 ft/sec. Erosion at the outlet of concrete-lined channels is generally a problem due to the high velocities. Measures should be taken to reduce the velocity and erosion potential at the outlet by use of outlet protection measures (see *Outlet Protection Practice*).

Concrete Lining Installation

Where excavation is required, channels will be excavated from one side, leaving vegetation on the opposite side.

Excavation should be at the locations and grades shown on the drawings.

Spoil material resulting from channel excavation should be disposed of according to the design plan.

Install concrete lining using concrete of the specified design strength according to the lines and grades in the design plan.

Installation of concrete linings usually includes some bank shaping. If bank shaping is included, follow details in the design plan and refer to the construction guidelines in *Streambank Protection Practice*.

Place filter material and weep holes according to the plans. Place concrete according to American Concrete Institute standards. Concrete on sloping surfaces should be placed from the bottom of the slope toward the top, at the required thickness, and with good vibration.

As required by the design plan, install expansion joints at the locations shown in the plan.

As required by the design plan, install welded wire fabric in the concrete forms before placing concrete.

Divert flow around the concrete lining until the concrete has reached 75% of its design strength (usually 7 days after concrete placement).

Table CS-4 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [3]
Tensile strength (lb) [1]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [1]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Minimum average roll value (weakest principal direction).
2 U.S. standard sieve size.
3 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to class IV. Needle-punched geotextile is required for all other classes.

Grade Stabilization Structures

For streams with fish inhabitation, a fisheries biologist should be consulted before the design is finalized and the structure installed, to ensure fish transport will not be adversely affected by the structure.

Where excavation is required, channels will be excavated from one side, leaving vegetation on the opposite side.

Excavation should be at the locations and grades shown on the drawings.

Spoil material resulting from clearing, grubbing and channel excavation should be disposed of according to the design plan.

Install the structure to the lines and grades shown in the design plan.

If earthfill is required, install according to the design plan and refer to the construction guidelines for *Sediment Basin* embankments.

If rock riprap is required, install according to the design plan and refer to the installation requirements listed earlier for *Riprap-Lined Swale*.

Other products used, including concrete, masonry, steel, aluminum or treated wood, should be installed according to details in the design plan. Installation usually includes some bank shaping. If bank shaping is included, follow details in the design plan and refer to the construction guidelines in the *Streambank Protection Practice*.

Erosion Control

Seeding, fertilizing and mulching of the disturbed areas should be done immediately after construction and should conform to the guidelines in the design plan. If vegetation establishment specifications are not included in the design plan, see the appropriate practice (*Permanent* or *Temporary Seeding*) for guidelines. If planting needs to be deferred until the next planting season, the disturbed areas should be protected with mulch (see *Mulching Practice* if details are not included in the design plan).

Safety

Store all construction materials well away from the stream. Consider weather forecasts when determining risks of damage by flooding.

Equipment used to construct channel stabilization measures should be free of leaks of fuel and hydraulic fluids to prevent contamination of surface waters. Operation of equipment in the stream should be minimized. At the completion of each workday, move all construction equipment away from the stream to prevent damage to equipment by flooding. Consider weather forecasts when determining risks of flooding.

The following precautions should be taken:

- Exercise caution on steep slopes.
- Fence the area and post warning signs if trespassing is likely.
- All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.
- Equipment should not be operated within flowing water in the stream.

Construction Verification

Check material and finished grades to determine if job meets specifications in the design plan.

Common Problems

Variations in site conditions indicate practice will not function as intended; changes in plan may be needed.

Design specifications for materials cannot be met; substitution may be required. Unapproved substitutions could result in failure of the practice.

Maintenance

All structures should be maintained in an “as built” condition.

Check the stream channel at the construction site after each major event until the job is considered mature and a success.

Structural damage caused by storm events should be repaired as soon as possible to prevent further damage to the structure or erosion of the streambank.

Unwanted brush or excessive sediment that will impede flow should be removed to maintain design conditions.

References

BMPs from Volume 1

Chapter 4

BMPs from Volume 2

Chapter 4

Riparian/Forested Buffer

Vegetated Filter Strip

Additional Resources

Allen, H.H., and Fischenich, J.C. (1999) “Coir geotextile roll and wetland plants for streambank erosion control,” *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-04), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Biedenharn, D.S., Elliot. C.M., and Watson, C.C. (1997) “The WES Stream Investigation and Streambank Stabilization Handbook.” http://chl.erdc.usace.army.mil/Media/2/8/7/StreambankManual.pdf.

Fischenich, C. (1999). "Irrigation systems for establishing riparian vegetation," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-12), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fisher, R.A., and Fischenich, J.C. (2000). “Design recommendations for riparian corridors and vegetated buffer strips,” *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Stream Diversion Channel (SDC)

Practice Description

A stream diversion channel is a temporary practice to convey stream flow in an environmentally safe manner around or through a construction site while a permanent structure or conveyance is being installed in the stream channel.

Planning Considerations

Construction projects often cross and impact live streams, creating a potential for excessive sediment delivery into the stream. In cases where in-stream work is unavoidable, a temporary stream diversion channel should be planned. In-stream projects of this nature are subject to the rules and regulations of the U.S. Army Corps of Engineers for in-stream modifications (Clean Water Act Section 404 permit) and, if applicable, MDEQ CWA Section 401 water quality certification. Temporary stream diversions shall be used only on streams with a drainage area less than 1 square mile (640 acres). Detailed engineering analysis and design should be used for larger drainage areas to ensure a stable diversion channel. For sites with very small drainage areas, the designer may consider temporary blocking and overland pumping of the stream. To avoid crossing a live stream, the planner or designer should consider allowing access for construction of the permanent structure only from the side opposite the stream diversion channel. At locations where access from both sides of the stream is required to construct the permanent structure in the stream channel, a *Temporary Stream Crossing (TSC)* may be necessary. It is best to locate this crossing either up- or down-stream of the stream diversion channel.

Vegetation along the existing stream channel should be left undisturbed and protected with effective sediment-control practices until such time as the diversion channel is constructed and can safely convey stream flows. Construction equipment should not be allowed to operate in flowing waters and should be operated and maintained according to the *Housekeeping (HK) Practice*. Excavated materials should be stockpiled away from the stream and diversion channel and protected to ensure the material does not erode and enter the stream system. The stream diversion channel should be planned and installed in such a manner and time (dry season) that the impact to fisheries and the aquatic environment is minimized. A pictorial representation of a stream diversion channel is shown in Figure SDC-1.

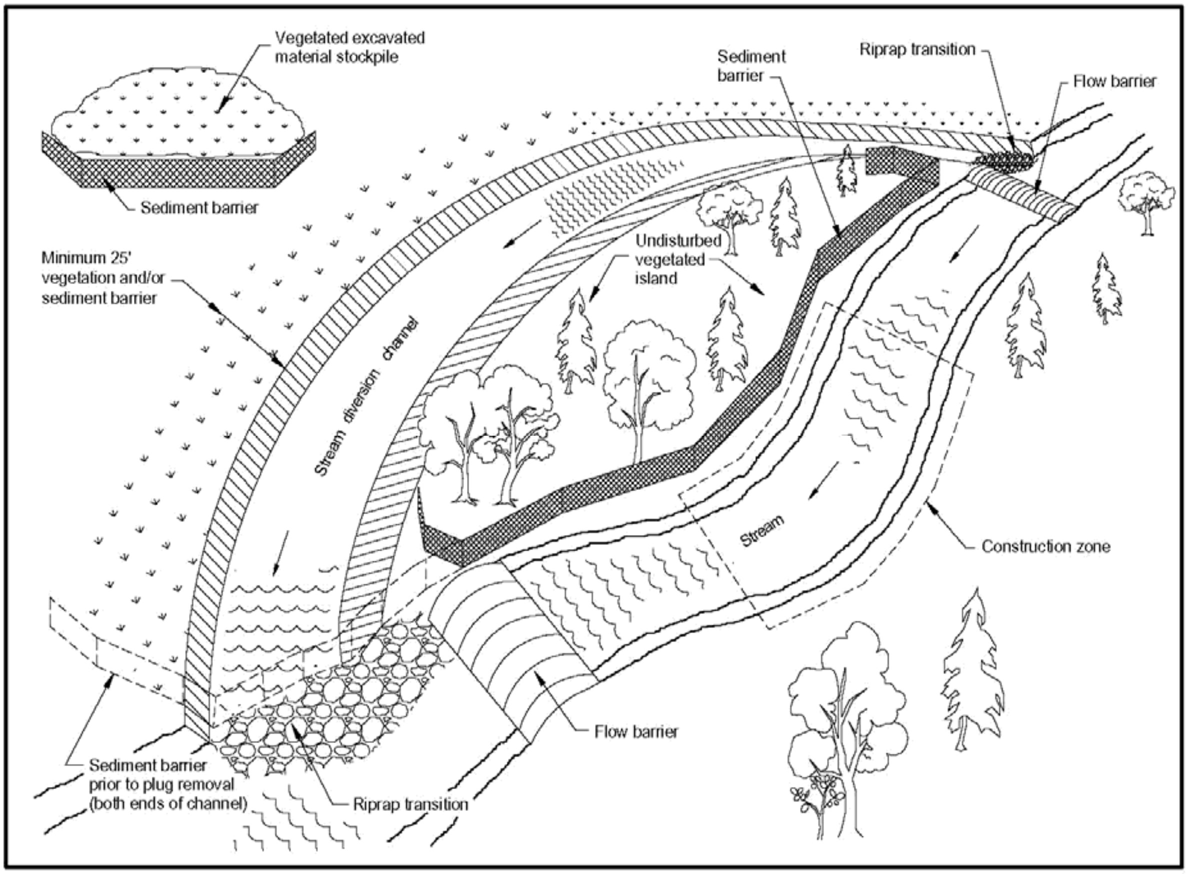


Figure SDC-1 Typical Stream Diversion Channel Layout

Design Criteria and Construction

Prior to the start of construction, stream diversion channels are required to be designed by a qualified design engineer registered in the State of Mississippi.

Size

The combination of bottom width, depth, and gradient shall be sufficient to provide the required flow capacity. The minimum bottom width of the stream diversion channel shall be 6 feet or equal to the bottom width of the existing stream bed, whichever is greater. The bottom surface should be shaped or configured to ensure adequate concentrated and unobstructed flow of water during periods of low flow.

Side Slope

Side slopes of the stream diversion channel shall be no steeper than 2 horizontal to 1 vertical (2:1).

Gradient

The diversion bottom grade may be variable, dependent on site conditions, but shall be sufficient to ensure continuous flow of water in the diversion at velocities not exceeding the allowable velocities for the selected channel lining material. The stream diversion channel length should be the same or greater than the length of the stream diverted.

Capacity

The capacity of the stream diversion channel shall be at least bankfull capacity of the existing stream. Consideration should be given to providing greater capacity where construction is expected to extend over several weeks or months.

Channel Lining

The stream diversion channel shall be lined to prevent erosion of the channel and sedimentation in the stream. The lining should be selected based on the velocity at bankfull flow. Use Table SDC-1 for general guidance on the type of lining to be used. Pre-manufactured products, like turf reinforcement mats (TRM), cellular blocks, and similar products, shall be designed and installed according to the manufacturer's recommendations.

Table SDC-1 Stream Diversion Channel Linings

Lining Materials	Acceptable Velocity Range
Geotextile fabric, polyethylene film, light-weight TRM, block sod	0 – 2.5 fps
Geotextile fabric, heavy-weight TRM	2.5 – 9.0 fps
Class I riprap and geotextile	9.0 – 13.0 fps

Riprap linings shall be designed in accordance with the guidance contained in the *Channel Stabilization (CS) Practice*. Class I non-woven geotextile shall be used underneath riprap lining for high-velocity applications.

When rolled products such as polyethylene film or geotextile fabric are used as a channel lining, the product should be placed so that one width of material will cover the entire channel bottom and slopes, while also providing enough material for a minimum 6-inch anchorage at the top of the bank. The upstream end of the material shall be buried at least 2 feet from top-of-bank to top-of-bank with additional trench anchorages of at least 1 foot by 1 foot at 50-foot intervals. Upstream sections of material shall overlap downstream sections by at least 2 feet, and overlap should occur at a trench anchorage location. Polyethylene film shall be at least 6 mil thick and capable of maintaining strength against the effects of ultraviolet light for a period of at least 60 days.

Block sod shall be covered with erosion-control netting and staked at minimal 3-foot by 3-foot spacing, and also staked at the upstream edge of each piece of sod.

Transitions

Additional protection such as riprap may be needed at the entrance and exit portion of the stream diversion channel to ensure velocities do not scour the existing stream bed or bank.

Sequence of Construction

To minimize detrimental effects to the environment and the aquatic community, the stream diversion channel should be quickly and carefully installed, well maintained, and removed as soon as possible when the construction area is stable. A sequence of construction should be specified in the contract work. While the sequence of construction should be tailored to the specific site, the general process should be as follows:

- Install sediment barrier at locations alongside stream to intercept runoff from the construction of the stream diversion channel.
- Install sediment barrier around or downstream of stockpile location.
- Maintain vegetation around stream.
- Clear downstream portion of stream diversion channel except for the area of the temporary plug.
- Begin excavation of the stream diversion channel at least 25 feet from the outlet and maintain this undisturbed plug.
- Stockpile excavated material at designated location and clear additional portions of the stream diversion channel as needed for excavation operations.
- Complete the excavation and leave at least a 25-foot undisturbed plug at the entrance to the stream diversion channel.
- Dewater the excavated area as needed for installation of the lining, and pump the dewatered material to a settling basin before any discharge is allowed.
- Install the lining in diversion channel.
- Excavate the downstream plug and install the transition riprap.
- Adjust sediment barrier locations as needed for stream protection.
- Excavate the upstream plug and install the transition riprap.
- Install an upstream flow barrier, forcing flow into the diversion channel.
- Allow time for aquatic organisms to move or migrate downstream.
- Install a downstream flow barrier if needed.
- Seed and mulch the stockpile and the disturbed area around the stream diversion channel.
- Complete the “in-stream” work.
- Divert flow into the completed “in-stream” conveyance system.
- Place sediment barriers for protection while decommissioning the stream diversion channel.
- Remove channel linings as needed, recycle or properly dispose of the material.
- Place excavated material into diversion channel.
- Apply seed and mulch to disturbed areas.

Site Preparation

Determine exact location of underground utilities.

Maintain vegetation around the stream until the stream diversion channel has been fully completed including vegetation. Clear only enough of the stream-diversion channel area for the next day’s work.

The centerline of the stream diversion channel should be established in the plans or by the responsible engineer. Slope and grade stakes should be established for use during excavation.

Erosion and Sediment Control

Sediment barrier or other sediment-control practices to protect the stream from the construction of the diversion channel should be installed prior to any land disturbance. The stockpile for excavated material should be located well away from the work area with sediment-control practices installed prior to placement of stockpiled materials. All construction areas should be seeded and mulched as soon as work is complete. Maintain a minimum 25-foot vegetated grass filter around the stream diversion channel.

Excavation

A 25-foot undisturbed plug should be left at the exit and entrance of the stream diversion channel until the diversion channel itself has been finished. The stream diversion channel should be excavated according to the dimensions and grade shown in the construction plans, beginning at the downstream end next to the plug and continuing in an upstream direction. The grade of the stream diversion channel should be uniform and continuous in order to tie into the existing stream bottom elevations without any overfalls that would create turbulence. Construction equipment should not be allowed to operate in flowing waters. Construction equipment should be well maintained to prevent drip/leaks of oil, hydraulic fluid, etc. Water that collects in the stream diversion channel excavation should be pumped as necessary to a settling basin prior to its discharge. The excavated material should be hauled to the stockpile location.

Lining Placement

Different lining materials can be specified for the stream diversion channel. Install the selected linings according to the construction specifications.

When rolled products like polyethylene film or geotextile fabric are specified for use as a channel lining, the product should be placed so that one width of material will cover the entire channel bottom and slopes while also providing enough material for a minimum 6-inch anchorage at the top of the bank. The upstream end of the material shall be buried at least 2 feet from top-of-bank to top-of-bank with additional trench anchorages of at least 1 foot by 1 foot at 50-foot intervals. Upstream sections of material shall overlap downstream sections by at least 2 feet and occur at a trench anchorage location. Polyethylene film shall be at least 6 mil thick and capable of maintaining strength against the effects of ultraviolet light for a period of at least 60 days.

Pre-manufactured products, such as turf reinforcement mats (TRM), cellular blocks, and other similar products, shall be designed and installed according to the manufacturer's recommendations.

Block sod shall be covered with erosion-control netting and staked at minimal 3-foot by 3-foot spacing, and also at the upstream edge of each piece of sod.

Generally, Class I non-woven geotextile fabric is used underneath riprap linings. Additional protection such as riprap may be needed at the entrance and exit portions of the stream diversion channel to ensure scour does not occur in the existing stream bed or bank.

Stream Diversion

After the lining between the upstream and downstream plugs has been installed, the downstream plug should be removed first and the transition installation completed. Next, the upstream plug should be removed and the transition installation completed. Finally, the stream flow should be diverted into the stream diversion channel using an upstream flow barrier, as specified in the plans and in such a manner as to minimize sediment delivery into the stream. Allow time for the stream to drain so that aquatic organisms have an opportunity to move or migrate downstream. The downstream flow barrier, if required, can then be installed so that work can commence for the installation of the permanent structure.

Construction Verification

Check finished grades and cross sections throughout the length of the stream diversion channel.

Verify the stream diversion channel cross-section dimensions at several locations to confirm plan specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

The topography of the site does not allow the practice to function as intended and changes in the plan are needed.

The design specifications for materials cannot be met and substitutions may be necessary. Unapproved substitutions could result in an unstable diversion channel.

Maintenance

Inspect the stream diversion channel at regular intervals and especially after storm events; check for lining displacement, erosion of the lining, and erosion at the transition areas.

Repair damaged lining and erosion promptly.

Once the permanent structure has been completed, flow can be diverted into the new conveyance structure and the stream diversion channel decommissioned. The decommissioning should occur in such a manner as to minimize erosion and sediment runoff into the stream system. Lining materials should be recycled or disposed of properly.

References

BMPs from Volume 1

Chapter 4

Housekeeping (HK) 4-43
Channel Stabilization (CS) 4-342
Temporary Stream Crossing (TSC) 4-382

MDOT Drawing ECD-17

MDOT Drawing ECD-18

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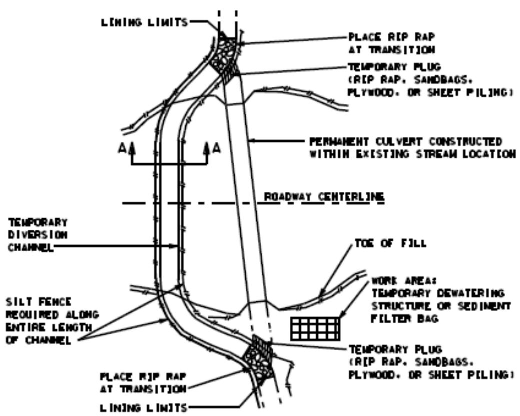
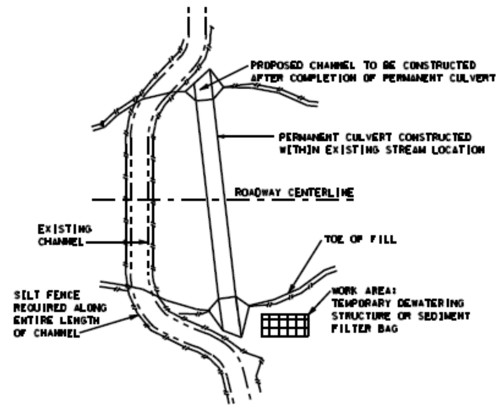


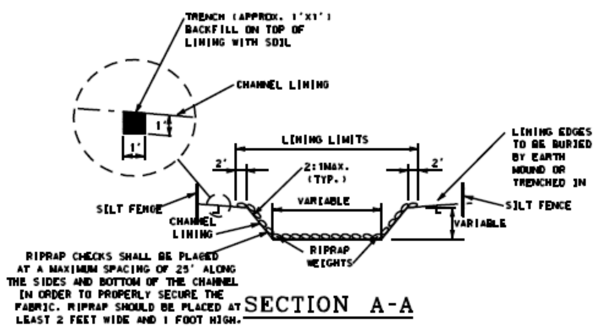
CULVERT CONSTRUCTED WITHIN EXISTING STREAM



CULVERT CONSTRUCTED OUTSIDE EXISTING STREAM

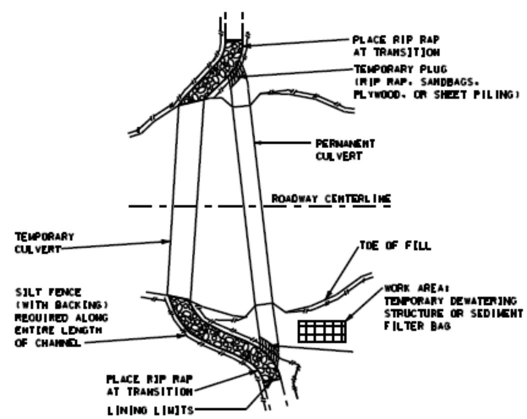
NOTES:

1. TEMPORARY DIVERSION CHANNELS MAY BE USED TO DIVERT NORMAL STREAM PATH FLOW FROM AN ERODIBLE AREA UNTIL SUCH AREAS CAN BE STABILIZED.
2. TYPE III FILTER FABRIC OR PRE-FAB DITCH LINER MAY BE USED FOR CHANNEL LINING.
3. RIP-RAP WITH FILTER FABRIC MAY BE USED FOR CHANNEL FLOW VELOCITIES OF 3.0 FPS TO 9.0 FPS. THE RIP-RAP SHALL BE SIZED 300 LB
4. LOCATIONS OR TYPES OF TEMPORARY DIVERSION WILL NOT BE SHOWN ON THE PLANS
5. DIVERSION CHANNEL SHALL BE STABILIZED AND INSPECTED BY THE ENGINEER BEFORE FLOW IS DIVERTED.
6. DURING CONSTRUCTION OF DIVERSION CHANNEL, DAMAGE TO THE EXISTING STREAM, CANOPY REMOVAL, AND DEPTH OF THE CHANNEL CONSTRUCTION SHALL BE MINIMIZED.
7. CONSTRUCTION OF THE CHANNEL RELOCATIONS AND CULVERTS SHALL PROCEED AS FOLLOWS:
   - 7.1. CONSTRUCT A MEANDERING TEMPORARY CHANNEL CHANGE ADJACENT TO THE PROPOSED CULVERT TO DIVERT WATER TEMPORARILY DURING THE CULVERT CONSTRUCTION. TEMPORARY EROSION CONTROL MEASURES SHALL BE INSTALLED IN ACCORDANCE WITH THE STANDARD SPECIFICATIONS.
   - 7.2. RELOCATE CHANNEL AND CONSTRUCT CULVERT SIMULTANEOUSLY.
   - 7.3. SOD AND/OR RIP-RAP RECONSTRUCTED BANKS AT TRANSITIONS. THE UPPER CHANNEL PLUG IS TO REMAIN IN PLACE UNTIL SUBNOTE (7.1) THROUGH (7.4) UNDER THIS HEADING ARE COMPLETED TO INSURE THAT ALL CONSTRUCTION IS IN THE DRY.
   - 7.4. IF AN EARTH PLUG IS NECESSARY AT THE DOWNSTREAM END OF THE CHANNEL IT SHOULD BE REMOVED FIRST, THEN REMOVE THE UPPER PLUG TO RELEASE WATER INTO THE RECONSTRUCTED CHANNEL.
   - 7.5 PLUGS SHOULD REMAIN IN PLACE UNTIL PERMANENT STABILIZATION OF THE NEW WATER COURSE IS COMPLETED. REMOVAL OF PLUGS SHOULD ONLY BE PERFORMED FOLLOWING ACCEPTANCE OF ALL STABILIZATION WORK BY THE ENGINEER.
8. THE DETAILS PROVIDED DEPICT TYPICAL TEMPORARY DIVERSION CHANNELS.
9. THE CONTRACTOR MAY PROPOSE THE USE OF OTHER DIVERSION OPTIONS SUCH AS PIPING, PUMPING OR STAGED CONSTRUCTION.
10. THE EFFECTIVE AREA OF FLOW IN THE TEMPORARY CHANNEL OR CULVERT SHALL BE AT LEAST ONE-HALF THAT OF THE EXISTING STRUCTURE.



SECTION A-A

TEMPORARY DIVERSION CHANNEL WITH GEOTEXTILE FABRIC



TEMPORARY CULVERT USED DURING CONSTRUCTION

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

TEMPORARY STREAM DIVERSION

WORKING NUMBER: ECD-17

SHEET NUMBER

FILENAME: EROSION CONTROL-ECD-17.DGN

DESIGN TEAM ____ CHECKED ____ DATE ____

BY | REVISION | DATE

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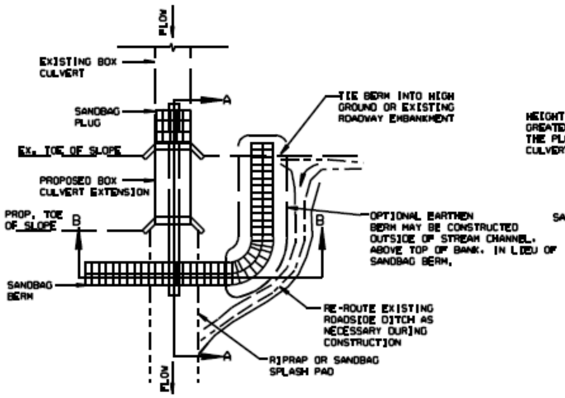
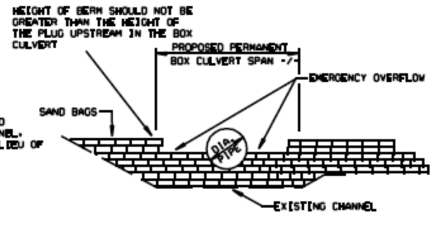
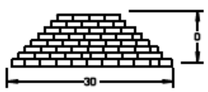


PLAN VIEW

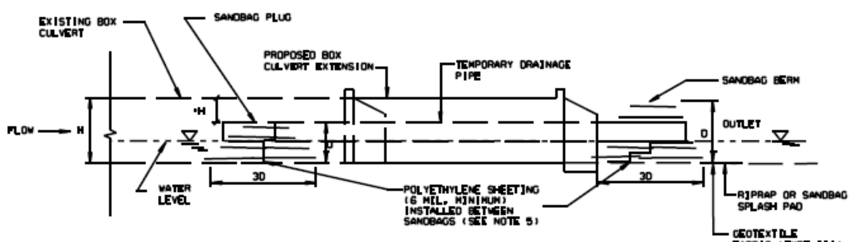


SECTION B-B



SAND BAG PLUG & BERM CROSS SECTION

(SEE NOTE 4)



SECTION A-A

MAXIMUM SPAN FOR PIPE SUPPORTS, FEET					
DIAMETER OF PIPE (IN.)	STEEL THICKNESS (IN.)				
	0.064	0.079	0.109	0.138	0.168
	2" X 1/2" CORRUGATION				
24	13	15	20		
36	12	15	20	25	
48	11	14	19	25	30
60		14	19	24	29
72			18	24	29
	5" X 1" OR 3" X 1" CORRUGATION				
36	9	11			
48	9	11	15		
60	8	10	14	18	
72	8	10	14	18	22

FOR PIPE SIZES NOT SHOWN REFER TO NEXT LARGER SIZE

GENERAL NOTES

1 SUSPENDED PIPE DIVERSIONS MAY BE USED TO ALLOW BOX CULVERT EXTENSIONS TO BE CONSTRUCTED, WHILE SEPARATED FROM FLOWING WATER, THUS REDUCING SEDIMENTATION. OPTIONAL FLEXIBLE PIPE DIVERSION MAY BE UTILIZED ON STREAMS WITH INTERMITTENT FLOW WHERE THE DURATION OF CONSTRUCTION IS EXPECTED TO BE BRIEF.

2 EXCAVATION SLOPES FOR BOX CULVERT EXTENSIONS SHALL BE PROTECTED WITH TYPE III FILTER FABRIC PRIOR TO CONSTRUCTION OF THE BOX.

3 SUSPENDED PIPE DIVERSIONS MAY BE USED WHERE ADVERSE IMPACTS WILL NOT BE CAUSED BY WATER PONDED UPSTREAM OF THE PIPE.

4 THE SANDBAG PLUG AT THE UPSTREAM END OF THE SUSPENDED PIPE DIVERSION SHOULD BE CONSTRUCTED TO A HEIGHT EQUAL TO THREE QUARTERS OF THE RISE OF THE BOX CULVERT.

5 POLYETHYLENE SHEETING (6 MIL. MINIMUM) SHALL BE PLACED INSIDE THE SANDBAG PLUG IN THE BOX CULVERT AND IN THE SAND BAG BERM WITHIN THE CHANNEL IN ORDER TO PROVIDE THE BEST POSSIBLE SEAL. SANDBAGS ON THE DOWNSTREAM SIDE OF THE SHEETING SHOULD BE PLACED FIRST, AND THEN SHEETING PLACED ON THESE BAGS. AS MUCH AS POSSIBLE, THE SHEETING SHOULD BE FITTED AROUND THE PIPE. THE REMAINING SANDBAGS WOULD THEN BE PLACED ON THE SHEETING. WHERE MULTIPLE SHEETS ARE USED, THEY SHOULD OVERLAP A MINIMUM OF 18 INCHES.

6 THE PROPOSED CULVERT CONSTRUCTION SHALL BE SEALED FROM THE EXISTING STREAM BY MEANS OF A SANDBAG BERM WHICH SHOULD BE AT THE SAME HEIGHT AS THE PLUG INSIDE THE BOX CULVERT. THIS BERM SHALL BE TIED INTO EITHER HIGH GROUND ADJACENT TO THE CHANNEL OR THE EXISTING ROADWAY EMBANKMENT. IT SHALL BE PROVIDED WITH A SPILLWAY EQUAL IN WIDTH TO THE BOX CULVERT AND AT A HEIGHT LOWER THAN THE REST OF THE BERM.

7 THE TEMPORARY DRAINAGE PIPE SHALL BE SUPPORTED AT ALL JOINTS AND AT INTERVALS NOT TO EXCEED MAXIMUM VALUES SPECIFIED IN THE TABLE "MINIMUM SPAN FOR SUPPORTS." SUPPORTS MAY CONSIST OF SANDBAGS, CONCRETE BLOCKS, WOODEN FRAMES, OR ANY OTHER MATERIAL SUFFICIENT TO SUPPORT THE WEIGHT OF THE PIPE WHEN IT IS FLOWING FULL. SUPPORTS AT JOINTS SHALL BE A MINIMUM OF 18 INCHES IN LENGTH, ALONG THE TEMPORARY DRAINAGE PIPE AND CENTERED ON THE JOINT. SUPPORTS SHOULD "CRADLE" THE TEMPORARY DRAINAGE PIPE TO ENSURE THAT IT WILL NOT ROLL DURING CONSTRUCTION OF THE BOX CULVERT.

8 ALL PIPE JOINTS SHALL BE PROPERLY BANDED OR OTHERWISE PROVIDED WITH A REASONABLE SEAL AGAINST LEAKAGE.

9 THE OPTIONAL FLEXIBLE PIPE DIVERSION USING PUMPS MAY BE USED AS AN ALTERNATE FOR SUSPENDED PIPE DIVERSIONS (UPSTREAM AND DOWNSTREAM).

10 CONSTRUCTION SHALL PROCEED AS FOLLOWS:
10A. INSTALL TEMPORARY DRAINAGE PIPE ON ITS SUPPORTS INSIDE THE CULVERT TO BE EXTENDED.
10B. CONSTRUCT THE SANDBAG PLUG AT THE UPSTREAM END OF THE SUSPENDED PIPE DIVERSION.
10C. CONSTRUCT THE SANDBAG BERM AT THE DOWNSTREAM END OF THE SUSPENDED PIPE DIVERSION.
10D. ONCE THE BOX CULVERT EXTENSION HAS BEEN COMPLETED, REMOVE THE DOWNSTREAM SANDBAG STRUCTURE. EXCEPT FOR THOSE BAGS NEEDED TO SUPPORT THE END OF THE PIPE. THE UPSTREAM SANDBAG STRUCTURE SHOULD THEN BE REMOVED GRADUALLY, IN ORDER TO ALLOW THE UPSTREAM WATER LEVEL TO DRAW DOWN AT A SAFE RATE.
10E. REMOVE THE TEMPORARY DRAINAGE PIPE, SUPPORTS AND ANY REMAINING SANDBAGS.

11 TEMPORARY DRAINAGE PIPE, SANDBAG PLUGS, BERMS, AND SUPPORTS SHALL BE INSPECTED WEEKLY OR AFTER EVERY RAIN EVENT. ANY NEEDED REPAIRS SHALL BE DONE IMMEDIATELY. ANY DEBRIS WHICH HAS ACCUMULATED AT THE INLET OF THE SUSPENDED PIPE DIVERSION SHALL BE IMMEDIATELY REMOVED.

12 RIP RAP MAY BE SUBSTITUTED FOR SAND BAGS

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

TEMPORARY STREAM DIVERSION (BOX EXTENSIONS)

BY | REVISION | DATE

WORKING NUMBER: ECD-18

SHEET NUMBER

FILENAME: EROSION CONTROL\ECD-18.DGN

DESIGN TEAM ______ CHECKED ______ DATE ______

Streambank Protection (SP)

Practice Description

Streambank protection is the stabilization of the side slopes of a stream. Streambank protection can be vegetative, structural, or a combined method (bioengineering) in which live plant materials are incorporated into a structure. Vegetative protection is the least costly and the most compatible with natural stream characteristics. Additional protection is required when hydrologic conditions have been greatly altered and stream velocities are excessively high. Streambank protection is often necessary where failure mechanisms cause erosion. According to Fischenich and Allen (2000), banks fail and erode because they exist in a dynamic environment that is constantly subjected to various forces. River banks fail in one of four ways: 1) hydraulic forces remove erodible bed or bank material; 2) geotechnical instabilities result in bank failures; 3) mechanical actions cause a reduction in the strength of the bank; or 4) a combination of the above factors causes failure. These modes of failure have distinct characteristics. An investigation must be conducted to determine the specific mode of failure because this is indicative of the problem. These modes of failure are further discussed in Fischenich and Allen (2000). Streambank protection is often necessary in areas where development has occurred in the upstream watershed and full channel flow occurs several times a year.

Planning Considerations

Since there are several different methods of streambank protection, the first step in the design process is a determination of the type protection to be used at the site. Items to consider include:

- Overall condition of the stream within and adjacent to the reach to be stabilized.
- Current and future watershed conditions.

- Amount of discharge at the site.
- Flow velocity at the site.
- Sediment load in the stream.
- Channel slope.
- Controls for bottom scour.
- Soil conditions.
- Present and anticipated channel roughness.
- Compatibility of selected protection with other improvements at the site.
- Changes in channel alignment.
- Fish and wildlife habitat.

Due to the varied nature of these considerations, an interdisciplinary team consisting of engineers, soil bioengineers, hydrologists, and fishery biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream, the team should consider performing a geomorphic analysis of the stream. All local, state, and federal laws, especially laws relating to Clean Water Act Section 404 permits, should be followed during the design and construction process.

Design Criteria and Construction

Velocities

As a general rule, use vegetation alone with velocities up to 6 ft/sec if the stream bottom is stable. Use structural (to include soil bioengineered) protection for velocities greater than 6 ft/sec. The design velocity should be the velocity associated with the peak discharge of the design storm for the channel. Any protection method should take into consideration a variety of site conditions, to include an analysis of failure mechanisms, and should be designed and/or reviewed by the aforementioned interdisciplinary team.

Channel Bottom

The channel bottom must be stabilized before installing bank protection. Grade control in the channel bottom may be needed to prevent downcutting (see *Channel Stabilization Practice*).

Permits

All local, state, and federal laws should be complied with during the design and construction of bank protection. If fill is to be placed in wetlands or streams, the U.S. Army Corps of Engineers should be contacted regarding a 404 permit for the work.

Aquatic Zone

This area includes the stream bed and is normally submerged at all times. No planting is required in this zone.

Wetland Plants/Shrub Zone

This zone is on the bank slopes above mean water level and is normally dry except during floods. Plants with high root densities, high root shear and tensile strength, and an ability to transpire water at high rates are recommended for this zone. Willows, silver maples, and poplars are examples of species to use here.

Normally, grasses are not used in this area, but they can be if velocities are low and the grass will not be submerged frequently or for long periods of time. Wetland plants such as various sedges, rushes, and bulrushes can be utilized just below the shrub zone and are often used in bioengineering techniques.

Tree Zone

This area is at the top of the streambank. Plants in this area usually provide shade for the stream and riparian habitat for wildlife. Upland but flood-tolerant species should be planted in this location.

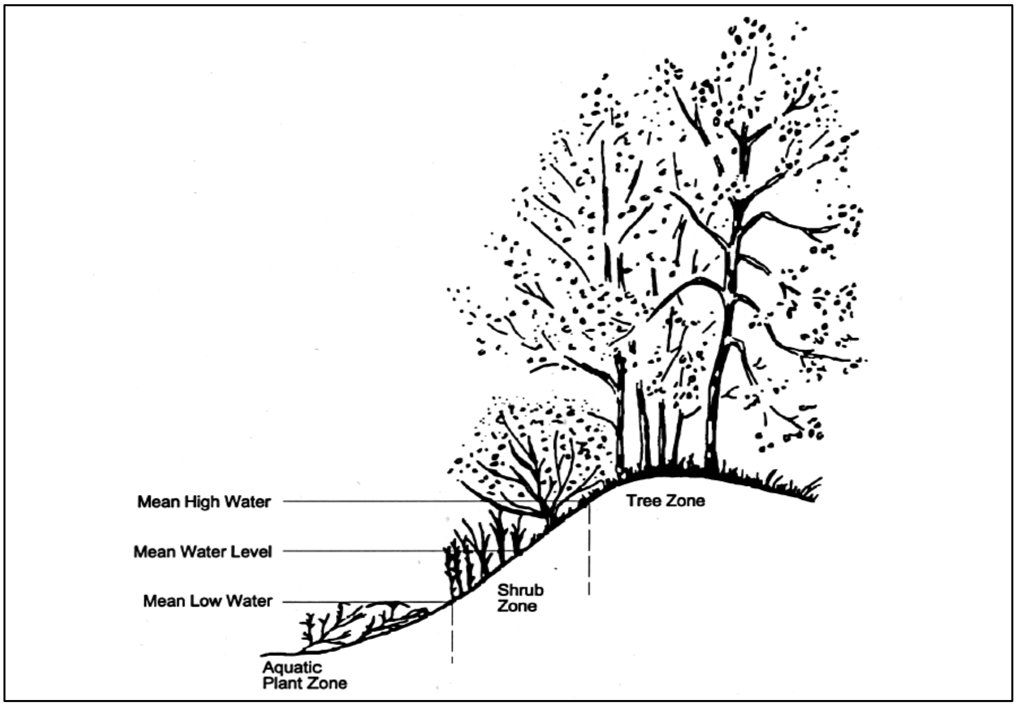


Figure SP-1 Vegetative Zones for Streambank Protection

Vegetative Measures

When vegetation is used alone, without toe protection, this practice can be used when velocities are less than 6 ft/sec. Greater velocities can be tolerated given adequate toe and flank protection at the upper and lower ends of the practice, but each stream reach addressed should be analyzed and designed by the interdisciplinary team. The design team should consider the natural zones of a streambank community when selecting vegetation for use in the protection design. Native plant materials should be used for establishment and long-term success. No exotic or invasive species should be used.

Prior to start of construction, streambank protection, for each unique channel reach, should be designed by a qualified design professional and/or an interdisciplinary team. Plans and specifications should be referred to by field personnel throughout the construction process.

Scheduling

Installation scheduling should be phased according to the following considerations. Hard structures such as rock and other inert materials could be installed during a period not suitable for vegetative establishment, whereas vegetation could be planted during the appropriate time for more assurance of its survival. For instance, vegetation would be better established in the late winter/early spring after hard structures have been installed or concurrent with hard-structure installation, depending on the design plan. Hard structures could be installed during a construction season prior to vegetative establishment, with the vegetation being installed the following spring. For vegetation on high banks, schedule that installation during a planting period tailored for optimum survival of the plant species used. In addition, use local weather forecasts to avoid installation activities during rain events that can potentially create abnormal flows and flooding.

Site Preparation

Follow all local, state, and federal government regulations on stream modifications.

Determine exact location of all underground activities.

Stabilize the channel bottom as specified in the design plan before streambank protection measures are installed.

Installation

Plant live plant materials, cuttings, or other forms of plant materials according to the planting plan. Options for protective vegetation measures are described in detail in the upcoming soil bioengineering section.

Safety

The following precautions should be taken:

Exercise caution on steep slopes.

Fence the area and post warning signs if trespassing is likely.

Store equipment, tools, and materials well away from the stream during non-work periods. Consider weather forecasts when determining risks of damage to equipment, tools, and materials by flooding.

All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.

Equipment should not be operated within flowing water in the stream.

Construction Verification

Check to see that planting and seeding was done in compliance with the design specifications.

Structural Measures

Structural Protection

Structural protection is used in areas where velocities exceed 6 feet per second, along channel bends, in areas with highly erodible soils, and in areas of steep channel slopes. Common measures are riprap, gabions, fabric-formed revetments, and reinforced concrete.

Prior to start of construction, streambank protection, for each unique channel reach, should be designed by a qualified design professional and/or an interdisciplinary team. Plans and specifications should be referred to by field personnel throughout the construction process.

Scheduling

Schedule installation during a period that is least likely to have flooding and that includes the planting season for the species that are to be established in association with the structural measures.

Site Preparation

Follow all local, state, and federal government regulations on stream modifications.

Determine exact location of all underground activities.

Stabilize the channel bottom as specified in the design plan before streambank protection measures are installed.

Remove brush and trees only if absolutely necessary to make the site suitable to install the planned measures.

Grade or excavate the areas specified in the design plan, but limit earthmoving to that absolutely necessary to make the site suitable to install the planned measures

Riprap

This is the most commonly used material for streambank protection. The following criteria should be used when designing riprap bank protection.

Riprap should be designed to be stable under the design flow conditions using the following procedure:

Determine the design velocity.

1) Use velocity and Figure SP-2 to determine d_{100} rock size.
2) Use d_{100} from Figure SP-2 as d_{90} to select rock gradation from Table SP-1.

Streambanks should be sloped at 2:1 or flatter.

Where needed to prevent movement of soil from the channel bank into the riprap, place a filter fabric between the soil and riprap. Filter fabric should meet the requirements for Class I geotextile as shown in Table SP-3.

The toe of the riprap should extend a minimum of 1 foot below the stream channel bottom or anticipated scour depth to prevent failure of the riprap protection.

The top of the riprap should extend up to the 2-year water surface elevation as a minimum, unless it is determined that a lesser height in combination with vegetative measures will provide the needed protection. The remainder of the bank above the riprap can be vegetated.

Install riprap of the specified gradation to the lines and grades shown in the design plan. Installation usually includes some bank shaping.

Place geotextile fabric or a granular filter between the riprap and the natural soil and placement of the rock.

Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.

Riprap may be placed by equipment. Care should be taken to avoid punching or tearing of the geotextile fabric cloth during placement of rock. Avoid dropping rock onto the fabric more than 1/2-1 foot from the equipment delivering the rock. This will more amply prevent punching or tearing the fabric. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet with the upstream edge over the downstream edge. If the damage is extensive, replace the entire geotextile fabric.

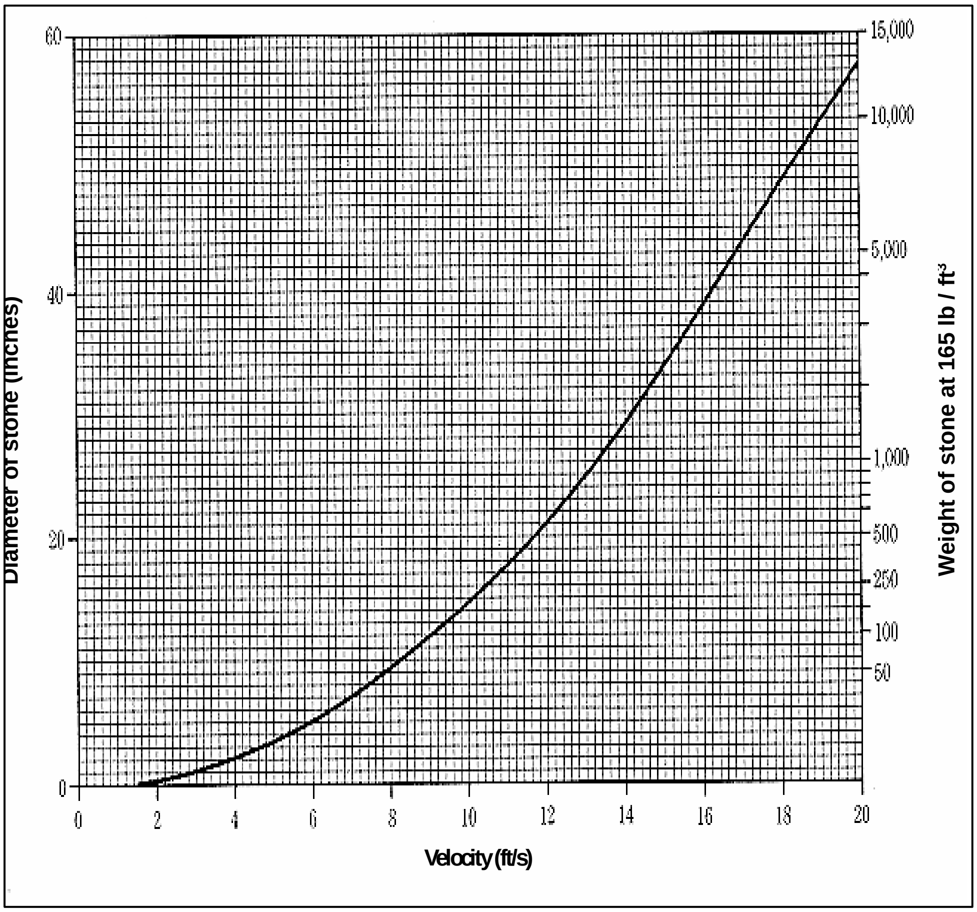


Figure SP-2 Isbash Curve

Table SP-1 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Table SP-2 Requirements for Nonwoven Geotextile

Property	Test method	Class I	Class II	Class III	Class IV [3]
Tensile strength (lb) [1]	ASTM D 4632 grab test	180 minimum	120 minimum	90 minimum	115 minimum
Elongation at failure (%) [1]	ASTM D 4632	≥ 50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minimum	60 minimum	40 minimum	40 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]	As specified max. #40 [2]
Permittivity sec^{-1}	ASTM D 4491	0.70 minimum	0.70 minimum	0.70 minimum	0.10 minimum

Table copied from NRCS Material Specification 592.

1 Minimum average roll value (weakest principal direction).
2 U.S. standard sieve size.
3 Heat-bonded or resin-bonded geotextile may be used for Classes III and IV. They are particularly well suited to Class IV. Needle-punched geotextile is required for all other classes.

Gabions

These rock-filled wire baskets are very labor intensive to construct, but they are semi-flexible and permeable. Gabions should be designed and constructed according to manufacturer's guidelines and recommendations. They should be filled with durable rock. Use only durable crushed limestone, dolomite, or granite rock. Shale, siltstone, and weathered limestone should not be used. If needed, a filter fabric can be used between the gabions and the soil subgrade. Fabric will be selected from the table for geotextiles shown above.

Fabric-Formed Revetments

These are manufactured, large, quilted envelopes that can be sewn or zipped together at the site to form continuous coverage of the area to be protected. Once the fabric is in place, it is pumped full of grout to form a solid, hard and semi-impervious cover. Revetments should be designed and installed according to manufacturer's recommendations.

Reinforced Concrete

A qualified design professional using sound and accepted engineering procedures should design this protection method. Installation usually includes some bank shaping, placing a filter fabric or a granular filter between the streambank material and the retaining wall or bulkhead, and anchoring. The design should include a solid foundation for the retaining wall and a method of draining excess water from behind the wall.

Anchor the foundation for these structures to a stable, nonerodible base material such as bedrock. Also, water stops should be installed at all joints in concrete retaining walls.

All structural protection methods should begin and end along stable reaches of the stream.

Combined Methods of Protection

Combinations of vegetative and structural protection can be used in any area where a structural measure would be used. An example of exceptions would in the vicinity of highway bridges and culverts where heavy armorment with rocks, concrete, etc., is required to prevent erosion of the highway. Common measures include cellular matrix confinement systems, grid pavers, and bioengineering techniques. As with structural measures, all combined methods should begin and end along stable reaches of the stream. See Figures SP-3 and SP-4 for examples of combined methods of protection.

Figure SP-3 Retrofitted urban stream using a bioengineered approach. Note hard, encapsulated-rock toe in lower zone and then coir geotextile rolls to be planted with wetland plants in upper-bank zones.

Figure SP-4 Same stream, after bioengineered restoration. This type of bioengineered stream improves habitat, water quality, and numerous other functions that cannot be achieved with hardened stream channels.

Cellular Confinement Matrices

These are commercially available products made of heavy-duty polyethylene formed into a honeycomb type matrix. The product is flexible to conform to surface irregularities. The combs may be filled with soil, sand, gravel, or cement. Where soil is used to fill the combs, vegetation may also be established. These systems should be designed and installed according to manufacturer's recommendations.

Grid Pavers

These are modular concrete units with interspaced voids. They are used to armor the bank and provide an area for vegetation as well. Pavers come in a variety of shapes and sizes with various anchoring methods. They should be designed and installed according to manufacturer's recommendations.

Soil Bioengineering

Soil bioengineering is the combination of biological, mechanical, and ecological techniques to control erosion and stabilize soil through the use of vegetation alone or in combination with engineered structures and materials. This may include the use of both woody and herbaceous vegetation. An interdisciplinary team of engineers, soil bioengineers, hydrologists, and fishery biologists should be consulted for the planning and design required for soil bioengineering projects. This method of stream protection is more complex than the scope of this manual permits; however, additional resources are listed at the end of this section and in **Appendix I**. Examples of the more commonly used techniques are listed below.

Woody Vegetation

Plant Species

Use native, locally harvested species that root easily and are suitable for the intended use and adapted to site conditions, such as willow. Plants are usually harvested from a nearby local area.

Woody Vegetation Cutting Size

Normally ⅜″ to 2″ in diameter and from 2 to 6 feet long (length will depend on project requirements). Three types of cuttings are common:

- Pole cuttings, generally from shrubs and trees ½ to 3 inches in diameter;
- Post cuttings, trees larger than 3 inches in diameter but smaller than 6 inches; and
- Bundled cuttings that contain shrub and tree cuttings smaller than ½ inch but no smaller than ⅜″

Harvesting

Cut plant materials at a blunt angle, 8″ to 10″ from the ground, leaving enough trunk so that cut plants will regrow.

Transportation and Handling

Bundle cuttings together on harvest site, removing side branches. Keep material moist. Handle carefully during loading and unloading to prevent damage. Cover to protect cuttings from drying out.

Installation Timing

Deliver to construction site within 8 hours of harvest and install immediately, especially when temperatures are above 50º F. Store up to 2 days if cuttings are submerged, "heeled in" moist soil, shaded, and protected from wind.

Season

Install during plants' dormant season, generally late October to March.

Soil

Must be able to support plant growth. Compact backfill to eliminate voids, and maintain good branch cutting-to-soil contact.

Herbaceous Vegetation

Plant Species

Use native, locally harvested species that root easily and are suitable for the intended use and adapted to site conditions. Plants are usually harvested from a nearby local area. Herbaceous plants such as sedges and bulrushes can be planted as seeds, clumps, or rhizomes depending on the species.

Planting Methods

Herbaceous plantings can be established through a variety of techniques: container stock, bare root plants, transplant plugs, rhizomes, clumps, and seeds. Methods of planting will be dependent on the plant species as well as the habitat specifics. The *Surface Stabilization Practices* in this volume discuss vegetation suitable for Mississippi in greater detail and should be referenced before any planting project.

Harvesting

Plant materials for herbaceous plantings have the following harvesting recommendations:

- Transport plugs: Plugs are often used for wetland plants and therefore should remain moist. Plugs should be 3-12 inches in diameter, excavated 5-6 inches deep. Extraction rate should not exceed 1 square foot in a 10-foot area. Plugs should be kept moist at all times.
- Rhizomes: These are the underground horizontal stems and can be collected in the early spring or at the end of the growing season. Rhizomes can be dug up and divided into sections. Rhizomes should be kept cool.
- Clumps: Clumps of herbaceous vegetation are generally harvested using a backhoe. Digging in 12-15 inches deep is sufficient for most plants collected with this method. Clump plantings should be kept moist.

Transportation and Handling

Transportation and handling of herbaceous plants depends somewhat on the planting method chosen. For container stock plants, refer to the provider or plant nursery's suggestions on acclimating and moisture needs. For harvested plants, see the notes listed in the Harvesting section above.

Season

Install during plants' dormant season, generally late October to March.

Soil

Must be able to support plant growth. Compact backfill to eliminate voids and maintain good branch cutting-to-soil contact.

Protective Vegetation

Live staking, live fascines, brush layers, and branchpacking are soil bioengineering practices that use the stems or branches of living plants as a soil reinforcing and stabilizing material. Eventually the vegetation becomes a major structural component of the bioengineered system.

Live Staking

Live staking is the use of live, rootable vegetative cuttings, inserted and tamped into the ground. As the stakes grow, they create a living root mat that stabilizes the soil. Use live stakes to peg down surface erosion-control materials. Most native willow species root rapidly and can be used to repair small earth slips and slumps in wet areas.

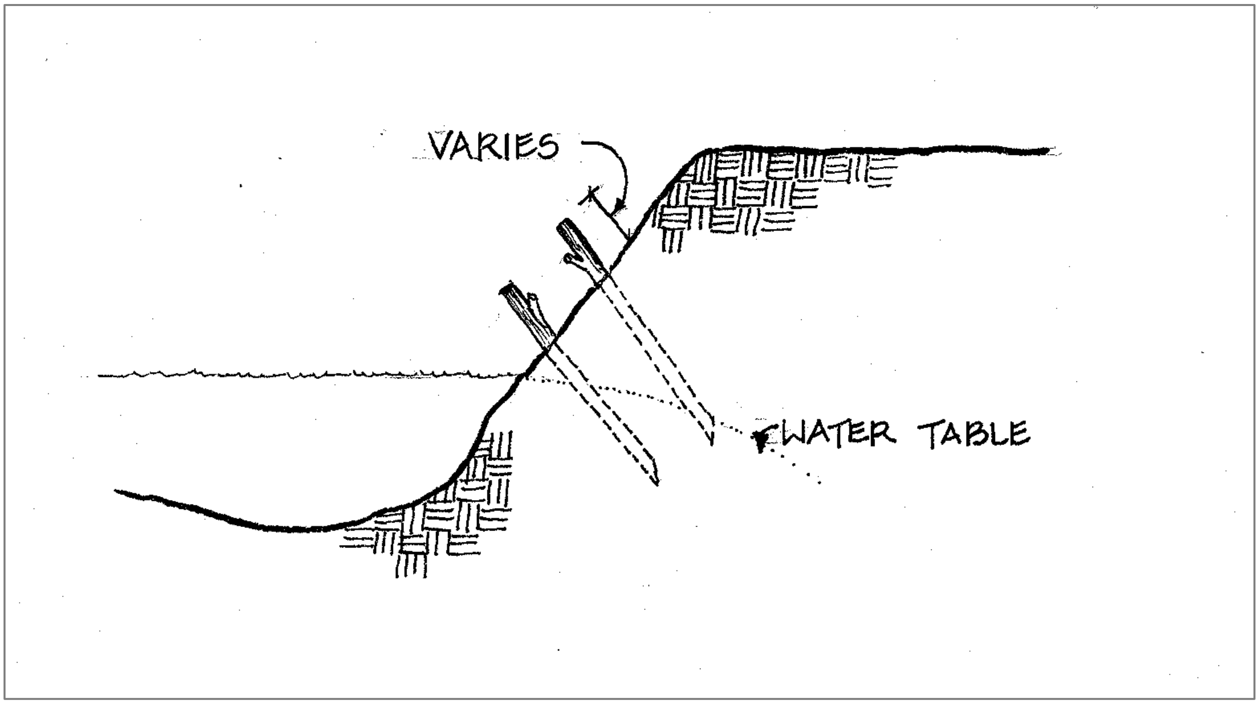


Figure SP-5 Pole Plantings – End of stake should reach water table, while the height above the ground will vary (Bentrup, 1998)

To prepare live material, cleanly remove side branches, leaving the bark intact. Use cuttings ½″ to 1½″ in diameter and 2 to 3 feet long. Cut bottom ends at an angle to insert into soil. Cut top square. Tamp the live stake into the ground at right angles to the slope, starting at any point on the slope face. Buds should point up. Install stakes 2 to 3 feet apart using triangular spacing with from 2 to 4 stakes per square yard. An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammerhead filled with shot or sand). Four-fifths of the live stake should be underground with soil packed firmly around it after installation. Replace stakes that split during installation.

Live Fascines

Live fascines are long bundles of branch cuttings bound together into sausage-like structures. They should be placed in shallow contour trenches and at an angle on wet slopes to reduce erosion and shallow face sliding. This practice is suited to steep, rocky slopes, where digging is difficult.

To prepare live materials, make cuttings from species such as young willows or shrub dogwoods that root easily and have long, straight branches. Make stakes 2½ feet long for cut slopes and 3 feet long for fill slopes. Make bundles of varying lengths from 5 to

30 feet or longer, depending on site conditions and limitations in handling. Use untreated twine for bundling. Completed bundles should be 6″ to 8″ in diameter. Orient growing tips in the same direction. Stagger cuttings so that root ends are evenly distributed throughout the length of the bundle. Install live fascine bundles the same day they are prepared. Prepare dead stakes 2½ feet long, untreated 2″ by 4″ lumber, cut diagonally lengthwise to make two stakes. Live stakes will also work. Beginning at the base of the slope, dig a trench on the contour large enough to contain the live fascine. Vary width of trench from 12″ to 18″, depending on angle of the slope. Trench depth will be 6″ to 8″, depending on size of the bundle. Place the live fascine into the trench. Drive the dead stakes directly through the bundle every 2 to 3 feet. Use extra stakes at connections or bundle overlap. Leave the top of the stakes flush with the bundle. Install live stakes on the downslope side of the bundle between the dead stakes.

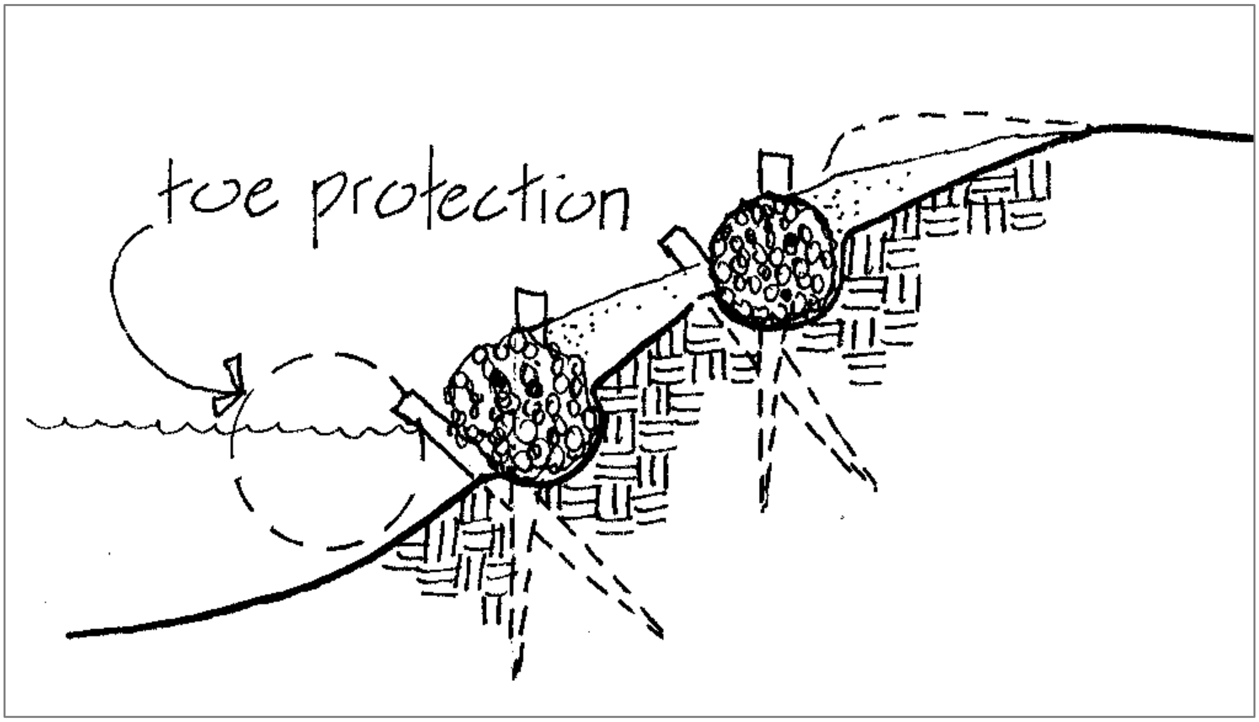


Figure SP- 6 Fascine placement (Bentrup, 1998)

Brush Layering

Brush layering is similar to live fascine systems. Both involve placing live branch cuttings on slopes. However, in brush layering, the cuttings are oriented at right angles to the slope contour. Also, the cuttings used in brush layering are not bound in bundles like fascines. Brush layering can be used on slopes up to 2:1 (horizontal: vertical) in steepness.

Install toe protection if needed to prevent undercutting. Then, starting at the toe of the slope, excavate benches horizontally, on the contour, or angled slightly down the slope to aid drainage. Construct benches 2 to 3 feet wide. Slope each bench so that the outside edge is higher than the inside.

Crisscross or overlap live branch cuttings on each bench. Place growing tips toward the outside of the bench. The branches should not extend more than 18″ from the bank to prevent damage during high flows. Place backfill on top of the root ends and compact to eliminate air spaces. Growing tips should extend slightly beyond the fill to filter sediment. Soil for backfill can be obtained from excavating the bench above. Space brush layer rows 3 to 5 feet apart, depending upon the slope angle and stability.

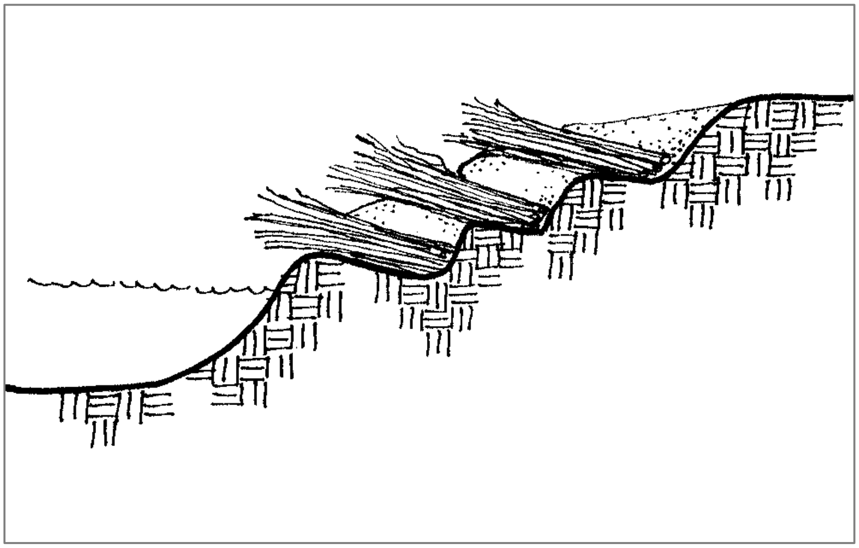


Figure SP-7 Brush Layering (Source: Bentrup, 1998)

Brush layering can be used between encapsulated soil lifts; lifts are encapsulated in erosion-control fabric (or similar material such as burlap). This setup can be used where space is limited and a more vertical structure is required.

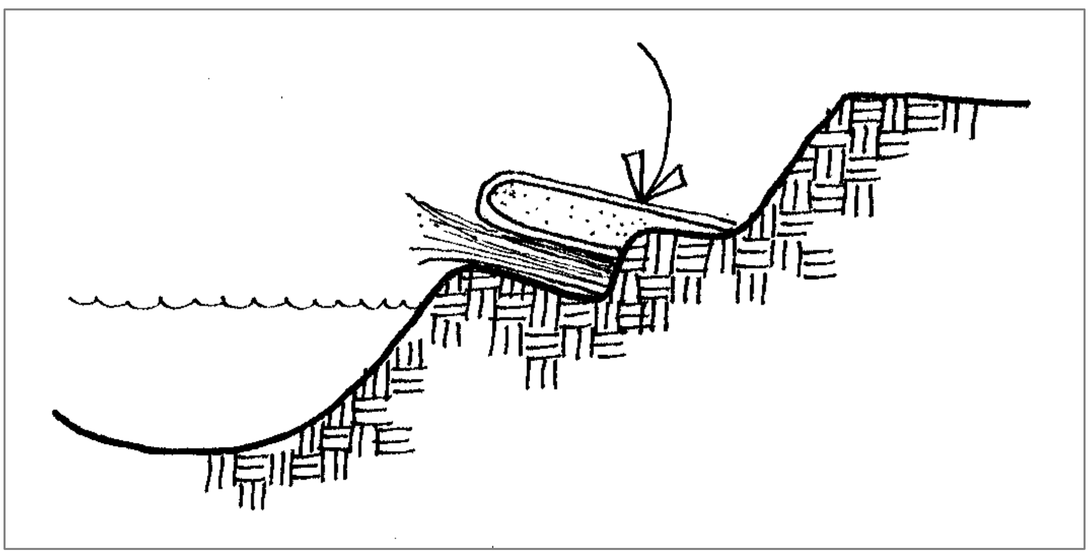


Figure SP-8 Brush Layering with Erosion Control Fabric (Source: Bentrup, 1998)

Branchpacking

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes (no greater than 4 feet deep or 5 feet wide). Use for earth reinforcement and mass stability of small earthen fill sites.

Make live branch cuttings from ½″ to 2″ in diameter and long enough to reach from soil at the back of the trench to extend slightly from the front of the rebuilt slope face.

Make wooden stakes 5 to 8 feet long from 2″ by 4″ lumber or 3″ to 4″ diameter poles. Start at the lowest point and drive wooden stakes vertically 3 to 4 feet into the ground. Set them 1 to 1½ feet apart. Place a layer of living branches 4″ to 6″ thick in the bottom of the hole, between the vertical stakes, and at right angles to the slope face. Place live branches in a crisscross arrangement with the growing tips oriented toward the slope face. Some of the root ends of the branches should touch the back of the hole. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the branch cuttings. The final installation should match the existing slope. Branches should protrude only slightly from the rebuilt slope face.

The soil should be moist or moistened to ensure that live branches do not dry out.

Woody Vegetation with Inert Structures

Live cribwalls, vegetated rock gabions, and joint plantings are soil bioengineering practices that combine a porous structure with vegetative cuttings. The structures provide immediate erosion, sliding, and washout protection. As the vegetation becomes established, the structural elements become less important.

Live Cribwall

A live cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber. Use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness or where space is limited and a more vertical structure is required. It should be tilted back if the system is built on a smooth, evenly sloped surface.

Make live branch cuttings ½″ to 2″ in diameter and long enough to reach the back of the wooden crib structure. Build the constructed crib of logs or timbers from 4″ to 6″ in diameter or width. The length will vary with the size of the crib structure. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability. Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart and parallel to the slope contour. Place the next set of logs or timbers at right angles to the slope on top of the previous set. Place each set of timbers in the same manner and nail to the preceding set. Place live branch cuttings on each set to the top of the cribwall structure with growing tips oriented toward the slope face. Backfill the cribwall, compact the soil for good root-to-soil contact, then apply seed and mulch.

Vegetated Rock Gabions

Vegetated gabions combine layers of live branches and gabions (rectangular baskets filled with rock). This practice is appropriate at the base of a slope where a low wall is required to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large, lateral earth stresses. Use where space is limited and a more vertical structure is required. Overall height, including the footing, should be less than 5 feet.

Make live branch cuttings from ½″ to 1″ in diameter and long enough to reach beyond the rock basket structure into the backfill. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability and ensure rooting. Place the wire baskets in the bottom of the excavation and fill with rock. Backfill between and behind the wire baskets. Place live branch cuttings on the wire baskets at right angles to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. Root ends must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it. Repeat the construction sequence until the structure reaches the required height.

Joint Planting

Joint planting or vegetated riprap involves tamping or pushing live cuttings into soil between the joints or open spaces in rocks that have previously been placed on a slope. Use where rock riprap is required. Joint planting is used to remove soil moisture, to prevent soil from washing out below the rock, and to increase slope stability over riprap alone.

Make live branch cuttings from ½″ to 1½″ in diameter and long enough to extend into soil below the rock surface. Remove side branches from cuttings leaving the bark intact. Tamp or push live branch cuttings into the openings of the rock during or after construction. Care should be taken to avoid splitting the cutting by tamping. The root ends should extend into the soil behind the riprap. Mechanical probes may be needed to create pilot holes for the live cuttings so that they can be pushed into substrate without stripping their bark or splitting the cutting by tamping. It is critical to ensure the soil is packed around the cutting to prevent air pockets. "Mudding" (filling the hole with water and then adding soil to make a mud slurry) can remove air pockets. Place cuttings at right angles to the slope with growing tips protruding from the finished face of the rock.

Safety

Store all construction materials well away from the stream. Consider weather forecasts when determining risks of damage by flooding.

At the completion of each workday, move all construction equipment out of and away from the stream to prevent damage to equipment by flooding. Consider weather forecasts when determining risks of flooding.

The following precautions should be taken:

Exercise caution on steep slopes.

Fence the area and post warning signs if trespassing is likely.

All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.

Equipment should not be operated within flowing water in the stream.

Construction Verification

Check cross section of the channel, thickness of structural product used, and confirm the presence of filter cloth between the product and the streambank.

Check to see that planting and seeding was done in compliance with the design specifications.

Common Problems

Consult with a qualified design professional if any of the following occur:

Variations in topography on site indicate practice will not function as intended; changes in plan may be needed.

Design specifications for vegetative or structural protection cannot be met; substitution may be required. Unapproved substitutions could result in erosion damage to the streambank.

Maintenance

Check the streambank for rill and gully erosion after every storm event.

Repair eroded areas with appropriate plantings, structural materials, or new plants.

Check the streambank for signs of voids beneath gabions, riprap, and concrete. Deterioration of the filter fabric or granular material should be repaired; make needed repairs with similar material.

Protect new plantings from livestock.

Check the streambank for reduction in stream capacity, caused by overgrowth of vegetation on the streambank. Selectively remove overgrown vegetation at regular intervals to maintain capacity and to maintain desired plant communities.

References

BMPs from Volume 1

Chapter 4

MDOT Drawing PD-1

Additional Resources

Allen, H.H., and Fischenich, J.C. (1999) "Coir geotextile roll and wetland plants for streambank erosion control," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-04), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/elpubs/pdf/sr04.pdf.

Bentrup, G., and Hoag, C. (1998) "The Practical Streambank Bioengineering Guide" Interagency Riparian/Wetland Plant Development Project. USDA.

Freeman, G., and Fischenich, C. (2001). "Units and Conversions for Stream Restoration Projects," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-28), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

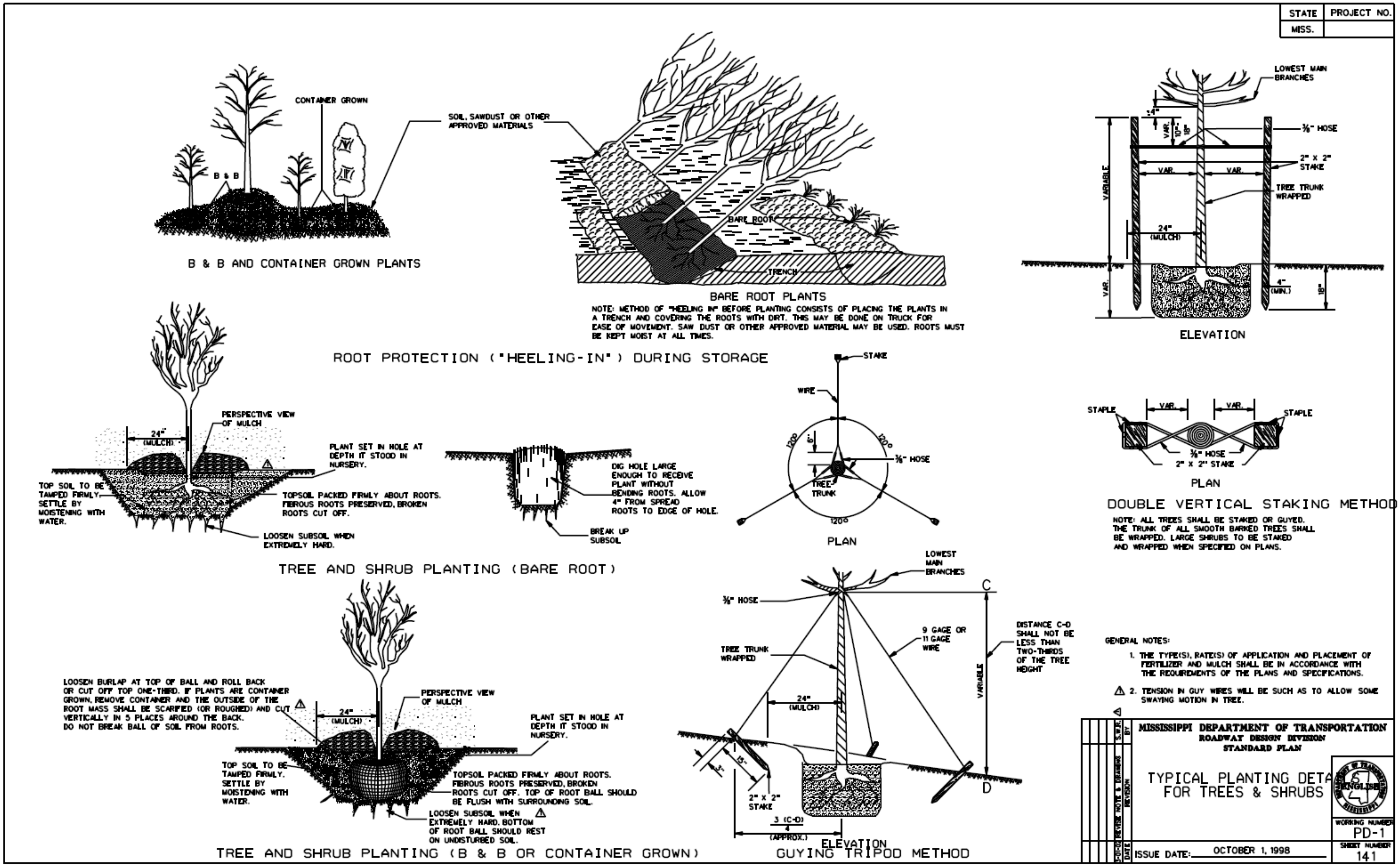
Fischenich, C. (1999). "Irrigation systems for establishing riparian vegetation," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-12), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fischenich, J.C., and Allen H. (2000). U.S. Army Engineer Research and Development Center, Environmental Laboratory, SR-W-001. http://el.erdc.usace.army.mil/elpubs/pdf/srw00-1/srw00-1.pdf.

Fischenich, C., and Morrow, J., Jr. (1999). "Streambank Habitat Enhancement with Large Woody Debris," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-13), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fisher, R.A., and Fischenich, J.C. (2000). "Design recommendations for riparian corridors and vegetated buffer strips," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Sotir, R.B., and Fischenich, J.C. (2001), "Live and Inert Fascine Streambank Erosion Control," *EMRRP Technical Notes Collection* (ERDC TN-EMRRP-SR-31), U.S. Army Engineer Research and Development Center, Vicksburg, MS.
www.wes.army.mil/el/emrrp.


STATE PROJECT NO.
MISS.
CONTAINER GROWN
B & B
B & B AND CONTAINER GROWN PLANTS
SOIL, SAWDUST OR OTHER APPROVED MATERIALS
BARE ROOT
TRENCH
BARE ROOT PLANTS
NOTE: METHOD OF "HEELING IN" BEFORE PLANTING CONSISTS OF PLACING THE PLANTS IN A TRENCH AND COVERING THE ROOTS WITH DIRT. THIS MAY BE DONE ON TRUCK FOR EASE OF MOVEMENT. SAW DUST OR OTHER APPROVED MATERIAL MAY BE USED. ROOTS MUST BE KEPT MOIST AT ALL TIMES.
ROOT PROTECTION ("HEELING-IN") DURING STORAGE
LOWEST MAIN BRANCHES
⅜" HOSE
2" X 2" STAKE
TREE TRUNK WRAPPED
VARIABLE
VAR.
24" (MULCH)
4" (MIN.)
18"
ELEVATION
PERSPECTIVE VIEW OF MULCH
PLANT SET IN HOLE AT DEPTH IT STOOD IN NURSERY.
TOP SOIL TO BE TAMPED FIRMLY, SETTLE BY MOISTENING WITH WATER.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF.
LOOSEN SUBSOIL WHEN EXTREMELY HARD.
DIG HOLE LARGE ENOUGH TO RECEIVE PLANT WITHOUT BENDING ROOTS. ALLOW 4" FROM SPREAD ROOTS TO EDGE OF HOLE.
BREAK UP SUBSOIL
TREE AND SHRUB PLANTING (BARE ROOT)
STAKE
WIRE
120°
TREE TRUNK
PLAN
STAPLE
⅜" HOSE
2" X 2" STAKE
PLAN
DOUBLE VERTICAL STAKING METHOD
NOTE: ALL TREES SHALL BE STAKED OR GUYED. THE TRUNK OF ALL SMOOTH BARKED TREES SHALL BE WRAPPED. LARGE SHRUBS TO BE STAKED AND WRAPPED WHEN SPECIFIED ON PLANS.
LOOSEN BURLAP AT TOP OF BALL AND ROLL BACK OR CUT OFF TOP ONE-THIRD. IF PLANTS ARE CONTAINER GROWN, REMOVE CONTAINER AND THE OUTSIDE OF THE ROOT MASS SHALL BE SCARIFIED (OR ROUGHED) AND CUT VERTICALLY IN 5 PLACES AROUND THE BACK. DO NOT BREAK BALL OF SOIL FROM ROOTS.
TOPSOIL PACKED FIRMLY ABOUT ROOTS. FIBROUS ROOTS PRESERVED, BROKEN ROOTS CUT OFF. TOP OF ROOT BALL SHOULD BE FLUSH WITH SURROUNDING SOIL.
LOOSEN SUBSOIL WHEN EXTREMELY HARD. BOTTOM OF ROOT BALL SHOULD REST ON UNDISTURBED SOIL.
TREE AND SHRUB PLANTING (B & B OR CONTAINER GROWN)
9 GAGE OR 11 GAGE WIRE
DISTANCE C-D SHALL NOT BE LESS THAN TWO-THIRDS OF THE TREE HEIGHT
C
D
3 (C-D) / 4 (APPROX.)
ELEVATION
GUYING TRIPOD METHOD
GENERAL NOTES:
1. THE TYPE(S), RATE(S) OF APPLICATION AND PLACEMENT OF FERTILIZER AND MULCH SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE PLANS AND SPECIFICATIONS.
2. TENSION IN GUY WIRES WILL BE SUCH AS TO ALLOW SOME SWAYING MOTION IN TREE.
MISSISSIPPI DEPARTMENT OF TRANSPORTATION
ROADWAY DESIGN DIVISION
STANDARD PLAN
TYPICAL PLANTING DETAILS FOR TREES & SHRUBS
ENGLISH
WORKING NUMBER PD-1
SHEET NUMBER 141
ISSUE DATE: OCTOBER 1, 1998

Temporary Stream Crossing (TSC)

Practice Description

A temporary stream crossing is a short-term road crossing constructed over a stream for use by construction traffic to prevent turbidity and stream-bed disturbance caused by traffic. A temporary stream crossing can be a low-water crossing, a culvert crossing, or a bridge with or without embankment approaches. Temporary stream crossings are applicable on construction sites where traffic must cross steams during construction.

Planning Considerations

A stream crossing can be an open ford, a pipe (culvert), or bridge crossing. Stream crossings can be a useful practice to provide a means for construction traffic to cross flowing streams without damaging the channel or banks or causing flooding, and to keep sediment generated by construction traffic out of the stream. Stream crossings are generally applicable to flowing streams with drainage areas less than 1 square mile. A qualified design professional should design permanent structures to handle flow from larger drainage areas.

Careful planning can minimize the need for stream crossings, and the qualified design professional should always try to avoid crossing streams. Whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream. Temporary stream crossings are a direct source of water pollution; they may create flooding and safety hazards; they can be expensive to construct; and they cause costly construction delays if damaged by flooding.

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the flow regime. However, these structures are also undesirable in that they could cause a channel constriction, which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

Fords made of stabilizing material such as rock are often used in steep areas subject to flash flooding, where normal flow is shallow (less than 3″) or intermittent. Fords should only be used where crossings are infrequent. Fords are especially adapted for crossing wide, shallow watercourses. Generally, do not use fords where bank height exceeds 5 ft. Rock material used for the ford may be washed out during large storm events and require the rock to be replaced. Mud and other contaminants are brought into the stream on vehicles using ford crossings unless crossings are limited to no-flow conditions.

The criteria contained in this practice pertain primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, the qualified design professional must also be sure that the structure is capable of withstanding the expected loads from heavy construction equipment. The qualified design professional must also be aware that such structures are subject to the rules and regulations of the U.S. Army Corps of Engineers for in-stream modifications (404 permits).

Design Criteria and Construction

Prior to start of construction, a temporary stream crossing should be designed by a qualified design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Scheduling

To minimize stream disturbance, attempt to construct temporary stream crossings during dry periods and relatively low flows. Use local weather forecasts to avoid installation during rain events that can potentially create turbidity.

Site Preparation

Ensure that all necessary materials are on the site before any work begins. If planned, construct a bypass channel and dewater the construction site before undertaking other work.

Installation and Removal Low Water Crossing

Excavate the foundation for the temporary crossing according to the design plan and in such a manner that the final finished surface is level with the stream bed.

Excavate roadways through the abutment approaches (bank) to the crossing according to the design plan.

Place the specified type of geotextile over the width and length of the crossing subgrade and anchor it in place as specified in the plans. Next, place riprap of the specified gradation to the required thickness across the channel. Finally, place a wearing course of gravel or crushed rock of the specified gradation to the required thickness over the riprap.

Remove gravel and excess rock riprap as soon as it is no longer needed. Restore original contours to the channel, leaving rock riprap level with the stream bed.

Culvert Crossings or Spans (Bridges)

The structure should be large enough to convey the flow expected from a 2-year frequency, 24-hour duration storm without appreciably altering the stream flow characteristics. The structure may be a span or culvert. If culverts are used, see Table TSC-1 for aid in selecting the appropriate size. (Multiple culverts may be used in place of one large culvert, if they have the equivalent capacity of the larger one). The minimum-sized culvert that may be used is 18″.

Where culverts are installed (Figure TSC-1), compacted soil will be used to form the crossing. The depth of soil cover over the culvert should be equal to ½ the diameter of the culvert or 24″, whichever is greater. To protect the sides of the fill from erosion, riprap shall be used and designed in accordance with the practice *Outlet Protection*.

The length of the culvert should be adequate to extend the full width of the crossing, including side slopes.

The grade of the culvert pipe should be at least 0.25″ per foot.

The top of the compacted fill should be covered with 6″ of Mississippi Department of Transportation coarse aggregate No. 1 stone (3/4″ to 4″).

The approaches to the structure should consist of stone pads meeting the following specifications:

Stone: Mississippi Department of Transportation coarse aggregate No. 1.

Minimum thickness: 6″.

Minimum width: equal to the width of the structure.

Minimum approach lengths: 25 feet.

Place a 4″ layer of moist, clayey, workable soil (not pervious material such as sand, gravel, or silt) around the culvert. Compact by hand to at least the density of the embankment soil. (Do not raise the culvert from the foundation when compacting under the culvert haunches.) Continue with backfill of the pipe in 4″ to 6″ uncompacted layers, scarifying the surface between each compacted layer. All backfill material within 2 feet of the pipe (beside the pipe and above the pipe) should be compacted with hand tampers only.

Extend the end of the culvert 2 feet beyond the toe of the fill slope. The outlet end of the culvert should be placed on a stable natural stream bed. If this is not possible, install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.

All backfill material within 2 feet of a culvert (beside the pipe and above the pipe) should be compacted with hand tampers only. Heavy equipment should not be allowed on top of the culvert until a minimum of 2 feet of hand-compacted material is placed.

If an embankment is required, use fill from predetermined borrow areas. It should be clean, stable mineral soil free of roots, woody vegetation, rocks, and other debris. It must be wet enough when placed to form a ball without crumbling yet not so wet that water can be squeezed out. Compact the fill material in 6″ to 8″ continuous layers over the length of the embankment. One way is by routing construction equipment over the embankment so that each layer is traversed by at least one wheel of the equipment. Construct and compact the culvert-crossing embankment to 10% above the design height to allow for settling.

Remove culvert as soon as it is no longer needed and restore stream bed to original contour.

Table TSC-1 Culvert Selection Guide (pipe, diameter, inches)

Drainage Area (Acres)	**Average Slope of Watershed**			
	1%	4%	8%	16%
1-25	30	30	36	36
26-50	30	36	42	48
51-100	36	48	48	54
101-150	42	48	60	60
151-200	42	54	72	72
201-250	48	60	72	72
251-300	48	60	72	72
301-350	48	60	72	2X60
351-400	54	72	2X60	2X60
401-450	54	72	2X60	2X60
451-500	54	72	2X60	2X72
501-550	60	72	2X60	2X72
551-600	60	72	2X60	2X72
601-640	60	72	2X60	2X72

Assumptions for determining USDA-NRCS Peak Discharge Method; CN = 70; Rainfall depth (average for Mississippi) = 4.3″ for 2-year/24-hour storm; No tailwater exists; and the depth of water at the inlet invert is 1.5 X diameter.

Culvert crossings and spans should be designed with features that will prevent damage, destruction or removal during major flood events (i.e., cabling, emergency bypass, etc.).

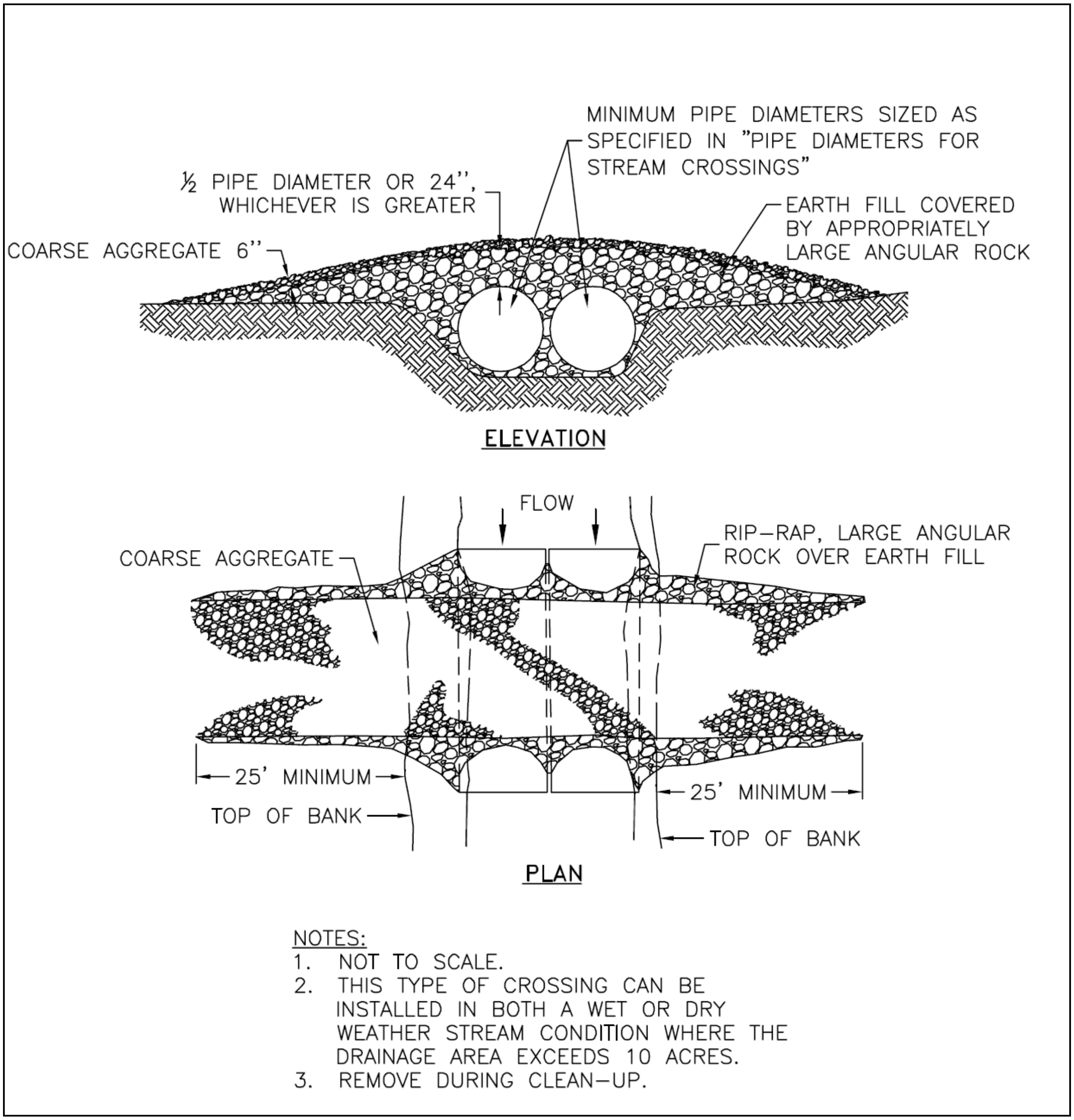


Figure TSC-1 Culvert Stream Crossing

Fords (see Figure TSC-2)

Streambanks should be excavated to provide approach sections of 5:1 or flatter.

The width of the ford crossings should be wide enough for the construction equipment to use safely.

Filter fabric material designed for use under riprap (see *Channel Stabilization Practice*) should be installed on the excavated surface of the ford according to the manufacturer's recommendations. The fabric should extend across the bottom of the stream and at least 25 feet up each approach section. All edges of the fabric should be keyed in a minimum of 1 foot.

Mississippi Department of Transportation coarse aggregate No. 1 stone, 6″ thick should be installed on the filter fabric and also should be used to fill the 1-foot keyed edges of the fabric.

The final surface of the stone in the bottom of the watercourse should be the same elevation as the watercourse bottom to eliminate any overfall and possible scour problems.

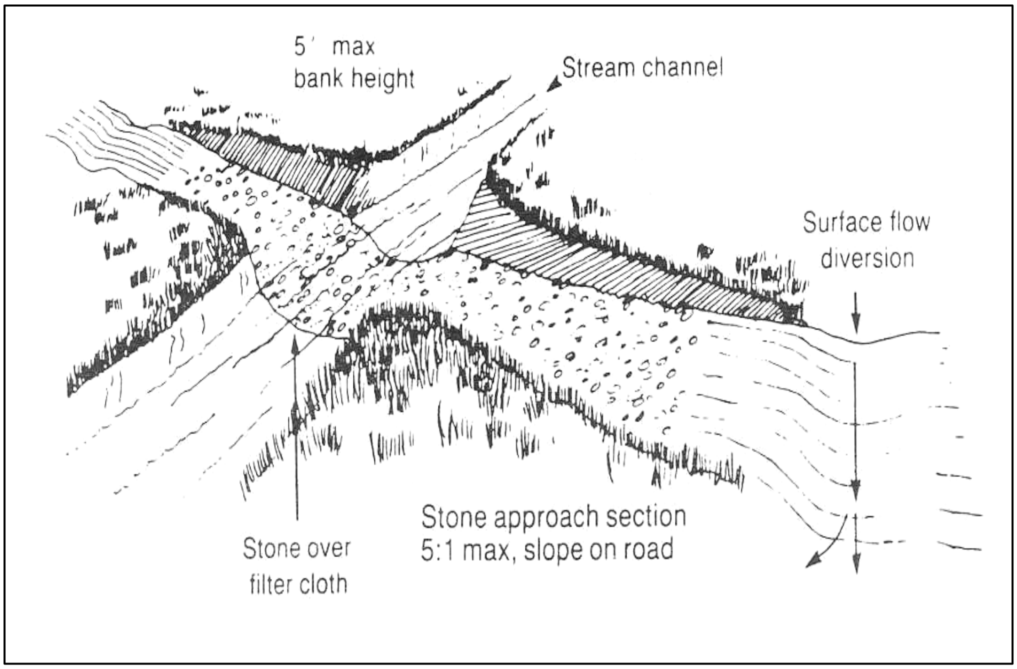


Figure TSC-2   Ford Stream Crossing

Bridge Excavation

If excavation is required, excavate roadways through the abutment approaches (bank) according to the design plan.

Construct the bridge or install a prefabricated structure according to the design plan. A cable should be tied to one corner of the bridge frame, with the other end fastened to a secure object to prevent flood flows from carrying the bridge downstream.

Embankment

Use fill from predetermined borrow areas. It should be clean, stable mineral soil free of roots, woody vegetation, rocks, and other debris and must be wet enough to form a ball without crumbling yet not so wet that water can be squeezed out.

Compact the fill material in 6″ to 8″ continuous layers over the length of the embankment. One way is by routing construction equipment over the embankment so that each layer is traversed by at least one wheel of the equipment.

Construct and compact the temporary stream crossing embankment to 10% above the design height to allow for settling.

Erosion Control (all kinds of temporary stream crossings)

Minimize the size of all disturbed areas and vegetate as soon as each phase of construction is complete. Riprap or establish vegetation on the slopes of the embankment of the temporary stream crossing. Riprap should be placed on the entrance slope of culvert systems according to the design plan.

Direct all overland flow at low velocity to the ditches along the approach roads.

Safety

Store all construction materials well away from the stream. Consider weather forecasts when determining risks of damage by flooding.

Equipment used to construct stream crossings should be free of leaks of fuel and hydraulic fluids to prevent contamination of surface waters. Operation of equipment in the stream should be minimized. At the completion of each workday, move all construction equipment away from the stream to prevent damage to equipment by flooding. Consider weather forecasts when determining risks of flooding.

The following precautions should be taken:

- Exercise caution on steep slopes.
- Fence the area and post warning signs if trespassing is likely.
- All equipment used for practice installation should be free of leaks of gas, oil, and hydraulic fluid. Measures should be in place to prevent accidental spills from entering the stream.
- Equipment should not be operated within flowing water in the stream.

Construction Verification

Check finished grade and size of culvert. Check to see if culvert is free of obstructions.

Common Problems

Consult with qualified design professional if any of the following occur:

Variations in topography on site indicate crossing will not function as intended; changes in plan may be needed.

Design specifications for fill or conduit cannot be met; substitution may be required. Unapproved substitutions could result in the crossing being washed out.

Maintenance

Inspect the temporary stream crossing for damage to the structure or the vegetation after each storm event.

Repair any damages found during inspections.

Remove debris, trash, and other materials that restrict flow from the culvert or bridge

References

Additional BMPs from Volume 1

Chapter 4

MDOT Drawing ECD-16

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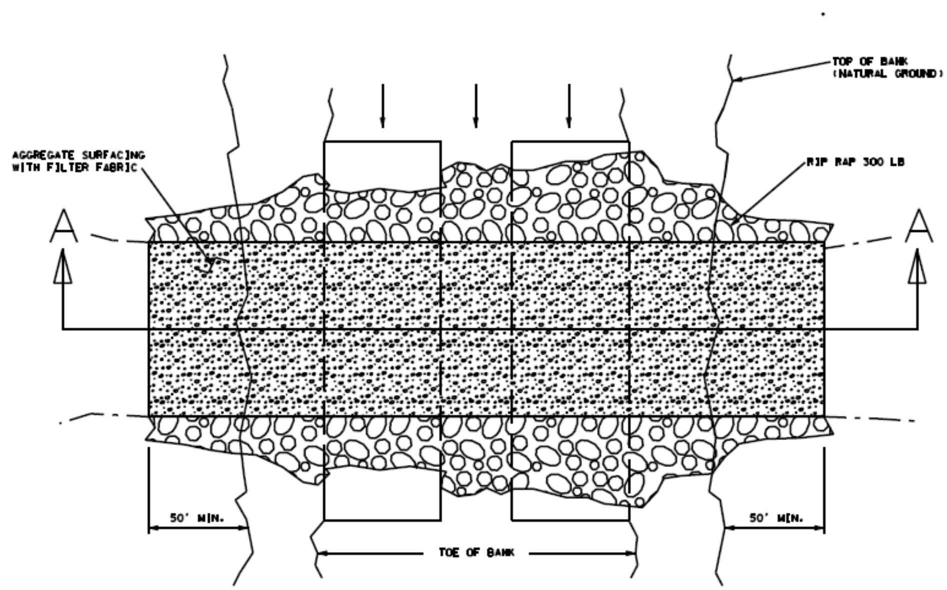
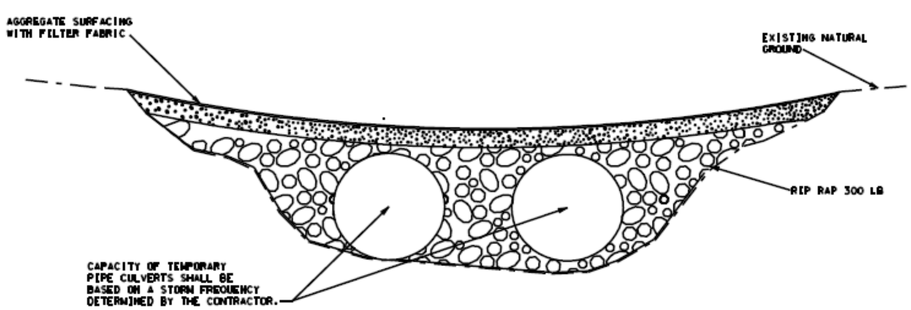


PLAN VIEW

TEMPORARY CULVERT STREAM CROSSING

TEMPORARY CULVERT STREAM CROSSING



SECTION A-A

NOTES:

1. TEMPORARY CULVERT STREAM CROSSINGS PROVIDE A MEANS FOR VEHICLES AND EQUIPMENT TO SAFELY CROSS A WATERCOURSE WHILE MINIMIZING DAMAGE TO THE CHANNEL AND/OR BANKS.
2. TEMPORARY CULVERT STREAM CROSSINGS, WHEN PERMITTED BY THE ENGINEER, SHALL BE CONSTRUCTED TO SAFELY PASS EXPECTED MEAN WATER FLOW OF THE STREAM FOR THE TIME OF YEAR AND LENGTH OF TIME THAT THEY ARE INSTALLED.
3. TEMPORARY STREAM CROSSINGS SHALL BE DESIGNED TO ENSURE STRUCTURAL INTEGRITY AND STABILITY, AND MAINTAIN NORMAL DOWNSTREAM FLOWS. THE USE OF INSTREAM CROSSINGS AND INSTREAM AGGREGATE FILL SHALL BE MINIMIZED TO THE EXTENT PRACTICABLE.
4. A CONTINUOUS PROGRAM OF EFFECTIVE EROSION AND SEDIMENT CONTROL MEASURES SHALL BE IMPLEMENTED PRIOR TO AND CONCURRENT WITH ANY TYPE OF CONSTRUCTION ACTIVITY WITHIN THE BANKS OF A STREAM. WHEN A CROSSING IS NO LONGER NEEDED, THE STREAMBED AND STREAM BANKS SHALL BE RESTORED TO PRE-DISTURBANCE CONDITIONS, OR SUCH A CONDITION THAT PROVIDES SUBSTANTIALLY EQUIVALENT PROTECTION OF WATER QUALITY.
5. LOCATIONS OR TYPES OF TEMPORARY CULVERT STREAM CROSSINGS WILL NOT BE SHOWN ON THE PLANS AS REQUIRED ITEMS .
6. THE CONTRACTOR MAY PROPOSE OTHER OPTIONS FOR TEMPORARY STREAM CROSSINGS SUCH AS STEEL/TIMBER BRIDGE OR MATS.
7. THE DETAILS PROVIDED DEPICT A TYPICAL TEMPORARY CULVERT STREAM CROSSING.
8. TEMPORARY STREAM CROSSINGS WILL NOT BE MEASURED FOR SEPERATE PAYMENT. ALL COSTS FOR MATERIALS, LABOR, EQUIPMENT, CONSTRUCTION, REMOVAL AND MAINTENANCE SHALL BE ABSORBED IN OTHER ITEMS OF WORK

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

TEMPORARY CULVERT
STREAM CROSSING

WORKING NUMBER
ECD-16
SHEET NUMBER

DATE REVISION BY

FILENAME: EROSION CONTROL\ECD-16.DGN

DESIGN TEAM ____ CHECKED ____ DATE ____

Handbook for

Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas

Volume 2
Stormwater Management

Mississippi Department of Environmental Quality
Published 2011

Volume 2 Stormwater Runoff Management Manual

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(Available in *Appendices: Developing Plans & Designing Best Management Practices*)

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Chapter 1
Introduction to Stormwater Runoff Processes

Background

Water flowing over the land during and immediately following a rainstorm is called stormwater runoff. The runoff passing a particular point is equal to the total amount of rainfall upstream of that point less the amounts of infiltration, transpiration, evaporation, surface storage, and other losses. The amount of these losses is a function of climate, soils, geology, topography, vegetative cover and, most importantly, land use.

In an undeveloped area, stormwater runoff is managed by nature through the hydrologic cycle. The cycle begins with rainfall. Rain either stands where it falls and evaporates or it is absorbed into the ground near the surface, to feed trees and vegetation, ultimately to be returned to the atmosphere by transpiration; or it percolates deeply into the ground replenishing the groundwater supply. The remainder of the rainfall collects into rivulets. This collected runoff increases in quantity as it moves down the watershed, through drainageways, streams, reservoirs and to its ultimate destination, rivers and then the sea. Evaporation from the sea surface begins the cycle again.

This simple explanation of the hydrologic cycle belies its complexity. Nature's inability to accommodate severe rainfalls without significant damage, even in undeveloped areas, is very apparent. Nature's stormwater management systems are not static but are constantly changing. Streams meander, banks erode, vegetation changes with the seasons, lakes fill in with sediment and eventually disappear. The stripping of ground and tree cover by fire can change an entire system, forcing new natural accommodations throughout the system.

The volume of stormwater runoff is governed primarily by infiltration characteristics and is related to the land use, soil type, topography, and vegetative cover. Thus, runoff is directly related to the percentage of the area covered by roofs, streets, and other impervious surfaces. Water intercepted by vegetation and evaporated or transpired is lost from runoff. A small portion of the water that infiltrates into the soil and groundwater is delivered to the stream as delayed flow and does not contribute directly to peak stormwater runoff. Impervious surfaces normally contribute almost all of the total rain immediately to stormwater runoff.

There are four distinct yet interrelated effects of land use changes on the hydrology of an area:

1) Changes in peak flow characteristics; 2) changes in total runoff; 3) changes in water quality; and 4) changes in the hydrologic amenities (Leopold, 1968). The hydrologic amenities are what might be called the appearance or the impression that the river, its channel, and its valleys leaves with the observer.

Of all land use changes affecting the hydrology of an area, urbanization is the most forceful. As an area becomes urbanized, the peak rate of runoff and volume of runoff increase. These effects are caused by 1) a reduction in the opportunity for infiltration, evaporation, transpiration, and depression storage; 2) an increase in the amount of imperviousness; and 3) modification of the surface drainage pattern, including the associated development of stormwater management facilities.

As land is developed, the impervious surfaces that are created increase the amount of runoff during rainfall events, disrupting the natural hydrologic cycle. Without stormwater controls, the increased runoff can erode stream channels, increase pollutant loadings, cause downstream flooding, and prevent groundwater recharge. The increased runoff can degrade water quality in all types of waters, including those classified as water supply watersheds, shellfish areas, and nutrient-sensitive waters. Protecting these waters is vital for a number of reasons, including the protection of fish and wildlife habitat, human health, recreation, and drinking water supplies.

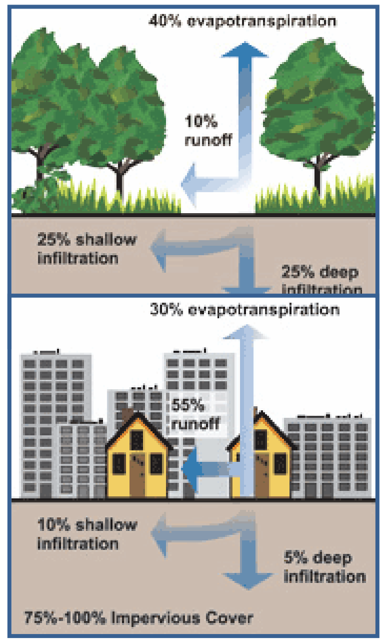


Figure 1 Stormwater runoff in natural and urban areas (Source: EPA)

The management of all water pollution sources is a stated goal of the 1987 amendments to the Clean Water Act. To fulfill the requirements of the Clean Water Act, the Mississippi Department of Environmental Quality (MDEQ) has examined water pollution within the State and has developed permit programs to address that pollution. Some of the programs have resulted in the promulgation of specific stormwater regulations to address overall water pollution issues. In addition, there are several county and local governments that have also implemented stormwater regulations to address specific local water pollution issues. Most of these programs attempt to protect, maintain, and restore water uses to the surface waters through the use of narrative-based effluent limitations in the form of “best management practices” (BMPs).

Introduction to BMPs

Stormwater BMPs are implemented as a way of treating or limiting pollutants and other damaging effects of stormwater runoff. There are two major categories of BMPs: non-structural and structural. The management of stormwater runoff through non-structural BMPs is the preferred method of reducing pollution from developing urban and suburban areas. In cases where the preferred methods are not feasible or sufficient, or where stormwater controls are being used to retrofit existing development, engineered or structural BMPs are viable solutions to reducing pollution. Both non-structural and structural BMPs are discussed in more detail in the following sections.

Non-Structural BMPs

Non-structural BMPs are typically passive or programmatic and tend to be source control or pollution prevention BMPs that reduce pollution in runoff by reducing the opportunity for the stormwater runoff to be exposed to the pollutants. In many circumstances it may be easier and less costly to prevent the pollutants from entering the drainage system rather than to control them with end-of-pipe structural BMPs. Used properly, the non-structural BMPs can be very effective in controlling pollutants and in greatly reducing the need for structural BMPs. In addition, non-structural BMPs tend to be less costly and easier to design and implement. Typically, the measures do not require maintenance but do require administrative resource commitments to ensure that they are continually implemented. Non-structural BMPs normally do not have technical or engineering designs associated with them. Some typical non-structural BMPs are listed below:

- Public education and participation.
- Land use planning and management (vegetative controls, reduced impervious areas, disconnected impervious areas).
- Material use controls (housekeeping practices, safer alternative products, pesticide and fertilizer use).
- Material exposure controls (material storage control, vehicle-use reduction).
- Illegal dumping controls (storm drain stenciling, household hazardous waste collection, used oil collection).
- Spill prevention and cleanup (vehicle spill control, above ground tank spill control).
- Connection controls (illicit connection detection, removal, and prevention, leaking sanitary sewer control).
- Street and storm drain maintenance (roadway cleaning, catch basin cleaning, vegetation controls, storm drain flushing, roadway/bridge maintenance, drainage channel, and creek maintenance).

Structural BMPs

Structural BMPs refer to physical structures designed to remove pollutants from stormwater runoff, reduce downstream erosion, provide flood control, and promote groundwater recharge. Structural BMPs typically require engineering design and engineered construction. The several types of structural BMPs vary greatly in their design, and they each have advantages and disadvantages relative to each other. Some structural BMPs provide considerable stormwater quantity handling capability through the use of infiltration and/or detention/retention facilities (e.g., infiltration devices, constructed stormwater wetlands, wet detention basins). Others provide many types of pollutant removal mechanisms such as sedimentation, filtration, microbial action, and plant uptake (e.g., bioretention, constructed stormwater wetlands). Some BMPs provide high levels of both stormwater quantity handling and pollutant removal ability. In addition, structural BMPs can be divided into those that help reduce the pollutants or quantity of stormwater entering a collection system (e.g., permeable pavement, filter strips, green roofs), and those that treat the stormwater at the “end of pipe” (e.g., sand filter, constructed stormwater wetlands, wet detention basins). The following structural BMPs are discussed in detail within this design manual:

- Bioretention
- Sand Filter
- Stormwater Wetlands
- Wet Detention Basin
- Filter Strip
- Grassed Swale
- Infiltration Devices
- Restored Riparian Buffer
- Dry Extended Detention Basin
- Permeable Pavement Systems
- Rooftop Runoff Management

Selecting the Right BMP

Selecting the most appropriate BMPs for a development is an art as well as a science, if done correctly. This section provides the link between stormwater regulatory requirements and physical site constraints, as well as issues of cost and community acceptance.

For several reasons, no one BMP is best for every site. First, different BMPs are better suited for different aspects of stormwater treatment and control (sediment removal, nutrient removal, and volume control). One particular BMP might not provide all of the required treatment goals of the regulations that apply to a site. Additionally, each site has unique features, such as slope, soils, size, and development density that encourage the use of some types of BMPs and eliminate the use of other types of BMPs. Issues of cost and community acceptance are also vital to consider in the BMP selection process.

General BMP Selection Guidance

Prior to selecting a structural BMP, a designer should first consider if it is possible to reduce the impervious surfaces on the site. Reducing impervious surfaces can minimize or eliminate the need for structural BMPs. Strategies for reducing impervious surfaces are discussed in depth in Chapter 2.

If structural BMPs will be required, the following process is recommended for selecting the appropriate one to use:

- First, determine the treatment the primarily stormwater treatment and control requirement (e.g., sediment control, nutrient control, volume control).
- Second, determine which BMPs will meet the treatment requirements and create a “short list.”

- Third, see which of the “short list” BMPs will be appropriate for the physical site characteristics.
- Fourth, consider other factors such as construction cost, maintenance effort, community acceptance, and wildlife habitat.

When a site has a lot of physical constraints and the regulatory requirements are stringent, it can be especially challenging to find a BMP that will fit the bill. In this case, it may be necessary to modify the BMP design for the site characteristics (see individual BMP chapters) or to provide a combination of BMPs that are suitable for the site, in series, to provide the required level of stormwater treatment.

Getting even further into the art of good BMP design requires blending the BMP into the natural environment to make it an aesthetic enhancement rather than a thing to hide (especially in areas with considerable pedestrian traffic such as residential, commercial, and office locations). This often requires collaboration between various professions such as civil engineers and landscape architects.

When siting BMPs within a site, they should conform to the natural features of the landscape such as drainage swales, terraces, and depressions. Many of the more “natural” BMPs can readily achieve these goals, such as filter strips, grassed swales, and restored riparian buffers. Other natural-looking BMPs such as bioretention and stormwater wetlands can be blended right into natural areas of site designs, or even create new, small-sized natural areas within normally barren portions of the site, such as parking lots, walking areas, and outdoor plazas.

MDEQ recommends reintroducing runoff from impervious surfaces into the natural environment as close to the surface as possible. Ideally, impervious surfaces should be hydrologically divided so that runoff is delivered in smaller volumes that can be accommodated by smaller, less expensive and less obtrusive BMPs. In general, MDEQ recommends against constructing large “end-of-pipe” facilities because of their high cost, maintenance requirements, consumption of land, and disruption of the landscape.

Reducing Impervious Surfaces

Most stormwater rules provide an option to meet certain low-density development criteria and then typically no engineered stormwater controls will be required. Keeping the percent impervious surface low when possible is the preferred method of stormwater control. In addition, reducing the percentage of impervious cover in a high-density development will reduce the size of BMPs that are needed.

Some of the options for reducing impervious surfaces are listed below and discussed in the *Planning* and *Site Design* sections of Chapter 4. The local planning jurisdiction will usually determine the flexibility that exists to try them.

- *Narrower Residential Streets*
- *Green Parking/Shared Parking*
- *Eliminating (or Minimizing) Curbs and Gutters*

- *Open Space Design*
- *Traditional Neighborhood Developments*
- *Mixed-use Developments*

Chapter 2 of this manual provides general information on site-design principles that address reducing impervious surfaces. Chapter 4 provides specifics on *Planning* and *Site Design* practices for reducing impervious surfaces.

Comparison of BMP Treatment Capabilities

If the low-density option is not chosen, then one or more structural BMPs will be needed. For structural BMPs, one or more of the following general requirements will apply:

- There will be a volume of stormwater that must be captured and treated prior to release (typically first 1 inch or first 1.5 inches of rainfall).
- The post-construction peak stormwater discharge rate must be reduced to no greater than the pre-construction peak stormwater discharge rate (usually for the 2-year, 24-hour storm).

Table 1-1 presents the total suspended solids (TSS), nitrogen (N), and phosphorus (P) removal efficiencies of the various BMPs discussed in this manual. These removal efficiencies assume that the BMPs are designed in accordance with the design requirements presented in Chapter 4. The removal efficiencies presented are in accordance with the September 8, 2004, memorandum *Updates to Stormwater BMP Efficiencies* from the North Carolina Department of Environment and Natural Resources (DENR), Division of Water Quality (DWQ) Stormwater Unit (DWQ, 2004).

Fecal coliform reduction is currently regulated as a narrative requirement rather than a quantitative requirement. Effort must be made to reduce fecal coliform levels in sensitive waters. The current main mechanism for reducing fecal coliform in stormwater BMPs is through exposure to UV light (sunlight), which happens regularly in devices containing areas that become temporarily inundated with stormwater. Fecal coliforms can be deposited and exposed to UV light. Additionally, in bioretention cells, fecal coliforms can be reduced by filtration, drying events between storms, and sedimentation. Some scientists also believe predation from other microbes can significantly reduce fecal coliform numbers (Hathaway and Hunt, 2008). BMPs are ranked relatively for fecal coliform removal in Table 1-1.

Table 1-1
BMP Ability for Stormwater Quantity Control

	Quantity Control	TSS Removal Efficiency	TN Removal Efficiency	TP Removal Efficiency	Fecal Removal Ability	High Temperature Concern
Bioretention without IWS*	Possible	85%	35%	45%	High	Med
Bioretention with IWS* *Coastal Counties*	Possible	85%	60%	60%	High	Med
Bioretention with IWS* *Non-Coastal Counties*	Possible	85%	40%	45%	High	Med
Stormwater wetlands	Yes	85%	40%	40%	Med	High
Wet detention basin	Yes	85%	25%	40%	Med	High
Sand filter	Possible	85%	35%	45%	High	Med
Filter strip	No	25-40%	20%	35%	Med	Low
Grassed swale	No	35%	20%	20%	Low	Low
Restored riparian buffer	No	60%	30%	35%	Med	Low
Infiltration devices	Possible	85%	30%	35%	High	Low
Dry extended detention basin	Yes	50%	10%	10%	Med	Med
Permeable pavement system	Possible	0%	0%	0%	Low	Med
Rooftop runoff management	Possible	0%	0%	0%	Low	Med

*IWS = Integrated water system

Comparison of BMP Site Constraints

The basic nature of stormwater BMPs often places them in low-lying areas and next to existing waterways, which can put them at odds with other regulations. The designer must always be aware of other regulations when siting BMPs. A non-exhaustive list of possible environmental regulatory issues is provided below:

- Jurisdictional wetlands
- Stream channels
- 100-year floodplains
- Stream buffers
- Forest conservation areas

– Critical areas
– Endangered species

BMPs should also be sited in a manner that avoids the following types of infrastructure:

– Utilities
– Roads
– Structures
– Septic drain fields
– Wells

A BMP will not work unless it is sited appropriately. It is very important to visit the site and obtain information about the size of the drainage area, soils and slopes, as well as depth to groundwater table and bedrock.

The various site considerations for siting BMPs are presented in Table 1-2 below. Each of these considerations is discussed below.

The **size of drainage area** is a primary consideration in selecting a BMP. Some BMPs will work only with a drainage area that is sufficient to provide a permanent pool of water. Other BMPs, such as bioretention areas and sand filters, are specifically designed to handle smaller flows and could easily become overwhelmed if sited at the outlet of a large drainage area.

The **space required** for a BMP is another important consideration, particularly if the site does not have a lot of space to accommodate a BMP. It is important to note, however, that some of the BMPs that require a small space are relatively expensive (i.e., sand filter) or do not have high treatment capabilities (i.e., grassed swale).

The **head required** (elevation difference) will also affect the BMP selected. In areas of low relief, excavations are often required for basins, which can be expensive. In addition, some devices require several feet of hydraulic head, which may not be available in low-relief areas.

Steep slopes will affect the BMP selection process. Larger BMPs, such as wet detention basins and extended detention wetlands, may not fit well on a site where there is not a relatively flat area to site them or may result in an impractically large embankment height. Also, steep slopes may create excessive water velocities for some systems (e.g., filter strips, swales, restored riparian buffer). When an entire site has steep slopes, it may be best to provide a number of smaller BMPs that can fit into the existing contours of the site.

A **shallow water table** can limit some types of BMP systems. For example, bioretention areas require a minimum depth to groundwater of 2 feet; otherwise, the bioretention area will actually function as a stormwater wetland.

A **shallow depth to bedrock** can greatly limit BMP options. Shallow bedrock can restrict the use of infiltration systems, prevent the excavation of basins, and limit the hydraulic functions of certain BMPs. The BMP options in this scenario may be limited to filter strips, restored riparian buffers, and rooftop runoff management.

High sediment input can limit the longevity of certain BMPs, especially sand filters, bioretention, infiltration systems, stormwater wetlands, and permeable pavement. These BMPs should not be placed in locations where high sediment loads are expected upstream in the future (typically from future development). Alternatively, high sediment loads that might adversely affect BMPs can be overcome by providing filter strips and sediment basins in up-gradient areas.

Poorly drained soils are another BMP siting consideration. For example, poorly drained soils may exclude the use of any system relying on infiltration, such as bioretention areas without an underdrain (however, this problem can be corrected with the use of an underdrain.) Poorly drained soils may be very well suited, however, for BMPs that retain water, such as a wet detention basin or a stormwater wetland.

Table 1-2
Possible Siting Constraints for BMPs

BMP	Size of Drainage Area*	Space Required	Head Required	Works with Steep Slopes?	Works with Shallow Water Table?	Works with Shallow Depth to Bedrock?	Works with High Sediment Input?	Works with Poorly Drained Soils?
Bioretention without IWS	S	High	Med	Y	N	N	N	Y
Bioretention with IWS	S	High	Med	Y	N	N	N	N
Stormwater wetlands	S-L	High	Med	N	Y	N	Y	Y
Wet detention basin	M-L	High	High	N	Y	N	Y	Y
Sand filter	S	Low	Med	Y	N	N	N	Y
Filter strip	S	Med	Low	N	Y	Y	N	Y
Grassed swale	S	Low	Med	Y	Y	N	N	Y
Restored riparian buffer	S-M	Med	Low	N	Y	Y	N	Y
Infiltration devices	S-M	High	Low	N	N	N	N	N
Dry extended detention basin	S-L	Med	High	N	N	N	Y	Y
Permeable pavement system	S-M	N/A	Low	N	N	N	N	Y
Rooftop runoff management	S	Variable	Low	Y	Y	Y	Y	Y

* S = small, M = medium, L = large drainage area

Comparison of BMP Costs and Community Acceptance

Construction costs and operation and maintenance efforts for each of the BMPs are listed in Table 1-3. However, it is important to note that some of the lowest cost or lowest maintenance-level BMPs also have some of the lowest treatment capabilities. Using low-cost BMPs could result in a need for additional BMPs to achieve the requirements, thereby increasing costs and maintenance requirements. In addition, several of the lowest cost BMPs may be difficult to integrate into the natural features of a site or may be the least desirable from an aesthetic or safety point of view. Often, a slightly more expensive or maintenance intensive BMP may be a better choice for overall site design.

Sometimes, community and environmental factors seem the least important; however, they can have a big impact on the public perception and acceptance of a site development. For instance, a prospective homeowner may think twice before buying a lot or home bordering a large, fenced-in, dry extended detention basin with a large corrugated metal riser pipe and occasional mosquito outbreaks after storms. However, if the BMP were designed as a bioretention device or a stormwater wetland, it could serve as an aesthetic amenity on the site, possibly with birds, frogs, and fish. Table 1-3 provides information on each BMP's safety concerns, community acceptance, and wildlife habitat.

Table 1-3
Cost, Community and Environmental Issues for BMPs

	Construction Cost	Maintenance Level	Safety Concerns	Community Acceptance	Wildlife Habitat
Bioretention	Med-High	Med-High	N	Med-High	Med
Stormwater wetland	Med	Med	Y	Med	High
Wet detention basin	Med	Med	Y	Med	Med
Sand filter	High	High	N	Med	Low
Filter strip	Low	Low	N	High	Med
Grassed swale	Low	Low	N	High	Low
Restored riparian buffer	Med	Low	N	High	Med-High
Infiltration device	Med-High	Med	N	Med-High	Low
Dry extended detention basin	Low	Low-Med	Y	Med	Low
Permeable pavement system	Med-High	High	N	Med	N/A
Rooftop runoff management	Med	Med	N	High	Low

Chapter 2

General Planning Concepts for Stormwater Management and Overview of Low-Impact Site Design and Smart Growth Concepts

Stormwater planning was instituted out of the necessity to move stormwater runoff from impervious surfaces to prevent localized flooding, with little regard for water quality. A system of underground pipes was developed to quickly move the excess stormwater into streams and coastal waters. Over time, the U.S. Environmental Protection Agency (EPA) determined that, while this system minimized the risk of flooding, stormwater flow was carrying a large number of pollutants into natural waterways and harming the ecosystems that inhabited them, which led to the development of Phase I and II Stormwater Regulations. For the purposes of this manual, the planning concepts associated with stormwater runoff management have been broken down into two broad categories: Smart Growth Concepts and Low-Impact Development. However, no single approach or strategy will work for every community. Each community should evaluate its unique conditions and characteristics to determine the most appropriate approach or combination of approaches. Smart Growth and Low-Impact Development categories will overlap in many places and, in some cases, may be used interchangeably. Additional discussion of the BMPs suggested below can be found in Chapter 4.

Smart Growth Concepts

Smart Growth encourages economic growth that helps the economy while also protecting the environment, and revitalizing existing communities. Although many of its goals are focused on development rather than environmental protection, evidence shows that implementing a Smart Growth program has a number of environmental benefits. Core principles include directing new growth toward established areas and promoting a compact and mixed-use pattern of development as well as a greater reliance on transit, walking, and biking. Some of the many tools governments may use to implement Smart Growth include zoning, street design, and open space conservation. The EPA formed the Smart Growth Network as a means to provide information about strategies to make growth compatible with environmental quality and to share best practices being implemented around the country. The Smart Growth Network's publication *This Is Smart Growth* describes program benefits in the following way, "When communities choose smart growth strategies, they can create new neighborhoods and maintain existing ones that are attractive, convenient, safe, and healthy. They can foster design that encourages social, civic, and physical activity. They can protect the environment while stimulating economic growth. Most of all, they can create more choices for residents, workers, visitors, children, families, single people, and older adults—choices in where to live, how to get around, and how to interact with the people around them. When communities do this kind of planning, they preserve the best of their past while creating a bright future for generations to come" (International City/County Management Association, not dated).

What Are the Key Elements of Smart Growth?

Smart Growth lays out a series of principles to guide development based on research and experience. The ultimate goal of these principles is to help communities experience the benefits of economic growth while also expanding opportunities and improving quality of life. The principles below provide guidance for how that might occur:

Ten Smart Growth Principles

- Provide for a compatible mixture of land uses
- Take advantage of compact building design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Strengthen and direct development towards existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair and cost effective
- Encourage community and stakeholder collaboration in development decisions

Typical Components of Smart Growth Development

Smart Growth offers a number of strategies that may be used as BMPs to produce a better stormwater management program at the state, county or local level. Developers may also incorporate several of the design strategies, listed below, in their stormwater prevention plan preparation to improve their project's ability to manage stormwater. Mississippi does not have a comprehensive statewide law on Smart Growth, as do Florida and Maryland. However, the State does have existing statutes and permits related to stormwater management, which encourage the utilization of many of the following Smart Growth strategies. Through the State's existing statutes on stormwater management, however, it encourages the MS4s in its jurisdiction to employ many of the following Smart Growth strategies.

Regional Planning

Regional planning encourages cities to look beyond their political boundaries to find solutions to larger stormwater management problems. Intergovernmental cooperation at a watershed level can improve the water quality of streams, rivers, and other water bodies that cross political lines. Benefits include a reduction in imperviousness by directing development to appropriate areas, identifying and preserving critical ecological and open space resources, and making the best use of land that is already served with infrastructure and a high level of impervious surface cover. Regional planning organizations in

Mississippi include the State's Planning and Development Districts and its four Metropolitan Planning Organizations, which focus on transportation planning. The Department of Marine Resources protects coastal waters in the southern part of the state. County-wide utility authorities provide services to multiple city and rural jurisdictions. In many situations, city and county governments may also find it advantageous to work together to address issues of regional water quality.

Infill Development

Infill development occurs on previously undeveloped lots within urban areas. It has the benefit of being served by existing water, wastewater, transportation and other infrastructure. The EPA indicates in its model Phase II permit (available at http://www.epa.gov/npdes/pubs) that cities may use infill development as a post-construction minimum control measure. Local governments most commonly indicate to developers where they would like infill to occur through their zoning ordinance, usually administered by a jurisdiction's planning department. The zoning ordinance itself governs features of development such as the maximum size of structures on a lot, the lot coverage, parking required, and landscaping regulations. Some jurisdictions also use financial or regulatory incentives to encourage developers to locate specific types of development in designated areas. A primary benefit of infill development is that it reduces the level of impervious cover in undeveloped areas and does not require building new roads, parking and other surfaces that reduce stormwater infiltration, groundwater flow and aquifer recharge.

Redevelopment

Redevelopment is similar to infill except that it refers to properties that have already been developed for another use. These sites are likely to be covered with impervious surface and to be of limited to no value to the stormwater management system. A redevelopment program might be administered through a "Main Street" or Brownfields program, which surveys and markets a number of potential sites for redevelopment. In the planning stages of a redevelopment project, developers must consider existing street and circulation patterns, zoning codes, and the suitability of building configurations to contemporary use. Benefits of redevelopment include bringing more active uses to an area and increasing the tax rolls. By recycling these sites and granting them new life, governments also reap the broader benefits of development on an existing property by reusing impermeable surface and preserving land at the outer fringe. Redevelopment strategies are further discussed in the *Planning Section* of Chapter 4.

Development Districts

Cities or counties establish development districts to set apart specific areas in which to achieve comprehensive planning and urban design goals. These areas are characterized by more complex and coordinated rezoning, transportation and planning efforts, and generally require a higher degree of cooperation among different entities to encourage development. The districts are most commonly outlined in the city or county's zoning ordinance, and administered by planning departments. However, they may also be created through a specific plan or policy to address an issue such as Brownfields redevelopment. Among the most common types of development districts are Main Street districts, Brownfields redevelopments, Transit-Oriented Districts (TODs), and Business Improvement Districts (BIDs). Development districts specifically associated with a Smart Growth approach include Smart Code, Traditional Neighborhood Developments (TNDs), and Unified Development Ordinances. As with "infill development" and "redevelopment," this strategy improves stormwater management by directing new growth toward already developed locations instead of toward green sites at the city's fringe. These districts may also set standards for transportation networks and other infrastructure that reduces impermeable coverage and improves stormwater management. Development Districts are further discussed in the *Planning Section* of Chapter 4.

Tree and Canopy Programs

Preserving mature trees and encouraging new tree planting provides a number of environmental benefits. Increasingly, urban forestry policies are focusing on developing a full canopy, rather than just requiring the preserving or planting of individual trees. A more complete tree canopy system improves stormwater management by more effectively capturing rainwater, controlling erosion, and absorbing and filtering many of the pollutants associated with stormwater runoff. Tree ordinances are typically implemented by public works or parks departments. Local extension agents may also be able to provide better information about what types of trees are appropriate and provide the maximum environmental benefits for an area. There are a number of strategies to improve the quality of tree canopy, including street tree ordinances, pedestrian plans, and tree planting programs. Urban Forestry may be adopted specifically as a BMP in a stormwater management program and is discussed further in Chapter 4.

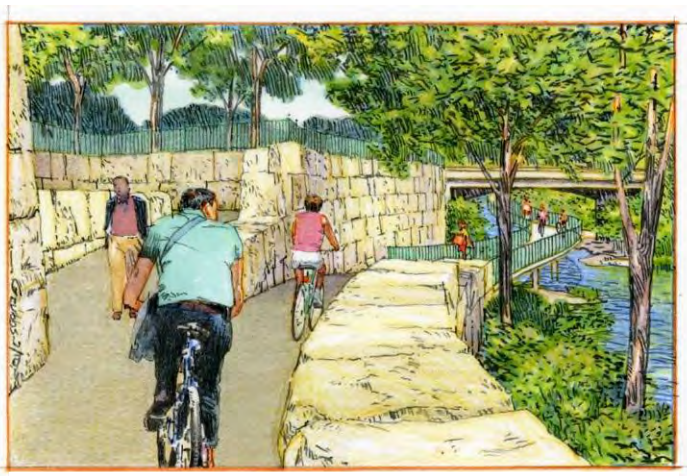
Parking Policies for Parking Reductions

Many areas have an oversupply of parking because of zoning that focuses on minimum parking requirements for each land use. Considering that a one-inch rainstorm on a one-acre meadow would produce 218 cubic feet of runoff, a parking lot of the same size would produce 3,460 cubic feet (Schueler, 1995). The more parking in a community, the greater the amount of impervious surface cover and the bigger the challenge for stormwater management. Parking policies are usually administered by planning departments or departments of public works through zoning and subdivision ordinances. To reduce impervious surface, communities can redefine how parking demand is determined and ultimately reduce the overall number of parking spaces. Some strategies to manage the amount of parking provided in a community include parking overlay districts, on-street parking, combining spaces into structured parking garages, shared parking, and parking pricing. Green parking technologies, such as pervious pavers, help promote the infiltration of stormwater in parking spaces. Making pedestrian trips more pleasant and attractive can also reduce parking demand. This strategy can bring about significant improvements in a jurisdiction's stormwater management system. (See the *Street Design and Patterns*, *Green Parking*, *Pervious Interlocking Concrete Paving*, *Pervious Asphalt Pavement*, and *Pervious Concrete* practices in Chapter 4.)

Fix It First Infrastructure Policies

The buildings in mature neighborhoods and commercial districts are typically served by an infrastructure network that provides users with safe, clean, comfortable shelter from the elements. Roads connect them with other locations in the area, drinking water is provided, and storm and sanitary sewers safely control the disposal of excess water. Public works departments generally maintain roadways, while local water departments or regional utility authorities often provide water and wastewater services and maintain the systems. "Fix It First" policies prioritize repairs to keep existing infrastructure in working order before investing in new roads and infrastructure. A policy of systematically replacing older sewer infrastructure lowers the frequency of stormwater-related problems. Sewer overflows during heavy rains, for example, are often caused by deteriorating or over-extended pipes. Fix It First policies help ensure older areas of town remain attractive to new investment and improve the success of local efforts to promote redevelopment or infill.

Smart Growth Street Designs



Smart Growth Design Concept (graphic by McCann Adams Studio, Austin, TX)

Designing Smart Growth streets requires thinking about more than the fastest way to get a car from one destination to another. It involves planning a well-connected network of transportation options for drivers, transit users, pedestrians, and bicyclists. Street design standards may be defined by the local public works department or by local subdivision guidelines, which are generally administered by planning departments. Smart Growth designs are characterized by narrower roadways and a lower degree of impervious surface. This equates to a reduction in the width of residential streets, and increased opportunities for filtration of common neighborhood pollutants such as sediment, bacteria, and nutrients.

For the larger network, it means connecting streets through neighborhoods and to each other. The hierarchical model of neighborhood street, collector road, and arterial street produces more paved surface than a Smart Growth design, using multiple turning lanes, wide intersections and access lanes to minimize congestion that stems in part from many disconnected roadways spilling into a larger system. The stormwater performance of Smart Growth street systems can also be improved by policies that reduce the amount of runoff entering curbs and gutters. Better connected streets improve the rate of pedestrian and other non-motorized trips. By reducing the width of all the streets in the transportation network, Smart Growth street design increases opportunities for infiltration of common pollutants (sediment, bacteria, and nutrients). (See the *Street Design and Patterns*, *Alternative Turnarounds*, *Eliminating Curbs and Gutters*, and *Narrower Residential Streets* practices in Chapter 4.)

Stormwater Utilities

The State of Mississippi currently administers stormwater regulations through the Department of Environmental Quality. County or city governments prepare local Stormwater Management Plans at the local level and enforce regulations through regular inspections. Many states have taken an additional step, investigating where the rate structure of other utility programs, such as electricity and gas service, might be unintentionally subsidizing new growth at the expense of more cost-efficient service areas. A stormwater utility establishes an organization where a user helps finance stormwater improvements related to growth and development.

Integrating Smart Growth and Stormwater Management

After several years of focusing on the impact of individual development sites or subdivisions on stormwater management, there is now greater interest in how new developments impact neighborhoods and watersheds. Research by the EPA found that high-density housing development of up to eight units an acre produces a lower total runoff per year than eight homes spread across eight acres. If those eight units are sited in an area that is already developed, it potentially frees unused land for conservation. This research supports Smart Growth's contention that infill development, or denser growth that occurs in urbanized areas, is more environmentally friendly than low-density sprawling neighborhoods. Even though development at one unit per acre appears greener, the percentage of paved surface per lot is usually much greater, leading to a higher level of runoff. Landscaped lawns also have compacted surfaces from repeated maintenance that do not always perform at a higher level than paved areas. The North Central Texas Council of Governments set out to improve their region's stormwater with a guide of how different common planning tools could be adapted to better manage regional runoff (EPA, 2005). Employing the concepts of Smart Growth to stormwater management and using available planning tools helps shift the focus toward development in appropriate areas and with techniques that ultimately lessen the impact on a region's waterways.

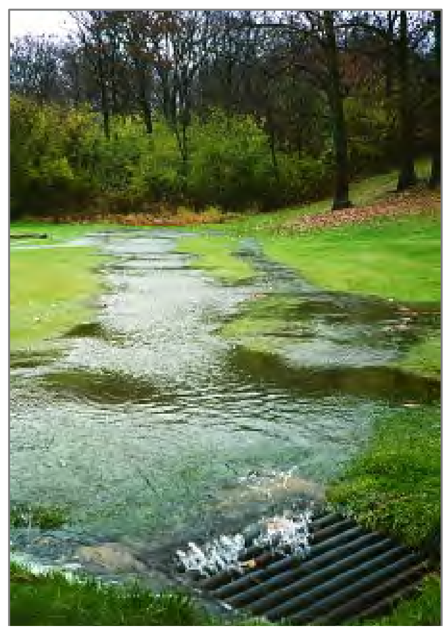


Figure 1 Stormwater Runoff (Source: James M. Pease, National Institute of Health)

Low-Impact Development

Low-Impact Development, or LID, is "an innovative stormwater management approach with a basic principle that is modeled after nature: manage rainfall at the source using uniformly distributed decentralized micro-scale controls" (LID, 2007). It is the practice of taking steps during the design stage of development to minimize changes to the hydrologic cycle (runoff and infiltration after a storm). LID strategies integrate green space, native landscaping, natural hydrologic functions, and various other techniques to reduce runoff from developed land (NRDC, 2001). These types of practices encourage infiltration and reduce the volume of stormwater discharged from the site. Many innovative site designs and stormwater management practices are grouped together under the heading of LID, but true LID strategies have certain key distinctions. The key distinctions of LID include the following:

- Stormwater management at a local scale to minimize impact of development on the local watershed.
- Ecosystem-based. Development is designed as a functional part of the ecosystem (not apart from it).
- Relies on advanced technologies more than conservation and growth management (Smart Growth plans).

LID promotes hydrologic function at the lot level. It addresses stormwater through small, cost-effective landscape features and integrated management practices, also known as IMPs.

Integrated Management Practices

The term IMP is used to define controls that are integrated throughout the project and provide landscape amenities. The terms BMP and IMP are frequently used interchangeably. When Integrated Management Practices are linked together, they form *BMP trains* that address water quantity and water quality in succession. Such a train could be created by linking a rain barrel (overflow) to a rain garden, and the overflow drain of the rain garden to a constructed wetland.

History of LID

Many communities are turning to LID practices to assist with stormwater management. Conventional solutions to handling stormwater runoff are not always compatible with community interests, or local, state, and federal water quality regulations. Prince George's County, Maryland, is known as the originator of the LID movement, and has pioneered many stormwater-management practices and protective policies since the early 1980s. The State of Wisconsin has also promoted LID since the late 1980s, but dates to the early 1900s in the origin of sustainable products such as Milorganite, a fertilizer used in the golf course industry made from the byproduct of the Milwaukee sanitary sewer system.

What Are the Key Elements of LID?

The key elements of LID include the following:

- Conservation
- Small-scale controls
- Customized site design
- Pollution prevention and education
- Directing runoff to natural areas

The preservation of native trees, understory vegetation, and natural drainage processes is important in LID development. They are enhanced by small-scale controls on the lot level that mimic natural hydrology. The customized design of LID controls protects hydrologic processes, reduces pollutant loads, and sends stormwater to areas of infiltration to facilitate groundwater recharge.

Planners, engineers, and other design professionals should consider using LID because it enhances the local environment, protects public health, improves community livability, and saves developers and local governments' money. Use of LID practices can often provide a 25%-30% reduction in costs associated with site development, stormwater fees, and maintenance for residential developments. These savings are recognized through reductions in clearing, grading, pipes, ponds, inlets curbs, and paving.

Low-Impact Development practices are easily applied to open space, roof tops, streetscapes, parking lots, sidewalks, and medians. The preservation of existing open space or the creation of new open space allows for large conservation areas where stormwater can infiltrate into the ground and promote groundwater recharge. Rooftop gardens or green roofs provide excellent insulation in warm climates and reduce heat island effects in urban environments. LID promotes narrow streets and driveways, which reduce impervious surfaces as well as flooding and pollution from stormwater. Typically, there are no curbs and gutters in LID developments, and houses are generally closer to the street. Shared driveways are also quite common.

Typical LID design components

Components generally considered in LID design include vegetation, pervious surfaces, and bioretention systems. Vegetation removes water through evapotranspiration and assists in pollutant removal through nutrient cycling. Pervious surfaces allow stormwater to infiltrate into underlying soils, promoting groundwater recharge and pollutant processing while reducing the volume of rainwater runoff. Bioretention systems detain water long enough for infiltration and pollution removal to occur. Bioretention systems may be designed as buffer strips, rain gardens, stormwater wetlands, and grass swales.

Bioretention Areas

Bioretention areas, also known as bioretention filters or rain gardens, capture and temporarily store water. Water is conveyed to the treatment

Figure 2 Rain Garden (Source: lid-stormwater.net)

area as sheet flow. Bioretention areas can be designed to capture the first inch of rain and allow it to soak into the soil, watering the plants in the rain garden. Rain gardens are typically saucer-shaped depressions that have six to eighteen inches of water when completely filled with stormwater. They are designed to detain water long enough for infiltration and pollutant removal to occur, but not cause mosquito problems.

Rain gardens are attractive gardens that typically use native plants. Native plants should be used because they are more drought tolerant and require less maintenance. Pollutant removal is facilitated by microbes that live in the soil and interact with the plant roots. Rain gardens are designed to drain within 24 to 48 hours, eliminating potential mosquito habitat. Pathogens are left high and dry as water is absorbed.

Landscaping is critical to the performance and functioning of a rain garden. A diversity of plant types should be included to replicate a natural ecosystem. Trees should be spaced at least 10 feet apart, hardwood mulch should be used (not pine bark; it floats), and plants should be both water tolerant and drought tolerant.

Rain gardens come in many shapes and sizes and can be used in commercial and residential landscapes, parking lots and medians, highway drainage, and on golf courses. There are several different types of rain gardens, and the design can be modified to fit many uses. Rain gardens often take advantage of existing low spots, are excavated and filled with amended soil to aid in the drainage process, and may include an overflow drain—consisting of a perforated pipe or an existing stormwater outlet that has been raised to aid the ponding of water. Bioretention areas are further discussed in Chapter 4.

Rain Barrels and Cisterns

Rain barrels are small roof stormwater recapture systems that store residential rooftop runoff for localized use. Water collected in a rain barrel would normally flow through a gutter system or from a roof onto the ground, potentially causing erosion. A rain barrel can save approximately 1,300 gallons of water during peak summer months of normal rainfall. For every inch of rain that falls on a catchment area of 1,000 square feet, approximately 600 gallons of rainwater can be collected. All systems should use covered barrels or cisterns that keep the water from accumulating leaves and other contaminants. Perhaps the simplest use of a rain barrel is to situate the barrel under one of the gutter downspouts and use the water on sensitive indoor plants. Storing rainwater for garden and outdoor work use helps recharge groundwater naturally by slowing down and reducing stormwater runoff.

Cisterns work on the same principle as rain barrels but typically have a large storage capacity. Modern cisterns are manufactured of plastic and may or may not be completely enclosed. They often have a lid made of the same material as the cistern, which is removable by the user. In the United States, cisterns are predominantly used for irrigation; however, some areas promote reuse of gray water (water from hand washing, dish washing, etc.) for toilet flushing.

Filter Strips, Vegetated Swales, and Constructed Stormwater Wetlands

Filter strips can be designed as landscape features within parking lots or other areas to collect flow from large impervious surfaces. Vegetated swales use grass or other vegetation to reduce runoff velocity and allow infiltration, while high-volume flows are channeled away safely. They function as alternatives to curb and gutter systems. Wetlands can be constructed to treat stormwater runoff by storing stormwater and trapping pollutants. These practices are outlined in detail in Chapter 4.

Pervious Paving

Pervious pavements allow air and water to pass through the surface, providing groundwater recharge. "If used properly, porous pavements can facilitate biodegradation of the oils from cars and trucks, help rainwater infiltrate soil, decrease urban heating, replenish groundwater, allow tree roots to breathe, and reduce total runoff, including the magnitude and frequency of flash flooding" (Ferguson, 2005). In his book, *Porous Pavements*, Ferguson identifies nine categories of porous pavement: decks, open-celled paving grids, open-graded aggregate, open-jointed paving blocks, plastic geocells, porous asphalt, pervious concrete, porous turf, and soft paving.

Mixing Structural and Nonstructural Post-Construction BMPs

Mixing structural and nonstructural post-construction BMPs allows for flexibility in creating appropriate BMP efficiency and cost reductions for pollutant removal. The resulting configuration resembles a *BMP train*, or a string of mix-and-match BMPs that are customized to a site's pollutant situation. There are now several BMP calculators (typically Excel format) that calculate the train's efficiency and cost.

The benefits of LID provide a high level of water quality treatment. LID tends to control volume of the first flush (first ½ inch to 1 inch) of runoff. It is cost effective for developers and local governments, and is aesthetically pleasing. LID increases quality of water in local streams, rivers, lakes or bays. It also controls impacts to our natural ecosystems through selective BMP implementation. Instead of large investments in complex and costly centralized conveyance and treatment infrastructure, LID allows for the integration of treatment and management measures into urban site features. This involves strategic placement of distributed lot-level controls that can be customized to more closely mimic a watershed's hydrology and water quality regime. The result is a hydrologically functional landscape that generates less surface runoff, less pollution, less erosion, and less overall damage to lakes, streams, and coastal waters.

Better Site Design

The Center for Watershed Protection has collected 22 principles of planning and site design into its "Better Site Design: A Handbook for Changing Development Rules in Your Community." The principles discussed in this section of the MDEQ Manual are primarily geared toward an audience of planners, engineers, developers and officials working in the development of new communities. As with LID and Smart Growth, many of these principles overlap the ideas presented by LID and Smart Growth while others can be used in conjunction with LID and Smart Growth ideals for the best possible site design.

The Better Site Design handbook groups the 22 principles into three sections: Residential Streets and Parking Lots, Lot Development, and Conservation of Natural Areas.

Residential Streets and Parking Lots

These principles are focused on reducing the impervious cover caused by paving for residential streets and parking areas.

Principle 1: Street Width

Residential streets should be designed so that the minimum necessary pavement is utilized for travel lanes, on-street parking, and emergency, maintenance and service vehicles access.

Principle 2: Street Length

Incorporate alternative street layouts so that street length can be decreased, thereby increasing the number of homes per unit length.

Principle 3: Right-of-Way Width

Wherever possible, residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Wherever feasible, utilities and storm drains should be located within the pavement section of the right-of-way.

Principle 4: Cul-De-Sacs

Alternative turnarounds should be considered in place of traditional cul-de-sacs. The number of residential street cul-de-sacs should be reduced and should have the minimum required radius allowed to accommodate emergency and maintenance vehicles.

Principle 5: Vegetated Open Channels

Vegetated open channels should be incorporated for stormwater treatment and conveyance where density, topography, soils, and slope allow.

Principle 6: Parking Ratios

Current local parking ratios should be enforced as both a maximum and a minimum for a particular land use in order to prevent excess parking space construction. Existing parking requirements should be assessed in light of local and national experience to see if lower ratios are warranted and feasible.

Principle 7: Parking Codes

Parking codes should be reviewed and revised to lower parking requirements, especially in areas where mass transit and shared parking are available.

Figure 3 Parking Lot Retention (Source: EPA)

Principle 8: Parking Lots

Options such as providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in overflow parking areas can help reduce the overall imperviousness of parking lots.

Principle 9: Structured Parking

Shared and structured parking reduces impervious surfaces but can often be cost prohibitive. Offering economic incentives can help encourage the development of these types of parking.

Principle 10: Parking Lot Runoff

Create functional landscaping areas such as bioretention areas and filter strips, which can aid in the treatment of stormwater runoff from parking lots.

Lot Development

The lot development principles deal with increasing open space while reducing site imperviousness through setback, frontage, sidewalk and driveway restrictions.

Principle 11: Open Space Design

Promote open space design that incorporates smaller lot sizes. Open space design not only reduces impervious surface area but also reduces construction costs, conserves natural areas, provides community recreational space, and promotes watershed protection.

Principle 12: Setbacks and Frontages

Reducing side yard setbacks allows narrower frontages to reduce total road length. Reducing front yard setback requirements allows shorter driveway lengths. Both practices will reduce the overall imperviousness of the community.

Principle 13: Sidewalks

Advocate for alternatively designed sidewalks in residential subdivisions. Locating sidewalks on only one side of the street reduces total site imperviousness while still connecting pedestrian areas.

Principle 14: Driveways

Promote alternative driveway options such as permeable paving and shared driveways.

Principle 15: Open Space Management

Development of community open space should include designated management and responsibly authority for managing both natural and recreational open spaces.

Principle 16: Rooftop Runoff

Avoid routing rooftop runoff directly onto impervious surfaces such as driveways, roadways or into the stormwater conveyance system. Instead, direct rooftop runoff to yards, open channels or other vegetated areas to allow infiltration.

Conservation of Natural Areas

Principles 17-22 address codes and ordinances that promote the conservation of natural areas. These principles help to reduce stormwater runoff pollution by promoting hydrologic functions found naturally within microwatersheds.

Principle 17: Buffer Systems

In development, buffer systems create naturally vegetated buffer along perennial streams, which generally encompasses the 100-year floodplain, steep slopes, and freshwater wetland areas.

Principle 18: Buffer Maintenance

The riparian buffer needs to be preserved, restored, and maintained with native vegetation to function properly throughout the delineation, plan review, construction, and occupancy stages of development.

Principle 19: Clearing and Grading

Clearing and grading of natural vegetation should be limited to the extent possible to allow lot development, access roads and fire protection. Community open spaces should include areas of mature-growth native vegetation that can be protected from future development.

Principle 20: Tree Conservation

Tree conservation can be accomplished by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Community open space, street rights-of-way, parking lot islands, and other landscaped areas can be managed to promote natural vegetation.

Principle 21: Conservation Incentives

Conservation incentives such as density compensation, buffer averaging, property tax reduction, stormwater credits, and by-right open space development should be used to encourage conservation of stream buffers, forests, meadows, and other natural areas.

Principle 22: Stormwater Outfalls

New stormwater outfalls should not discharge untreated stormwater into jurisdictional wetlands, sole-source aquifers, or other sensitive areas.

Chapter 3
Stormwater Pollution Prevention Plan Preparation

A Stormwater Pollution Prevention Plan (SWPPP) will identify potential sources of pollution, describe the implementation of best management practices, and provide a schedule for maintenance and inspection procedures. The Stormwater Pollution Prevention Plan often includes erosion and sediment control measures, as well, and will have similar elements as the Erosion and Sediment Control Plan discussed in *Volume 1 – Chapter 3*. Both this chapter (on SWPPP preparation) and the Erosion and Sediment Control chapter of Volume 1 should be reviewed before developing a plan.

Permit Requirements

Large Construction

A SWPPP is required for Large Construction General Permit authorization in the State of Mississippi. The SWPPP must be kept at the project site or locally available.

Small Construction

The owner or operator must complete the Small Construction Notice of Intent and keep the form at the project site or locally available. In addition, the owner or operator must develop and implement a SWPPP. The SWPPP must be kept at the project site or locally available. **The Small Construction General Permit has no submittals to the MDEQ unless specifically requested.**

SWPPP Elements

The following provides an in-depth description of items required by the Large Construction General Permit. Items followed by asterisk (*) are required by the Small Construction General Permit. Copies of these permit documents are available in Appendix B.

Introduction

In this section, provide a narrative of general site information including project name, location, and size. The owner or operator (see definitions) should be identified, including complete mailing address and telephone numbers.

Project Overview

The project overview section will include a narrative discussion of the project location, size, development purposes, previous uses of the site, adjacent sites' land uses, and site access information. A discussion of wetland impacts can be presented here as well as conservation practices for the proposed project.

Site Description

This section should include a description of soils, vegetation, wetland and upland areas, receiving waters and other characteristics of the site such as drainage patterns, etc.

Project Schedule

The proposed project schedule should be included in this section. See the Construction Phasing/Sequencing BMP profile page (in Chapter 4 of Volume 1) for more information on construction phasing.

Potential Sources of Stormwater Pollution

This section should include a narrative description of the potential sources of pollution and the BMPs identified to control the potential pollutants. Examples of potential pollutant sources include, but are not limited to, litter and debris, sediments, gasoline, diesel, oil, pesticides, fertilizers, aggregate materials stockpiles, liquid material storage, material loading/unloading, solids disposal dumpster, and vehicle and equipment parking, storage and fueling.

Identification of the person or persons responsible for pollution prevention on-site should be included in this section.

Erosion and Sediment Control Best Management Practices

A description of the erosion and sediment control best management practices should be included in the SWPPP, as sediment is a potential pollutant in any land disturbance activity. *Volume 1 – Chapter 3* discusses the creation of an erosion- and sediment-control plan. *Volume 1 – Chapter 4* identifies Best Management Practices for the control of erosion and sediment during construction activities.

The Large Construction General Permit and Small Construction General Permit should be referenced for specific requirements for erosion and sediment control.

Post-Construction Best Management Practices

For sites that will have post-construction stormwater BMPs, a narrative description should be included in the SWPPP. This narrative should identify the BMP, the approximate location, and the proposed function of the BMP.

Non-Stormwater Dischargers

A narrative description of the allowable non-stormwater discharges expected on-site should be provided. A list of allowable non-stormwater discharges is provided in both the Large and Small Construction General Permits.

Preventative Maintenance and Good Housekeeping

A narrative should be provided, discussing the preventative measure(s) and good housekeeping practices that will be implemented before, during, and after the construction activities.

Maps

Prepare a scaled site map showing original and proposed contour lines; drainageways; north arrow; all erosion, vegetative, and structural sediment controls; and post-construction stormwater BMPs.

Implementation

Indicate the order in which activities will take place. When work is discontinued for 30 days or more in a disturbed area or completed, appropriate vegetative and structural practices must be initiated within seven calendar days. Several general implementation principles are given below.

- **Install** downslope and perimeter controls *before* other site work. Build sediment basins *before* major site grading.
- **Divert** upslope water around area before major site grading.
- **Do not disturb** an area until it is necessary.
- **Time** construction activities to limit impact from seasonal weather.
- **Cover or stabilize** disturbed areas as soon as possible.
- **Do not remove** temporary controls until *after* site stabilization.

More information on *Construction Phasing/Sequencing* can be found in Volume 1 – Chapter 4.

Recordkeeping

Provide a narrative account for the proposed recordkeeping activities.

Inspections

The SWPPP should outline procedures for site inspections, including the frequency of inspection and the responsible party for inspecting the project site. This section should include detailed inspection procedures as well. During permit coverage, all erosion controls must be inspected at least once per week for a minimum of four inspections per month and as often as necessary to ensure that appropriate erosion and sediment controls have been properly constructed and maintained and to determine if additional or alternative control measures are required. The MDEQ strongly recommends that coverage recipients perform a “walk-through” inspection of the construction site before anticipated storm events. The inspection information must be recorded on the forms developed and provided by the MDEQ. These forms are available on the MDEQ Web site at www.deq.state.ms.us (on the General Permits Branch page).

Monitoring

Indicate the procedure for monitoring, if applicable. At the time of publication, monitoring under the Large Construction General Permit is strictly voluntary and the results are not required to be documented and/or reported. Recommended monitoring procedures are outlined in the Large Construction General Permit.

Maintenance

A description of a maintenance schedule for all disturbed areas, material storage areas, and erosion and sediment controls that were identified as part of the plan shall be included in the SWPPP. Non-functioning controls shall be repaired, replaced or supplemented with functional controls within 24 hours of discovery or as soon as field conditions allow.

Final Stabilization

Procedures for final stabilization of disturbed areas should be outlined in the SWPPP.

Chapter 4
Best Management Practices Design

Introduction

This chapter provides detailed information for best management practices (BMPs) commonly used for the control of erosion and sediment on active construction sites. Practices for stormwater control will be installed in accordance with an approved site plan. (Reference Chapter 3, of both Volume 1 and Volume 2, for guidance on developing the erosion- and sediment-control plans and the Stormwater Pollution Prevention Plan. Appendix D provides examples of such plans.) The plan should list the sequence of construction activities. Each construction activity contributing to erosion of soil or changes in sediment-laden runoff should have an appropriate practice or practices to control erosion, sediment, and runoff. Minimizing the area exposed to erosion at any one time can significantly reduce erosion and sediment occurrence on the site.

Proper installation and maintenance of structural and vegetative practices approved in the site plan will be considered essential for compliance with the plan or associated permit. This chapter includes practice design standards and construction specifications along with applicable drawings. Design limitations are provided to maintain design integrity, safety, and purpose of the practices.

Purpose of BMP Manual

The purpose of this manual is to assist designers, developers, owners, contractors, and local officials in determining what stormwater regulations apply to their situation, what the BMP to meet those regulations might be, and how to then design and maintain that particular erosion and sediment control BMP. It is intended to provide the competent design professional with the information necessary both to properly meet the minimum requirements of Mississippi's stormwater programs and to be able to design a stormwater BMP that meets the water quality objectives. However, it does not cover every aspect of the civil engineering and structural design necessary for proper BMP system design and construction, nor does it cover every site situation that may occur, or every possible erosion and sediment control solution. The design professional is responsible for the design and construction of a properly functioning BMP that meets all of the applicable regulations, including the water quality objectives, and that considers all the unique conditions of an individual site. Where the designer determines that conformance with this manual would create an unreasonable hardship or where an alternative design may be more appropriate, alternative designs, materials, and methodologies will be considered on a case-by-case basis.

This manual is meant to supplement (not supplant) Mississippi's stormwater regulations by explaining the BMPs that will be allowed and their design criteria, in an easy-to-understand manner. In addition, local communities are free to adopt more stringent requirements than those presented in this manual. In general, if any part of this manual lists requirements different from those imposed by any other ordinance, rule, regulation, or other provision of law, whichever provision is more restrictive or imposes higher protective standards for human or environmental health, safety, and welfare shall control.

Figures, example calculations, operation and maintenance items, etc., are used throughout this manual. The intention is to provide the reader with visual assistance in device functions, siting, and concepts, as well as guidance on designing, operating, and maintaining specific BMPs. The figures, example calculations, operation and maintenance items, etc., will not represent the proper solution for every situation, and they may contain items that do not exactly fit the requirements listed in the section. The user of this manual must look at these items and use his or her professional judgment as to their proper use in a specific situation (however, any variance from a requirement must be clearly indicated). In the event of a conflict or inconsistency between the text of this manual and any heading, caption, figure, illustration, table, map, etc., the text shall control.

Also used throughout this manual is the phrase "design professional." This phrase is a generic title for a qualified, registered, Mississippi professional engineer, surveyor, soil scientist, or landscape architect, performing services only in his or her area of competence. Other individuals may be authorized as a "design professional," if they can demonstrate proper knowledge and ability to the Mississippi Department of Environmental Quality.

Conservation Easements

Practice Description

Conservation easements are voluntary agreements that allow individuals or groups to limit the type or amount of development on their property. A conservation easement can cover all or just a portion of a property and it can be either permanent or temporary. Easements typically describe the resource they are designed to protect (e.g., agricultural, forest, historic, or open space easements), and they explain and mandate the restrictions on the uses of the particular property. Easements can relieve property owners of the burden of managing these areas. They do so by shifting responsibility to a private organization, such as a land trust or government agency, that is better equipped to handle maintenance and monitoring issues. In some cases, tax benefits might be realized by property owners who place conservation easements on some or all of their property.

Conservation easements may indirectly contribute to water quality protection. Land set aside in a permanent conservation easement has a prescribed set of uses or activities that generally restrict future development. The location of the land held in a conservation easement should be evaluated to determine its ability to provide water quality benefits. Property along stream corridors and shorelines can act as a vegetated buffer that filters out pollutants from stormwater runoff. The ability of a conservation easement to function as a stream buffer depends on the width of the easement and in what vegetated state the easement is maintained. Easements may also be used to provide tax benefits for other desirable practices, like tree and natural areas conservation (Center for Watershed Protection (CWP), 1998).

Planning Considerations

Conservation easements are designed to ensure that the land is preserved in its current state long after the original owners no longer control the property. By agreeing to give up or restrict development rights for a parcel of land, landowners can guarantee their property will remain in a prescribed state for perpetuity while receiving tax benefits.

Conservation easements have been used in all parts of the country, and many private groups (on both the national and local levels) exist to preserve natural lands and to manage the conservation easements. States also use conservation easements and land purchase programs to protect significant environmental features and tracts of open space.

Regardless of whether a conservation easement is held by a government agency or a private land trust, certain management responsibilities must be addressed by the easement holder. The following is a list of some of these management duties:

- Ensure that the easement's language is clear and enforceable.
- Develop maps, descriptions and baseline documentation of the property's characteristics.
- Monitor the use of the land on a regular basis.
- Provide information about the easement to new or prospective property owners.
- Establish review and approval processes for land activities stipulated in the easement.
- Enforce the easement's restrictions through the legal system, if necessary.
- Maintain property/easement-related records.

Design Criteria

Often, state agencies and private land trusts have specific qualifications for a property before they will enter into an easement agreement with landowners. Table 1 contains examples of criteria used by private land trusts to determine if a property is worth managing in a conservation easement.

Table 1 Typical criteria that land trusts use to determine feasibility of entering into conservation easement agreement

Criteria	Details
Natural resource value	Does the property provide a critical habitat or important environmental aspects worth preserving?
Uniqueness of the property	Does the property have unique traits worth preserving?
Size of land	Is the land large enough to have a natural resource or conservation value?
Financial considerations	Are funds available to meet all financial obligations?
Perpetuity	Is the conservation agreement a perpetual one?
Land trust's mission	Does the property align with the land trust's mission and the organization's specific criteria?

Maryland has been nationally recognized for its programs that provide funding for state and local parks and conservation areas. The state is one of the first to use real estate transfer taxes to pay for land conservation programs. Several programs are funded through this transfer tax of one-half of one percent ($5 per thousand) of the purchase price of a home or land, or other state funding programs. Conservation programs include these:

Program Open Space. This program is responsible for acquiring 150,000 acres of open space for state parks and natural resource areas, and more than 25,000 acres of local park land. Every county must create a Land Preservation and Recreation Plan that outlines acquisition and development goals in order to receive a portion of the 50 percent that is granted to local governments (USEPA, 2006b).

Maryland Environmental Trust. This trust is a state-funded agency that helps citizen groups form and operate local land trusts. It offers the land trusts technical assistance, training, grants for land protection projects and administrative expenses, and participation in the Maryland Land Trust Alliance (MNDR, 2001a).

Rural Legacy Program. This is a Smart Growth Initiative that redirects existing state funds into a focused and dedicated land preservation program specifically designed to limit the adverse effects of sprawl on agricultural lands and natural resources. The program purchases conservation easements for large contiguous tracts of agricultural, forest, and natural areas subject to development pressure, and purchases fee interests in open space where public access and use are needed (MNDR, 2001b).

Maintenance

A conservation area's pollutant removal efficiency depends on how much land is conserved, the techniques used to conserve it, and the specific nature of the easement. Conservation easements are assumed to contribute water quality benefits, but no national studies proving this have been released.

Table 2 Annual maintenance costs of different types of green space uses (CWP, 1998)

Land Use	Approximate Annual Maintenance Costs
Natural open space Only minimum maintenance, trash/debris cleanup	$75/acre/year
Lawns Regular mowing	$270 to $240/acre/year
Passive recreation	$200/acre/year

Development Districts

Practice Description

Development districts, often referred to as special zoning districts, are created for the purpose of permitting property development. Development districts are characterized by larger site areas (typically 5 or more acres), and their construction requires complex and coordinated rezoning, transportation, and planning efforts. Examples of special zoning districts include, but are not limited to, the following:

- Transit Oriented Development districts,
- Business Improvement Districts,
- Traditional Neighborhood Designs,
- Brownfields Redevelopment Projects, and
- Main Street Revitalization Districts.

A development district's stormwater handling performance is typically assessed at the site, neighborhood, regional or watershed levels. While the construction of a development district may involve a higher percentage of imperviousness than surrounding or conventional patterns, satisfying development needs on a smaller footprint brings benefits. In addition, the coordinated planning effort can help identify strategic opportunities for infiltration, stormwater recapture, and treatment.

Planning Considerations

A city, county or town's Planning or Zoning Department usually develops plans for development districts. Stormwater managers may need to meet with planning counterparts to coordinate plans, since the common, stand-alone elements found in stormwater management plans for individual sites (such as site coverage limitations, infiltration requirements, and rules discouraging sidewalks) can run counter to the urban design elements of successful development districts.

A development district's effectiveness can be viewed at the site, neighborhood, and watershed levels. Redevelopment can significantly reduce the demand for new development elsewhere in the watershed. Designs that repair existing infrastructure and treat stormwater on-site are particularly beneficial. Where urban redevelopment occurs on open lots that serve a stormwater handling function, the city and developer will need to assess the impacts neighborhood-wide and mitigate accordingly.

Clustering, open space, and other "green" designs offer stormwater and water quality benefits to communities considering new housing developments. However, the site's design needs to be combined with watershed and regional planning designs that curb uncontrolled, large-scale growth. It is important to consider neighborhood and watershed outcomes. Will new conservation development spur unplanned development? Does conservation development complement the community's overall conservation goals? How does the new development relate to jobs, schools, and services?

The costs of developing and implementing coordinated development districts vary. The primary drivers of these costs are consultant and staff time to develop or align plans; repair or establishment of water, sewer, and transportation infrastructure; and any incentives a city, county, or township provides to developers or public/private partnerships. For developers, costs can vary from a conventional site plan, dependent upon the combinations of BMPs and the relative cost of a more complex site development plan. However, many redevelopment projects command a premium market price due to their location or enhanced desirability.

Design Criteria

Development districts can be incorporated anywhere. One main consideration for rural areas might be a lack of zoning or other land use classification. Subdivision regulations or drainage district requirements may impede plans to establish a mix of uses or higher densities. For urban areas, look for designs that reuse existing impervious surface and infrastructure and provide opportunities to repair infrastructure or handle stormwater on-site. For conservation subdivisions or designs, look closely at the connections among transportation, community services, and jobs. The water quality benefits of conservation clustering can be negated if the new housing becomes part of a development pattern that includes dispersed uses, demands for upgrades to urban-level services and transportation, and a lack of connections among infrastructure elements.

Compact Project and Community Design

Compact project and community design is a powerful strategy for reducing a development's footprint and, hence, its stormwater impact. Reducing an individual building's footprint is another strategy, though there are circumstances that call for greater lot coverage in districts where higher development intensity is needed (near transit stations, for example). Compact development also lends itself to more environmentally friendly transportation options, such as walking and biking, or shorter and less frequent automobile trips.

Street Design and Transportation Options

Well-designed, compact communities are served by a highly connected street and trail system designed for multiple modes of transportation. The pattern need not be a grid; in some areas, topography and environmentally sensitive areas will influence where roads go. A compact district also provides for more efficient use and reuse of infrastructure.

Mix of Uses

A community's transportation options increase when jobs, housing, and commercial activities are located close together. Efficiencies for providing infrastructure also emerge. Fewer auto trips reduce the need to accommodate standard parking requirements. Mixing daytime and nighttime uses increases the opportunities for businesses to share parking spaces.

Regional Applicability

Development districts can be large redevelopment efforts, infill projects, or new "greenfields" projects. The regional applicability is strong since successful development districts coordinate multiple objectives, including environmental protection and stormwater control. These districts also tend to handle more development intensity and a mix of uses on a smaller footprint; Thus, they also have applicability for watershed planning and source water protection.

Ultra-Urban Applicability

Although land constraints and large developable sites can be a challenge, certain types of development district planning, such as transit oriented development and business improvement districts, are common in urban areas.

Urban development and redevelopment projects are more likely to be served by heavier transit, follow a traditional street pattern, and be governed by a complex set of existing land development requirements. Municipalities can use a combination of policies to promote desired densities. Some of these policies include the following:

- Transfer of development rights receiving zones – A system in which a landowner in a "preservation area" or "sending zone" gets credits for forgoing development rights that he can sell or have a "bank" consolidate. Developers can buy and use these credits to gain permission for denser development in "receiving zones," which are areas targeted for denser development,

- Bonus densities – which permit developers who agree to complete projects or project additions that meet specific goals to increase density,

- Create mixed-use zoning,
- Create form-based zoning codes,
- Modify parking policies that, for example, create a maximum number of parking spaces allowed and have better management of on-street parking,
- Create sidewalk improvement programs,
- Encourage micro-detention stormwater handling areas such as use of rain gardens or stormwater BMPs that serve multiple purposes (i.e., green roofs),
- Encourage street tree canopy programs,
- Create financial incentives (tax-increment financing, vacant property reform),
- Enact or promote programs to enhance transit use,
- Enact rehabilitation codes for older buildings using proprietary devices (e.g., in-pipe filtration devices).

Suburban Settings

Suburban development districts are likely to take advantage of existing development and infrastructure, and require connections among older developed areas. In addition to some of the policies in urban settings, planners and developers in suburban settings could consider the following BMPs and policies to aid in protecting water resources:

- Promote Grayfields programs to redevelop underperforming malls and strip malls,
- Create highway corridor redevelopment programs,
- Enhance retail and housing districts around park and ride lots,
- Adopt Smart Growth street design standards at local and state levels,
- Establish infill policies,
- Adopt traditional neighborhood design manuals that integrate transportation.

Rural Settings

Rural development districts are likely to occur on undeveloped or sparsely developed land. Successful rural development districts will complement or spur rural employment opportunities, such as agriculture, manufacturing, or warehousing and distribution. To protect water resources on a regional scale, planners should encourage conservation of rural settings to offset increased impervious areas in urban and suburban settings.

Policies that encourage economic development while retaining rural character include:

- Create transfer of development rights sending zones,
- Establish water protection overlay zones,
- Connect housing with rural job and transportation centers,

- Create watershed-wide impervious surface trading programs,
- Create design manuals for rural housing or housing in environmentally sensitive areas,
- Encourage “Main Street” redevelopment programs in older downtowns.

Common Problems

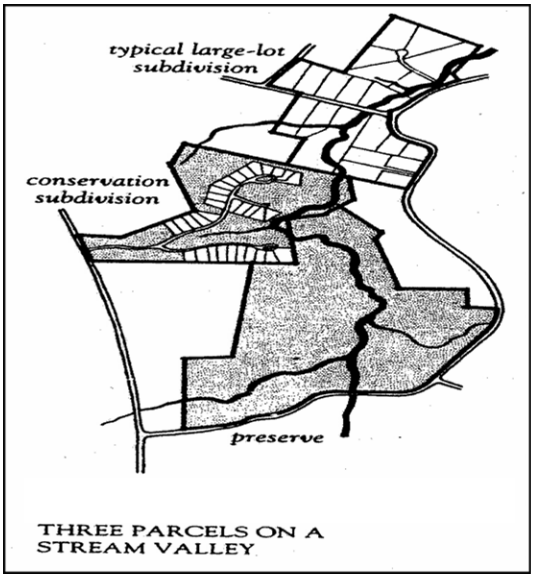
If the stormwater regulations for redevelopment districts are more stringent than those for greenfields, cities may find it difficult to attract developers. Rules for water protection and stormwater should be consistent watershed-wide.

During the site design process, pressures may develop to eliminate elements critical to a development district’s environmental performance. For example, a successful development district will shorten, combine, or eliminate auto trips. However, if pressure mounts to increase parking or decrease connections among uses, a city or county may be unable to reduce the amount of impervious surfaces, diminishing transportation and water benefits.

Maintenance

Various design elements will direct a development district’s maintenance plan, although it is likely to include a combination of BMPs. Comprehensive redevelopment plans include common urban design elements like tree-lined streets, water features, and landscaping. Planners and stormwater professionals should look to these features to achieve urban design and water quality goals, and plan their maintenance procedures accordingly.

Infrastructure Planning



Practice Description

Infrastructure planning involves changes in the regional growth planning process to contain "sprawl" development. Sprawl development is the expansion of low-density development into previously undeveloped land. The American Farmland Trust has estimated that the United States is losing about 50 acres an hour to suburban and exurban development (Longman, 1998). This sprawl development requires local governments to extend public services to new residential communities whose tax payments often do not cover the cost of providing those services. For example, in Prince William County, Virginia, officials have estimated that the cost of providing services to new residential homes exceeds what is brought in from taxes and other fees by $1,600 per home (Shear and Casey, 1996).

Infrastructure planning concentrates public services such as water, sewer, roads, schools, and emergency services in the suburban fringe and directs new growth into previously developed areas, discouraging low-density development. Generally, this is done by drawing a boundary or envelope around a community, beyond which major public infrastructure investments are discouraged or not subsidized. Meanwhile, economic and other incentives are provided within the boundary to encourage growth in existing neighborhoods. By encouraging housing growth in areas that are already provided with public services, communities not only save infrastructure development costs, but reduce the impacts of sprawl development on urban streams and improve water quality within the watershed.

Planning Considerations

Sprawl development occurs in all regions of the country and has recently become the subject of many new programs to counteract its impacts. These programs seldom focus on the water quality implications of sprawl growth, instead concentrating on economic and transportation issues. Even so, methods such as infrastructure planning can reduce the impact of new development. Promoting the infill and redevelopment of existing urban areas in combination with other better site design techniques will decrease impervious cover levels and lessen the amount of pollution discharged to urban streams.

Sprawl development negatively impacts water quality in several ways. One of the most significant impacts comes from the increase in impervious cover that is associated with "sprawl" growth. Rooftops, extension of road systems, and additional paved surfaces from driveways create an overall increase in imperviousness. This increase in the impervious cover level of an area directly influences local streams and water quality by increasing the volume of stormwater runoff. These elevated runoff levels impact urban streams in several ways, including enlarging stream channels, increasing sediment and pollutant loads, degrading stream habitat, and reducing aquatic diversity (Schueler, 1995). Sprawl has been reported to generate 43 percent more runoff that contains three times greater sediment loads than traditional development (South Carolina Coastal Conservation League, 1995).

Design Criteria

Various techniques have been used to manage urban growth while conserving resources. Although none of these techniques specifically concentrates on infrastructure planning, each of the techniques recognizes that directing growth to areas that have been previously developed or promoting higher density development in areas where services exist prevents sprawl development and helps communities to mitigate the water quality impacts of economic growth. Two of these techniques are described below.

Urban Growth Boundaries

This planning tool establishes a dividing line that defines where a growth limit is to occur and where agricultural or rural land is to be preserved. Often, an urban services area is included in this boundary that creates a zone where public services will not be extended.

Infill/Community Redevelopment

This practice encourages new development in unused or underutilized land in existing urban areas. Communities may offer tax breaks or other economic incentives to developers to promote the redevelopment of properties that are vacant or damaged.

Common Problems

Intense development of existing areas can create a new set of challenges for stormwater program managers. Stormwater management solutions can be more difficult and complex in ultra-urban areas than in suburban areas. The lack of space for structural stormwater controls and the high cost of available land where structural controls could be installed are just two problems that program managers will face in managing stormwater in intensely developed areas.

Infrastructure planning is often done on a regional scale and requires a cooperative effort among all the communities within a given region in order to be successful. Stormwater managers will need to develop lines of communication with other state and local agencies and community leaders to ensure that infrastructure plans direct growth to those areas that will have the least impacts on watersheds and water quality.

Open Space Design

Practice Description

Open space design is an alternative site planning technique that concentrates development to preserve open areas and green space. This is a rethinking of typical residential site development practices in that it gives extra consideration to preserving the natural integrity of the site. By keeping some areas in an undeveloped state, this design strategy can reduce negative impacts from stormwater such as increased runoff from impervious surfaces and pollutant inputs. Open space design has been shown to reduce construction costs while increasing property values because of the desirable open space amenity that is preserved. Other costs associated with additional stormwater management measures, clearing costs, and downstream flooding due to increased runoff volumes can also be reduced using open space design.

Planning Considerations

The many misconceptions about open space design can be obstacles to its implementation. Some developers fear that designing to preserve open space will lead to longer plan reviews, higher costs, and lower market value. However, open space design can actually provide cost savings, as less area is cleared and fewer interventions are needed to manage stormwater. One open space development example (Liptan and Brown, 1996) demonstrated a cost savings of $800 per lot for site development. Other studies report cost savings for infrastructure ranging from 11 to 66%. Local ordinances may need to be revised to remove restrictions that stand in the way of implementing essential components of open space design.

According to the Center for Watershed Protection, open space designs have the following water quality advantages relative to a conventional development:

- Reduced impervious cover.
- Reduced pollutant loads to streams and other water resources.

- Reduced potential pressure to encroach on resource buffer areas.
- Reduced soil erosion potential by reducing the amount of clearing and grading on the site.
- Preservation of green space.
- Preservation of open space for recreation.
- Lower capital cost of development.
- Lower stormwater-management costs by concentration of runoff in one area and reducing runoff volumes.
- A wider range of feasible sites to locate stormwater BMPs.
- Lower costs of future public services needed by the development.
- Possible increase in property values.
- Creation of urban wildlife habitat "islands."
- Support for other community planning goals, such as pedestrian movement, neighborhood enhancement, farmland preservation, affordable housing, and architectural diversity (CWP, 1998).

The first step for many jurisdictions to encourage open space developments is to adopt a local ordinance that permits open space design in conventional residential zones, or to amend their current zoning ordinances to accomplish that goal. Essential elements of such an ordinance are described in the Design Criteria, Implementation, and Maintenance sections that follow. The Center for Watershed Protection has also developed an Open Space Model Ordinance to serve as a template for jurisdictions who wish to adopt such an ordinance (CWP, not dated). Whatever the method used to implement open space designs, it should include long-term provisions for the acceptable use and maintenance of the land that is preserved. With the proper regulations in place, the developer must create and follow a site plan for the project that meets the criteria below.

Design Criteria

Flexible Development Regulations

To implement open space design, the land use ordinance governing the area must allow for variations in site layout to help achieve a more compact development. Flexible and smaller lot sizes, varying setbacks, and frontage distances for the residential zone are some of the specific features that a developer working within an open space framework will need (USEPA, 2006b).

Open Space and Natural Area Conservation Requirements

An open space design reduces the level of impervious cover as compared to a conventional development and preserves the maximum acreage for natural area conservation. To achieve stormwater benefits, the majority of the preserved open space must be contiguous. Some strategies to minimize the amount of paved area are unpaved walkways and the use of permeable paving materials. Open space can also be maximized by requiring narrower streets, smaller building setbacks, and shared driveways.

Consolidation and Use of Open Space

The typical open space development creates 10-50% less impervious cover and reduces the need to clear and grade 35-60% of the site. The remaining open space can serve multiple functions. The site layout may preserve some areas to meet environmental requirements for stormwater management and conservation and others to provide future residents with attractive recreational amenities. Some of the high-priority uses for the preserved open space are

- Resource buffers,
- High-quality forest resources,
- Individual trees,
- Critical habitat areas,
- High-quality soil resources (CWP, not dated)

Implementation

Delineation of Boundaries

The boundaries of designated open space areas, recreation areas, stormwater management facilities, and green space shall be clearly delineated on plans, including record plats, and marked to distinguish these areas from private property. Development in designated open spaces in the future is prohibited.

Density of Development

The total number of residential units allowable within an open space development shall not exceed the number of units that would otherwise be allowed in the existing zoning district using conventional development.

Preservation of Open Space

The majority of the land preserved for open space should be contiguous to achieve the maximum environmental and recreational benefits. The model ordinance proposes that up to 50% of open space be preserved as green space. If open space design is used as a BMP for stormwater management, all Mississippi state design, construction, maintenance, and public safety requirements must be met.

Common Problems

It is sometimes difficult to convince developers to adopt an open space design because of a concern that it will be both more expensive to develop and less marketable. The land use ordinances governing open space design must therefore foster development that meets market demands while protecting the environment. Decisions also need to be made about the locations where it is most beneficial to direct open space development. Finally, the issue of management is crucial to the long-term success of open space design. Long-term maintenance is primary among the concerns, but the developer must also delegate the necessary authority for managing issues such as liability and emergency vehicle access to a responsible entity in the public or private sector.

Maintenance

Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the open space is protected by one of these three strategies: a legally enforceable deed restriction, a conservation easement enforced by a local government or land trust, or maintenance agreements. In most communities, the authority for managing open space falls to a homeowner or community association or a land trust.

When managing open space as a natural area, annual maintenance costs are very low. The annual maintenance cost for managing an acre of natural area is less than $75 (CWP, 1998). It may be useful to develop a habitat plan for natural areas that may require periodic management actions.

Protection of Natural Features

Practice Description

Undeveloped sites often have natural features such as wetlands, riparian areas, floodplains, aquifer recharge areas, mature trees, woodlands, and other wildlife habitat, which provide environmental, aesthetic, and recreational benefits if preserved and protected from the impacts of construction and development. Restricted areas such as floodplains and steep slopes should also be protected from possible impacts from construction activities. Natural area protection is not limited to undeveloped land; properties that are being redeveloped might have attractive open space, well-drained soils, or riparian areas that should be identified and considered for preservation early in the planning process. The Better Site Design Handbook provides guidance on how a development can protect a site’s natural features by reducing street lengths. It emphasizes the need for clearing and grading, applying open space design, promoting tree conservation, and taking advantage of conservation incentives (CWP, 1998).

Natural features and open space can be protected both during the development process and after a site is occupied through a combination of

(1) Site planning techniques,

(2) Construction site BMPs, and

(3) Measures employed after the site is in use.

Planning Considerations

Natural area preservation has been achieved in numerous developments nationwide that have been both environmentally and economically successful. For example, the Chapel

Run residential development in Sussex County, Delaware, was initially proposed as a conventional residential development containing 142 half-acre lots. Site designers chose to preserve a wooded area with highly permeable soils as a means to control stormwater. To accommodate this open space, lot sizes were reduced from a half-acre to a quarter-acre and condensed into a cluster design, resulting in the preservation of approximately 68 percent of the site. Total capital costs for the clustered development were estimated to be $1,174,716, whereas a traditional design would have cost $2,460,200, yielding an estimated cost savings of $1,285,484 (Delaware DNREC, 1997). Many developments with open, shared areas have seen a greater increase in property value than those in comparable, traditional developments.

Additional examples of successful open space preservation, as reported by the National Association of Homebuilders, are summarized in the table below (NAHB, 2006).

Location	**Description**	**Result**
Garnet Oaks, Bethel Township, PA	80 homes on 58 acres	51% of the land preserved as open space, including woodlands, tree specimens, and structures from the property's original estate Housing price premiums are based in part on the lots' proximity to open space
Newpoint, Beaufort, SC	124 single-family homes on 54 acres	Site layout preserved small wetlands and saved large existing trees, some in the greenway between street and sidewalk The Riverside green and community dock provide neighborhood access
Prairie Crossing, Grayslake, IL	337 single-family homes on 667 acres	350 acres devoted to prairies, pastures, farms, fields, gardens, marshes, lakes Community-supported organic garden The community is the western anchor of the Liberty Prairie Reserve, a 2,500-acre preserve of forest, marshes, prairies, and farmland
The Fields of St. Croix, Lake Elmo, MN	90 homes on 226 acres	60 percent of the community's land preserved as permanent open space Home sites are clustered near a wooded ridge overlooking the site's ponds and open space Historic Civil War-era barn was preserved and used as a community center Thirty acres of prairie restoration featuring native plants indigenous to the area Existing wooded slopes, which are home to oak trees and provide excellent wildlife habitat, preserved The open space is permanently guaranteed by a conservation easement granted to the Minnesota Land Trust

Cost consideration comparisons for preserving natural areas and open space versus traditional development are difficult to determine because the quantity and type of natural features vary from site to site. In general, however, additional costs can be incurred when preserving natural areas because additional planning and inspections might be needed to meet local regulatory requirements using innovative site designs. Also, the need for smaller construction equipment could increase costs if equipment operators need to maneuver around trees and other protected features. These increased costs can be offset by decreased costs for clearing, grading, temporary erosion control, seeding, and landscaping because less area is disturbed. Savings can be substantial; the cost of clearing, grading, and installing stormwater control measures is estimated to be up to $5,000/acre, with annual maintenance costs adding an additional $800 to $1,500 (Schueler, 1997). Additionally, reduced infrastructure costs can be realized in developments that use clustering because of shorter road lengths, elimination of curbs and gutters, and the use of vegetated areas and swales instead of structural stormwater controls. Finally, long-term costs for landscape maintenance can be reduced because natural areas do not require the same level of maintenance as turf grass; eliminating the need to mow, fertilize, and perform other lawn maintenance activities can save a homeowner $1,000 to $1,500 annually (Delaware DNREC, 1997).

Developers can use conservation easements to maintain open space over the long term. This easement ensures that the land will not be developed and will remain protected.

Design Criteria

Developments can be planned around significant environmental features, which can then be marketed as amenities. In *Conservation Design for Subdivisions* (1996), Randall Arendt describes a process to delineate a “development envelope” where buildings and infrastructure can be placed to avoid impacting natural features. The first step in this process is to assemble background information, which includes the following:

- Determine the local context: is the area agricultural, forested, etc.?
- Map significant features as candidate conservation areas, including floodplains, slopes, soils, wildlife habitats, woodlands, farmland, historical/cultural sites, views, aquifer recharge areas, and others.
- Rank conservation areas based on how special, unique, irreplaceable, environmentally valuable, historic, or scenic they are.
- Identify areas where buildings and infrastructure should be placed that would minimally impact conservation areas.
- Establish the layout of buildings and infrastructure, employing such techniques as clustering buildings and using smaller lots, shared driveways, and narrower streets (Arendt, 1996).

This process of site evaluation and design can allow significant features to be preserved while maintaining the desired overall site density (although density in localized parts of the development will be higher when open space is set aside). Some negative perceptions are associated with protecting natural features. Developers want to achieve a particular development density when building subdivisions or commercial sites. Also, for residential developments, lot size is an important factor in determining lot prices. Setting aside natural areas can take up space that would otherwise be used for yards, parking, transportation infrastructure, and other built features. Developers can accommodate overall site density using clustering techniques, smaller lots, and more efficient street layouts. To offset lost premiums from smaller individual lots, developers can market a lot's proximity to natural areas and attractive views as amenities.

Implementation

When areas of the property with environmental significance have been identified for protection, extra care is needed during site preparation to protect these features. Developers should indicate a limit of disturbance and the location of protected areas in construction site stormwater pollution prevention plans (SWPPPs) and on site maps. Also, they should post signs with prohibitions and educate workers about the importance of and special considerations for the protected areas. Without training and explicit signage, areas slated for protection could be damaged by vehicle traffic, stored materials, and other construction-related activities. Construction operators should check areas regularly to identify problems and determine if additional controls such as more training, more explicit signage, and more obvious barriers are needed. Operators should also look for signs of unintended consequences of construction activities on the natural areas, such as changes in hydrology, flooding, or accidental spills, and take appropriate actions to mitigate the damage.

The following sections describe specific practices that developers and construction site operators can employ to protect each type of resource.

Mature Trees or Woodlands

Surround the area to be protected with bright orange fencing placed at or beyond the tree's dripline. Prohibit clearing and grubbing, limit heavy equipment traffic, and prohibit material storage inside the barrier. Include signage that details specific prohibitions and educate employees. Visually monitor vegetation to ensure that it is not being damaged by construction activities (e.g., soil compaction from heavy equipment traffic might cause localized flooding in nearby natural areas).

Steep Slopes

Steep slopes and related vegetation should be protected. Fence off these areas and assess whether additional erosion control is needed to prevent erosion. Check erosion controls on upslope areas that will be cleared and graded, and ensure that runoff from these areas is diverted away from or around the slope, using either a pipe slope drain or a diversion placed at the top of the slope. Post signs prohibiting heavy vehicle traffic and educate crews about the sensitivity of steep slopes to erosion.

Well-Drained Soils and Aquifer Recharge Areas

Areas with well-drained soils and those that feed aquifers should be protected from compaction. Maintain vegetation if possible, or if the area is cleared, minimize heavy traffic by fencing the area and posting signs. Before planting permanent vegetation, aerate the soil to ensure that runoff infiltrates. These areas may be critical later to the success of post-construction BMPs by limiting the volume of runoff that needs to be treated.

Wetlands and Riparian Areas

Establish a buffer around marshes, swamps, or other wetlands and along stream corridors in which no construction activity occurs. Avoid stream crossings wherever possible.

When absolutely necessary, set up perimeter sediment controls (e.g., silt fence) and visually monitor the protected areas, especially after each storm, to check for damage from flooding and for signs of impacts from the construction activity, including sedimentation, vegetation dieback, erosion, dumping, or fish kills. Set up stream crossings to minimize disturbance of streamside vegetation and in-stream habitat. Post signs and educate workers about the sensitive nature of the area and include prohibitions for storing or dumping materials.

Wildlife Habitat

Contact a local wildlife authority if you find nests, dens, or other animal habitat on the property. These can be removed or relocated before construction begins.

The presence of threatened or endangered species or habitats critical to their survival on the site might require a consultation with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service. You should ensure that you are in compliance with all regulations, including the Endangered Species Act.

Floodplains

The placement of buildings in floodplains is typically restricted because of the risk of safety concerns and property damage, so these areas should remain outside the limit of disturbance. (Restrictions will vary from one municipality to the next, so check with local authorities about floodplain restrictions in your area.) Establish perimeter controls, including fencing, and post signage that prohibits dumping and material storage in these areas. Inspect protected areas on a regular basis to ensure that vegetation has not been disturbed and that no dumping has occurred.

Common Problems

Concerns about cost and local ordinances are the most likely barrier to implementing a site plan that protects existing natural features. Education about the many cost savings associated with this strategy as well as techniques to achieve the desired number of units while protecting natural areas may be helpful to overcoming developers' reluctance. Local zoning codes should also be reviewed for provisions that restrict the use of clustering, reduced road widths, and other techniques for natural area preservation. Developers should work with local regulatory agencies to determine whether they can obtain waivers to protect natural features.

Maintenance

Once a site is developed and occupied, natural areas become amenities for the site's occupants. These natural areas also become the responsibility of the owner or occupant. Developers should provide information about each natural area or protected feature, to describe the area's importance and outline the activities that should be prohibited to adequately protect the resource.

Developers should also provide guidance to occupants on how these areas should be maintained. For example, a preserved prairie or riparian stream buffer should not be mown or manicured like turf. Homeowners or maintenance crews would need to employ special procedures to preserve native species, such as using integrated pest management practices like hand-weeding and limiting chemical use. The same practices should be used in areas where traditional landscape maintenance activities could threaten water quality, such as in or adjacent to wetlands and riparian areas or where endangered species are present. Interpretive signage can be posted to educate occupants and visitors about the significance of the features and to describe prohibited activities such as mowing, dumping, and vehicle traffic. Barriers can be installed to protect the natural areas from damage without detracting from their aesthetics and function. These barriers can include strategic placement of low fences, walls, bollards, or large rocks that unobtrusively limit access to the areas.

Redevelopment

Before

After

Practice Description

Redevelopment occurs in areas that have previously been developed for another use. These sites are likely to be highly impervious and of limited value to the stormwater management system. The definitions of development and redevelopment vary in stormwater guidance documents and National Pollution D- E- S- stormwater permits. In some states and localities, development and redevelopment are subject to the same stormwater management requirements. Redevelopment of already impervious surfaces, however, can be a key strategy for reducing net increases in impervious surfaces and associated degradation to receiving waters. By recycling these sites and granting them new life, governments reap the broader benefits of development on an existing property by reusing impermeable surface and mitigating developmental impacts on a green field site. Because redevelopment will take advantage of existing roadways and building sites, it is likely to follow many of the Better Site Design principles associated with street width and length. Its primary advantage for stormwater management, however, is that it provides opportunities for conserving natural areas in the surrounding community that might otherwise be subject to greater development pressure (CWP, 1998).

Planning Considerations

Redevelopment can be accomplished on a site-by-site basis, but it can also be part of a larger local or regional effort to spur investment and development activity. Many jurisdictions create redevelopment districts, such as business improvement districts, Main Street programs for older downtowns, brownfields programs, vacant property campaigns, and efforts to revive older, underperforming shopping malls. The transfer of development rights can help spur redevelopment by directing development demand to existing activity centers. In established development districts, infrastructure upgrades associated with redevelopment can be used for repairs such as replacing deteriorating pipes that are contributing to water quality impairments.

In districts with multiple redevelopment-ready properties, economic factors, such as location near amenities and proximity to transit, guide which properties are redeveloped first. Because these properties may or may not be the ones that will deliver the highest succession of stormwater benefits, it is helpful to prioritize areas that can provide the greatest opportunities for detention facilities or other desired BMPs.

Although redevelopment can just maintain the current level of stormwater runoff, by employing a strategic series of BMPs, this new development may actually lead to a net improvement in regional stormwater.

Design Criteria

Design of redevelopment projects will vary considerably with land variations. Common land constraints include irregularly shaped properties, small lots, legacy contamination, and noncompliant building features/footprints. Water quality considerations can also influence the selection of structural BMPs used to manage the project's stormwater. In some cases, the main factor may be flow reduction, while in others cases the focus will be the filtration of nutrients or heavy metals.

Stormwater Retrofit

In areas with degraded waterways, redevelopment activity can complement efforts to improve the quality and reduce the quantity of stormwater runoff. The BMPs chosen for redevelopment, however, need to consider the unique circumstances of the redevelopment project. Micro-detention, urban forestry techniques and structured soils are often recommended for urban areas. Green building techniques and green roofs may also be good choices. As noted above, cities and counties will want to coordinate infrastructure repair and upgrades with redevelopment efforts so that water and wastewater capacity are not barriers to redevelopment.

Implementation

Redevelopment is highly useful in urban areas, especially where the area is fully built out. Some of the strategies for redevelopment are described below.

Green Roofs

Green roofs help reduce the urban "heat island" effect as well as peak stormwater flows by absorbing stormwater on-site. The vegetated cover also helps protect and insulate the roof, extending its life and reducing heating and cooling costs. See more discussion on green roofs in the *Site Design* section of this chapter.

Micro-Detention

Micro-detention techniques seek to absorb some or all stormwater runoff on the development site. Since the entire volume of stormwater generated on-site is rarely entirely infiltrated, micro-detention is typically only one of a series of BMPs. Common landscaping features, such as small garden areas, tree grates, perimeter hedges, and even rain gardens (also known as *Bioretention*) can enhance stormwater handling and micro-detention. In urban buildings with basements and underground garages, infiltration may occasionally not be an option. Pollutants that might be carried with infiltrating water should also be considered; hence, infiltrating techniques are not recommended for stormwater hotspots.

Alternative Pavers and Porous Pavement

Alternative pavers, porous asphalt, and permeable concrete reduce stormwater flows by allowing water to infiltrate their porous surfaces and soak into the ground beneath. Pervious pavers can reduce runoff volumes at a considerably lower cost than traditional storm drain systems.

Infrastructure Upgrades

Storm sewer overflows and leaking older pipes (referred to as inflow and outflow) can be significant environmental problems in urban areas. Redevelopment offers an opportunity, through enhanced tax revenues resulting from increased economic activity, to upgrade storm grates and pipes. However, capacity at wastewater treatment plants may be a barrier to redevelopment. In addition, the condition of receiving waters and total maximum daily limits can be hurdles to any development activity in an urban area.

In-pipe and Small Structural Devices

A growing number of devices are coming on the market that provide a range of mitigation functions. These devices commonly work to separate large debris collected in runoff, intercept sediments, and improve water quality. They range in size, cost, and maintenance needs. They can be included in the suite of structural and nonstructural BMPs chosen for redevelopment projects and districts.

Common Problems

As a stormwater strategy, redevelopment can require larger regional cooperation. To growing rural districts, a redevelopment strategy for established commercial centers might not be viewed as advantageous.

The BMPs required for redevelopment need to be compared to BMPs required for new development. Watersheds that choose redevelopment as a stormwater strategy should make sure the BMP cost and permit review requirements for redevelopment are comparable to those required for new development. Because redevelopment is often more complex than new development, design and building costs can be higher. Where infrastructure upgrades are needed, the costs can be considerable, particularly where treatment capacity or aging infrastructure is the limiting factor. However, in many cases, redevelopment projects can command a premium price, and some or all of the costs can be recovered.

Street Design and Patterns

Practice Description

The EPA, watershed researchers, and local governments have developed extensive guidance on the design of "green streets," which focuses on narrower widths, infiltration, and eliminating curbs and gutters. Streets designed to these specifications have substantial benefits for stormwater management. However, the underlying pattern of streets is just as influential, particularly as it relates to development patterns in a neighborhood and region.

Smart Growth street designs are based on a network of well-connected streets that support multiple transportation modes. Some Smart Growth approaches to street design include decreasing street widths, adjusting the vehicular level of service (LOS), creating LOS for other modes of transportation, and designing connected street networks to support multiple uses. The Better Site Design principles of the Center for Watershed Protection offer detailed guidance for how improvements to residential streets and parking lots can improve stormwater management in a community. Specific model development principles are offered with respect to street width and length, rights of way, driveways, cul-de-sacs, and alternative turnarounds (CWP, 1998).

Planning Considerations

A variety of agencies control street and road designs at the regional level. State Departments of Transportation (DOT) typically control the design and operations of highways and larger arterial streets. When developing streets, state DOTs often refer to manuals such as the American Association of State and Highway Transportation Officials' (AASHTO) "Green Book," or manuals developed by the Institute for Transportation Engineers (ITE). Conventional street layouts today tend to follow a hierarchical system, with a multitude of smaller roads that serve residential areas feeding into larger roads and arterials. These arterials funnel traffic onto larger regional roads and highways. This system is often highlighted for its role in congestion, since the funneling of traffic creates congested chokepoints and severely limits alternative routes from place to place. This system also arose as part of a highly separated and dispersed land use system that is becoming less dominant in contemporary development.

As local governments and states demand connected, multi-modal street networks, AASHTO and ITE have recognized the need for alternative standards. In response, ITE has published “Traditional Neighborhood Development Street Design Guidelines” (1999) and “Neighborhood Street Design Guidelines” (2003). Public officials may also use the Better Site Design handbook (CWP, 1998) to conduct a review of their own codes and ordinances to determine if they allow for greener alternatives to the conventional street layout and network. The Model Development principles in that handbook are designed to facilitate changes to codes and ordinances where desired.

Design Criteria

Smart Growth street designs can be divided into two categories: street design in new projects and modification of existing street patterns. The main benefit of Smart Growth street design rests on the ability to support a higher level of development intensity on a smaller footprint. This benefit manifests itself well at the regional and neighborhood levels. Alternative types of street designs can cut costs as well, reducing the need for paving materials for longer streets and more parking. For both redevelopment and new development projects, installing conventional sidewalks, curbs, and gutters is typically more expensive than the installation of the roadway itself.

Street Design in New Projects

Smart Growth street designs incorporated into new projects are typically part of an overall site design that seeks to meet transportation, economic, and multi-modal objectives. On a local level, cities and counties such as Cary, North Carolina, and Portland, Oregon, have enacted “connected streets” policies so that new residential or mixed-use development projects have more than one link to neighboring retail, commercial, or transportation centers.

Standard road design practice has been to make decisions about stormwater BMPs after the roadway has already been designed. This not only limits options, but often focuses attention on end-of-pipe treatment BMPs rather than in-line measures or preventive measures, which are generally less expensive to build and maintain, and more effective at protecting water quality. For new development or redevelopment of any part of a transportation system, stormwater management features should be an integral part of the design, not “add-on” features. Though there is not one set standard, street designs should meet the following objectives:

- Support a mix of uses.
- Develop parking plans to optimize the number of spaces and layout for multi-modal connections.

- Incorporate features such as boulevard islands, rotary islands, parking lot islands, swales, and sidewalk tree and groundcover planters to capture, filter, and infiltrate runoff. These features may already be incorporated for aesthetics or traffic-calming purposes, and can be used to manage stormwater as well.
- Integrate sidewalks, crosswalks, and traffic-calming approaches to support bicycling, walking, and automobile traffic.
- Design for shorter block lengths.
- Engineer narrower street widths to facilitate pedestrian crossings and moderate automobile speed while meeting the needs of emergency responders.
- Provide access lanes, on-street parking and turning lanes to complement the land development design, sidewalks, and building setbacks.

Once the underlying layout has been established, transportation and stormwater engineers can look for additional strategies to further reduce stormwater volume and pollutants. Separate stormwater sewers typically discharge runoff with little or no treatment into receiving bodies. Thus, avoiding or minimizing the use of standard curb and gutter collection and conveyance systems should be a goal of any project.

Poorly draining soils do not have to preclude the use of these measures, as good designs and soil amendments can facilitate some level of infiltrative capacity almost anywhere. In areas with existing curb and gutter, and limited short-term options for major retrofits, the inlets and catch basins of storm sewers in a Smart Growth development or redevelopment project might require additional BMPs or design modifications.

Modification of Existing Streets

Local governments can use several methods to incorporate Smart Growth features and stormwater benefits to existing streets. Some of these strategies will include

- Connecting disconnected streets, lanes, and cul-de-sacs,
- Where a new street is impossible, adding paths to link housing and other uses,
- Using unused streetscape to add public parking, increase the number of spaces, and introduce bike lanes.

These strategies are often used in connection with site design features like tree planters and vegetated bulb-outs that can be designed to handle and treat stormwater. Where possible, a street retrofit should take advantage of opportunities to improve the drainage system or add structural and non-structural BMPs to lessen the flow of stormwater volumes or filter pollutants. This will require a new approach to street repair and retrofits. Departments of Public Works and stormwater engineers will need to consult with land-use planners and site designers on reducing volume and treating stormwater before runoff enters the public conveyance system. In some areas, the stormwater inlets can be retrofitted with trash separation and filtration controls. A connected system need not be a formal grid of streets. Often the connections are determined not only by the street layout, but by linkages among activity centers like schools, neighborhoods, and jobs. Site planners might need to avoid introducing streets and hardscape in or around environmentally sensitive land or water resources.

Effectiveness

The effectiveness of a Smart Growth street design can be at the street, neighborhood, and watershed levels. At the watershed level, the benefits of Smart Growth street designs for both redevelopment and new development emerge from absorbing development demand on a smaller footprint. During initial construction, less land disturbance results in less exposure and risk of sedimentation. Quantitatively, the best management practices will be preventative in nature since development takes place on a smaller area.

More transportation options mean that some car trips may be eliminated or shortened. The benefits of shrinking the footprint of parking and better managing existing street space are straightforward, but watersheds also benefit from reduced tailpipe-related deposits and from devoting what was single parking use to multi-use (shared parking and retail, for example). This efficiency also represents environmental benefits.

Implementation

The objective of this BMP is to minimize impervious surface at the watershed level through a more thoughtful approach to roadway design, parking requirements, and connections between streets and modes of traffic. This may involve concentrating development in urbanized areas to preserve green space elsewhere in the watershed. Smart Growth street designs can involve more coverage per acre in a district, but far less on a sub-watershed scale.

For construction standards with respect to road widths and parking ratios, consult the BMPs given in this manual for:

- Green Parking (see *Site Design* section of this chapter),
- Narrower Residential Streets (see *Site Design* section of this chapter),
- Redevelopment (see *Planning* section of this chapter).

Common Problems

As referenced, limitations to implementing innovative street designs might occur within the existing stormwater regulations. Blanket regulations that require land set-asides, mandatory infiltration, or swales can pose barriers to better site design. For example, mandated sizing requirements for swales might consume land needed for connections to a higher intensity transit district. While preserving these standards for certain parts of the watershed, incentives can be created for alternative street designs by modifying stormwater management requirements in targeted areas. In addition, there are reasonable, low-maintenance, stormwater-management measures that can be used (even in densely developed, highly impervious areas) that result in very low runoff.

Although most literature on stormwater management discourages “connected impervious surfaces,” local governments need to recognize that, as part of an overall Smart Growth design, “connected streets” confer stormwater benefits. The placement of intense and connected development is not appropriate in every part of a watershed. However, concentrating growth and development in certain parts of the watershed to protect more sensitive areas, such as headwaters, can be a viable strategy.

Developers who are accustomed to a conventional, separate pattern of development may sometimes resist new rules that require connecting internal streets to neighboring projects, adding sidewalks or introducing a mix of uses. Likewise, residents on unconnected streets may oppose efforts to improve connections within existing neighborhoods.

Finally, the street system alone will not bring about stormwater benefits. The relationship among the street layout, the development plan, and existing activity centers is crucial for obtaining stormwater benefits.

Maintenance

Even in circumstances where the overall surface area of a Smart Growth street layout results in less impervious coverage, there are maintenance considerations. Separate stormwater sewers typically discharge runoff with little or no treatment into receiving bodies. Thus, typical maintenance considerations for curb and gutter designs include street sweeping, catch basin cleaning, clearing blocked sewer lines, repairing and replacing failed pipes, and other aspects of maintaining buried, hard infrastructure.

Maintenance of aboveground bioretention/infiltration features such as swales and infiltration trenches largely includes vegetation maintenance. Depending on locations and designs, removal of accumulated sediment and debris is also usually necessary. Porous or pervious surface materials generally do not have additional maintenance requirements. In-line and end-of-pipe commercial swirl or filter devices require regular clean-out. All types of systems should have regular inspections to ensure they are functioning properly.

Urban Forestry

Practice Description

Urban forestry is the study of trees and forests located in and around towns and cities. Since trees absorb water, patches of forest and the trees that line streets can help provide some of the stormwater management required in an urban setting. Urban forests help break up a landscape of impervious cover, provide small but essential green spaces, and link walkways and trails.

Successful urban forestry requires a conservation plan for individual trees as well as forest areas larger than 10,000 sq ft. A local forest or tree ordinance is one technique for achieving conservation and, when specific measures to protect and manage these areas are included, urban forests and trees can help reduce stormwater management needs in urban areas. Guidance on conservation of natural areas in the Better Site Design handbook is useful for jurisdictions that wish to incorporate urban forestry in their stormwater management plan. Model development principles that apply to urban forestry include clearing and grading, tree conservation, riparian buffers, and stormwater outfalls (CWP, 1998).

Planning Considerations

From a stream preservation perspective, it is ideal to preserve as much contiguous forest as possible. However, this may not be an option in many urban areas. If forested areas are fragmented, it is ideal to retain the closest fragments together. In rapidly urbanizing areas, where clearing and grading are ongoing, tree preservation areas should be clearly marked.

Delineating lines along a critical root zone (CRZ) rather than a straight line is essential to preserving trees. It can also help reduce homeowner complaints about tree root interference into sewer or septic lines.

Numerous environmental and stormwater benefits result from urban forestry. Urban forests can act as natural stormwater management areas by filtering particulate matter (including pollutants, some nutrients, sediments, and pesticides) and by absorbing water. A study done by the U.S. Department of Agriculture's Center for Urban Forest Research found that a medium-sized tree can intercept 2,380 gallons of rain per year (CUFR, not dated).

Trees also absorb carbon dioxide, decrease temperatures, and provide habitat for urban wildlife. Urban forestry reduces noise levels and provides recreational benefits. There are numerous economic benefits to urban forests, including proven increases in property values. In addition, by preserving trees and forests, the costs of clearing and grading as well as erosion and sediment control can be reduced during construction. Maintenance costs are also minimized by keeping areas as natural as possible.

Annual maintenance costs of different types of green spaces (CWP, 1998)

Land Use	Approximate Annual Maintenance Costs
Natural Open Space *Only minimum maintenance, trash/debris cleanup*	\$75/acre/year[1]
Lawns *Regular mowing*	\$270 to \$240/acre/year[2]
Passive Recreation	\$200/acre/year[1]

[1] "Economic Impacts of Protecting Rivers, Trails and Greenway Corridors," 4th ed. 1995. Rivers, Trails and Conservation Assistance Program, National Park Service, Western Office, San Francisco, CA.
[2] "The Economic Benefits of Wildlife Habitat Enhancement on Corporate Lands." 1992. Wildlife Habitat Enhancement Council, Silver Springs, MD.

Design Criteria

An urban forestry plan should include measures to establish, conserve, or reestablish preservation areas. The basic building block of the plan is the critical root zone, or the area around a tree required for its survival. The CRZ is determined by tree size, species, and soil conditions. For isolated specimen trees, the CRZ can be estimated as 1/2 feet of radial distance for every inch of tree diameter. In larger areas of trees, the CRZ of forests can be estimated at 1 foot of radial distance for every inch of tree diameter, or a minimum of 8 feet.

Forest Preservation Ordinance

A forest preservation ordinance is one way to set design standards outlining how a forest should be preserved and managed. The ordinance should outline some basic management techniques and contain some of the following typical elements of a forest conservation plan:

- A map and a narrative description of the forest and surrounding area that includes topography, soils, streams, current forested and unforested areas, tree lines, critical habitats, and 100-year floodplain.
- An assessment that establishes preservation and reforestation areas.
- A forest conservation map that outlines forest retention areas, reforestation, protective devices, limits of disturbance, and stockpile areas.
- A schedule of any additional construction in and around the forest area.
- A specific management plan, including tree and forest protection measures.
- A reforestation and a forestation plan.

Site-Level Tree Preservation

An ordinance can also be developed that addresses tree preservation at the site level, both during construction and post-construction. This type of ordinance can be implemented on a smaller scale and integrated with a proposed development's erosion and sediment control and stormwater pollution prevention plans, which many communities require of new developments.

American Forests, a non-profit organization dedicated to preserving and restoring forests, adopted an ecosystem restoration and maintenance agenda in 1999. Their goal is to assist communities in planning and implementing tree and forest actions to restore and maintain healthy ecosystems and communities (American Forests, 2000). The agenda presents the organization's core values and policy goals as the basis for policy statements. It also provides information to help community-based partners prepare their own policy statements. Key policy goals include

- Increasing public and private sector investment in ecosystem restoration and maintenance activities;
- Promoting an ecosystem workforce through training, apprenticeship programs, and new job opportunities;
- Building support for innovative monitoring systems to ensure collaborative learning and adaptive management; and
- Encouraging a "civic science" approach to ecosystem research that respects local knowledge, seeks community participation, and provides accessible information for communities.

Common Problems

One of the biggest limitations to urban forestry is development pressure. Ordinances, conservation easements, and other techniques designed into management programs can help alleviate future development pressures. The size of the land may also limit the ability to protect individual trees. In such areas, a tree ordinance may be a more practical approach.

Forests may also harbor undesirable wildlife elements such as insects and other pests. If forests border houses, this may be a concern for residents.

Maintenance

Maintenance considerations for urban forests may require fringe landscaping and trash pickup. By using native vegetation and keeping the area as natural as possible, maintenance efforts can be minimized.

Alternative Turnarounds

Practice Description

Alternative turnarounds are designs for end-of-street vehicle turnaround that replace cul-de-sacs and reduce the amount of impervious cover created in residential neighborhoods. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a stormwater perspective, this creates a huge bulb of impervious cover, increasing the amount of stormwater runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

There are numerous alternatives to the traditional 40-foot cul-de-sac that create less impervious cover. These include reducing cul-de-sacs to 30-foot radius, hammerheads, loop roads, and creating pervious islands in the center.

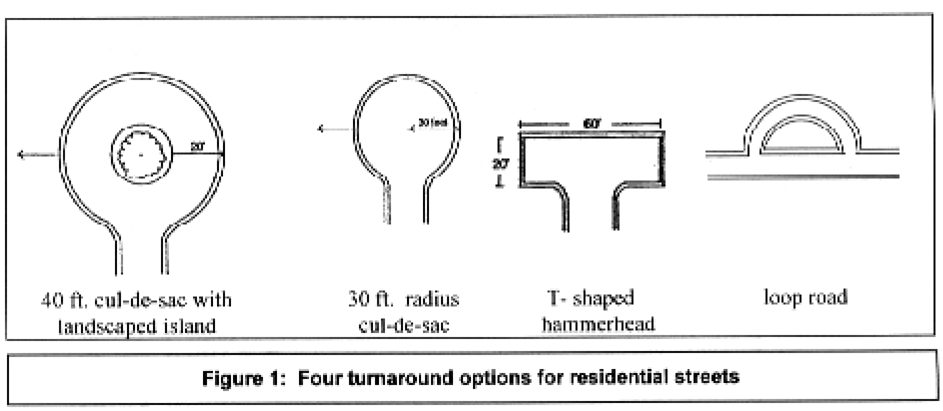


Figure 1: Alternative turnaround options (CWP, 1998)

Planning Considerations

Alternative turnarounds can be applied in the design of residential, commercial, and mixed use developments. Combined with alternative pavers, green parking, curb elimination and other techniques, the total reduction to site impervious cover can be dramatic, reducing the amount of stormwater runoff from the site. With proper designs, much of the remaining stormwater can be treated on-site.

Sufficient turn-around area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. Fire trucks, service vehicles, and school buses are often cited as examples for increased turning radii. However, research shows that some fire trucks are designed for smaller turning radii. In addition, many new larger service vehicles are designed using a tri-axle, and schools buses usually do not enter individual cul-de-sacs.

Implementation of alternative turnarounds will also have to address local regulations and marketing issues. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds. Also, cul-de-sacs are often featured as highly marketable and, while alternative turnarounds can still capture the end of the street appeal, actual research on market preference is not widely known. Local regulations often dictate requirements for turnaround radii, and some of the alternatives may not be allowed by local codes. In addition, marketing perceptions may also dictate designs, particularly in residential areas. While changing local codes is no small effort, by initiating a local site planning roundtable, communities can change some of these regulations through a cluster ordinance or through a collective effort to review local codes to promote better site design.

Since alternative turnarounds reduce the amount of impervious cover created, construction savings can be an incentive (asphalt costs $0.50–$1.00 per square foot in materials alone). Bioretention is estimated at $6.40 per cubic foot and, while it costs more than providing a naturally vegetated area, it can help reduce overall stormwater costs.

Design Criteria

The primary goals of the alternative turnaround BMP is to reduce impervious surface. This can be achieved through reducing the size of cul-de-sacs or eliminating cul-de-sacs from roadway design. The designs in Figure 1 above show four options for achieving this goal, which range from placing a planter in the center of a traditional cul-de-sac to creating a small loop in the road to route traffic effectively while using less pavement.

Maintenance

If islands are constructed as part of a turnaround, these areas will need to be maintained. Kept as a natural area, the costs could be minimal. Bioretention areas will also require maintenance. The other options create less asphalt to repave, and maintenance will remain the same and cost less ("Alternative Turnarounds," USEPA 2006).

Eliminating Curbs and Gutters

Practice Description

This practice promotes grass swales as an alternative to curbs and gutters along residential streets. Curbs and gutters are designed to quickly convey runoff from the street to the storm drain and, ultimately, to a local receiving water. Consequently, they provide little or no removal of stormwater pollutants. Indeed, curbs often act as traps where deposited pollutants remain until the next storm washes them away. Many communities require curbs and gutters as standard elements of road sections. In fact, many communities discourage the use of grass swales. Revisions to current local road and drainage regulations are needed to promote greater use of grass swales along residential streets.

Planning Considerations

The use of engineered swales in place of curbs and gutters should be encouraged in low- and medium-density residential zones where soils, slope, and housing density permit. However, eliminating curbs and gutters is generally not feasible for streets with high traffic volume or extensive on-street parking demand (i.e., commercial and industrial roads). Nor is it a viable option in arid and semi-arid climates where grass cannot grow without irrigation.

Removal of curbs and gutters decreases the peak flow discharge to receiving waters. Furthermore, under the proper design conditions, grass swales can be effective in removing pollutants from urban stormwater (Schueler, 1996).

Engineered swales are a much less expensive option for stormwater conveyance than the curb and gutter systems they replace. Curbs and gutters and the associated underground storm sewers have been documented to cost as much as $36 per linear foot, which is roughly twice the cost of a grass swale (Schueler, 1995). Consequently, when curbs and gutters are eliminated, the cost savings can be considerable.

Design Criteria

A series of site factors must be evaluated to determine whether a grass swale is a viable replacement for curbs and gutters at a particular site.

Contributing drainage area

Most individual swales cannot accept runoff from more than 5 acres of contributing drainage area. Typically, they serve 1-2 acres each.

Soils

The effectiveness of swales is greatest when the underlying soils are permeable (hydrologic soil groups A and B). The swale may need more engineering if soils are less permeable.

Slope

Swales generally require a minimum slope of 1 % and a maximum slope of 5 %.

Water Table

For most designs, swales should be avoided if the seasonally high water table is within 2 feet of the proposed bottom of the swale.

Development Density

The use of swales is often difficult when development density becomes more intense than four dwelling units per acre, simply because the number of driveway culverts increases to the point where the swale essentially becomes a broken-pipe system. Typically, grass swales are designed with a capacity to handle the peak flow rate from a 10-year storm, and fall below erosive velocities for a 2-year storm.

Construction and Installation

Although there are different design variations of the grassed swale, some design considerations are common to all. An overriding similarity is the cross-sectional geometry. Swales often have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1 horizontal: vertical), though rectangular and triangular channels can also be used. Designing the channel with flat side slopes increases the wetted perimeter. The wetted perimeter is the length along the edge of the swale cross section where runoff flowing through the swale contacts the vegetated sides and bottom. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage sorption, filtering, and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope.

Another similarity among designs is the type of pretreatment needed. In all design options, a small forebay should be used at the front of the swale to trap incoming sediments. A pea gravel diaphragm, a small trench filled with river-run gravel, should be constructed along the length of the swale and used as pretreatment for runoff entering the sides of the swale. Other features designed to enhance the performance of grassed swales are a flat longitudinal slope (generally between 1 percent and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the flow velocity within the channel. The dense vegetation also helps reduce velocities, protects the channel from erosion, and acts as a filter to treat stormwater runoff. During construction, it is important to stabilize the channel while the vegetation is becoming established, either with a temporary grass cover or with natural or synthetic erosion control products. In addition to treating runoff for water quality, grassed swales must convey runoff from larger storms safely. Typical designs allow the runoff from the 2-year storm (i.e., the storm that occurs, on average, once every two years) to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms such as a 10-year storm safely.

The following discussion identifies design and construction practices for three variations of open-channel practices: the grassed channel, the dry swale, and wet swale. For a detailed discussion of *Grass Swales*, see *Volume 1 – Chapter 4*.

Grassed Channels

Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Of all of the options, grassed channels are the least expensive but also provide the least reliable pollutant removal. An excellent application of a grassed channel is as pretreatment to other structural stormwater practices. A major difference between the grassed channel and many other structural practices is the method used to size the practice. Most stormwater-management water quality practices are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel is a flow rate-based design. Based on the peak flow from the water quality storm (this varies regionally, but a typical value is the 1 inch/24-hr storm), the channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in Design of Stormwater Filtering Systems (CWP, 1996).

Dry Swales

Dry swales are similar in design to bioretention areas. These designs incorporate a fabricated soil bed into their design. The native soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is installed at the bottom of the soil bed. This underdrain is a gravel layer that encases a perforated pipe. Stormwater treated in the soil bed flows into the underdrain, which routes this treated stormwater to the storm drain system or receiving waters. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal.

Wet Swales

Wet swales intersect the groundwater and behave similarly to a linear wetland cell (see *Constructed Stormwater Wetland Practice*). This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. This design also has potentially high pollutant removal. Wet swales are not commonly used in residential or commercial settings because the shallow standing water may be a potential mosquito-breeding area (“Grassed Swales,” USEPA 2006).

Common Problems

A number of real and perceived limitations hinder the use of grass swales as an alternative to curb and gutters:

The pavement edge along the swale can experience more cracking and structural failure, increasing maintenance costs. The potential for pavement failure at the road/grass interface can be alleviated by “hardening” the interface with grass pavers or geo-synthetics placed beneath the grass. Other options include placing a low-rising concrete strip along the pavement edge.

The shoulder and open channel will require more maintenance. In reality, maintenance requirements for grass channels are generally comparable to those of curb and gutter systems. The major requirements involve turf mowing, debris removal, and periodic inspections.

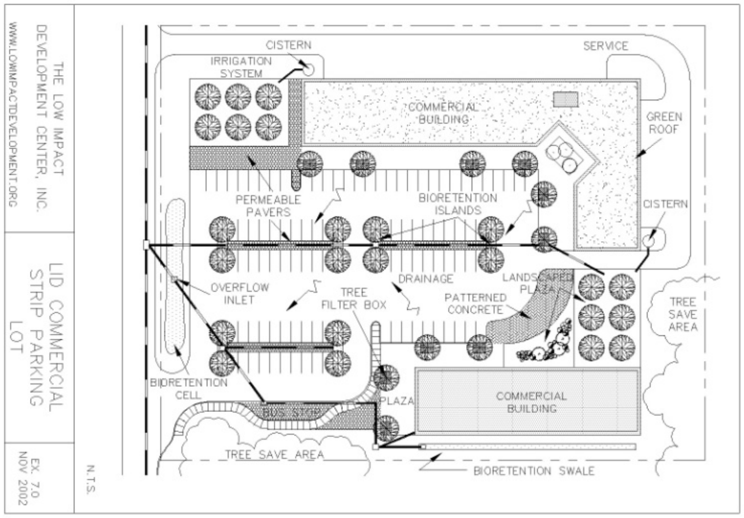
Some grass swales can have standing water, which make them difficult to mow, and can cause nuisance problems such as odors, discoloration, and mosquitoes. In reality, grass channels are not designed to retain water for any appreciable period of time.

Other concerns involve fears about utility installation and worries that the grass edge along the pavement will be torn up by traffic and parking. While utilities will need to be installed below the paved road surface instead of in the right-of-way, most other concerns can frequently be alleviated through the careful design and integration of the open channels along the residential street.

Maintenance

The major maintenance requirement for grass swales is mowing during the growing season, a task usually performed by homeowners. In addition, sediment deposits may need to be removed from the bottom of the swale every ten years or so, and the swale may need to be tilled and re-seeded periodically. Occasionally, erosion of swale side slopes may need to be stabilized. The overall maintenance burden of grass swales is low in relation to other stormwater practices, and it is usually within the competence of the individual homeowner. The only major maintenance problem that might arise pertains to “problem” swales that have standing water and are too wet to mow. This particular problem is often alleviated by amending the soil with rocks and well-drained soils to promote drainage.

Green Parking



Practice Description

Green parking uses a combination of techniques to decrease the parking lot's impact on surrounding drainage patterns. Applied correctly, this can dramatically reduce impervious cover and, consequently, the amount of stormwater runoff. Some techniques include setting maximums for the number of parking spaces created, minimizing the dimensions of parking lot spaces, using permeable pavers in overflow parking areas, using bioretention areas to treat stormwater, encouraging shared parking, and providing economic incentives for structured parking. Green parking strategies can be used in both new developments and redevelopment ("Green Parking," USEPA 2006).

Planning Considerations

Applied together, green parking techniques can effectively reduce the amount of impervious cover, protect local streams, save expenses on stormwater management, and visually enhance a site. Proper bioretention area design can help meet stormwater management and landscaping requirements while keeping maintenance costs at a minimum. Some limitations to applying green parking techniques include applicability, cost, and maintenance. For example, shared parking is practical only in mixed-use areas, and structured parking may be limited by the cost of land versus construction.

The pressure to provide parking spaces can come from fear of complaints as well as bank loan requirements. This may pressure developers to construct more parking than necessary and to be a barrier to providing the greenest parking lot possible. Green parking lots, however, can dramatically reduce the amount of impervious cover created. The level of effectiveness depends on how much impervious cover is reduced as well as the combination of techniques used to provide the greenest parking lot. While the pollutant removal rates of bioretention areas have not been directly measured, their capability is considered comparable to a dry swale, which removes 91% of total suspended solids, 67% of total phosphorous, 92% of total nitrogen, and 80-90% of metals (Schueler, 1996).

Implementation

Minimize Dimensions of Parking Spaces

Minimizing the dimensions of parking spaces is another green parking lot technique. Besides reducing the length and width of all spaces, parking stall dimensions can be reduced by providing compact vehicle spaces. While large sport utility vehicles (SUVs) are often cited as barriers to stall minimization techniques, most local parking codes require stall widths wider than the widest SUVs ("Green Parking," USEPA 2006).

Amend Parking Ratios

Many commercial areas require excessively high parking ratios based upon the highest hourly parking demand during peak seasons. Changing the calculation method to account for actual average parking demand instead can help jurisdictions set a maximum number of parking spaces. The table below provides examples of conventional parking requirements and compares them to average parking demand.

Conventional Minimum Parking Ratios (Source: ITE, 1987; Smith, 1984; and Wells, 1994)			
Land Use	Parking Requirement		Actual Average Parking Demand
	Parking Ratio	Typical Range	
Single family homes	2 spaces per dwelling unit	1.5 - 2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0 - 6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0 - 10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5 - 2.0	1.48 per 1000 ft^2 GFA
Medical/ dental office	5.7 spaces per 1000 ft^2 GFA	4.5 - 10.0	4.11 per 1000 ft^2 GFA
GFA = Gross floor area of a building without storage or utility spaces.			

Alternative Pavers

Utilizing alternative pavers is also an effective green parking technique. These can replace conventional asphalt or concrete in both new developments and redevelopment projects. Alternative pavers can range from medium to relatively high effectiveness in meeting stormwater quality goals.

The different types of alternative pavers include gravel, cobbles, wood mulch, brick, grass pavers, turf blocks, natural stone, pervious concrete, and porous asphalt.

Bioretention Areas

Bioretention areas can effectively treat stormwater in a parking lot. Stormwater is directed into a shallow, landscaped area and temporarily detained. The runoff then filters down through the bed of the storage area and is infiltrated into the subsurface or collected into an underdrain pipe for discharge into a stream or another stormwater facility. Bioretention areas can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of bioretention areas, refer to the *Bioretention (Rain Gardens) Practice*.

Shared & Structured Parking

Shared parking in mixed-use areas and structured parking are also green parking techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings. Costs may dictate the usage of structure parking, but building upwards or downwards can help minimize surface parking.

Common Problems

As referenced above, cost and maintenance are the major limitations on green parking techniques. Alternative pavers are currently recommended only for overflow parking because of the considerable cost of maintenance, and bioretention areas can be costly to construct. Strategies like setting maximums for parking spaces, minimizing stall dimensions, and encouraging shared parking can result in considerable construction cost savings, however, and all of the green parking techniques can also reduce stormwater management costs.

Alternate Pavers

Alternative pavers require proper installation and more maintenance than conventional asphalt or concrete. Accessibility, climate, soil type, traffic volume, and long-term performance should be considered along with costs and stormwater quality controls when choosing paving materials. Use of alternative pavers in cold climates will require special consideration since snow shovels are not practical for many of these surfaces. Sand is particularly troublesome if used with paving blocks since the sand that ends up in between the blocks cannot effectively wash away or be removed. In addition, salt used to de-ice can infiltrate directly into the soil and cause potential groundwater pollution.

Soil types will affect the infiltration rates and should also be considered when using alternative pavers. Clayey soils (D soils) will limit the infiltration on a site. If groundwater pollution is a concern, use of alternative pavers with porous soils should be carefully considered.

Maintenance

Alternate Pavers

The durability and maintenance cost of alternative pavers also limits use to low traffic-volume areas. For the reasons cited above, alternative pavers for parking are recommended for light-use residential areas that do not require accessibility and for parking overflow areas. At the same time, alternative pavers can abate stormwater management costs. Used in combination with other better site design techniques, the cumulative effect on stormwater can be dramatic.

Bioretention

Bioretention requires regular landscaping maintenance, including measures to ensure that the area is functioning properly. In many cases, bioretention areas require intense maintenance initially, but less is needed over time. Many tasks can be completed by a landscaping contractor, who may already be hired at the site. Landscaping maintenance requirements can be less resource intensive than traditional landscaping practices such as elevated landscaped islands in parking areas.

Typical Maintenance Activities for Bioretention Areas ("Green Parking," USEPA 2006)

Activity	Schedule
Remulch void areas Treat diseased trees and shrubs Mow turf areas	As needed
Water plants daily for 2 weeks	At project completion
Inspect soil and repair eroded areas Remove litter and debris	Monthly
Remove and replace dead and diseased vegetation	Twice per year
Add mulch Replace tree stakes and wires	Once per year

Green Roofs

Practice Description

There are two primary strategies for constructing green roofs (vegetated roof covers and roof gardens): to detain rainfall and to promote evapotranspiration of runoff. Some innovative projects even capture larger quantities of water for management with strategies such as roof ponding areas and cisterns. The vegetated roof blankets the roof area with a layer of living vegetation. These are particularly effective when applied to extensive roofs, such as those commonly used on commercial, multifamily, and institutional buildings. However, they can be applied to virtually any building, including single-family residences. Vegetated roof covers are an effective means of retarding runoff from roof surfaces. Initially during a rainfall event, nearly all precipitation striking the foliage is intercepted. As rain continues, water percolates into and begins to saturate the growth media and root zone of the cover. Significant quantities of water do not begin to drain from the roof until the field capacity of the medium is filled. For small rainfall events, little runoff occurs and most of the precipitation eventually returns to the atmosphere.

Roof gardens (which are also called “intensive green roofs”) are landscaped environments that may include planters and potted shrubs and trees. Roof gardens can be custom-made naturalized areas, designed for outdoor recreation, and perched above congested city streets. Because of the special requirements for access, structural support, and drainage, roof gardens are found most frequently in new construction. The services of a professional engineer are required to evaluate the structural and drainage constraints associated with roof garden design. For larger storms, both types of green roofs can delay and slow the peak runoff significantly.

Planning Considerations

Green roofs are useful for a wide range of construction types. They provide very effective stormwater management for small- to mid-size events. By employing a green roof, developers can often conserve space on-site that would otherwise be required for detention or retention facilities. Experts believe this strategy may even extend the life expectancies of roofs, primarily by shielding from ultraviolet light (UV and temperature extremes. It reduces heat island effects caused by impervious surfaces, and can even bring down heating and cooling costs in the building. It adds aesthetic value to residential and commercial property; provides attractive textures and colors; and creates habitat for birds and insects. There are some disadvantages to this BMP, however. It often requires additional structural strengthening to hold the weight of the structure. Although roof gardens require only normal garden maintenance, the location may make it more difficult to inspect and correct problems. The vegetated roof cover style of green roof cannot be walked on, although a roof garden can handle foot traffic. Buildings that employ rooftop detention strategies may experience leaks. These are also among the most expensive practices per square foot of treated area.

Design Criteria

When preparing a design for a green roof, whether it is a vegetated roof or a roof garden, there are several requirements that must be met. The project must begin with a vegetation plan prepared by a horticulturalist versed in green roofs. The design and implementation will also require the participation of a structural engineer to verify that the roof structure and structure strength are adequate to accommodate these BMPs. The design must include access to the roof for regular inspection and maintenance. If roof slopes are greater than 20 degrees, support systems must be installed to avoid slippage of the growing medium and plants. Specific design criteria for these two primary types of green roofs are detailed below.

Vegetated Roof Covers

Because of recent advances in synthetic drainage materials, vegetated roof covers are now feasible on most conventional flat and gently sloping roofs. A lightweight, efficient drainage layer is placed between the growth medium and the impermeable membrane protecting the roof surface. This layer rapidly conveys water off the roof surface and prevents it from ponding. Vegetated roof covers also serve to protect roof materials and prolong their life, primarily by shielding from UV and temperature extremes. European data show that green roofs can double the life span of a roof.

Although vegetative roof covers are most effective during the growing season, they are also beneficial during the winter months if the vegetative matter from the dead or dormant plants is left in place and intact.

The emphasis of the design should be to promote rapid roof drainage and minimize the weight of the system. It is advisable to obtain the services of specialized installers because of the many factors that may influence the design.

Waterproof Roof Liner

In some instances, the impermeable lining can be the watertight tar surface, which is conventional in flat-roof construction. However, where added protection is desired, a layer of plastic or a rubber membrane can be installed immediately beneath the drainage net or sheet drain.

Drainage Net or Sheet Drain

The drainage net or sheet drain is a continuous layer that underlies the entire cover system. A variety of lightweight, high-performance, drainage products function well in this environment. The product selected should be capable of conveying the discharge associated with the design storm without ponding water on top of the roof cover. The drainage layer must have a good hydraulic connection to the roof gutters, drains, and downspouts. To prevent the growth medium from clogging the drainage layer and to prevent roots from penetrating the roof surface, a geotextile should be installed immediately over the drainage net or sheet drain. Some products have the geotextile bonded to the upper surface of the drainage material. A root retardant (such as copper sulfate) is typically included in this geotextile.

Lightweight Growth Medium

The depth of the growth medium should be as small as the cover vegetation will allow, which is typically 3 to 6 inches. Low-density substrate materials with good water-retention capacity (e.g., mixtures containing expanded slate, expanded shale, expanded clay, and terra cotta) should be specified. Media appropriate for this application will retain 40 to 60 percent water by weight and have bulk dry densities between 35 and 50 lb/ft^3. The makeup of the media will vary depending on the types of plants used, but an example media makeup would be 55% expanded slate, 30% root zone sand, and 15% compost. Care should be taken when specifying compost because it will break down over time, and the depth of the media will therefore decrease. A photograph of expanded slate is provided as Figure 1. Earth and topsoil are too heavy for most applications, as well as being too wet for succulent and other recommended vegetation, and too dry for grasses.

Figure 1
Expanded Slate

Vegetation

A limited number of plants can thrive in the roof environment where periodic rainfall alternates with periods that are hot and dry. Effective plant species must tolerate mildly acidic conditions and poor soil; prefer very well-drained conditions and full sun; tolerate dry soil; and be vigorous colonizers. It should also be noted that conditions can be much wetter for longer periods near a gutter or drain and drier near the peaks. Succulents have shown to be very successful in vegetative roof covers, and are preferred to grasses. Both annual and perennial plants can be used. Vegetative roof covers may need provisions for occasional watering (e.g., conventional lawn sprinklers) during extended dry periods. A vegetation plan prepared by a horticulturalist versed in green roof vegetation is required.

Hydraulics

Vegetative roof covers influence runoff in two ways: intercepting rainfall during the early part of a storm, and limiting the release rate. Hydrologic properties are specific to the growth medium. If information is not provided by the supplier, prospective media should be laboratory-tested to establish:

- Porosity
- Moisture content at field capacity
- Moisture content at the wilting point
- Saturated hydraulic conductivity

Rainfall retention properties are related to field capacity and wilting point. Appropriate media for this application should be capable of retaining water at the rate of 40 percent by weight, or greater. The medium must be uniformly screened and blended to achieve its rainfall retention potential. During the early phases of a storm, the media and root systems of the cover intercept and retain most of the rainfall, up to the retention capacity. For instance, a 3-inch cover with 40 percent retention potential effectively controls the first 1.2 inch of rainfall. Although some water percolates through the cover during this period, this quantity is generally negligible compared with the direct runoff rate without the cover in place. Capture rates are dependent on rainfall intensity, antecedent rainfall, time of year, evapotranspiration, and roof pitch. Green roofs on pitches steeper than 1:12 do not function as well as for water quality and quantity control. Vegetated roof covers should be kept on slopes of 8 percent or less, if they are being used to mitigate water quality or quantity.

Once the field capacity of the cover is attained, water drains freely through the medium at a rate that is approximately equal to the saturated hydraulic conductivity of the medium. The maximum release rate from the roof can be controlled by selecting the appropriate medium. The medium is a mechanism for “buffering” or attenuating the peak runoff rates from roofed areas. The attenuation can be important even for large storms. By using specific information about the hydraulic properties of the cover medium, the effect of the roof cover system on the runoff hydrograph can be approximated with numerical modeling techniques. As appropriate, the predicted hydrographs can be added into site-wide runoff models to evaluate the effect of the vegetative roof covers on site runoff. The hydraulic analysis of roof covers requires the services of a properly licensed design professional experienced in this type of drainage design.

Drainage nets or sheet drains with transmissivities of 15 gallons per minute per foot or higher are recommended. When assessing a drainage layer design, designers should evaluate the roof topography to establish the longest travel distances to a roof gutter, drain, or downspout. If flow converges near drains and gutters, the design unit flow rate should be increased accordingly. The drainage layer should be able to convey the design unit flow rate at the roof grade without water ponding on top of the cover medium.

For storms larger than the design storm, direct roof runoff will occur. The design flow rates should be based on the largest runoff peak attenuation considered in the design of the vegetated roof cover.

Weight Considerations

Roof designs are dictated by state and local building codes and standards. They must account for maximum design loads contributed by dead loads, live loads, and snow or water accumulation. The design of a vegetative roof cover can alter the dead loads to the system, and it should therefore be closely coordinated with the structural design of the building. Dead loads for vegetated roof covers include the planting medium, vegetation, drainage system, and water in the pore space. However, the additional weight is partly offset by the removal of the gravel ballast.

By using appropriate materials, the total weight of fully saturated vegetated roof covers can readily be maintained below 35 pounds per square foot (psf). It is also possible that the minimum weight design focus for the vegetated roof cover might be too light to satisfy the ballast requirements for flat tar roofs. As required, deepening the medium can increase the weight of the cover system.

Roof Gardens

Roof gardens generally are designed to achieve specific architectural objectives. The load and hydraulic requirements for roof gardens vary according to the intended use of the space. Intensive roof gardens typically include design elements such as planters filled with topsoil, decorative gravel or stone, and containers for trees and shrubs. Complete designs also may detain runoff ponding in the form of water gardens or storage in gravel beds. A wide range of hydrologic principles may be used to achieve stormwater-management objectives, including runoff peak attenuation and runoff volume control.

Effective designs ensure that all direct rainfall is cycled through one or more devices before being discharged to downspouts as runoff. For instance, rainfall collected on a raised tile patio can be directed to a medium-filled planter where some water is retained in the root zone and some is detained and gradually discharged through an overflow to the downspout.

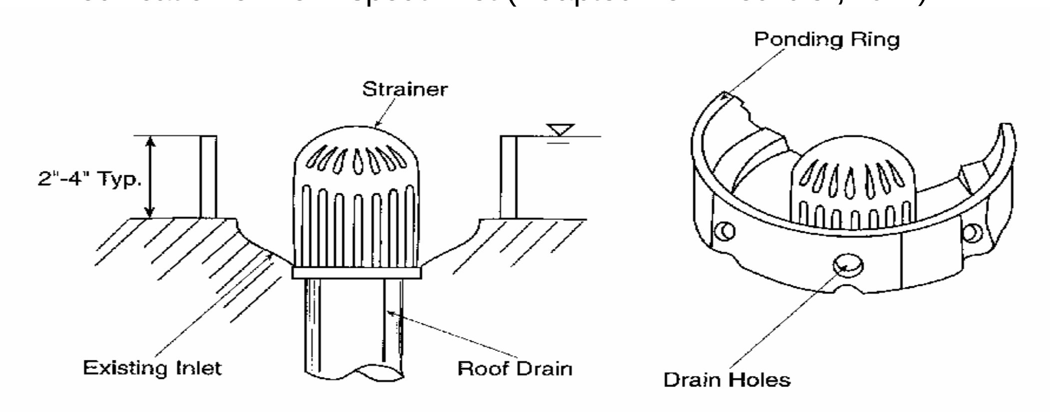
Roof Ponding Areas

Roof ponding measures can be designed for rainfall events of all sizes. However, the structural loads associated with the impounded runoff may impose limitations on their use. This is especially true if ponding areas must also accommodate runoff derived from adjacent roof surfaces.

Flat roofs can be converted to ponding areas by restricting the flow to downspouts. Figure 2 shows a simple device that can be used to modify downspout inlets. The device features drain holes that retard outflow as the water level rises and a weir ring that allows free drainage once the design ponding level is attained. It is essential that a structural engineer verify that the existing roof can carry this extra weight. Some form of emergency overflow is advisable and can be as simple as a free overflow through a notch in the roof parapet wall.

Figure 2

Modification of Downspout Inlet (Adapted from Tourbier, 1974)



The inputs needed for analysis of roof ponding systems are similar to those needed for design of dry ponds and other runoff peak attenuation facilities. These are:

- Input hydrograph
- Depth-storage function
- Depth-discharge function

Because the roof is impermeable, the runoff hydrograph is simply the rainfall distribution for the design storm multiplied by the area of the roof.

The depth to storage relationship can be computed from the topography of the roof. For perfectly flat roofs, the storage volume of a ponding level is equal to the roof area times the ponding level.

The depth-discharge relationship is unique to the outlet device used. For simple ponding rings, the following discharge equation can be used:

O = 3.141 CD(d - H)3/2

where:

O = outflow rate (cfs)
C = discharge coefficient (typically 3.0 but may vary depending on the shape the flow device)
D = diameter of the ring (ft)
d = depth of ponding (ft)
H = height of the ring (ft)

With this information, the attenuation effectiveness of the roof ponding system can be predicted by using the Modified Puls or other storage-routing procedure. The performance of the ponding area can be adjusted by changing the height or diameter of the ponding ring.

Cisterns

Cisterns, or rainbarrels, are a method of collecting and storing rainwater for future use. Uses include irrigation, vehicle washing, toilet flushing, and laundry operation. Cisterns are effective for reducing runoff if they are used correctly. Cisterns must be designed to capture an appropriate volume of water that will be re-used onsite on a regular basis. Cisterns that are not used regularly will remain full, not collect rainfall from future storms, and not reduce runoff. Cistern pumps can be included in a design where an increase in water pressure is needed. Pumps should be designed to accommodate the necessary pressure and flow for the system.

Construction and Installation

The main construction guideline is to engage professionals who are experienced with rooftop runoff management BMP installation. Preferably, the same team can undertake all phases of the project from waterproofing to planting to ensure continuity from the design to construction process.

Additional Roof Loading

Additional loading is one of the main factors controlling the feasibility and cost of a rooftop runoff management BMP. New extensive green roofs can be accommodated in building design for a minor additional cost. Rooftop runoff management BMPs on an existing building need to consider the bearing capacity of the structure. It is also possible to use roof areas where point loading can be increased over columns or along a bearing wall, to allow areas for deeper growing medium and larger plants. A structural engineer must be consulted to verify roof and structure strength.

Access to the Roof

Access to the roof is required for inspection and maintenance. For example, materials need to be carried to the roof for soil and plant replacements. Suitable exterior or interior access or elevator stops need to be provided to allow this access. For 1- to 3-story structures, blower trucks or shingle lifts may be used.

Waterproof Membrane

A waterproof membrane is an essential component of a rooftop runoff management BMP. It is recommended that a membrane be installed at the same time the rooftop runoff management BMP is deployed. In addition, good drainage must be provided to prevent extended contact with water and reduce the possibility for leaks and for plant mortality due to drowning or rotting. Roof appurtenances such as parapets, skylights, mechanical systems, and vents should be well protected with a gravel skirt, and when necessary, weep drains.

If the waterproof membrane contains organic material (e.g., bitumen) plant roots may penetrate it. Also, the chemical composition of the membrane should be compatible with the surfaces with which it will be in contact. Membranes developed specifically for rooftop runoff management BMPs contain a root-deterring chemical or metal foil at the seams to prevent root damage (Peck and Kuhn, 2004).

Horizontal Strapping

On a roof slope greater than 20 degrees, horizontal strapping or other support systems must be installed to avoid slippage and slumping of the growing medium and plants.

Timing of Roof Planting

The timing of planting depends on the local climate and season. Planting in the summer may require additional irrigation. Fall planting depends on the availability of plants and whether there is sufficient time to allow for the plants to become established before late winter. Mid-spring planting (February–April) is recommended for much of Mississippi.

Common Problems

Consult with qualified design professional if any of the following occur:

- Weeds are present
- Vegetation is dead or diseased
- The structure is clogged
- The structure is damaged
- Clogging has occurred
- Other damage has occurred

Maintenance

Two to three yearly inspections are recommended to check for weeds and damage. After installation, weekly visits may be needed to ascertain the need for irrigation.

Both regular plant maintenance and maintenance of the waterproofing membrane are required. All rooftop runoff management measures must be maintained periodically. Furthermore, the vegetative measures require routine care and maintenance typical of any planted area. The maintenance includes attention to plant nutritional needs, irrigation as required during dry periods, and occasional weeding. The cost of maintenance can be significantly reduced by judiciously selecting hardy plants that will out-compete weeds. In general, fertilizers must be applied periodically. Fertilizing usually is not a problem on flat or gently sloping roofs where access is unimpeded and fertilizers can be uniformly broadcast. However, fertilization is not recommended if the roof is to be used for water quality improvement. Treading on the cover system should not damage properly designed vegetated roof covers. Maintenance contracts for routine care of the vegetative cover frequently can be negotiated with the installer.

Retrofits of existing roofs must incorporate easy access to gutters, drains, spouts, and other components of the roof drainage system. Foreign matter, including leaves and litter, should be removed promptly.

Narrower Residential Streets

Practice Description

This better site design practice promotes reducing the width of streets to lower the level of impervious cover associated with new residential development. By doing so, stormwater runoff and associated pollutant loads may also be reduced. Currently, many communities require residential street widths of 32, 36, and even 40 feet. Wide streets provide two parking lanes and two moving lanes, but they often provide more parking than is necessary. Narrowing street widths requires a more efficient use of the public realm and individual lots to match community needs. In many residential settings, street widths can be as narrow as 22 to 26 feet without sacrificing emergency access, on-street parking, or vehicular and pedestrian safety. Even narrower access streets can be used when only a handful of homes need to be served. Driveways make up an average of 20% of a subdivision's impervious surface, a figure which jurisdictions can reduce by allowing the use of alternative paving, shorter driveways, or even shared driveways (Schueler, 1995). Currently, developers often have little flexibility to design narrower streets because most communities require wide residential streets as a standard element of their local road and zoning standards. Revisions to current local road standards are often needed to promote greater use of narrower residential streets.

Planning Considerations

Narrower streets can be used in residential developments generating less than 500 or fewer average daily trips (ADT). Such developments generally consist of 50 single family homes. Narrower streets may also be feasible for streets generating 500 to 1,000 ADT. However, they will not work for arterials, collectors, streets that carry greater traffic volumes, and those streets on which traffic volume varies over time.

In most communities, existing local road standards will need to be modified to allow the use of narrower streets. Several communities have successfully implemented narrower streets, including Portland, Oregon; Bucks County, Pennsylvania; and Boulder, Colorado. In addition, there are numerous examples of communities where developers have successfully narrowed private streets within innovative subdivisions. Local communities may lack the authority to change road standards when state agencies retain the review of public roads, however. In these cases, street narrowing can be accomplished only on private streets that are maintained by residents rather than by a local or state agency.

Cities interested in adopting a narrow streets policy will benefit from consulting with a broad cross section of city officials and affected stakeholders, including public works departments, emergency personnel, residential communities, and business owners, among others. Outreach and local research can help correct misperceptions about the effects of narrow streets and can gain broader acceptance for their environmental, safety and aesthetic benefits (NSPS, 2000).

Design Criteria

Residential street design requires a balancing of competing objectives: design, speed, traffic volume, emergency access, parking, and safety. These objectives can be met in a much narrower roadway than that required by the traditional subdivision.

Safety

Roadway widths in residential areas with 50 homes or fewer can safely be as narrow as 22 feet, according to many national engineering organizations (CWP, 1998). Narrowing streets actually lowers traffic speeds, making streets safer (USDOT, 1997). By dedicating more of the right-of-way to pedestrians and bicyclists, street planners can also make these alternative forms of travel more attractive, further reducing the number of automobile trips and relieving traffic pressure on the roadway.

Emergency Access

Although emergency vehicle access is often given as the reason for wide roadway requirements in a subdivision, this may not be necessary. The U.S. Fire Administration indicates that a street width of 18 to 20 feet is adequate for accommodating a fire vehicle (CWP, 1998).

Parking

The right-of-way associated with parking provides a great deal of design flexibility for reducing impermeable surface. There are some cases where on-street parking may not be desirable at all. Where the street provides space for parking, however, alternative paving surfaces, like pervious pavers, can reduce the overall impervious cover. Extending the curb and devoting some existing parking spots to stormwater management is another design alternative. Streets with angled parking accommodate this strategy well. By taking in just one or two spaces, street designers can incorporate a rain garden within the curbline at the corner or the midblock (ICF, 2009).

Common Problems

Real and perceived barriers hinder wider acceptance of narrower streets at local levels. Advocates for narrower streets need to respond to the concerns of local agencies and the general public. Some of the more frequent concerns about narrower streets are listed below.

Inadequate On-Street Parking. Recent research and local experience have demonstrated that narrow streets can adequately accommodate residential parking demand. A single-family home typically requires 2 to 2.5 parking spaces. In most residential zones, this parking demand can be satisfied by one parking lane on the street and a driveway.

Car and Pedestrian Safety. Recent research indicates that narrow streets have lower accident rates than wide streets. Narrow streets tend to lower vehicle speeds and act as traffic-calming devices. Furthermore, sidewalk access can be provided if needed. Although this might add additional impervious area, net impervious area can be decreased due to greater reductions in street width.

Emergency Access. When designed properly, narrower streets can easily accommodate fire trucks, ambulances, and other emergency vehicles.

Large Vehicles. Field tests have shown that school buses, garbage trucks, moving vans, and other large vehicles can generally safely negotiate narrower streets, even with cars parked on both sides.

Utility Corridors. It is often necessary to place utilities underneath the street rather than in the right-of-way.

Maintenance

Narrower streets should slightly reduce road maintenance costs for local communities, since they present a smaller surface area to maintain and repair.

Riparian/Forested Buffer

Photo Source: NRCS

Practice Description

Riparian buffers are natural or constructed ecosystems along a shoreline, wetland, or stream where trees, grasses, shrubs, and herbaceous plants filter pollutants from stormwater runoff and shallow groundwater flow prior to discharge to receiving waters. Buffers are designed to remove sediment and other insoluble contaminants from runoff, to allow increased time for infiltration of soluble nutrients and pesticides, and to protect aquatic habitat by providing shade to watercourses to help maintain temperature norms and sound barriers to or from outside areas. Buffer zones also provide natural visual aesthetics for all land disturbance activities. Where natural buffer zones are not present or are inadequate, artificial buffer zones may be engineered using silt fences, diversions, vegetative practices and other BMPs. For additional information on Stream Protection, review the final section of Chapter 4 of Volume 1.

There are three primary types of buffers: water pollution hazard setbacks, vegetated buffers, and engineered buffers. Water pollution hazard setbacks are areas separating potential pollution hazards from waterways. Vegetated buffers are natural areas that divide land uses or provide landscape relief. Engineered buffers are specifically designed to treat stormwater before it enters streams, lakes, or wetlands.

Planning Considerations

Buffers can be applied to new development through the establishment of specific preservation areas and by sustaining management through easements or community associations. For existing developed areas, an easement may be needed from adjoining landowners. A local ordinance can help set specific criteria for buffers to achieve stormwater management goals.

Buffer zones will vary depending on location and application. In some cases, their water quality objectives may be combined with a screening function for the noise and visual pollution of construction activities. Separate criteria will apply for various forms of land-disturbing activities:

1. Activities adjacent to a perennial stream or permanent water body
2. Silvicultural operations
3. Construction or other land-disturbing activities
4. Agricultural activities

The State of Mississippi does not require formal designs or plans for buffers except in the case of activities adjacent to a permanent water body, in which case a description of the water body, slope of adjacent land, and erodibility of soils in the area will be provided to support buffer zone width selection. If an artificial buffer zone is required, pertinent design information will be provided.

Design Criteria

For optimal stormwater treatment, the following buffer designs are recommended. The buffer should consist of three lateral zones: a stormwater depression area leading to a grass filter strip that, in turn, leads to a forested buffer. The stormwater depression is designed to capture and store stormwater during smaller storm events and bypass larger storm flows directly into a channel. Runoff captured within the stormwater depression can then be spread across a grass filter designed for sheet flow conditions. The grass filter then discharges into a wider forest buffer designed to have zero discharge of surface runoff to the stream or full infiltration of sheet flow.

In general, a minimum width of at least 150 feet is recommended to provide adequate stream protection. The three-zone buffer system, consisting of inner, middle, and outer zones, is an effective technique for establishing a buffer. The zones are distinguished by function, width, vegetative target, and allowable uses.

– The inner zone protects physical and ecological integrity. It consists of a minimum of 25 feet plus wetland and critical habitats. The vegetative target consists of mature forest. Its allowable uses are restricted to flood controls, utility rights-of-way, footpaths, etc.

– The middle zone provides distance between upland development and the inner zone. It is typically 50 to 100 feet depending on stream order, slope, and 100-year floodplain. The vegetative target for this zone is managed forest. Usage is restricted to some recreational activities, some stormwater BMPs, and bike paths.

– The outer zone is the first zone to encounter runoff. It functions to prevent encroachment while slowing and filtering backyard runoff. The outer zone's width is at least 25 feet and, while forest is encouraged, turf-grass can be a vegetative target. The outer zone's uses are unrestricted. They can include lawn, garden, compost, yard wastes, and most stormwater BMPs ("Riparian Buffer," USEPA 2006).

Construction and Installation

General

Runoff from the disturbed areas should not be channeled into the buffer zone, but rather allowed to spread out over the entire buffer zone length. For concentrated flows, a level spreader may be required to allow for the proper functioning of the buffer zone.

Where a natural buffer zone is not available, or the required zone width is not attainable, provide flow barriers such as diversions, sediment traps, vegetative planting, and silt fences as needed.

Construction or Other Land-Disturbing Activities Adjacent to a Perennial Stream or Permanent Water Body

This represents the most stringent requirement that applies to buffer zones. At a minimum, a 150′ buffer zone will be left between the land disturbance activity and a water body. The buffer zone width may be greater than 150′ depending upon the soil type and slope of adjacent land.

Buffer Zones Adjacent to Permanent Water Bodies

Soil Erosion Hazard	Recommended Buffer Zone Width (Ft) (% Slope)		
	30	40	50
Slight			155
Moderate		170	200
Severe	170	210	250

**** Refer to County Soil survey for erosion hazard. MS Forestry Commission's Mississippi BMPs Handbook states that distances should be doubled for disturbed areas in municipal watersheds.**

Silvicultural Operations

Buffer zone requirements will adhere to the guidance provided by the Mississippi Forestry Commission (MFC) for silvicultural Best Management Practices including Streamside Management Zone and Filter Strip. For areas not adjacent to a permanent water body, a buffer zone of 15′ will be maintained on the perimeter of all silvicultural operations adjacent to property boundaries and public rights-of-way.

Construction or other Land-Disturbing Activities

For areas not adjacent to a permanent water body, a buffer zone of 15′ will be maintained on the perimeter of the construction site. This buffer zone will:

1. Reduce runoff velocities.

2. Filter sediment from runoff.

3. Act as a screen for "vision pollution."

4. Reduce construction and adjacent noise levels.

5. Reduce dust problems.

6. Improve the aesthetics of the area.

This type of buffer zone may be crossed by construction entrances, utilities construction, etc., but where natural vegetation is removed for these purposes, artificial buffer zone measures should be installed (e.g. construction entrance BMP, silt fence, diversion, etc.).

These post-construction measures should be incorporated into the design of the final post-construction landscape providing a permanent green strip on the perimeter of the completed project.

Common Problems

The table below describes some common obstacles to the best performance of riparian buffers at removing pollutants from stormwater and the design factors that can enhance their performance.

Factors that Enhance/Reduce Buffer Pollutant Removal Performance
(“Riparian Buffers,” USEPA 2006)

Factors that Enhance Performance	Factors that Reduce Performance
Slopes less than 5%	Slopes greater than 5%
Contributing flow lengths <150 feet.	Overland flow paths over 300 feet
Water table close to surface	Ground water far below surface
Check dams/level spreaders	Contact times less than 5 minutes
Permeable but not sandy soils	Compacted soils
Growing season	Non-growing season
Long length of buffer or swale	Buffers less than 10 feet
Organic matter, humus, or mulch layer	Snowmelt conditions, ice cover
Small runoff events	Runoff events >2 year event.
Entry runoff velocity less than 1.5 feet/sec	Entry runoff velocity more than 5 feet/sec
Swales that are routinely mowed	Sediment buildup at top of swale
Poorly drained soils, deep roots	Trees with shallow root systems
Dense grass cover, 6 inches tall	Tall grass, sparse vegetative cover

Maintenance

An effective buffer-management plan offers many aesthetic, environmental, and recreational benefits but must be adequately managed to function properly. The initial design should include establishment, management, and distinctions of allowable and prohibited uses in the buffer zones. Buffer boundaries should be well defined and visible before, during, and after construction. Without clear signs or markers defining the buffer, its boundaries can become invisible to local governments, contractors, and residents. In some cases, these sites may even be used as dumping grounds for those unaware of their purpose of protecting water quality. Regular clean-up and landscape maintenance will ensure that riparian buffers remain an asset to the community and build public support for the continued use of riparian buffers as a stormwater management practice (NCDENR, 2007). Particular attention must be paid to buffers designed to capture urban stormwater runoff. These sites will require more maintenance if the first zone is designated as a bioretention or other engineered depression area ("Riparian Buffer," USEPA 2006).

Grassed Swales

Practice Description

In the context of BMPs to improve water quality, the term swale (a.k.a. grassed channel, dry swale, wet swale, biofilter, or bioswale) refers to vegetated, open-channel management practices designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. Swales remove pollutants from stormwater by biofiltration, settling, and infiltration. Grassed swales filter pollutants as stormwater runoff moves through the leaves and roots of the grass. By reducing flow velocities and increasing a site's time of concentration, grassed swales contribute to reducing runoff peaks. Grassed swales that are designed with check dams or incorporate depression storage promote infiltration and can help contribute to satisfying a site runoff capture/storage requirement.

Variations of the grassed swale include the grassed channel, dry swale, and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch. These designs incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

Planning Considerations

Grassed swales can be applied in most situations with some restrictions. Swales are well suited for treating highway or residential road runoff because they are linear practices. Swales are also useful as one of a series of stormwater BMPs or as part of a treatment train, for instance, conveying water to a detention pond and receiving water from filter strips. Furthermore, swales are highly recommended by the proponents of design approaches such as Low Impact Development and Better Site Design.

The use of grassed swales in new development can be a cost-effective alternative to curb and gutter installation. The swale practices are considered more aesthetically pleasing, although there is the potential for standing water and possible mosquito infestations.

The effectiveness of a swale in both reducing the flow rates and volume of runoff, and removing pollutants, is a function of the size and composition of the drainage area, the slope and cross section of the channel, the permeability of the soil, the density and type of vegetation in the swales, and the swale dimensions. Broad swales on flat slopes with dense vegetation are the most effective. Removal efficiencies are highest for sediment-bound pollutants.

Design Criteria

In addition to the broad applicability concerns described above, designers need to consider site conditions. In addition, they need to incorporate design features to improve the longevity and performance of the practice while minimizing the maintenance burden.

Converting Erosion- and Sediment-Control Devices

Swales are often used as erosion- and sediment-sediment control measures during active construction. The same swales can later be used as grassed swale BMPs; however, all of the sediment must be removed, the channel configuration and slope must be re-established (if necessary), and the proper vegetation must be established. See the Grass Swale practice under Runoff Conveyance in Chapter 4 of Volume 1 of this Manual for more information on grass swales as erosion- and sediment-control devices.

Siting Considerations

In addition to considering the restrictions and adaptations of grassed swales to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question because some site conditions (i.e., steep slopes, highly impermeable soils) might restrict the effectiveness of grassed channels.

Drainage Area

Grassed swales should generally treat runoff from small drainage areas (less than 5 acres). If used to treat larger areas, the flows through the swale become too large to produce designs to treat stormwater runoff in addition to conveyance.

Capacity

The capacity of the swale must also be checked to ensure that it will be adequate after vegetation is fully established. The resistance to flow should be evaluated using the NRCS retardance factor for the vegetation selected (consult *Grass Swale* in Chapter 4 of Volume 1).

The flow depth of the design event should be evaluated using Manning's equation for the swale type used (parabolic, trapezoidal, or V-shaped). The design requirement is that the swales convey the design discharge while maintaining a 0.5-foot freeboard and without exceeding the maximum permissible velocity.

If driveways or roads cross the swale, the capacity of the culvert crossing the road or driveway may determine the depth of flow for the design event. In these instances, the culverts should be checked to establish that the backwater elevation does not exceed the banks of the swale. If the culvert discharges to a minimum tailwater condition, the exit velocity for the culvert should be evaluated for design conditions. If the maximum permissible velocity is exceeded at the culvert outlet, riprap or another measure to prevent scour must be used.

Slope

Grassed swales should be used on sites with relatively flat slopes of less than 4 percent slope; 1 to 2 percent slope is recommended. When site conditions require installing the swales in areas with larger slopes, check dams can be used to reduce the influence of the slope. Runoff velocities within the channel become too high on steeper slopes. This can cause erosion and does not allow for infiltration or filtering in the swale.

Soils/Topography

Grassed swales can be used on most soils, with some restrictions on the most impermeable soils. In the dry swale (see Design Variations section below), a fabricated soil bed replaces on-site soils in order to ensure that runoff is filtered as it travels through the soils of the swale.

Groundwater

The required depth to groundwater depends on the type of swale used. In the dry swale and grassed channel options, the bottom of the swale should be constructed at least 2 feet above the groundwater table to prevent a moist swale bottom or contamination of the groundwater. In the wet swale option, treatment is provided by creating a standing or slow-flowing wet pool, which is maintained by intersecting the groundwater.

Design Considerations

Although there are different design variations of the grassed swale (see Design Variations), some design considerations are common to all designs. An overriding similarity is the cross-sectional geometry. Swales often have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1), though rectangular and triangular channels can also be used. Designing the channel with flat side slopes increases the wetted perimeter. The wetted perimeter is the length along the edge of the swale cross section where runoff flowing through the swale contacts the vegetated sides and bottom. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage sorption, filtering, and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope.

Another similarity among designs is the type of pretreatment needed. In all design options, a small forebay should be used at the front of the swale to trap incoming sediments. A pea gravel diaphragm, a small trench filled with river-run gravel, should be constructed along the length of the swale and used as pretreatment for runoff entering the sides of the swale. Other features designed to enhance the performance of grassed swales are a flat longitudinal slope (generally between 1 percent and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the flow velocity within the channel. The dense vegetation also helps reduce velocities, protects the channel from erosion, and acts as a filter to treat stormwater runoff. During construction, it is important to stabilize the channel while the vegetation is becoming established, either with a temporary grass cover or with natural or synthetic erosion-control products. In addition to treating runoff for water quality, grassed swales must convey runoff from larger storms safely. Typical designs allow the runoff from the 2-year storm (i.e., the storm that occurs, on average, once every two years) to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms (typically a 10-year storm) safely.

Ponding and Infiltration

Ponding can be beneficial if intended and accepted, or it can be a negative if unintended. If unintended and not designed for, extended periods of standing water may result in nuisance conditions and create complaints from residents. Mosquitoes are typically the biggest concern; however, they should generally not be a problem because of the frequent flushing of the ponded water. Also, if wetland vegetation develops, mosquito predators such as other insects and birds often mitigate the mosquito problem. If wetland vegetation and standing water are persistent concerns, these problems can be reduced by maintaining more uniform, steeper slopes in the swale invert or by installing underdrains.

If temporary retention of small amounts of water is desired for enhanced treatment of the stormwater and ecological and visual diversity, there are many ways to achieve that goal. The paragraphs below discuss several methods for retaining water or otherwise modifying the typical swale hydrology. The retained water will infiltrate, be lost through evapotranspiration, or slowly released downstream. It should be noted that the maximum allowable ponding time within a channel is 48 hours, and an underdrain system must be provided if that requirement cannot be met.

Check Dams

A check dam is constructed of earth, stone, or timber 3 to 6 inches high to retain runoff from routine events. A weep hole may be added to enable the area behind an earthen or timber dam to drain slowly. However, the weep hole may be subject to clogging. Shorter check dams can act as level spreaders to help distribute the flow along the swale’s cross section.

Elevated Drop Inlets

A drop inlet can be used when a combined system of swales and storm sewers is being used. The swales would serve as the collector system, and the inlet into the main storm sewer system would be elevated slightly to retain runoff from routine events. The height of elevation would depend on the soil, the slope of the swale, and the tolerance for ponding. Wetland vegetation may develop in the ponded areas if the underlying soils are poorly drained.

Elevated Culverts

Elevated culverts are used for the same purpose as check dams and elevated drop inlets, to retain runoff from routine events. As with elevated drop inlets, wetland vegetation may develop in the ponded areas if the underlying soils are poorly drained.

Depression Storage

Small depressions along the bottom of the swale will trap and store stormwater for later infiltration into the soils. These depressions will also likely accumulate sediment at a quicker pace than other parts of the swale, and will also probably develop wetland vegetation.

Underdrains

Underdrains can enhance the performance of swales by providing additional filtration through soil, similar to the process that takes place in bioretention facilities. These “bioretention” swales have a layer of engineered soil underlain by a gravel layer surrounding a perforated pipe. This configuration also reduces ponding time where standing water may be a concern.

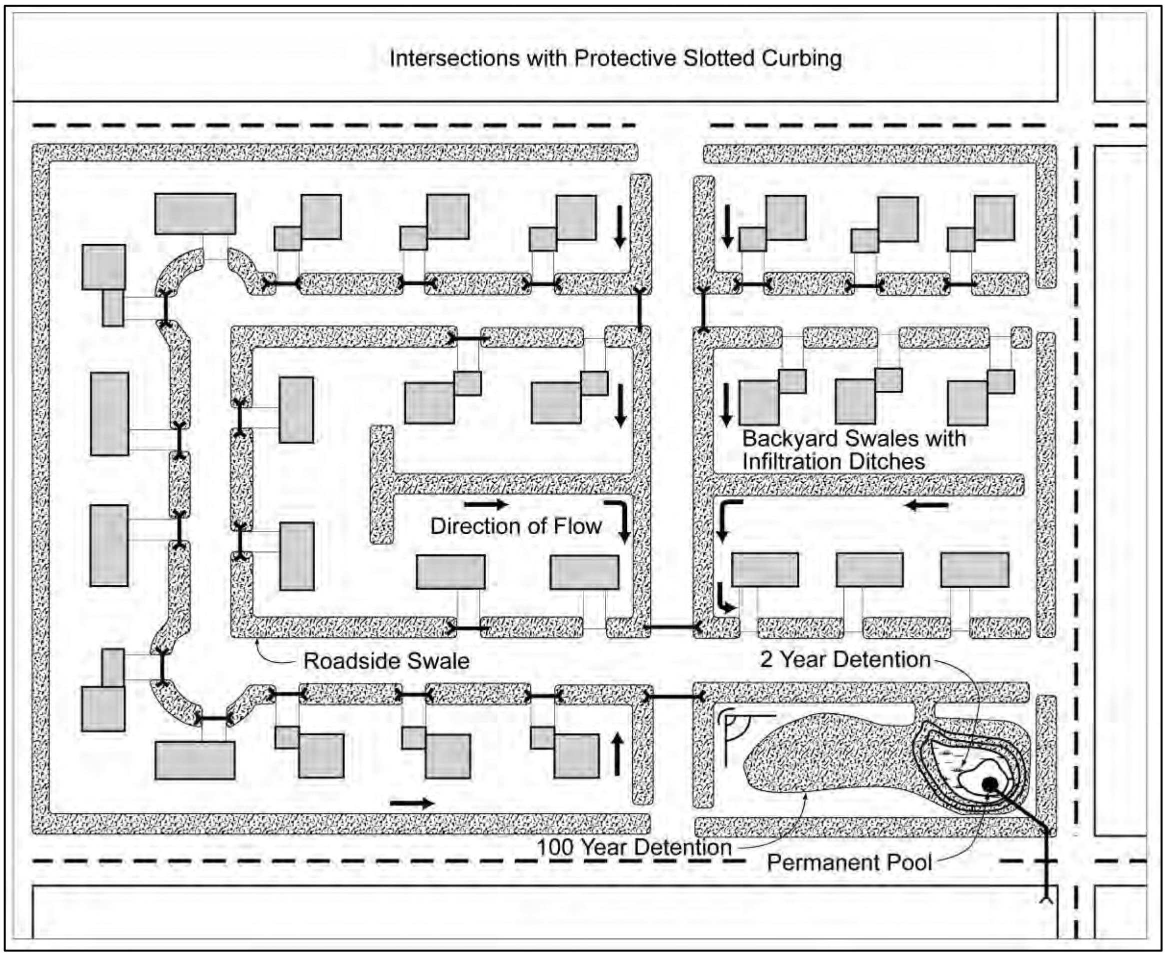


Figure 1 Schematic of Plan for Retrofit of Grassed Swales in Residential Subdivision

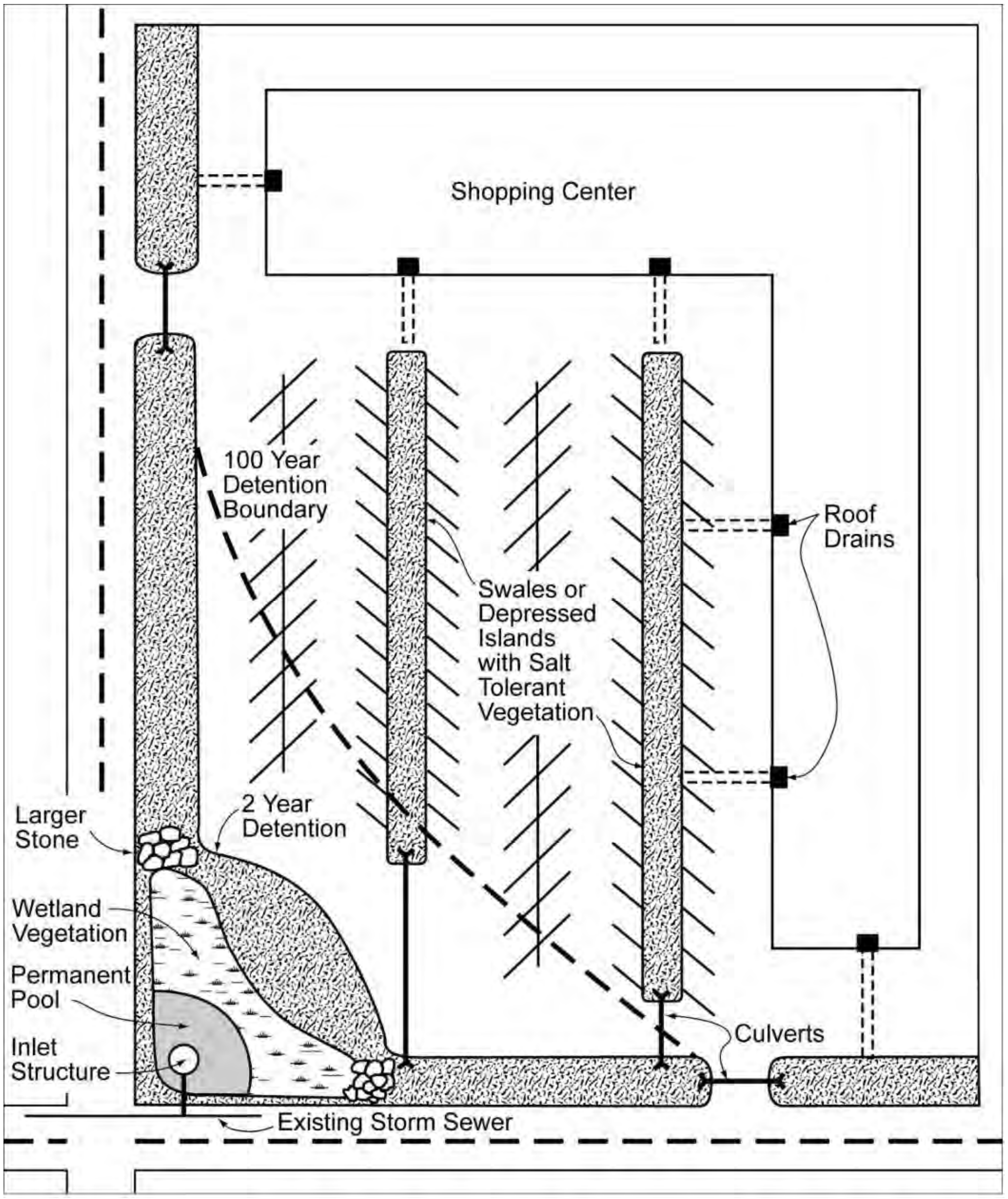


Figure 2 Example of Grassed Swale Used for Parking Lot

Design Variations

The following discussion identifies three variations of open-channel practices—the grassed channel, dry swale, and wet swale.

Grassed Channel

Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Of all of the options, grassed channels are the least expensive but also provide the least reliable pollutant removal. An excellent application of a grassed channel is as pretreatment to other structural stormwater practices. A major difference between the grassed channel and many other structural practices is the method used to size the practice. Most stormwater-management water quality practices are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel is a flow rate-based design. Based on the peak flow from the water quality storm, the channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in *Design of Stormwater Filtering Systems* (CWP, 1996).

Dry Swales

Dry swales are similar in design to bioretention areas (see *Bioretention Practice*). These designs incorporate a fabricated soil bed into their design. The native soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is installed at the bottom of the soil bed. This underdrain is a gravel layer that encases a perforated pipe. Stormwater treated in the soil bed flows into the underdrain, which routes this treated stormwater to the storm drain system or receiving waters. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal.

Wet Swales

Wet swales intersect the groundwater and behave similarly to a linear wetland cell (see *Constructed Stormwater Wetland Practice*). This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. This design also has potentially high pollutant removal. Wet swales are not commonly used in residential or commercial settings because the shallow standing water may be a potential mosquito breeding area.

Construction Considerations

To maximize the infiltration capacity of the swale, compaction of the soil underlying the swale should be avoided. For example, equipment for excavating or grading should operate from the side of the swale instead of the bottom of the swale.

Before vegetation is established in a swale, the swale is particularly vulnerable to scour and erosion. Therefore, protecting the seedbed with a temporary erosion-resistant lining (such as a geosynthetic or fiberglass roving) or other suitable erosion controls is generally necessary. Most vendors will furnish information about the Manning's coefficient (*n*) and will also specify the maximum permissible velocity or allowable unit tractive force (also referred to as the "tractive stress") for the lining material. Swales should be constructed and vegetated early in the construction schedule, preferably before area grading and paving increase the rate of runoff.

Temporary erosion-resistant channel linings should be used to stabilize the swale until the vegetation becomes established. The vendor's instructions for installing channel linings should be followed. If velocities will be high, designers should consider sodding the swale or diverting runoff until vegetation is established.

Common Problems

Grassed swales are relatively low-maintenance BMPs, but some potential problems include the following:

- Ponded water makes swale difficult to mow, and can cause nuisance problems such as odors, discoloration, and mosquitoes.
- Erosion due to improper vegetation establishment.
- Sediment accumulation due to inadequate erosion-control upstream.

Maintenance

Routine maintenance of grassed swales will include the removal of trash and debris.

If bare soil or signs of erosion are evident, regrade the soil to remove gully erosion and then re-sod and water until established.

Sediment should be removed if it accumulates within the swale.

Infiltration Basin

Practice Description

An infiltration basin is a shallow impoundment that is designed to infiltrate stormwater into the soil. This practice is believed to have a high pollutant-removal efficiency and can also help recharge the groundwater, thus increasing baseflow to stream systems. Infiltration basins can be challenging to apply on many sites, however, because of soils requirements. In addition, some studies have shown relatively high failure rates compared with other management practices.

Planning Considerations

Infiltration basins have select applications. Their use is often sharply restricted by concerns over groundwater contamination, soils, and clogging at the site. They work best in relatively small drainage areas and in drainage areas that are completely impervious or stable (to minimize the amount of sediment going to the BMP). Infiltration basins are frequently used to infiltrate runoff from adjacent impervious surfaces, such as parking lots. In these cases, a filter strip should be installed between the pavement and the device to trap sediment and litter before it is washed into the device. Another approach is to construct infiltration devices at the downgradient edges of areas with permeable pavement. In this case, the permeable pavement is the inlet to the device. Because water also will infiltrate through the base of the pavement, the size of the infiltration devices can be reduced significantly.

Design Considerations

When designing infiltration basins, designers need to carefully consider both the restrictions on the site and design features to improve the long-term performance of the practice.

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most infiltration basin designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, outlet, and landscaping.

Pretreatment

Pretreatment devices for removing sediment and solids must be used to protect infiltration devices from clogging. A few options for pretreatment include filter strips, grassed swales with check dams, concrete sumps, and forebays (sediment traps).

Consideration should be given to the inlet when infiltration facilities are designed. The type of inlet will depend on whether the upgradient source of runoff is overland flow or a concentrated source of discharge. Infiltration trenches require relatively even distribution over their length. An infiltration basin can be designed to accommodate a concentrated influent flow; however, an energy dissipater and/or level spreader may be needed.

Treatment

Treatment design features enhance the pollutant removal of a practice. For infiltration practices, designers need to stabilize upland soils to ensure that the basin does not become clogged with sediment. In addition, the facility needs to be sized so that the volume of water to be treated infiltrates through the bottom in a given amount of time. Because infiltration basins are designed in this manner, infiltration basins designed on less permeable soils should be significantly larger than those designed on more permeable soils.

Conveyance

Stormwater needs to be conveyed through stormwater-management practices safely and in a way that minimizes erosion. Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. In general, infiltration basins should be designed to treat only small storms (i.e., only for water quality). Thus, these practices should be designed “off-line,” using a flow separator to divert only small flows to the practice.

Outlet Design

Infiltration devices, by their very nature, do not have regular outlet devices. (The stormwater entering the BMP leaves through the soils.) They should, however, be designed with dewatering provisions in the event of failure. It can be dewatered by pumping out or allowed to gravity-drain through a pipe. If a dewatering outlet pipe is installed to facilitate emergency draining, a lockable watertight valve must be installed and kept closed at all times.

Landscaping

Landscaping can enhance the aesthetic value of stormwater practices or improve their function. In infiltration basins, the most important purpose of vegetation is to reduce the tendency of the practice to clog. Upland drainage needs to be properly stabilized with a thick layer of vegetation, particularly immediately following construction. In addition, providing a thick turf at the basin bottom helps encourage infiltration and prevent the formation of rills in the basin bottom.

Siting Considerations

Infiltration practices need to be located extremely carefully. In particular, designers need to ensure that the soils on the site are appropriate for infiltration, and that designs minimize the potential for groundwater contamination and long-term maintenance problems.

Converting Erosion- and Sediment-Control Devices

Often, the same basin can be used during construction as an erosion- and sediment-control device and later converted to an infiltration basin. Before conversion, all accumulated sediment must be removed and properly disposed of. Then, the appropriate modifications to the basin depth, geometry, and hydrology, as well as inlet and outlet structures, etc., must be made. A minimum of 6 inches of bottom material (below the design bottom of the original sediment and erosion control device) must be removed prior to conversion to a stormwater BMP, so appropriate design bottom depth changes must be considered. It is essential that the site be completely stabilized before the erosion- and sediment-control devices are removed or converted.

Drainage Area

Infiltration basins have historically been used as regional facilities, serving for both water-quantity and water-quality control. In general, the practice is best applied to relatively small drainage areas (i.e., less than 10 acres).

Slope

The bottom of an infiltration basin needs to be completely flat to allow infiltration throughout the entire basin bottom.

Soils/Topography

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the practice can infiltrate quickly enough to reduce the potential for clogging. Soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for groundwater contamination. A *site-specific* hydrogeologic investigation shall be performed to establish the suitability of site soils for the BMP. To be suitable for infiltration, underlying soils must have an infiltration rate of 0.52 inch per hour or greater, as initially determined from NRCS soil textural classification (typically hydrologic soil groups A and B) and subsequently confirmed by field geotechnical tests.

Groundwater

Designers always need to provide significant separation distance (2 to 5 feet) from the bottom of the infiltration basin and the seasonally high groundwater table, to reduce the risk of contamination. Infiltration practices should also be separated from drinking water wells.

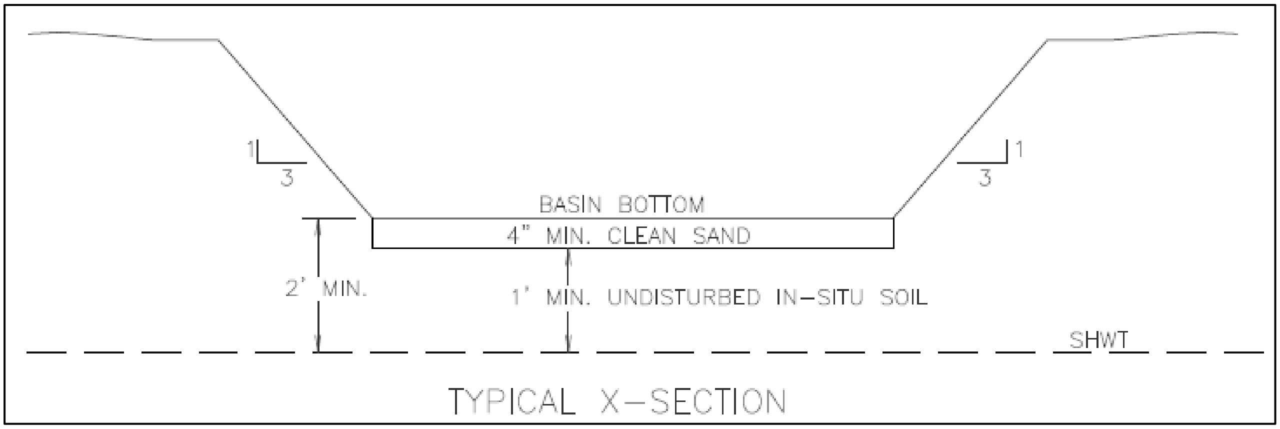


Figure 1 Typical Infiltration Basin: Cross Section
(Note: Retaining walls may be used in place of 3:1 vegetated side slopes)

Construction Considerations

Care should be used during installation to minimize compaction of soil on the bottom and walls of infiltration devices, since this will reduce the permeability at the soil interface. To avoid compacting the drainage media, lighter weight equipment and construction techniques that minimize compaction should be used.

Runoff shall not be directed into an infiltration device until the drainage area is stabilized. A construction sequence must be followed that reflects the need to stabilize the infiltration device. The longevity of infiltration devices is strongly influenced by the care taken during construction.

A minimum of one observation well shall be included in the design of an infiltration system to periodically verify that the drainage media are fully draining. The monitoring well shall consist of a 4- to 6-inch-diameter, perforated polyvinyl chloride (PVC) pipe with a locking cap. The well should be placed near the center of the facility or in the general location of the lowest point within the facility, with the invert at the excavated bottom of the facility.

Length, Width, Depth and Geometry

The sizing of an infiltration device is determined by the dewatering requirements. Infiltration devices must be able to completely dewater within 5 days. The time to dewater can be estimated roughly as the runoff capture volume for the device divided by the product of the hydraulic conductivity and the effective infiltrating area. This can be rearranged to produce the following equation for determining the effective infiltrating area needed:

$$A = \frac{V}{2 * (K * T)}$$

where:

A = effective infiltrating area (ft^2)
V = volume of water requiring infiltration (ft^3)
K = hydraulic conductivity of soil (in/hr)
T = dewatering time (days)

The volume of water requiring infiltration (V) is prescribed by the specific stormwater program that applies to the site, and the runoff characteristics of the site. If the infiltration device is not going to meet the volume control requirements, it is simply the volume of water that is diverted and stored for infiltration. The runoff capture storage volume of an infiltration device that is filled with a drainage medium is equal to the volume of the facility, multiplied by the porosity of the medium, plus any temporary ponding that may be allowed before the facility overflows.

The hydraulic conductivity of the soil (K) is the resultant value from the field testing performed on the site. The dewatering time (T) for infiltration devices must be 5 days or less. A value of less than 3 days is recommended for use in the formula.

Once the effective infiltrating area (A) is obtained from the formula, it can still be somewhat difficult to translate that into actual infiltration device dimensions. The value for A used in the formula is actually the larger of either the bottom surface area or one-half of the total (wetted) wall area. The determination of the length, width, and depth dimensions is therefore often an iterative process using the effective infiltrating area (A); the correction factor for true surface areas of the in situ soil interface; and typical length, width, and depth recommendations.

Infiltration basins may appear in a variety of geometries. Runoff frequently is piped to these devices from stormwater inlets on patios, parking areas, roofs, and other impervious areas. These devices may also receive runoff via sheet flow.

Common Problems

Although infiltration basins can be useful practices, they have several limitations. Infiltration basins are not generally aesthetic practices, particularly if they clog. If infiltration basins are designed and maintained so that standing water is left for no more than 3 days, mosquitoes should not be a problem. However, if an infiltration basin becomes clogged and takes 4 or more days to drain, the basin could become a source for mosquitoes. In addition, these practices are challenging to apply because of concerns over groundwater contamination and sufficient soil infiltration. Finally, maintenance of infiltration practices can be burdensome, and they have a relatively high rate of failure.

Maintenance

Regular maintenance is critical to the successful operation of infiltration basins.

Immediately after the infiltration basin is established, the vegetation will be watered twice weekly if needed until the plants become established (commonly six weeks).

No portion of the infiltration basin will be fertilized after the initial fertilization that is required to establish the vegetation.

If areas of bare soil and/or erosive gullies form, regrade the soil to remove the gully, plant a ground cover, and water until it has established.

The vegetation in and around the basin will be maintained at a height of approximately six inches.

Should sediment accumulation reach 75% of the original design depth, the source of sediment should be identified and remedied. The sediment shall be removed and the basin restored to original design specifics.

Infiltration Trench

Practice Description

An infiltration trench (a.k.a. infiltration galley) is a rock-filled trench with no outlet that receives stormwater runoff. Stormwater runoff passes through some combination of pretreatment measures, such as a swale and detention basin, and into the trench. There, runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. The primary pollutant removal mechanism of this practice is filtering through the soil.

Planning Considerations

Infiltration trenches have select applications. Although they can be applied in a variety of situations, the use of infiltration trenches is restricted by concerns over groundwater contamination, soils, and clogging.

Infiltration trenches are frequently used to infiltrate runoff from adjacent impervious surfaces, such as parking lots. In these cases, a filter strip should be installed between the pavement and the device to trap sediment and litter before they are washed into the device. Another approach is to construct infiltration trenches at the downgradient edges of areas with permeable pavement. In this case, the permeable pavement is the inlet to the device. Because water also will infiltrate through the base of the pavement, the size of the infiltration devices can be reduced significantly.

Design Criteria

Infiltration trenches are filled with large crushed stone or other media to create storage for the stormwater in the voids between the media. Other versions use precast concrete vaults with open bottoms to provide a large storage volume to hold stormwater for infiltration into the soil. Infiltration trenches are usually used to manage the runoff from parking lots and buildings.

Converting Erosion- and Sediment-Control Devices

Infiltration trenches shall not be used as sediment- and erosion-control devices.

Siting Considerations

Infiltration practices need to be sited extremely carefully. In particular, designers need to ensure that the soils on site are appropriate for infiltration and that designs minimize the potential for groundwater contamination and long-term maintenance.

Drainage Area

Infiltration trenches generally can be applied to relatively small sites (less than 5 acres), with relatively high impervious cover. Application to larger sites generally causes clogging, resulting in a high maintenance burden.

Slope

Infiltration trenches should be placed on flat ground, but the slopes of the site draining to the practice can be as steep as 15 percent.

Soils/Topography

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the stormwater can infiltrate quickly enough to reduce the potential for clogging. In addition, soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for groundwater contamination. To be suitable for infiltration, underlying soils must have an infiltration rate of 0.52 inch per hour or greater, as initially determined from NRCS soil textural classification (typically hydrologic soil groups A and B) and subsequently confirmed by field geotechnical tests. The infiltration rate and textural class of the soil need to be confirmed in the field; designers should not rely on more generic information such as a soil survey. Finally, infiltration trenches may not be used in regions of karst topography, due to the potential for sinkhole formation or groundwater contamination.

Groundwater

Designers always need to provide significant separation (2 to 5 feet) from the bottom of the infiltration trench and the seasonally high groundwater table, to reduce the risk of contamination. In addition, infiltration practices should be separated from drinking water wells.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most infiltration trench designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural stormwater-management practices, but it is particularly important for infiltration practices. To ensure that pretreatment mechanisms are effective, designers should incorporate “multiple pretreatment,” using practices such as grassed swales, vegetated filter strips, detention, or a plunge pool in series.

Treatment

Treatment design features enhance the pollutant removal of a practice. During the construction process, the upland soils of infiltration trenches need to be stabilized to ensure that the trench does not become clogged with sediment. Furthermore, the practice should be filled with large clean stones that can retain the volume of water to be treated in their voids. Like infiltration basins, this practice should be sized so that the volume to be treated can infiltrate out of the trench bottom in 24 hours.

Conveyance

Stormwater needs to be conveyed through stormwater management practices safely, and in a way that minimizes erosion. Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. Infiltration trenches should be designed to treat only small storms, (i.e., only for water quality). Thus, these practices should be designed “off-line,” using a structure to divert only small flows to the practice. Finally, the sides of an infiltration trench should be lined with a geotextile fabric to prevent flow from causing rills along the edge of the practice.

Maintenance Reduction

In addition to regular maintenance activities, designers also need to incorporate features into the design to ensure that the maintenance burden of a practice is reduced. These features can make regular maintenance activities easier or reduce the need to perform maintenance. As with all management practices, infiltration trenches should have an access path for maintenance activities. An observation well (i.e., a perforated PVC pipe that leads to the bottom of the trench) can enable inspectors to monitor the drawdown rate. Where possible, trenches should have a means to drain the practice if it becomes clogged, such as an underdrain. An underdrain is a perforated pipe system in a gravel bed, on the bottom of filtering practices, installed to collect and remove filtered runoff. An underdrain pipe with a shutoff valve can be used in an infiltration system to act as an overflow in case of clogging.

Landscaping

In infiltration trenches, there is no landscaping on the practice itself, but it is important to ensure that the upland drainage is properly stabilized with thick vegetation, particularly following construction.

Length, Width, Depth and Geometry

The sizing of an infiltration device is determined by the dewatering requirements. Infiltration devices must be able to completely dewater within 5 days. The time to dewater can be estimated roughly as the runoff capture volume for the device divided by the product of the hydraulic conductivity and the effective infiltrating area. This can be rearranged to produce the following equation for determining the effective infiltrating area needed:

$$A = \frac{V}{2 * (K * T)}$$

where:

A = effective infiltrating area (ft^2)
V = volume of water requiring infiltration (ft^3)
K = hydraulic conductivity of soil (in/hr)
T = dewatering time (days)

The volume of water requiring infiltration (V) is prescribed by the specific stormwater program that applies to the site, and the runoff characteristics of the site. If the infiltration device is not going to meet the volume control requirements, it is simply the volume of water that is diverted and stored for infiltration. The runoff capture storage volume of an infiltration device that is filled with a drainage medium is equal to the volume of the facility, multiplied by the porosity of the medium, plus any temporary ponding that may be allowed before the facility overflows.

The hydraulic conductivity of the soil (K) is the resultant value from the field testing performed on the site. The dewatering time (T) for infiltration devices must be 5 days or less. A value of less than 3 days is recommended for use in the formula.

Once the effective infiltrating area (A) is obtained from the formula, it can still be somewhat difficult to translate that into actual infiltration device dimensions. The value for A used in the formula is actually the larger of either the bottom surface area or one-half of the total (wetted) wall area. The determination of the length, width, and depth dimensions is therefore often an iterative process using the effective infiltrating area (A); the correction factor for true surface areas of the in situ soil interface; and typical length, width, and depth recommendations.

Trench depths shall be no more than 8 feet. It is recommended that the width of a trench (perpendicular to influent flow direction) be less than 25 feet. Broad, shallow trenches reduce the risk of clogging by spreading the runoff over a larger area for infiltration.

Construction Considerations

Care should be used during installation to minimize compaction of soil on the bottom and walls of infiltration devices, since this will reduce the permeability at the soil interface. To avoid compacting the drainage media, lighter weight equipment and construction techniques that minimize compaction should be used.

Runoff shall not be directed into an infiltration device until the drainage area is stabilized. A construction sequence must be followed that reflects the need to stabilize the infiltration device. The longevity of infiltration devices is strongly influenced by the care taken during construction.

Infiltration trenches should not be covered by an impermeable surface unless there is suitable maintenance access, the design specifies an H-20 loading capacity, and the application includes a cross section of the H-20 design. Direct access must be provided to all infiltration devices for maintenance and rehabilitation. OSHA safety standards should be consulted for trench excavation.

A minimum of one observation well shall be included in the design of an infiltration system to periodically verify that the drainage media are fully draining. The monitoring well shall consist of a 4- to 6-inch-diameter, perforated polyvinyl chloride (PVC) pipe with a locking cap. The well should be placed near the center of the facility or in the general location of the lowest point within the facility, with the invert at the excavated bottom of the facility.

Common Problems

Although infiltration trenches can be a useful management practice, they have several limitations. While they do not detract visually from a site, infiltration trenches provide no visual enhancements. Their application is limited due to concerns over groundwater contamination and other soils requirements. Finally, maintenance can be burdensome, and infiltration practices have a relatively high rate of failure.

Maintenance

Regular maintenance of infiltration trenches is needed to reduce the likelihood of BMP failure.

If grass filter strips are present, they should be monitored for areas of bare soil and/or erosive gullies. These items should be repaired immediately by re-grading the area and re-planting. The planted area should be protected using mulching until vegetation can be established.

Sediment accumulation can clog the filter strip, the flow diversion structure, or the trench itself. First, the source of the sediment should be identified and the erosion issues addressed. Then, the sediment should be removed and the device restored to initial design standards.

Permeable Interlocking Concrete Paving

Practice Description

Permeable interlocking concrete paving (PICP) consists of manufactured concrete units that reduce stormwater-runoff volume, rate, and pollutants. The impervious units are designed with small openings between permeable joints. The openings typically comprise 5% to 15% of the paver surface area and are filled with highly permeable, small-sized aggregates. The joints allow stormwater to enter a crushed stone aggregate bedding layer and base that supports the pavers, while providing storage and runoff treatment. PICPs are highly attractive, durable, and easily repaired; require low maintenance; and can withstand heavy vehicle loads.

Planning Considerations

PICP can replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. PICP has performed successfully in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from PICP allow it to be incorporated into municipal green infrastructure and low impact development programs. In addition to providing stormwater volume and quality management, light-colored pavers are cooler than conventional asphalt and help to reduce urban temperatures and improve air quality. The textured surface of PICP also provides traffic calming and provides an aesthetic amenity.

PICP should not be confused with concrete grid pavements (i.e., concrete units with cells that typically contain topsoil and grass). These paving units can infiltrate water, but at rates lower than PICP. Unlike PICP, concrete grid pavements are generally not designed with an open-graded, crushed stone base for water storage. Moreover, grids are for intermittently trafficked areas such as overflow parking areas and emergency fire lanes.

Design Criteria

PICP should be designed and sited to intercept, contain, filter, and infiltrate stormwater on site. Several design possibilities can achieve these design aspects. For example, PICP can be installed across an entire street width or an entire parking area. The pavement can also be installed in combination with impermeable pavements to infiltrate runoff and initiate a treatment train. Several applications use PICP in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements and roofs. This design economizes PICP installation costs while providing sufficient treatment area for the runoff generated from impervious surfaces. Inlets can be places in the PICP to accommodate overflows from extreme storms. The stormwater volume to be captured, stored, infiltrated, or harvested determines the PICP scale required.

Specific design requirements relating to the structural stability of permeable pavements are beyond the scope of this manual. The reader is referred to the AASHTO Flexible Pavement Method for structural design requirements. The following guidelines are presented to ensure that permeable pavements are properly located, designed, and constructed to meet water quality objectives.

1. A washed aggregate base must be used, and washed 57-size stone is generally acceptable. Fine particles from standard “crusher run” will clog the pores at the bottom of the pavement and will not be allowed.

2. Low traffic volume – less than 100 axles per day. Areas with higher traffic volume may be able to use permeable pavement in parking stalls, and use regular pavement in drive aisles.

3. As shown in Figure 1 below, the seasonal high water table must be at least 2 ft below the base of the permeable pavement or gravel storage layer. Water tables approaching the permeable pavement system will not allow water to exfiltrate.

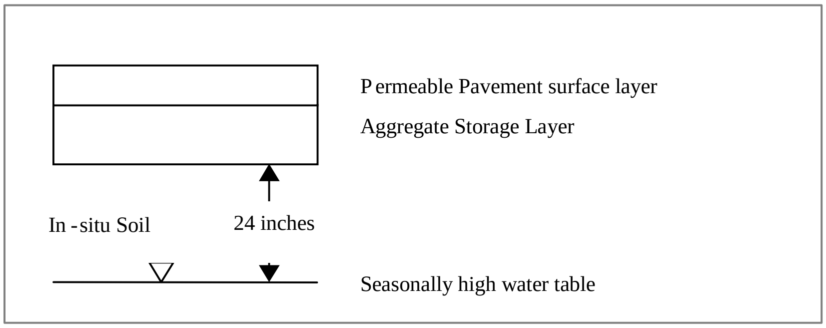


Figure 1 Schematic of Water Table Design Constraint

4. Permeable pavement should not be placed where upland land disturbance is occurring or will potentially occur. Land disturbance upland of the lot could result in frequent pavement clogging.

5. Avoid overhanging trees above the permeable pavement installation.

6. Steeper slopes can reduce the storage capacity of the permeable pavement, so it is important that the top of the soil subgrade (the bottom of the aggregate storage layer) be as close to flat as practicable (slope of ≤0.5%). If the top of the soil subgrade is >0.5%, baffles, partitions, berms, or terracing shall be installed to promote infiltration across the entire area of the subgrade and to reduce the potential for lateral flow. The surface of the permeable pavement shall be no more than 6%.

7. During preparation of the subgrade, special care must be made to avoid compaction of soils. Compaction of the soils can reduce the infiltration capacity of the soil.

8. Permeable pavement should not be designed to receive concentrated flow from roofs or other surfaces. Incidental run-on from stabilized areas is permissible, but the permeable pavement should be designed primarily to infiltrate the rain that falls on the pavement surface itself.

9. Permeable pavement systems are not allowed in areas, such as buffers, where impervious surfaces are not permitted.

10. The construction sequence will be inspected to ensure that the surface installation is planned to be completed after adjacent areas are stabilized with vegetation. Run-on to the permeable pavement from exposed areas can cause the system to perform ineffectively due to clogging.

Specific Design Considerations and Limitations

The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the paver surface, and the storage capacity of the stone base/subbase are the key stormwater-design parameters. To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. The increased depth also provides additional storage volume to compensate for the lower infiltration rate of the clay subgrade. Underdrains elevated above the subgrade clay soil are often used in PICP, further making it suitable for many clay soils by infiltrating some of the water and filtering and draining the remainder. In addition, an impermeable liner may be installed between the subbase and the subgrade to limit water infiltration when clay soils have a high shrink-swell potential or there is a high depth to bedrock or water table (NCSU, 2008).

Measures should be taken to protect PICP from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to pavers include filter strips and swales. Preventing sediment from entering the base or permeable pavement during construction is critical. Runoff from disturbed areas should be diverted away from the PICP until these areas are stabilized.

Common Problems

PICP has the potential to become clogged with sediment if not protected from disturbed areas during construction activities.

Slope plays a role in applicability of PICP. Slopes greater than 2% may require additional design considerations, including terracing of soil subgrade.

PICP can cause safety concerns for disabled persons, bicycles, pedestrians wearing high-heels, and the elderly (SPU, 2009). Many PICP paver designs are ADA compliant, and other areas may require solid interlocking concrete pavements.

Maintenance

The most prevalent maintenance concern is the potential clogging of the openings and joints between the pavers. Fine particles that can clog the openings are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use. However, while more particles become entrained in the pavement surface, it does not become impermeable. Studies of the long-term surface permeability of PICP and other permeable pavements have found high infiltration rates initially, a decrease, and then a leveling off with time. With initial infiltration rates of hundreds of inches per hour, the long-term infiltration capacity remains high even with clogging. When substantially clogged, surface infiltration rates usually well exceed 1 inch per hour, sufficient in most circumstances to effectively manage stormwater. Permeability can be increased with vacuum sweeping or, in extreme circumstances, by replacing the aggregate between pavers.

Pervious Asphalt Pavement

Practice Description

Pervious asphalt, also known as porous, permeable, “popcorn,” or open-graded asphalt, is standard hot-mix asphalt with reduced sand or fines that allow water to drain through it. Pervious asphalt over an aggregate storage bed will reduce stormwater runoff volume, rate, and pollutants. The reduced fines leave stable air pockets in the asphalt. The interconnected void space allows stormwater to flow through the asphalt and enter a crushed stone aggregate bedding layer and base that supports the asphalt while providing storage and runoff treatment. When properly constructed, pervious asphalt is a durable and cost-competitive alternative to conventional asphalt.

Planning Considerations

Pervious asphalt can be used for municipal stormwater-management programs and private development applications. The runoff volume and rate control, plus pollutant reductions, allow municipalities to improve the quality of stormwater discharges. Municipal initiatives, such as Portland’s Green Streets program (shown in the photo above), use pervious asphalt to reduce combined sewer overflows by infiltrating and treating stormwater on site. Private development projects use pervious asphalt to meet post-construction stormwater quantity and quality requirements. The use of pervious asphalt can potentially reduce additional expenditures and land consumption for conventional collection, conveyance, and detention stormwater infrastructure.

Pervious asphalt can replace traditional impervious pavement for most pedestrian and vehicular applications. Open-graded asphalt has been used for decades as a friction course over impervious asphalt on highways to reduce noise, spray, and skidding. Highway applications with all-pervious asphalt surfacing have been used successfully for highway pilot projects in the United States; however, generally, pervious asphalt is recommended for low-volume and low-speed applications (Hossain et al., 1992). Pervious asphalt performs well in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from pervious asphalt allow it to be incorporated into municipal green infrastructure and low impact development programs. The appearance of pervious asphalt and conventional asphalt is very similar. The surface texture of pervious asphalt is slightly rougher, providing more traction to vehicles and pedestrians.

Design Criteria

Pervious asphalt should be designed and sited to intercept, contain, filter, and infiltrate stormwater on site. Several design possibilities can achieve these objectives. For example, pervious asphalt can be installed across an entire street width or an entire parking area. The pavement can also be installed in combination with impermeable pavements or roofs to infiltrate runoff. Several applications use pervious asphalt in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements and roofs. This design economizes pervious asphalt installation costs while providing sufficient treatment area for the runoff generated from impervious surfaces. Inlets can be placed in the pervious asphalt to accommodate overflows from extreme storms. The stormwater volume to be captured, stored, infiltrated, or harvested determines the scale of permeable pavement required.

Pervious asphalt comprises the surface layer of the permeable pavement structure and consists of open-graded coarse aggregate, bonded together by bituminous asphalt. Polymers can also be added to the mix to increase strength for heavy load applications. The thickness of pervious asphalt ranges from 2 to 4 inches depending on the expected traffic loads. For adequate permeability, the pervious asphalt should have a minimum of 16% air voids. Additional subsurface components of this treatment practice (illustrated in Figure 1) include the following (National Asphalt Pavement Association, 2008):

- *Choke course* - This permeable layer is typically 1-2 inches thick and provides a level and stabilized bed surface for the pervious asphalt. It consists of small-sized, open-graded aggregate.
- *Open-graded base reservoir* - This aggregate layer is immediately beneath the choke layer. The base is typically 3-4 inches thick and consists of crushed stones typically 3/4 to 3/16 inch. Besides storing water, this high-infiltration rate layer provides a transition between the bedding and subbase layers.
- *Open-graded subbase reservoir* - The stone sizes are larger than the base, typically ¾ to 2½ inch stone. Like the base layer, water is stored in the spaces among the stones. The subbase layer thickness depends on water storage requirements and traffic loads. A subbase layer may not be required in pedestrian or residential driveway applications. In such instances, the base layer is increased to provide water storage and support.
- *Underdrain (optional)* - In instances where pervious asphalt is installed over low-infiltration rate soils, an underdrain facilitates water removal from the base and subbase. The underdrain is perforated pipe that ties into an outlet structure. Supplemental storage can be achieved by using a system of pipes in the

aggregate layers. The pipes are typically perforated and provide additional storage volume beyond the stone base.

- *Geotextile (optional)* - This can be used to separate the subbase from the subgrade and to prevent the migration of soil into the aggregate subbase or base.
- *Subgrade* - The layer of soil immediately beneath the aggregate base or subbase. The infiltration capacity of the subgrade determines how much water can exfiltrate from the aggregate into the surrounding soils. The subgrade soil is generally not compacted.

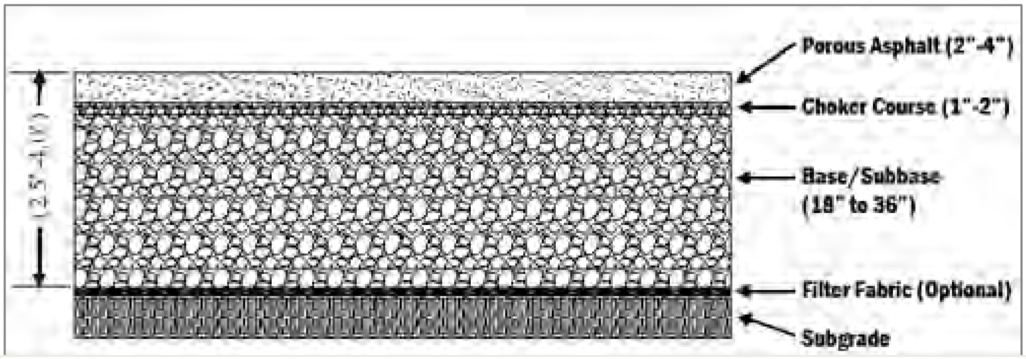


Figure 1 Typical Porous Asphalt Pavement Section (diagram adapted from USEPA, 1986)

The same equipment can be used for mixing and laying permeable asphalt as for conventional asphalt. The method for laying the asphalt will also be similar. During compaction of the asphalt, minimal pressure should be used to avoid closing pore space. Vehicular traffic should be avoided for 24 to 48 hours after pavement is installed.

The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the pervious asphalt, and the storage capacity of the stone base/subbase are the key stormwater-design parameters. To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. The increased depth also provides additional storage volume to compensate for the lower infiltration rate of the clay subgrade. Underdrains are often used when permeable pavements are installed over clay. In addition, an impermeable liner may be installed between the subbase and the subgrade to limit water infiltration when clay soils have a high shrink-swell potential, or if there is a high depth to bedrock or water table (Hunt and Collins, 2008).

Common Problems

Measures should be taken to protect permeable pavement from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to permeable pavement include filter strips and swales. Preventing sediment from entering the base of permeable pavement during construction is critical. Runoff from disturbed areas should be diverted away from the permeable pavement until these areas are stabilized.

Several factors may limit permeable pavement use. Pervious asphalt has reduced strength compared to conventional asphalt and will not be appropriate for applications with high volumes and extreme loads. It is not appropriate for stormwater hotspots where hazardous materials are loaded, unloaded, stored, or where there is a potential for spills and fuel leakage. For slopes greater than 2 percent, terracing of the soil subgrade base may likely be needed to slow runoff from flowing through the pavement structure.

Maintenance

The most prevalent maintenance concern is the potential clogging of the pervious asphalt pores. Fine particles that can clog the pores are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use. While more particles become entrained in the pavement surface, it does not become impermeable. Studies of the long-term surface permeability of pervious asphalt and other permeable pavements have found high infiltration rates initially, followed by a decrease, and then leveling off with time (Bean et al., 2007). With initial infiltration rates of hundreds of inches per hour, the long-term infiltration capacity remains high even with clogging. When clogged, surface infiltration rates usually well exceed 1 inch per hour, which is sufficient in most circumstances for the surface to effectively manage intense stormwater events (Interlocking Concrete Pavement Institute, 2000). Permeability can be increased with vacuum sweeping. In areas where extreme clogging has occurred, half-inch holes can be drilled through the pavement surface every few feet or so to allow stormwater to drain to the aggregate base. A stone apron around the pavement connected hydraulically to the aggregate base and subbase can be used as a backup to surface clogging or pavement sealing.

Due to the well-draining stone bed and deep structural support of pervious asphalt pavements, they tend to develop fewer cracks and potholes than conventional asphalt pavement. When cracking and potholes do occur, a conventional patching mix can be used. Freeze/thaw cycling is a major cause of pavement breakdown; pervious asphalt parking lots can have a lifespan of more than 30 years because of the reduced freeze/thaw stress (Gunderson, 2008).

Cold weather and frost penetration do not negatively impact surface infiltration rates. Pervious asphalt freezes as a pervious medium rather than a solid block because permeable pavement systems are designed to be well drained; infiltration capacity is preserved because of the open void spaces (Gunderson, 2008). However, plowed snow piles should not be left to melt over the pervious asphalt, as they can receive high sediment concentrations that can clog the pavement system more quickly.

Permeable pavements do not treat chlorides from road salts but also require less applied deicer. Deicing treatments are a significant expense, and chlorides in stormwater runoff have substantial environmental impacts. Reducing chloride concentrations in runoff is achieved only through reduced application of road salts, because removal of chloride with stormwater BMPs is not effective.

Pervious Concrete

Photo Courtesy of pavementinteractive.org

Practice Description

Pervious concrete, also known as pervious, gap-graded, or enhanced porosity concrete, is concrete with reduced sand or fines and allows water to drain through it. Pervious concrete is often constructed over an aggregate storage bed to allow for stormwater infiltration and temporary storage. This aggregate layer not only provides temporary stormwater storage but also helps to support the concrete. Pervious concrete has less sand and fines than standard concrete, which leaves stable air pockets in the concrete that allow water to flow through. This void space is generally between 15 and 35 percent. When properly installed, pervious concrete is a durable and low-maintenance paving option.

Planning Considerations

Pervious concrete can be used for municipal stormwater management programs and private development applications. The runoff volume and rate control, plus pollutant reductions, allow municipalities to improve the quality of stormwater discharges. Municipal initiatives, such as Chicago's Green Alley program, use pervious concrete to reduce combined sewer overflows and to minimize localized flooding by infiltrating and treating stormwater on site. Private development projects use pervious concrete to meet post-construction stormwater quantity and quality requirements. The use of pervious concrete can potentially reduce additional expenditures and land consumption for conventional collection, conveyance, and detention stormwater infrastructure. Public and private developments have used pervious concrete, which is a naturally brighter surface than traditional asphalt, to reduce lighting needs and increase nighttime safety.

Pervious concrete can replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. Pervious concrete can be designed to handle heavy loads, but surface abrasion from constant traffic will cause the pavement to deteriorate more quickly than conventional concrete. Pervious concrete has performed successfully in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from pervious concrete allow it to be incorporated into municipal green infrastructure and low impact development programs. In addition to providing stormwater volume and quality management, the light color of concrete is cooler than conventional asphalt and helps to reduce urban temperatures and improve air quality (Grant et al., 2003; Vingarzan and Taylor, 2003). Unlike the smoothed surface of conventional concrete, the surface texture of pervious concrete is slightly rougher, providing more traction to vehicles and pedestrians.

Design Criteria

Pervious concrete should be designed and sited to intercept, contain, filter, and infiltrate stormwater on site. Several design possibilities can achieve these objectives. For example, pervious concrete can be installed across an entire street width or an entire parking area. The pavement can also be installed in combination with impermeable pavements or roofs to infiltrate runoff. Several applications use pervious concrete in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements and roofs. This design economizes pervious concrete installation costs while providing sufficient treatment area for the runoff generated from impervious surfaces. Inlets can be placed in the pervious concrete to accommodate overflows from extreme storms. The stormwater volume to be captured, stored, infiltrated, or harvested determines the scale of permeable pavement required.

Pervious concrete comprises the surface layer of the permeable pavement structure and consists of portland cement, open-graded coarse aggregate (typically 5/8 to 3/8 inch), and water. Admixtures can be added to the concrete mixture to enhance strength, increase setting time, or add other properties. The thickness of pervious concrete ranges from 4 to 8 inches depending on the expected traffic loads. Additional subsurface components of this treatment practice are illustrated in Figure 1 and include the following (National Ready Mix Concrete Association (NRMCA), 2008):

- *Choke course* - This permeable layer is typically 1-2 inches thick and provides a level bed for the pervious concrete. It consists of small-sized, open-graded aggregate.
- *Open-graded base reservoir* - This aggregate layer is immediately beneath the choke layer. The base is typically 3-4 inches thick and consists of crushed stones typically 3/4 to 3/16 inch. Besides storing water, this high-infiltration rate layer provides a transition between the bedding and subbase layers.
- *Open-graded subbase reservoir* - The stone sizes are larger than the base, typically 2½ to 2¾ inch stone. Like the base layer, water is stored in the spaces among the stones. The subbase layer thickness depends on water storage

requirements and traffic loads. A subbase layer may not be required in pedestrian or residential driveway applications. In such instances, the base layer is increased to provide water storage and support.

- *Underdrain (optional)* - In instances where pervious concrete is installed over low-infiltration rate soils, an underdrain facilitates water removal from the base and subbase. The underdrain is perforated pipe that ties into an outlet structure. Supplemental storage can be achieved by using a system of pipes in the aggregate layers. The pipes are typically perforated and provide additional storage volume beyond the stone base.
- *Geotextile (optional)* - This can be used to separate the subbase from the subgrade and to prevent the migration of soil into the aggregate subbase or base.
- *Subgrade* - The layer of soil immediately beneath the aggregate base or subbase. The infiltration capacity of the subgrade determines how much water can exfiltrate from the aggregate into the surrounding soils. The subgrade soil is generally not compacted.

Properly installed pervious concrete requires trained and experienced producers and construction contractors. The installation of pervious concrete differs from conventional concrete in several ways. The pervious concrete mix has low water content and will therefore harden rapidly. Pervious concrete needs to be poured within one (1) hour of mixing. The pour time can be extended with the use of admixtures. A manual or mechanical screed set ½ inch above the finished height can be used to level the concrete.

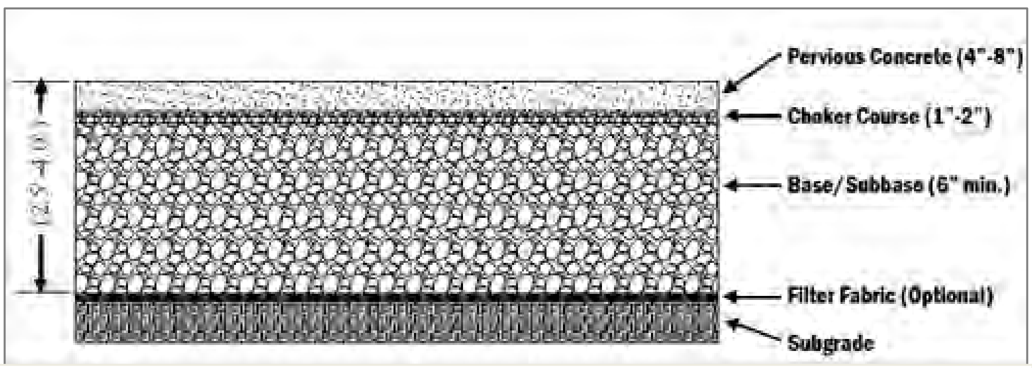


Figure 1 Typical Porous Asphalt Pavement Section (diagram adapted from USEPA, 1986)

Floating and troweling are not used, as these actions may close the surface pores. Consolidation of the concrete, typically with a steel roller, is recommended within 15 minutes of placement. Pervious concrete also requires a longer time to cure. The concrete should be covered with plastic within 20 minutes of setting and allowed to cure for a minimum of 7 days (NRMCA, 2008).

Siting Considerations

- Do not install in areas where hazardous materials are loaded, unloaded, or stored.
- Avoid high sediment-loading areas.
- Divert runoff from disturbed areas until stabilized.
- Do not use sand for snow or ice treatment.
- Periodic maintenance to remove fine sediments from paver surface will optimize permeability.

Common Problems

The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the pervious concrete, and the storage capacity of the stone base/subbase are the key stormwater design parameters. To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. The increased depth also provides additional storage volume to compensate for the lower infiltration rate of the clay subgrade. Underdrains are often used when permeable pavements are installed over clay. In addition, an impermeable liner may be installed between the subbase and the subgrade to limit water infiltration when clay soils have a high shrink-swell potential, or if there is a high depth to bedrock or water table (Hunt and Collins, 2008).

Measures should be taken to protect permeable pavement from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to permeable pavement include filter strips and swales. Preventing sediment from entering the base of permeable pavement during construction is critical. Runoff from disturbed areas should be diverted away from the permeable pavement until the areas are stabilized.

Several factors may limit permeable pavement use. Pervious concrete has reduced strength compared to conventional concrete and will not be appropriate for applications with high volumes and extreme loads. It is not appropriate for stormwater hotspots where hazardous materials are loaded, unloaded, stored, or where there is a potential for spills and fuel leakage. For slopes greater than 2 percent, terracing of the soil subgrade base may likely be needed to slow runoff from flowing through the pavement structure. In another approach for using pervious concrete slopes, lined trenches with underdrains can be dug across slope to intercept flow through the subbase (ACPA, 2006).

Maintenance

The most prevalent maintenance concern is the potential clogging of the pervious concrete pores. Fine particles that can clog the pores are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use. While more particles become entrained in the pavement surface, it does not become impermeable. Studies of the long-term surface permeability of pervious concrete and other permeable pavements have found high infiltration rates initially, followed by a decrease, and then leveling off with time (Bean et al., 2007a). With initial infiltration rates of hundreds of inches per hour, the long-term infiltration capacity remains high even with clogging. Permeability can be increased with vacuum sweeping. In areas where extreme clogging has occurred, half-inch holes can be drilled through the pavement surface every few feet or so to allow stormwater to drain to the aggregate base. Many large cuts and patches in the pavement will weaken the concrete structure.

Cold weather and frost penetration do not negatively impact surface infiltration rates. Permeable concrete freezes as a pervious medium rather than a solid block because permeable pavement systems are designed to be well drained; infiltration capacity is preserved because of the open void spaces (Gunderson, 2008).

Bioretention (Rain Gardens)

Practice Description

A bioretention cell consists of a depression in the ground filled with a soil media mixture that supports various types of water-tolerant vegetation. The surface of the BMP is depressed in bioretention facilities to allow for ponding of runoff that filters through the BMP media. Water exits the bioretention area via exfiltration into the surrounding soil, flow out an underdrain, and evapotranspiration. The surface of the cell is protected from weeds, mechanical erosion, and desiccation by a layer of mulch. Bioretention is an efficient method for removing a wide variety of pollutants, such as suspended solids, heavy metals, nutrients, and pathogens (North Carolina Cooperative Extension (NCCE), 2007). Bioretention areas provide some nutrient uptake in addition to physical filtration. If located at a site with appropriate soil conditions to provide infiltration, bioretention can also be effective in reducing peak runoff rates, reducing runoff volumes, and recharging groundwater.

Planning Considerations

Many development projects present a challenge to the designer of conventional stormwater BMPs because of physical site constraints. Bioretention areas are intended to address the spatial constraints that can be found in densely developed urban areas where the drainage areas are highly impervious. They can be used on small urban sites that would not normally support the hydrology of a wet detention pond and where the soils would not allow for an infiltration device. Median strips, ramp loops, traffic circles, and parking lot islands are good examples of typical locations for bioretention areas.

Bioretention units are ideal for distributing several units throughout a site to provide treatment of larger areas. Developments that incorporate this decentralized approach to stormwater management can achieve savings by eliminating stormwater-management ponds; reducing pipes, inlet structures, curbs and gutters; and having less grading and clearing. Depending on the type of development and site constraints, the costs for using decentralized bioretention stormwater-management methods can be reduced by 10 to 25 percent compared to stormwater and site development using other BMPs (Coffman, 1993).

Figure 1 Bioretention in Parking Lot Island

Bioretention facilities are generally most effective if they receive runoff as close as possible to the source. Reasons for this include: minimizing the concentration of flow to reduce entry velocity; reducing the need for inlets, pipes, and downstream controls; and allowing for blending of the facilities with the site (e.g., parking median facilities). For sites where infiltration is being utilized, it also avoids excessive groundwater mounding. Where bioretention takes the place of required green space, the landscaping expenses that would be required in the absence of bioretention should be subtracted when determining the actual cost (LID Center, 2003). Bioretention cells may also address landscaping/green space requirements of some local governments (Wossink and Hunt 2003).

Design Criteria

Design is an eight-step process:

1. Understand basic layout concepts.
2. Determine the volume of water to treat.
3. Determine the surface area required.
4. Select the soil media type.
5. Decide the depth of soil media.
6. Size the underdrain pipes (if necessary).
7. Select the appropriate overflow or bypass method.
8. Select plants and mulch.

Step 1: Understand Basic Layout Concepts

The layout of bioretention areas varies according to individual sites and to specific site constraints such as underlying soils, existing vegetation, drainage, location of utilities, sight distances for traffic, aesthetics, and ease of maintenance. Figure 2 illustrates a concept for a bioretention traffic island. These types of bioretention facilities typically take up no more space than what is required by typical zoning rules, and they provide stormwater treatment as well as site aesthetics. The following photographs are examples of existing bioretention cells that have been designed using these techniques. These cells blend into the landscape and appear to be typical flowerbeds or medians. Often, bioretention cells can be designed with flowering plants to enhance the landscape.

Examples of Previously Installed Bioretention Cells

Figure 2 shows an 8-inch gravel strip followed by 5 feet of grass for pretreatment along the side that receives water from the jogging trail. This is an example of both gravel strip pretreatment design as well as when to maintain the gravel strip. This strip has become over-grown with grass and has been clogged with sediment. The mulch has also become thin, and should be replaced.

Figure 2 Bioretention Cell with Pretreatment: Gravel and Grass (Needs Maintenance)

Figure 3 shows a bioretention cell with a pretreatment forebay. Notice the sediment that has settled onto the rocks. Without the forebay, this sediment would have collected on the top of the bioretention cell, clogged the soil media, and would have become a maintenance burden. Forebays that are located inside a cell should be lined in order to ensure that the treatment volume drains through the media.

Figure 3 Bioretention Cell with Pretreatment Forebay

Examples of Additional Design Options

Use of Flow Splitters

Bioretention units can be designed using a flow splitter so that only the treatment volume is directed into the cell. An example of this design is provided as Figure 4. This example shows a filter strip, though it is not required for every design.

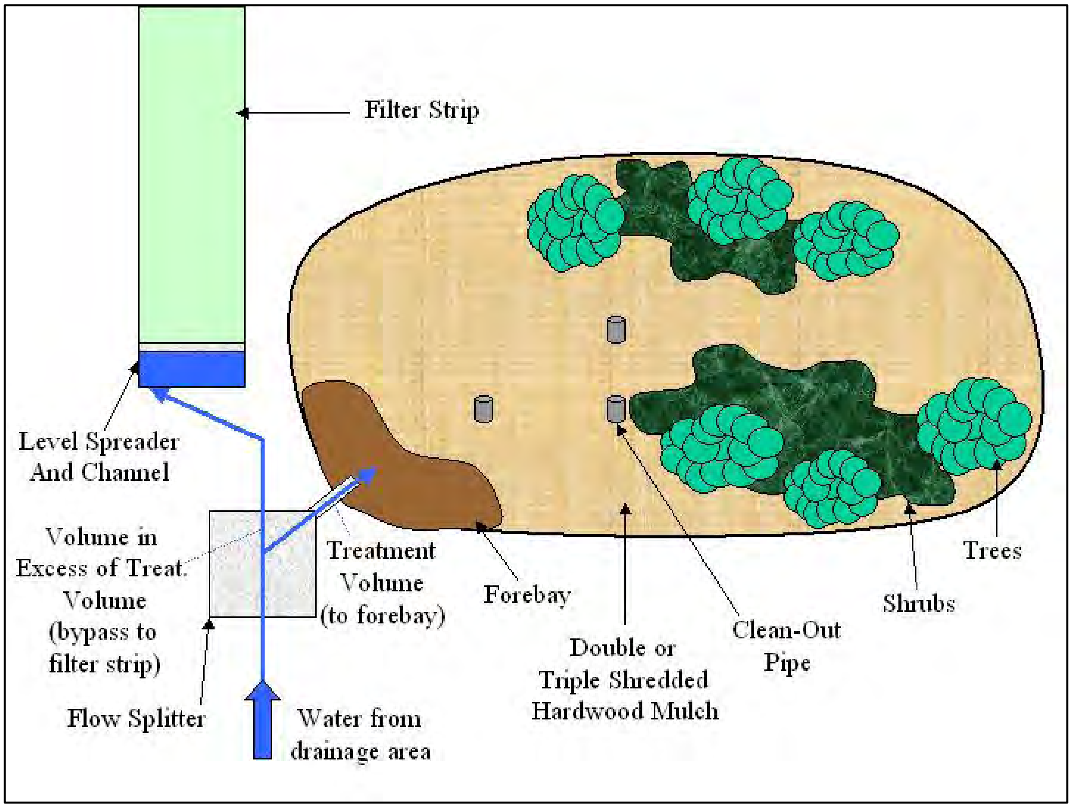


Figure 4 Typical Bioretention Cell Using a Flow Splitting Device (Source: North Carolina Department of Environment and Natural Resources (NCDENR)

Use of Overflow Devices

Bioretention units can be designed using an overflow device so that water in excess of the treatment volume overflows to a filter strip. An example of this design is provided in Figure 5. This example shows a filter strip, though it is not required for every design.

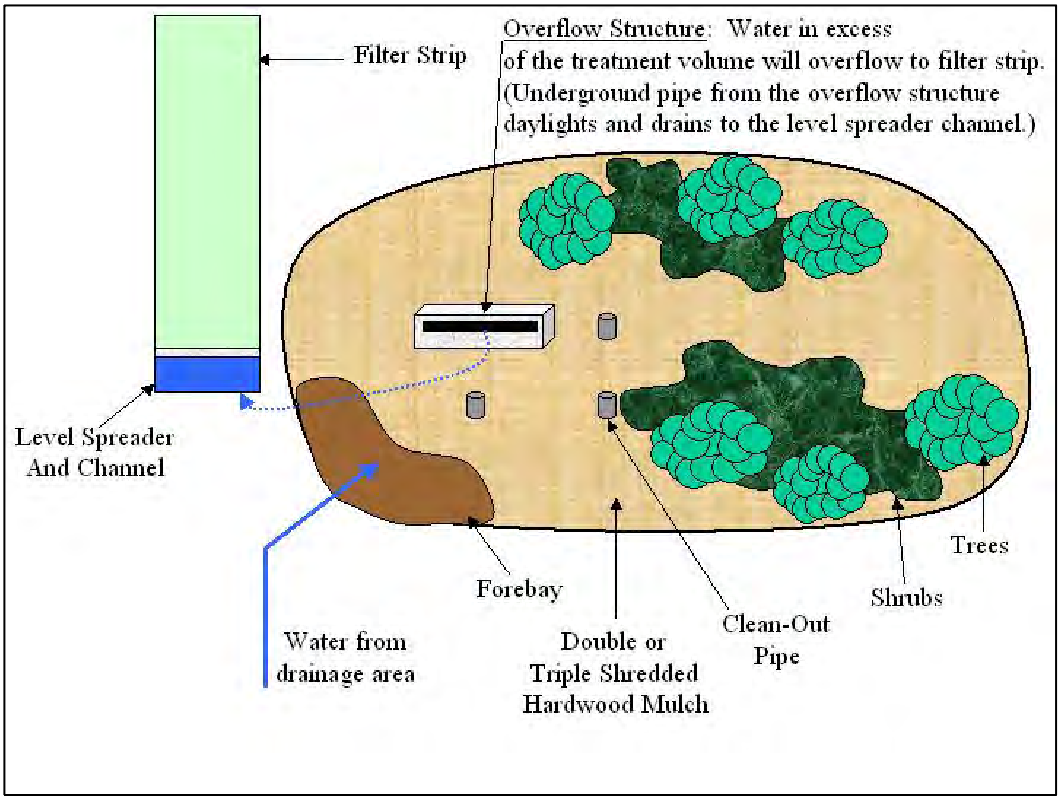


Figure 5 Typical Bioretention Cell Using an Overflow Device (Source: NCDENR)

Internal Water Storage Zones (IWS)

An internal water storage zone (IWS) can be created by the addition of an elbow in the underdrain piping at a 90-deg angle vertically perpendicular to the horizontal underdrain, either in retrofit conditions or in new installations. This upturned elbow on underdrains can force water to remain longer in the bottom of the cell, creating a saturated IWS. If this zone remains saturated long enough, anaerobic conditions are created, promoting denitrification and increased nitrogen removal (Passeport et al., 2009).

There are several benefits to using the upturned elbow and IWS. The IWS works for both pollutant and peak flow reduction as anaerobic conditions can be created to increase nitrogen removal. It also allows more water to infiltrate into the surrounding soils. If an upturned elbow is installed correctly in sufficiently permeable soils, it may only rarely generate outflows.

The use of upturned elbows and IWS can be especially beneficial in areas where surrounding sandy soils can be ideal for infiltration, reducing outflows and surface water runoff. Additionally, there is often a cost benefit for using upturned elbows, both for new installations and retrofits. In new installations, a cost-savings is associated with installation since the invert of the outlet is not as deep. Often with IWS, there can be less trenching and fewer materials associated with using it. In retrofits, upturned elbows can be cheaply added to existing bioretention cells where increased nitrogen and phosphorus removal rates are needed. Additionally, cells with IWS can be added as retrofits even in areas with restricted outlet depth.

For an internal water storage zone to work correctly, the underlying soils must have some permeability. In general, if the underlying soils are Group A or B soils with a low clay content, the IWS will be effective. If soils are too compacted, water will not infiltrate and may stagnate in the lower portion, causing problems for the BMP. Media depth above the bottom gravel and underdrain layer must be at least 3 feet. The top of IWS should be separated from the outlet and bowl surface by at least 12 inches (ideally 18 inches). See Figure 6.

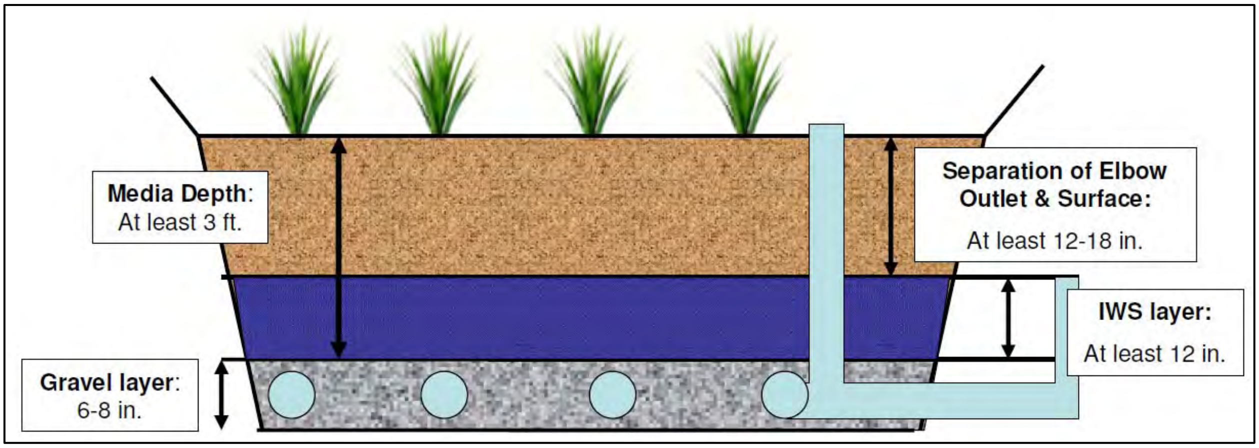


Figure 6 Bioretention Cell showing IWS Zones (Source: NCDENR)

Parking Lot Diversion Method

A bioretention area that can be installed along the perimeter of a parking lot is shown in Figure 7. The water is diverted to the bioretention area through the use of a curb diversion structure. A 2-foot buffer between the curb and the bioretention area serves as pretreatment and reduces the possibility of drainage seeping under the pavement section and creating “frost heave” during winter months. Flow diversion by curb diversion structures may not meet the volume attainment requirements.

A berm one foot in height separates the swale from the bioretention area. The bioretention area should be at an elevation such that, when the design ponding depth is reached, additional flow continues down the swale and is diverted from the bioretention cell.

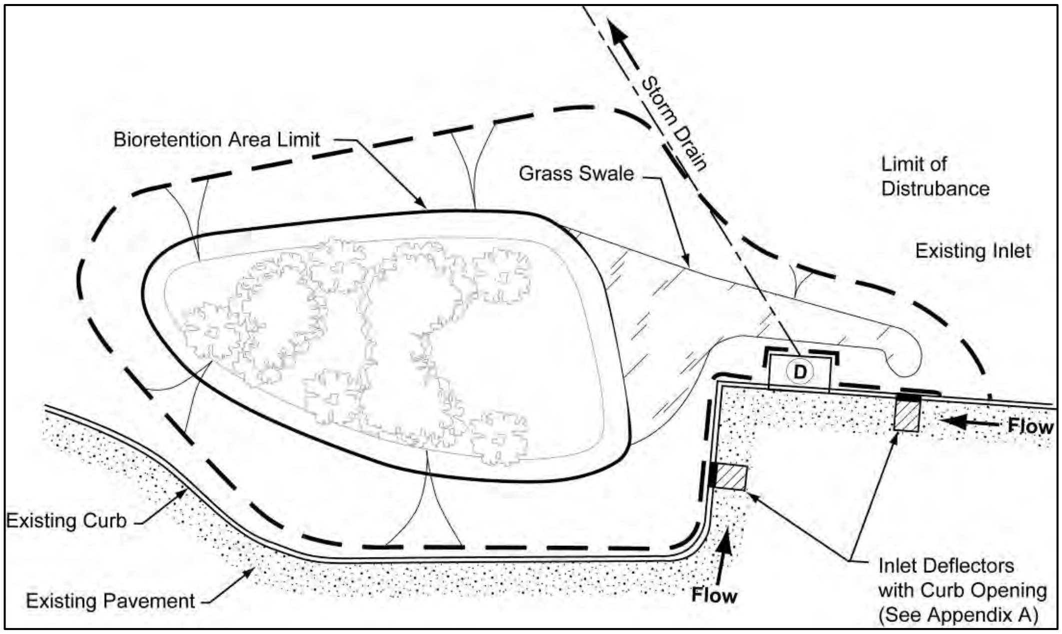


Figure 7 Parking Edge and Perimeter with Curb (Source: Prince George's County, 2000)

Bioretention Cells on Steep Slopes

Figure 8 depicts a bioretention terrace that can be used in sloping terrain (for 10-20% slopes). An impermeable or very low-permeability geomembrane must be used against the gabions or similar retaining structure to prevent flow from leaving the treatment unit through that surface. An underdrain could be placed at the low point of the filter if the native soil against which the unit is built will not provide adequate infiltration capacity.

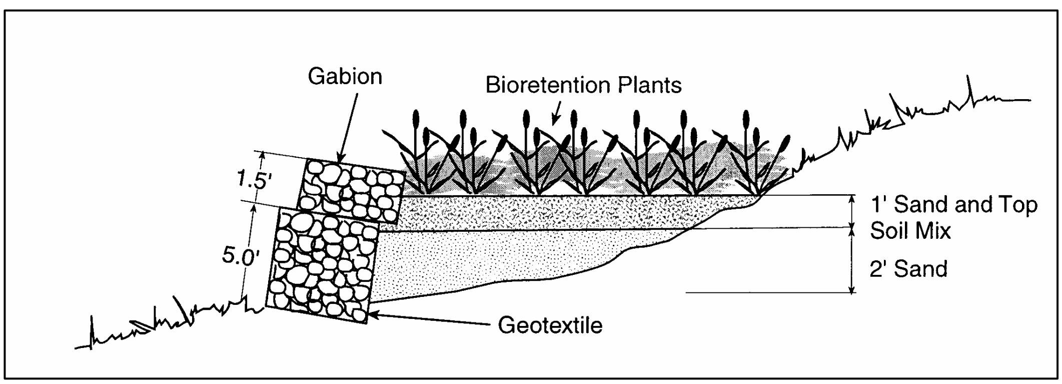


Figure 8 Bioretention Terrace Suitable for Use on Slopes 10-20%

Pretreatment Options

Inflow must enter a bioretention cell via sheet flow (1ft/sec for cells with mulch, or 3.0 ft/sec for grassed cells) or alternative energy-dissipating devices must be used. Sheet flow provides for the most even distribution of flow and the least energy (minimizing erosion). Sheet flow can be naturally provided, as in the case of a gently sloping parking lot with no curb and gutter or a vegetated buffer/filter strip, or it can be designed into the device by the use of a level spreader. In some instances sheet flow is not attainable and the inflow will enter from concentrated sources such as curb diversion structures, drainage pipes, grassy swales, etc. In these cases, a riprap-lined entrance, a forebay, or other energy-dissipating device must be used.

The water treatment volume shall be calculated as specified in Appendix A. The cell must be designed to have a pretreatment area. The most commonly used pretreatment devices are these:

1) A grass and gravel combination: This should consist of 8 inches of gravel followed by 3 to 5 feet of sod. See the *Sodding Practice* in Volume 1 for more information on sod installation.

2) A grassed water quality swale: A water quality swale shall be designed as specified in the *Grass Swale Practice*.

3) A forebay: The forebay should be 18-30 inches deep, and used only in areas where standing water is not considered a safety concern. The forebay should be deepest where water enters, and more shallow where water exits in order to dissipate hydraulic energy of the water flowing to the forebay. If there is a risk that water in the forebay could flow into the underdrain without first flowing to the cell, the forebay should also be lined.

Maintenance Considerations

When performing the following remaining steps of designing a bioretention cell, consider how landscape professionals will later access the site for maintenance. Because the soil must be able to accommodate fast water infiltration, it cannot be compacted by heavy equipment. Is the forebay accessible for heavy equipment to remove sediment from it without driving onto the cell? Are the clean-out pipes accessible? All aspects of design should consider future maintenance.

Construction Sequencing

The drainage area to the cell should be stabilized before cell construction begins in order to prevent clogging. For roadways draining to the cell, the subbase course (crusher run) and the base course layer of asphalt need to be in place prior to cell construction. If fines get washed into the excavated cell, they must be removed before building the cell, in order to restore the permeability of the in situ soils. It is recommended that the cell media be covered with impermeable plastic during construction.

Step 2: Determine the Volume of Water to Treat

Water Volume

An individual bioretention cell is intended to treat the first flush. *Appendix A: Erosion and Stormwater Runoff Calculations* details the volumetric calculation.

Siting Issues

Bioretention facilities shall not be used in areas with the following characteristics:

- The seasonal high water table is less than 2 feet below the bottom of the cell.

- Slopes are 20 percent or greater, unless bioretention terraces are planned.
- Further construction is planned on either the immediately surrounding site or in outparcels that may drain to the bioretention site. (The upstream contributing drainage area must be completely and permanently stabilized, e.g., gravel base course driving surface (preferably paved), or a dense and vigorous vegetative cover. The heavy sediment load from a bare-earth construction site will cause premature failure of a bioretention BMP.)
- The cell is inaccessible for maintenance.
- The cell will not comply with local landscape ordinances.

Contributing Drainage Basin

Consider the effect of large storms on potential erosion within the cell as well as potential overflow and downhill erosion upon water leaving the cell. The contributing area to an individual bioretention cell will typically be 5 acres or less, because many large watersheds will not have an area that is large enough to serve the treatment volume while also being high enough above the water table.

Step 3: Determine the Surface Area and Depth Required

The cell can be designed to hold the first inch of rainfall from the entire drainage area. The required surface area of the bioretention cell is equal to the required treatment volume (as calculated using the Simple Method outlined in *Appendix A*) divided by the ponding depth. No dimension (width, length, or radius) can be less than 10 feet. This is to provide sufficient space for plants.

Step 4: Select the Soil Media Type

The soil mix should be uniform and free of stones, stumps, roots, or other similar material greater than 2 inches. It should be a homogenous soil mix of 85-88 percent by volume sand (USDA Soil Textural Classification), 8 to 12 percent fines (silt and clay), and 3 to 5 percent organic matter (such as peat moss). The higher (12 percent) fines content should be reserved for areas where total nitrogen is the target pollutant. In areas where phosphorus is the target pollutant, lower (8 percent) fines should be used. Additionally, the phosphorus (P) content of the soil mix should be low. The P-Index for bioretention soil media should always range between 10 and 30, regardless of the target pollutant (Hunt and Lord, 2006). The P-Index is an extremely important design element. Cells that are constructed of high P-Index soils can export phosphorus.

The media should be tested to determine an actual drainage rate after placement. The permeability should fall between 1 and 6 inches per hour, and 1-2 inches per hour is preferred. As a rule of thumb, using the above-specified media, the infiltration rates should be approximately 2 in./hr and 1 in./hr for 8% and 12% fines, respectively, depending on the target pollutant. An estimated drainage rate for percent fines between 8 and 12 can be approximated during design by linear interpolation. If total suspended solids (TSS) or pathogens are the target pollutant, the higher permeability can be used because these two pollutants are removed on the surface of the bioretention cell rather than within the cell.

Step 5: Determine the Soil Media Depth

Different pollutants are removed in various zones of the bioretention cell using several mechanisms. The TSS are removed both in pretreatment and on the surface of the cell itself. For that reason, TSS removal is not a major factor in depth of the cell design. Depth is, however, an issue for other pollutants. Metals are removed in the top layer of mulch and the soil, as they are often bound to sediment. Additionally, two thirds of phosphorus entering the cell is attached to soil particles. As a result, this portion is removed on the surface. The remaining third is soluble and is removed 12 inches or more below the surface. Bacterial, viral, and protozoan pathogens can be killed on the surface and removed throughout the cell by several mechanisms: sun-exposure, drying, sedimentation, and filtration (Hathaway and Hunt, 2008). Temperature is reduced at approximately 48 inches below the surface. Nitrogen is removed 30 inches below the surface. Initial research at North Carolina State University shows that using an upturned underdrain pipe may increase nitrogen removal. The upturned piped creates an anaerobic zone that may facilitate nitrogen removal. (See the *Internal Water Storage Zones* section of this practice for more information.) Consider the types of pollutants to be removed, and select an appropriate media depth.

The ponding depth above the media and mulch shall be 12 inches or less (9 inches or less is preferred). This is based on both the typical inundation tolerance of the vegetation used in bioretention facilities as well as the ability of the ponded water to drain into the soil within the required time.

The depth of the media in a bioretention cell should be between 2 and 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil, and excavations deeper than 4 feet become more expensive. The depth should accommodate the vegetation (shrubs or trees). If the minimum depth of 2 feet is used, only shallow-rooted plants can be planted. Grassed bioretention cells with no IWS can be as shallow as 2 feet. However, if nitrogen is the target pollutant, the cell should have at least 30 inches of media because, as previously discussed, nitrogen is removed 30 inches below the surface. Bioretention facilities where shrubs or trees are planted can be as shallow as 3 feet. If large trees are to be planted in deep fill media, care should be taken to ensure that they would be stable and not fall over. As stated above, if IWS is used, cells must have a minimum depth of 3 feet.

If underdrain piping is used (which is only for cases in which the infiltration rate is less than 2 in./hr), the media is as shown in Figure 9. This figure shows a cross-sectional design. No. 57 stone shall be installed around the underdrain. Crusher run shall not be used around the underdrain, as it can form an impermeable layer (Amerson et al., 1991). For pretreatment, the gravel and grass option is presented in this figure because it is one of the most common pretreatment options. The design shown here is for a bioretention cell in a non-developing area. Bioretention cells should be used only in non-developing areas. If there is any concern that the surrounding area may be developed in the future, consider using an alternate BMP or protecting the BMP from sediment. If this is only a nominal concern, use 2 inches of either No. 8 or No. 89 washed choking stone in place of the filter fabric shown in Figure 9.

If an underdrain system is not used, the cross-sectional design of the cell will be the same although the underdrain will be omitted. Figure 9 is shown using the gravel and grass pretreatment option, though it could be modified to use any of the pretreatment methods.

This figure also shows an overflow structure. Typically, an overflow structure is adapted from an existing drainage culvert inlet.

In Figure 9, the vertical sides of the bioretention cell do not have to be at a specified angle. However, the surface area of the bottom of the cell should be maximized.

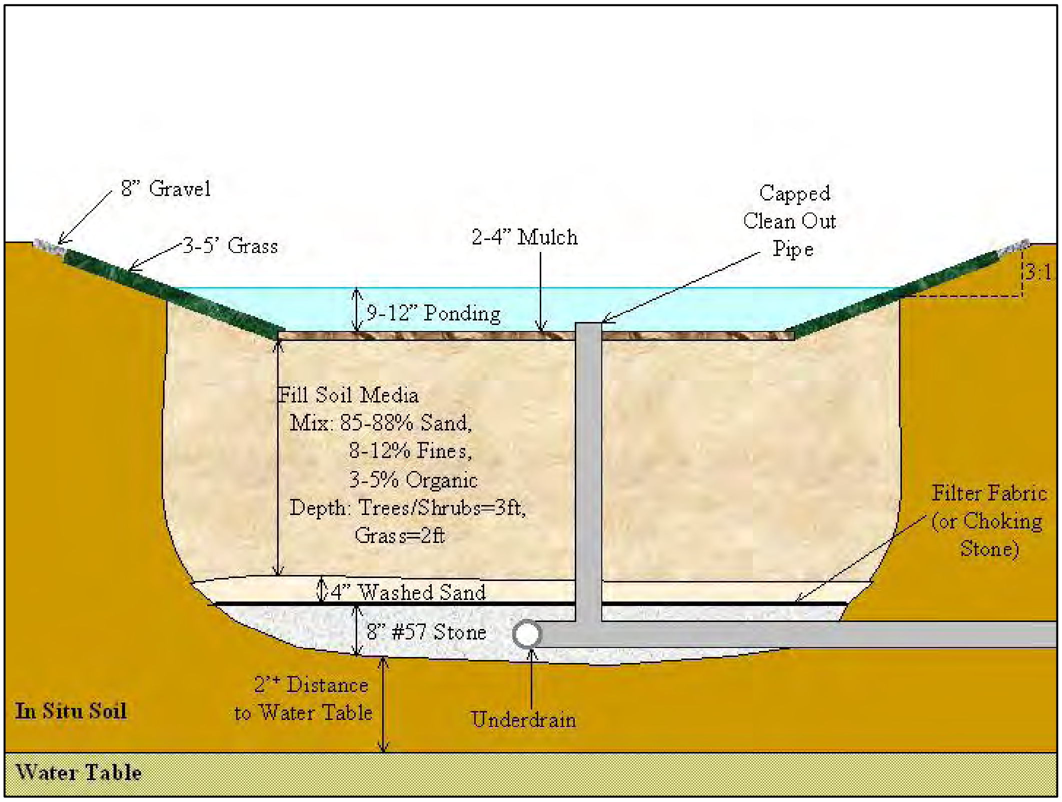


Figure 9: Bioretention Conceptual Layout: Cross-Section (Source: NCDENR)

Sediment Accumulation

There should be very little, if any, sediment accumulation in a bioretention cell, since the upstream drainage basin must be stabilized prior to bringing the bioretention cell into service, and since pretreatment is required prior to the BMP.

Drainage Considerations

Water shall pond above the cell for a maximum of 12 hours. Water must then drain to a level 24 inches below the surface of the cell within 48 hours (maximum) to allow the appropriate contact time for pollutant removal. This requirement is demonstrated in Figure 10. The time to drain the ponded volume is simply the depth of the ponding in inches, divided by the limiting drainage rate. If the cell has an underdrain, the length of time that it takes to drain the ponding volume of a bioretention cell is controlled by the infiltration rate of the media. If the cell does not have an underdrain and is an infiltration type system, it will be controlled by the lesser of the infiltration rate of the media or the infiltration rate of the native soil.

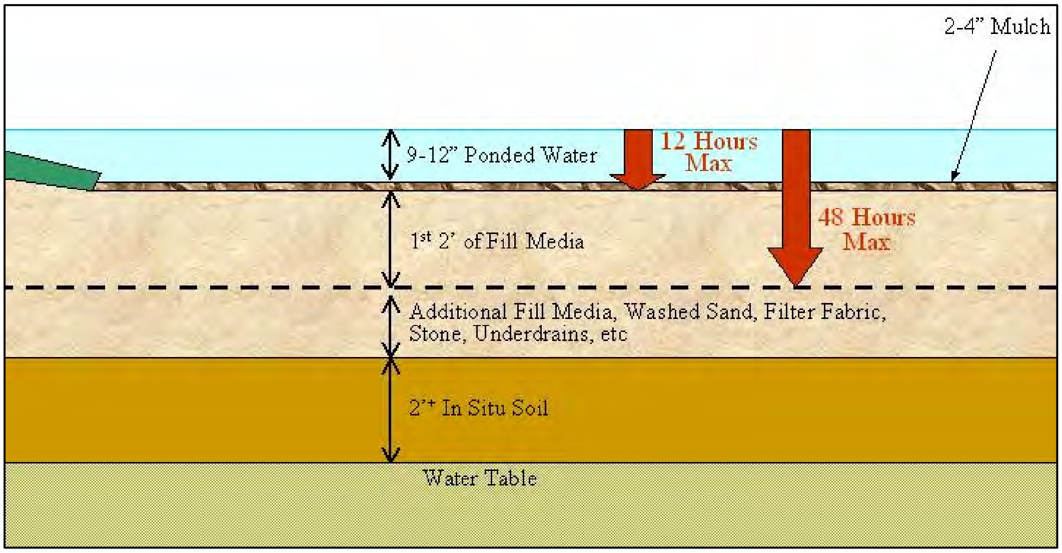


Figure 10: Bioretention Drain Time (Source: NCDENR)

Step 6: Size the Underdrains (if required)

The need for an underdrain is driven by the permeability of the in situ soil. If the in situ soil has a high permeability, the system can be designed as an infiltration type bioretention facility with no underdrains. If in situ soil permeability is less than 2 inches/hour, the bioretention facility will likely have an underdrain system. If the in situ soil drains more slowly than the planting media, the designer should include an explanation of how water will drain from the media. The underdrain system will connect to another BMP or to the conveyance system. Due to the risk of underdrain clogging, designers are encouraged to install more than one underdrain of smaller diameter in order to facilitate drainage. The minimum diameter of pipe for underdrain systems is four inches. As previously discussed, an upturned elbow may be used.

Clean-out pipes must be provided (minimum one per every 1,000 square feet of surface area). Clean-out pipes must be capped.

Step 7: Select the Appropriate Overflow Structure

The overflow structure should be sized to accommodate storm volumes in excess of the first flush. The first available outlet on the outlet structure should therefore be placed at the height of the first flush, which is the ponded level of the bioretention cell. Use the weir equation to consider the height of the water above the weir during overflow from large storm events. Typically, water can rise about 2 inches above the ponded water level. But, this height can be higher, about 4″-6″ above the ponded water level, if required by design restraints. A particular design storm is not specified for overflow structure design. Professional judgment should be used when considering potential flooding risks outside the bioretention cell.

Step 8: Select Plants and Mulch

Plants are an integral element of the bioretention system's pollutant removal and water filtration process. Plant roots aid in the physical and chemical bonding of soil particles necessary to form stable aggregates, improve soil structure, and increase infiltration capacity. Vegetated soils are more capable of more effective degradation, removal, and mineralization of total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, pesticides, chlorinated solvents, and surfactants than are nonvegetated soils (USEPA, 2000).

The primary design considerations for plant selection include the following:

1. Soil moisture conditions: Soil moisture conditions will vary widely within the bioretention facility from saturated (bottom of cell) to relatively dry (rim of cell), as well as over time. Therefore, the predominant plant material utilized should be facultative species adapted to stresses associated with both wet and dry conditions (MDER, 2002). In some cases, the in situ soil can be ripped and amended so that vegetation can grow.
2. Pollutant loadings: Since bioretention is often specified for use in impaired and/or nutrient-sensitive watersheds, strategic use of particular plants for phytoremediation purposes is crucial. Plants should tolerate typical pollutants and loadings from the surrounding land uses.
3. Above- and below-ground infrastructure in and near the bioretention facility: Plant selection should consider the surrounding conditions, including light pollution tolerance, wind, and above- and below-ground utilities. Slotted or perforated pipes should be more than 5 feet away from tree locations. Plants with taproots should not be used.
4. Adjacent plant communities and potential invasive species control.
5. Site distances and setbacks for roadway applications.
6. Visual buffering: Plants can be used to buffer structures from roads, enhance privacy among residences, and provide an aesthetic amenity for the site.
7. Aesthetics: Visually pleasing plant designs add to the property and encourage community and homeowner acceptance. Public education and participation in the plant selection and design should be encouraged to promote greater involvement in long-term care.
8. Grass may be used; however, grassed cells must be sodded (not seeded), and the sod must not be grown in soil that has an impermeable layer, such as clay.

Planting design will vary with the surrounding landscape context and design objectives. For example, the use of plants in bioretention areas could replicate a variety of native terrestrial ecosystems, including forests, ornamental gardens, meadows, hedgerows, and wetlands, as well as wildlife habitats.

A minimum of one tree, three shrubs, and three herbaceous species should be incorporated in the bioretention planting plan unless it is a grassed cell. A diverse plant community is necessary to avoid susceptibility to insects and disease. A recommended minimum planting density is 400 stems/acre. Bacteria die-off occurs at the surface where stormwater is exposed to sunlight and the soil can dry out. Therefore, it is best for bioretention cells to not be too densely vegetated in order to allow greater exposure to sunlight and consequent die-off of bacteria (NCCE 2007).

The plants selected should be able to tolerate typical stormwater pollutant loads, variable (often very dry) soil moisture, temporary submergence, and extended wet conditions. Consult a design profession for the selection of plants.

To increase survival rates and ensure quality of plant materials, the following general guidelines for plantings within bioretention facilities are recommended:

- All plant material should conform to the standards of the current edition of American Standards for Nursery Stock as approved by the American Standards Institute, Inc. All plant grades shall be those established by the current edition of American Standards for Nursery Stock [http://www.anla.org/applications/Documents/Docs/ANLAStandard2004.pdf].
- All plant materials should have normal, well-developed branches and vigorous root systems, and be free from physical defects, plant diseases, and insect pests.
- All plant materials should be tagged for identification when delivered.
- Optimum planting time is fall. Winter planting is acceptable. Spring is acceptable but will require more summer watering than fall planting. Summer planting is the least desirable, as it drastically increases plant mortality and requires regular watering immediately following installation.
- Plant size should be no less than 2.5″ diameter at breast height for trees; 3-gallon for shrubs; and 1-quart for herbaceous plants.
- Woody vegetation should not be planted at inflow locations.
- For best survival, trees should be planted with the top of the root ball partially out of the media. They should be planted to have from 1/3 to 1/2 of the root ball within the media. This would leave from 2/3 to 1/2 of the root ball above the media.

Local jurisdictions often have specific guidelines for the types and location of trees and other landscape plants planted along public streets or rights-of-way. Additionally, local landscape ordinances must be followed. Contact local authorities to determine if there are guidelines or restrictions to consider when making plant selections for your project.

The mulch layer plays an important function in the performance of the bioretention system by reducing weed establishment; regulating soil temperatures and moisture; reducing soil compaction from rainfall; preventing erosion; and promoting an environment suitable for soil microorganisms at the mulch/soil interface (important for filtering nutrients and other pollutants). Mulches prevent soil and possible fungi from splashing on the foliage, reducing the likelihood of soil-borne diseases (Evans, 2000). Mulch serves as a pretreatment layer by trapping the finer sediments that remain suspended after the primary pretreatment. Additionally, most attenuation of heavy metals in bioretention facilities occurs in the first 1-2 inches of the mulch layer (Hinman, 2005). Other considerations related to mulch are these:

- Mulch should be free of weed seeds, soil, roots, and other material that is not bole or branch wood or bark.
- Use commercially available double- or triple-shredded hardwood mulch. This mulch has been found to be less likely to wash away than other forms of mulch (such as pine).
- Mulch depth depends on the type of material used and the drainage and moisture-holding capacity of the soil. A 2-4 inch layer (after settling) is adequate for most applications. Excessive application of mulch can result in a situation where the plants are growing in the mulch and not the soil. Over-mulched plants are easily damaged during periods of drought stress. Mulching in an area that is poorly drained can aggravate the condition (Evans, 2000).
- Mulch can be applied any time of year; however, the best time to mulch is late spring after the soil has warmed.
- Mulch should be at least 6 months old (12 months is ideal).
- It should be placed uniformly, about 3 inches deep.
- Mulch should be renewed as needed to maintain a 2-4″ depth; on previously mulched areas, apply a one-inch layer of new material. It should be added 1-2 times per year and completely removed/replaced once every two years.

Siting Considerations

Some considerations for selecting a stormwater-management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and the drainage area, soil and subsurface conditions, and the depth of the seasonably high groundwater table. Bioretention can be applied on many sites, with its primary restriction being the need to apply the practice on small sites.

Drainage Area

Bioretention areas should, in general, be used on small sites (i.e., 5 acres or less). When used to treat larger areas, they tend to clog. In addition, it is difficult to convey flow from a large area to a bioretention area.

Slope

Bioretention areas are best applied to relatively shallow slopes (usually about 5 percent). However, sufficient slope is needed at the site to ensure that water that enters the bioretention area can be connected with the storm drain system. These stormwater-management practices are most often applied to parking lots or residential landscaped areas, which generally have shallow slopes.

Soils/Topography

Bioretention areas can be applied in almost any soils or topography, since runoff percolates through a man-made soil bed and is returned to the stormwater system.

Groundwater

Bioretention should be separated somewhat from the groundwater to ensure that the groundwater table never intersects with the bed of the bioretention facility. This design consideration prevents possible groundwater contamination.

Design Variations

One design alternative to the traditional bioretention practice is the use of a “partial exfiltration” system, used to promote groundwater recharge. Other design modifications may make this practice more effective in arid or cold climates.

Partial Exfiltration

In one design variation of the bioretention system, the underdrain is installed on only part of the bottom of the system. This design alternative allows for some infiltration, with the underdrain acting as more of an overflow. This system can be applied only when the soils and other characteristics are appropriate for infiltration (see *Infiltration Trench* and *Infiltration Basin*).

Common Problems

Bioretention areas have a few limitations. Bioretention areas cannot be used to treat a large drainage area, limiting their usefulness for some sites. In addition, although the practice does not consume a large amount of space, incorporating bioretention into a parking lot design may reduce the number of parking spaces available if islands were not previously included in the design.

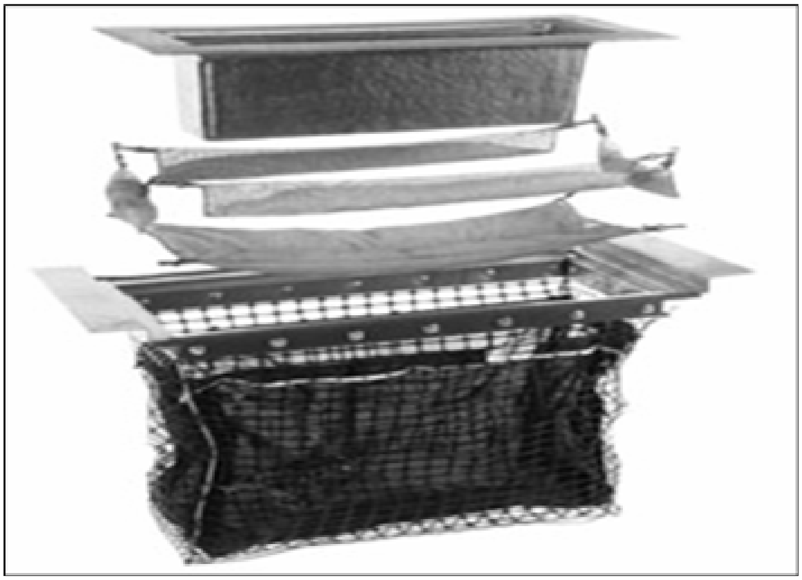
Maintenance

Common maintenance activities include re-mulching, treating diseased trees and shrubs, and mowing turf areas.

Newly planted vegetation should be watered regularly until properly established.

Erosion issues should be addressed immediately.

Catch Basin Inserts



Practice Description

Catch basins, also known as storm drain inlets and curb inlets, are inlets to the storm drain system. They typically include a grate or curb inlet and a sump to capture sediment, debris, and pollutants. Catch basins are used in combined sewer overflow watersheds to capture floatables and settle some solids, and they act as pretreatment for other treatment practices by capturing large sediments. The effectiveness of catch basins, that is, their ability to remove sediments and other pollutants, depends on their design (e.g., the size of the sump) and on maintenance procedures to regularly remove accumulated sediments from the sump.

Inserts designed to remove oil and grease, trash, debris, and sediment can improve the efficiency of catch basins. Some inserts are designed to drop directly into existing catch basins, while others may require retrofit construction.

Planning Considerations

Though they are used in drainage systems throughout the United States, many catch basins are not ideally designed for sediment and pollutant capture. Catch basins are ideally used as pretreatment to another stormwater-management practice. Retrofitting existing catch basins may substantially improve their performance. A simple retrofit option is to ensure that all catch basins have a hooded outlet to prevent floatable materials, such as trash and debris, from entering the storm drain system. Catch basin inserts for both new development and retrofits at existing sites may be preferred when available land is limited, as in urbanized areas.

Design Criteria

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 stormwater 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.

The basic design should also incorporate a hooded outlet to prevent floatable materials and trash from entering the storm drain system. Adding a screen to the top of the catch basin would not likely improve the performance of catch basins for pollutant removal, but it would help capture trash entering the catch basin (Pitt et al., 1997).

Several varieties of catch basin inserts exist for filtering runoff. One insert option consists of a series of trays, with the top tray serving as an initial sediment trap, and the underlying trays composed of media filters. Another option uses filter fabric to remove pollutants from stormwater runoff. Yet another option is a plastic box that fits directly into the catch basin. The box construction is the filtering medium. Hydrocarbons are removed as the stormwater passes through the box, while trash, rubbish, and sediment remain in the box itself as stormwater exits. These devices have a very small volume, compared to the volume of the catch basin sump, and would typically require very frequent sediment removal. Bench test studies found that a variety of options showed little removal of total suspended solids, partially due to scouring from relatively small (6-month) storm events (ICBIC, 1995).

One design adaptation of the standard catch basin is to incorporate infiltration through the catch basin bottom. Two challenges are associated with this design. The first is potential groundwater impacts, and the second is potential clogging, preventing infiltration. Infiltrating catch basins should not be used in commercial or industrial areas, because of possible groundwater contamination. While it is difficult to prevent clogging at the bottom of the catch basin, it might be possible to incorporate some pretreatment into the design.

Drainage Area

The total maximum drainage area should be 5,000 square feet (+5%) per unit for new development projects and 7,000 feet per unit for redevelopment projects.

Accessibility

The insert should be located so that is it readily accessible for maintenance requirements and so that it will not be blocked by parked vehicles.

Common Problems

Even ideally designed catch basins cannot remove pollutants as well as structural stormwater-management practices, such as wet ponds, sand filters, and stormwater wetlands.

Unless frequently maintained, catch basins can become a source of pollutants through resuspension.

Catch basins cannot effectively remove soluble pollutants or fine particles.

Maintenance

Typical maintenance of catch basins includes trash removal (if a screen or other debris-capturing device is used) and removal of sediment using a vacuum truck. Operators need to be properly trained in catch basin maintenance. Maintenance should include keeping a log of the amount of sediment collected and the date of removal. Some cities have incorporated the use of geographic information systems to track sediment collection and to optimize future catch basin cleaning efforts.

One study (Pitt, 1985) concluded that catch basins can capture sediments up to approximately 60 percent of the sump volume. When sediment fills greater than 60 percent of their volume, catch basins reach steady state. Storm flows can then re-suspend sediments trapped in the catch basin, and will bypass treatment. Frequent clean-out can retain the volume in the catch basin sump available for treatment of stormwater flows.

At a minimum, catch basins should be cleaned once or twice per year (Aronson et al., 1993). In some regions, it may be difficult to find environmentally acceptable disposal methods for collected sediments. The sediments may not always be land-filled, land-applied, or introduced into the sanitary sewer system due to hazardous waste, pretreatment, or groundwater regulations. This is particularly true when catch basins drain runoff from hot-spot areas.

Sand and Organic Filters

Practice Description

Sand filters are usually designed as two-chambered stormwater practices: the first is a settling chamber, and the second is a filter bed filled with sand or another filtering media. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering medium. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and multi-chamber treatment train. All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging design sites (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter).

Planning Considerations

Sand filters have been a proven technology for drinking water treatment for many years and more recently have been demonstrated to be effective in removing urban stormwater pollutants including total suspended solids, biological oxygen demand, fecal coliform, hydrocarbons, and metals. Since sand filters can be located underground, they can also be used in areas with limited surface space.

Sand filters are designed primarily for water quality enhancement; flow volume control is typically a secondary consideration. They are generally applied to land uses with a large fraction of impervious surfaces. Although an individual sand filter can handle only a small contributing drainage basin, multiple units can be dispersed throughout a large site. Sand filters can be of open basin design or of buried trench design (a closed basin). Sand filters typically employ underdrain systems to collect and discharge treated stormwater but can also be designed as infiltration type systems when located in soils with sufficient permeability or infiltration rates.

Sand filters are a good option to achieve water quality goals in retrofit studies where space is limited, because they consume very little surface space and have few site restrictions. It is important to note, however, that sand filters cannot treat a very large drainage area. Using small-site BMPs in a retrofit may be the only option for a retrofit study in a highly urbanized area, but it is expensive to treat the drainage area of an entire watershed using many small-site practices, as opposed to one larger facility such as a pond.

Design Criteria

Converting Erosion- and Sediment-Control Devices

A basin used for construction erosion and sediment control can be converted into an open basin-type sand filter if all sediment is removed from the basin prior to construction of the sand filter and proper sand filter design is followed. Buried trench-type sand filters are typically newly constructed after site construction and not placed in modified site construction sediment- and erosion-control basins. Sand filters are not to be brought on-line until site construction activities are completed and groundcover is fully stabilized.

Drainage Area

The maximum contributing drainage area to an individual sand filter shall be less than 5 acres; however, 1 acre or less is recommended. Multiple sand filters can be used throughout a development to provide treatment for larger sites.

Slope

Sand filters can be used on sites with slopes up to about 6 percent. It is challenging to use most sand filters in very flat terrain because they require a significant amount of elevation drop, or head (about 5 to 8 feet), to allow flow through the system. One exception is the perimeter sand filter, which can be applied with as little as 2 feet of head.

Soils/Topography

When sand filters are designed as a stand-alone practice, they can be used on almost any soil because they can be designed so that stormwater never infiltrates into the soil or interacts with the groundwater. Alternatively, sand filters can be designed as pretreatment for an infiltration practice, where soils do play a role.

Groundwater

Designers should provide at least 2 feet of separation between the bottom of the filter and the seasonally high groundwater table. This design feature prevents both structural damage to the filter and possibly, though unlikely, groundwater contamination.

Pretreatment

Erosive velocities and high sediment loads are a concern with sand filters. Sediment can quickly blind a sand filter and cause premature failure of the BMP. Two devices that reduce the impact of these factors on the sand filter are flow splitter devices and forebays.

Flow beyond the design flow can overload the hydraulic capacity of a sand filter (usually resulting in an overflow), cause erosion in open basin sand filters, and deliver more sediment to the sand filter than is necessary. Because of these issues, sand filters are required to be designed "off-line," meaning only the design volume of the stormwater flow is sent from the conveyance system into the treatment unit, and the excess is diverted.

A forebay or sedimentation chamber is required on all sand filters, to protect the sand filter from clogging due to sediment and to reduce the energy of the influent flow. The forebay can be in the form of an open basin (typical with an open basin sand filter design), or a subsurface concrete chamber (typical with a buried trench design). The forebay must contain ponded water (not be drained down with the sand filter). If a subsurface concrete chamber is provided, appropriate means of removing accumulated sediment must be demonstrated. Since individual sand filters treat relatively small volumes of stormwater and the design of the forebay is a percent of the total design volume, the forebay can also be very small. The minimum width (measurement parallel to flow direction) of the sedimentation chamber or forebay shall be 1.5 feet.

Following the sedimentation chamber or forebay, stormwater flow may be distributed over the surface of the sand filter in a variety of ways. In an open design, it could flow onto the sand filter as sheet flow via a level spreader. Depending on the geometry of the sand filter, however, that may not provide enough flow distribution to prevent overloading and clogging of the leading edge of the sand filter. One common method of distributing flow onto sand filters, both the open basin and buried trench types, is through the use of a pipe distribution or weir system.

Length, Width and Geometry

The area required for a sand filter device is calculated similar to many other BMP types. Since a sand filter must be completely drained within 40 hours, the ponding depth is a function of the media's infiltration rate. Once the ponding depth is known, the surface area can be calculated based on the design volume.

A sand filter consists of two parts, the sedimentation basin (which serves as a sort of forebay) and the sand filter itself. These two parts are collectively referred to as the "sand filter." An open basin type sand filter can be rectangular, square, circular, or irregular. Buried trench systems (closed basin systems) are often very rectangular, approaching linear. The important factor is that incoming stormwater is distributed relatively evenly over the surface of the sand filter. The following series of steps are used to determine the appropriate sand filter size.

Step 1: Compute the water quality volume (WQV) using Schueler's Simple Method, as described in Chapter 3 and summarized below, and the adjusted water quality volume (WQV_{Adj}) as defined below (CWP, 1996).

$$WQV(ft^3) = \frac{R_v(unitless)}{1} x \frac{A_D(acres)}{1} x \frac{43{,}560\,ft^2}{1Acre} x \frac{R_D inchRain}{1} x \frac{ft}{12in}$$

$$WQV_{Adj}(ft^3) = (0.75)WQV$$

- WQV: Water Quality Volume (ft^3). This is used to size the surface areas of the sedimentation chamber and the sand filter.

- WQV_{Adj}: Adjusted Water Quality Volume (ft^3). This is used as the volume that must be contained between the sedimentation chamber and the sand filter (above the sand).
- A_D: Drainage area to the sand filter (acres)
- R_v: Volumetric runoff coefficient (unitless) = 0.05 + 0.009(%Imp)
    - %Imp: Percent of impervious of land draining to the sand filter

Step 2: Determine the maximum and average head on the sand filter, and determine the surface areas of the sand filter and the sedimentation chamber.

Maximum Head on the Sand Filter

- $h_{MaxFilter}$(ft): Maximum head on the sand filter (ft). This head is typically measured from the top of the overflow weir, which separates the sediment chamber from the sand chamber, to the top of the sand and should be no more than 6 feet. Choose the maximum head so that the following equation is true:

$$h_{MaxFilter}(ft) = \frac{WQV_{Adj}(ft^3)}{A_S(ft^2) + A_f(ft^2)}$$

- A_s: Surface area of the sedimentation basin (ft^2)
- A_f: Surface area of the sand filter bed (ft^2)

$$h_A(ft) = \frac{h_{MaxFilter}(ft)}{2}$$

- h_A = Average head (ft). The average head on the sand filter is approximately equal to the average head on the sedimentation basin.

Sedimentation Basin Surface Area:

The minimum surface area for the sedimentation basin is determined by the Camp Hazen Equation:

$$A_s(ft^2) = -\frac{Q_o\left(\frac{ft^3}{\sec}\right)}{w\left(\frac{ft}{\sec}\right)} x \ln(1-E)$$

$$A_S(ft^2) = -\frac{\left(\frac{WQV(ft^3)}{24hr}\right)x\left(\frac{1hr}{3600\sec}\right)}{0.0004\left(\frac{ft}{\sec}\right)} x \ln(1-0.9)$$

$$A_S(ft^2) = 0.066WQV(ft^2)$$

$$A_S(ft^2) = 0.066\left[\frac{R_v(unitless)}{1} x \frac{A_D(Acres)}{1} x \frac{43{,}560(ft^2)}{(Acre)} x \frac{R_D(in)}{1} x \frac{1(ft)}{12(in)}\right](ft^2)$$

$$A_S(ft^2) = [240 * R_v(unitless) * A_D(acres)] * R_D(ft^2)$$

- Q_o: Average rate of outflow from the sedimentation chamber (ft^3/sec). (CWP, 1996)
- E: Trap efficiency of the chamber = 0.9 (unitless)
- w: Settling velocity of particle. Assume that the particles collected by the filter are 20 microns in diameter. For 20 microns, w = 0.0004 (ft/sec). This varies depending on the imperviousness of the land draining to the sand filter, but the value presented here is representative of most situations.

Sand Filter Bed Surface Area:
The minimum surface area for the sand filter bed is determined by Darcy's Law:

$$A_f\,(ft^2) = \frac{(WQV)(d_F)}{(k)(t)(h_A + d_F)}$$

- d_F: Depth of the sand filter bed, (ft). This should be a minimum of 1.5 ft.
- k: Coefficient of permeability for the sand filter bed = 3.5 (ft/day).
- t: Time required to drain the WQV through the sand filter bed (day). This time should be 40 hours (1.66 days).**Error! Bookmark not defined.**
- h_A: Average head (ft).
  - Determine the average head of water above the sand filter. The average head above the sand filter is half of the maximum head on the filter.

Step 3: Ensure that the water quality volume is contained:

- Ensure that this combination of variables will contain the required volume (WQV_{Adj} (ft^3)):
  - $\left[A_f\,(ft^2) + A_s\,(ft^2)\right] x \left[h_{MaxFilter}(ft)\right] \geq WQV_{Adj}\,(ft^3)$

Step 4: Additional design requirements:
For underground sand filters, provide at least 5 feet of clearance between the surface of the sand filter and the bottom of the roof of the underground structure to facilitate cleaning and maintenance.

Example Calculation

Design a sand filter to treat the first inch of water from a 1-acre site that is 100% impervious. There is 720 ft^2 of space available for this underground project.

Step 1 – Compute water quality volume

- Rv = 0.05 + 0.9(%Imp) = 0.05 + 0.009(100) = 0.95
- $WQV(ft^3) = \frac{0.95(unitless)}{1}\,x\,\frac{1(acres)}{1}\,x\,\frac{43{,}560\,ft^2}{1Acre}\,x\,\frac{1inchRain}{1}\,x\,\frac{ft}{12in} = 3{,}449\,ft^3$

  $WQV_{Adj}\,(ft^3) = (0.75)(3{,}449) = 2{,}587(ft^3)$

Step 2 – Determine filter bed and sedimentation basin surface areas with respect to water quality volume and maximum head

- $h_{MaxFilter}(ft) = \dfrac{2{,}586(ft^3)}{A_S(ft^2) + A_f(ft^2)}$, for maximum heads between 0.5 foot and 6 feet, the following combinations of variables will work:

$H_{MaxFilter}$ (ft)	WQV_{adj} (cu ft)	$A_s + A_f$ (sq ft)
0.5	2,586	5,172
1.0	2,586	2,586
1.5	2,586	1,724
2.0	2,586	1,293
3.0	2,586	862
4.0	2,586	647
5.0	2,586	517
6.0	2,586	431

- $A_s(ft^2)$ = 240*0.95*1 = 228 (ft^2) – This is the minimum value for the area of the sedimentation basin. Larger basins are acceptable.

- Choose a combination of A_f and h_A to meet the available space on-site. Typically, the sedimentation chamber and the sand filter bed should be approximately the same size. If 720 ft^2 of space is available, then A_s and A_f can both be 360 ft^2, and the maximum head on the sand filter is interpolated to be 3.6 ft. The average head is half of the maximum head, 1.8 ft. Check to ensure that the minimum area for the sand filter is attained:

  - $A_f(ft^2) = \dfrac{(3{,}449(ft^2))(1.5(ft))}{(3.5(ft/day))(1.66(day))(1.8(ft)+1.5(ft))} = 270\ ft^2$.

  This is the minimum value for the area of the sand filter. Larger sand filters are acceptable, and therefore the chosen combination of variables is acceptable for this design.

- There are several combinations of surface areas and depths that would be acceptable for this design. In this example:
  - $A_f = 360\ ft^2$
  - $A_s = 360\ ft^2$
  - $h_{MaxFilter} = 3.6$ ft
  - $h_A = 1.8$ ft

Step 3 – Verify volumes

- $2{,}592(ft^3) = [360(ft^2) + 360(ft^2)]x[3.6(ft)] \Rightarrow \geq\ 2{,}586(ft^3)$

Step 4 – Check additional design criteria

- Because this is an underground project, sufficient access must be provided to facilitate cleaning and maintenance.

Treatment

Treatment design features help enhance the ability of a stormwater-management practice to remove pollutants. In filtering systems, designers should provide at least 75 percent of the water quality volume in the practice, including both the sand chamber and the sediment chamber. The filter bed should be sized using Darcy's Law, which relates the velocity of fluids to the hydraulic head and the coefficient of permeability of a medium. In sand filters, designers should select a medium-sized sand as the filtering medium.

Media Requirements

The media in the sand filter shall be cleaned, washed, coarse masonry sand such as ASTM C33. The sand particles shall be less than 2 mm average diameter. The filter bed shall have a minimum depth of 18 inches, with a minimum depth of sand above the drainage pipe of 12 inches. The medium for organic filtering can be a combination of 50% peat and 50% sand or compost-only filter, both with a minimum depth of 18 inches. The peat/sand filter should be installed over a 6-inch layer of sand.

Conveyance

Conveyance of stormwater runoff into and through the filter should be conducted safely and in a manner that minimizes erosion potential. Ideally, some stormwater treatment can be achieved during conveyance to and from the filter. Since filtering practices are usually designed as "off-line" systems, meaning that they have the smaller water quality volume diverted to them only during larger storms, using a flow splitter, which is a structure that bypasses larger flows to the storm drain system or to a stabilized channel. One exception is the perimeter filter. In this design, all flows enter the system, but larger flows overflow to an outlet chamber and are not treated by the practice. All filtering practices, with the exception of exfilter designs, are designed with an underdrain below the filtering bed. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of filtering practices and used to collect and remove filtered runoff.

Drainage Considerations

The sand filter chamber shall drain completely within 40 hours. The length of time that it takes to drain the media of a filter is controlled by the infiltration rate of the media (or possibly the infiltration rate of the in situ soil if the system is designed as an infiltration type system).

Landscaping

Landscaping can add to both the aesthetic value and the treatment ability of stormwater practices. In sand filters, little landscaping is generally used on the practice, although surface sand filters and organic media filters may be designed with a grass cover on the surface of the filter. In all filters, designers need to ensure that the contributing drainage has dense vegetation to reduce sediment loads to the practice.

Common Problems

When the filtering capacity diminishes substantially (e.g., when water ponds on the surface for more than 40 hours), remedial actions must be taken. One possible cause of this problem is that collection pipe systems have become clogged. Annual flushing of pipe clean-outs is recommended to facilitate unclogging of the pipes without disturbing the filter area. If the water still ponds above the sand filter bed for more than 40 hours, the top few inches of media should be removed and replaced with fresh media. The removed sediments should be disposed of in an acceptable manner (e.g., landfill). If the problem still persists, more extensive rebuilding is required.

Maintenance

Typical annual maintenance requirements are:

- Check to see that the filter bed is clean of sediments, and the sediment chamber is no more than one-half full of sediment; remove sediment if necessary.
- Make sure that there is no evidence of deterioration, sailing, or cracking of concrete.
- Inspect grates (if used).
- Inspect inlets, outlets, and overflow spillway to ensure good condition and no evidence of erosion.
- Repair or replace any damaged structural parts.
- Stabilize any eroded areas.
- Ensure that flow is not bypassing the facility.

Vegetated Filter Strip

Practice Description

Vegetated filter strips (grassed filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow, so the practice may be “short circuited” by concentrated flows, receiving little or no treatment.

Planning Considerations

Filter strips are applicable in most regions, but are restricted in some situations because they consume a large amount of space relative to other practices. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal components of the “outer zone” of a stream buffer (see *Riparian/Forested Buffer Practice*), or as pretreatment to a structural practice. This recommendation is consistent with recommendations in the agricultural setting that filter strips are most effective when combined with another practice (Magette et al., 1989).

Urban Areas

Urban areas are densely developed urban areas in which little pervious surface exists. Filter strips are impractical in ultra-urban areas because they consume a large amount of space.

Stormwater Hot Spots

Stormwater hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater. A typical example is a gas station. Filter strips should not receive hot-spot runoff, because the practice encourages infiltration. In addition, it is questionable whether this practice can reliably remove pollutants. Therefore, it should definitely not be used as the sole treatment of hot-spot runoff.

Stormwater Retrofit

A stormwater retrofit is a stormwater-management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Filter strips are generally a poor retrofit option because they consume a relatively large amount of space and cannot treat large drainage areas.

Design Criteria

Siting Considerations

In addition to the restrictions and modifications to adapting filter strips to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting filter strips.

Recommended distances (for the location of the filter strip from surface waters) depend on the applicable rules:

– An engineered filter strip may not be placed within either inner zone of a riparian buffer. However, it may be placed within a stormwater setback/buffer.

– Wetlands will be allowed within the filter strip only on a case-by-case basis.

Drainage Area

Typically, filter strips are used to treat very small drainage areas. The limiting design factor, however, is not the drainage area the practice treats but the length of flow leading to it. As stormwater runoff flows over the ground’s surface, it changes from sheet flow to concentrated flow. Rather than moving uniformly over the surface, the concentrated flow forms rivulets that are slightly deeper and cover less area than the sheet flow. When flow concentrates, it moves too rapidly to be effectively treated by a grassed filter strip. (The use of a level spreader may be helpful in cases with concentrated flows.) Furthermore, this concentrated flow can lead to scouring. As a rule, flow concentrates within a maximum of 75 feet for impervious surfaces and 150 feet for pervious surfaces (CWP, 1996). Using this rule, a filter strip can treat one acre of impervious surface per 580-foot length.

Slope

Filter strips should be designed on slopes between 2 and 6 percent. Greater slopes than this would encourage the formation of concentrated flow. Except in the case of very sandy or gravelly soil, runoff would pond on the surface of slopes flatter than 2 percent, creating potential mosquito-breeding habitat.

Soils /Topography

Filter strips should not be used on soils with high clay content, because they require some infiltration for proper treatment. Very poor soils that cannot sustain a grass cover crop are also a limiting factor.

Groundwater

Filter strips should be separated from the groundwater by between 2 and 4 ft to prevent contamination and to ensure that the filter strip does not remain wet between storms.

Design Considerations

Filter strips appear to be a minimal design practice because they are basically no more than a grassed slope. However, some design features are critical to ensure that the filter strip provides some minimum amount of water quality treatment.

- A pea gravel diaphragm should be used at the top of the slope. The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip.
- The filter strip should be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½-inch of runoff over the entire drainage area to the practice.
- The filter strip should be at least 25 feet long to provide water quality treatment.
- Designers should choose a grass that can withstand relatively high-velocity flows and both wet and dry periods.
- Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

Common Problems

Filter strips have several limitations related to their performance and space consumption:

- The practice has not been shown to achieve high pollutant removal.
- Filter strips require a large amount of space, typically equal to the impervious area they treat, making them often infeasible in urban environments where land prices are high.
- If improperly designed, filter strips can allow mosquitoes to breed.
- Proper design requires a great deal of finesse, and slight problems in the design, such as improper grading, can render the practice ineffective in terms of pollutant removal.

Maintenance

- Immediately after the filter strip is established, grass will be watered twice weekly, if needed, until the plants become established (commonly six weeks).
- Once a year, the filter strip will be reseeded to maintain a dense growth of vegetation
- Stable groundcover will be maintained in the drainage area to reduce the sediment load to the vegetation.
- Every two weeks during the growing season, the filter strip will be mowed. Turf grass should not be cut shorter than 3 to 5 inches and may be allowed to grow as tall as 12 inches depending on aesthetic requirements (NIPC, 1993). Forested filter strips do not require this type of maintenance.
- Once a year, the soil will be aerated if necessary.
- Once a year, soil pH will be tested and lime will be added if necessary.

Constructed Stormwater Wetland

Practice Description

Stormwater wetlands provide an efficient biological method for removing a wide variety of pollutants (e.g. suspended solids, nutrients (nitrogen, N, and phosphorus, P), heavy metals, toxic organic pollutants, and petroleum compounds) in a managed environment.

Compared with wet ponds, sand filters, bioretention areas, and other stormwater BMPs, wetlands have the best median removal rate for total suspended solids (TSS), nitrate-nitrogen, ammonia-nitrogen, total phosphorus (TN), phosphate-phosphorus, and some metals. Stormwater wetlands can also be used to reduce pollution associated with high levels of fecal coliform and other pathogen contamination. Wetlands temporarily store stormwater runoff in shallow pools that support emergent and riparian vegetation. The storage, complex microtopography, and vegetative community in stormwater wetlands combine to form an ideal matrix for the removal of many pollutants. Stormwater wetlands can also effectively reduce peak runoff rates and stabilize flow to adjacent natural wetlands and streams.

Wetlands are effective sedimentation devices and provide conditions that facilitate the chemical and biological processes that cleanse water. Pollutants are taken up and transformed by plants and microbes, immobilized in sediment, and released in reduced concentrations in the wetland's outflow, as shown in Figure 1.

Plants improve water quality by slowing water flow and settling solids, transforming or immobilizing pollutants, and supplying reduced carbon and attachment area for microbes (bacteria and fungi). Dense strands of vegetation create the quiescent conditions that facilitate the physical, chemical, and biological processes that cleanse the stormwater. Many herbaceous wetland plants die annually. Because the dead plant material requires months or years to decompose, a dense layer of plant litter accumulates in the wetland. Like the living vegetation, the litter creates a substrate that supports bacterial growth and physically traps solids.

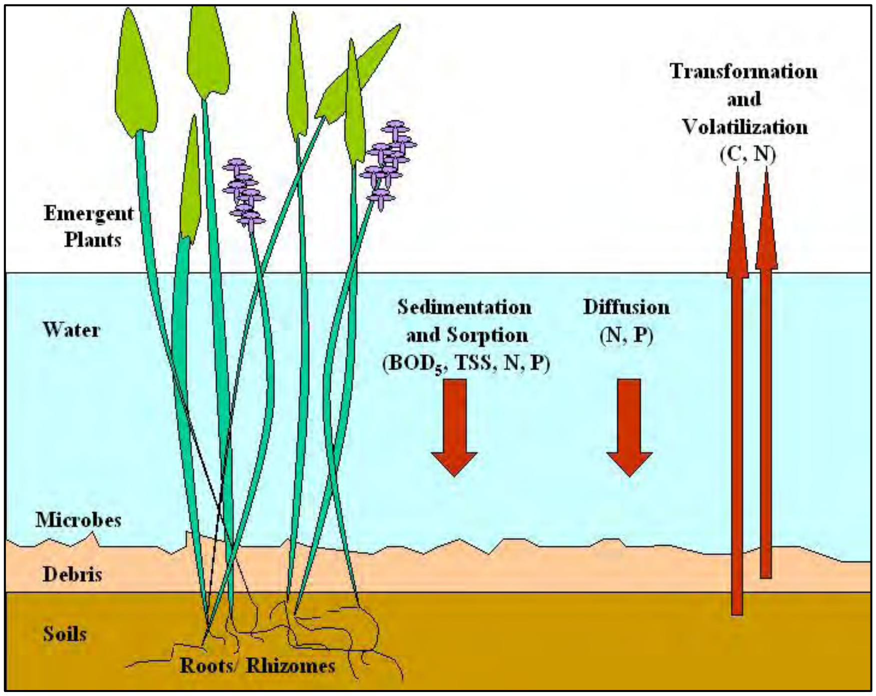


Figure 1 Wetland Microbes, Plants and Soil Transform and Take up Pollutants from Stormwater

Microorganisms, adhering to vegetation, roots, and sediment in the wetland, can decompose organic compounds and convert significant quantities of nitrate directly to nitrogen gas. Large amounts of nitrogen and phosphorus also can be incorporated in new soil and in the extra biomass of the wetland vegetation. Transformations can take place through both aerobic and anaerobic processes. For these reasons, maintaining the health of the vegetative community is critical for effective pollutant removal.

The ability of the emergent plants to settle and stabilize suspended solids in sediments and to reduce resuspension is important. The settling characteristic allows the wetland to remove pollutants such as phosphorus, trace metals, and hydrocarbons that are typically adsorbed to the surfaces of suspended particles.

Long-term data from stormwater wetlands indicate that treatment performance for parameters such as 5-day biochemical oxygen demand (BOD5), TSS, and TN typically does not deteriorate over the life of a stormwater wetland. The dissolved oxygen (DO) concentration in wetland outflows may be below 1.0 mg/L. Higher DO concentrations can be achieved by incorporating aeration techniques such as turbulent or cascading discharge zones, or mechanical mixing.

Planning Considerations

Stormwater wetlands occupy somewhat more surface area than a wet detention pond, but have the potential to be better integrated aesthetically into a site design because of the abundance of aquatic vegetation. Stormwater wetlands require a drainage area sufficiently large, or adequate groundwater or surface water supplies, to provide year-round hydration. In sloping terrain, wetland cells can be arranged in series on terraces.

Stormwater wetlands are appropriately located at the lower parts of the development site. Careful planning is needed to be sure that sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wet detention ponds, water loss by evaporation is an important concern.

Stormwater wetlands are designed in such a way that the distance the water flows from the entrance to the exit is maximized. This allows for sufficient contact time for pollutant removal.

Design Criteria

Converting Erosion- and Sediment-Control Devices

Often, the same basin can be used during construction as a sediment- and erosion-control device and later converted to a stormwater wetland. Before conversion, all accumulated sediment must be removed and properly disposed of; then, the appropriate modifications to the basin depth, geometry, and hydrology, as well as inlet and outlet structures, etc., must be made.

Siting Considerations

In addition to the restrictions and modifications to adapting stormwater wetlands to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting wetlands.

Drainage Area

Wetlands need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

Slope

Wetlands can be used on sites with an upstream slope of up to about 15 percent. The local slope should be relatively shallow, however. While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).

Soils/Topography

Wetlands can be used in almost all soils and geology.

Nutrient Reduction

The wetland substrate contains a mixture of sediment, plants, water, and detritus that collectively remove multiple pollutants through a series of complementary physical, chemical, and biological processes. Stormwater wetlands are effective at reducing TSS, TN, and TP.

Some wetlands can be constructed as a pond/wetland system. In these cases, part of the BMP is a pond and part of it is a wetland. These systems are slightly less effective at nitrogen removal than wetland-only designs. In some cases, the pond/wetland systems provide additional benefits that warrant a less effective nitrogen removal BMP and therefore should be considered based on the priority of pollutant removal.

Design Considerations

Design is a six-step process:

1) Understand basic layout concepts

2) Determine the volume of water to treat

3) Determine surface area and depth of each wetland zone

4) Select the soil media type

5) Select the appropriate outlet structure

6) Select plants

Step 1: Understand Basic Layout Concepts

Stormwater Wetland Components

Stormwater wetlands consist of six primary components. Figure 2 provides a conceptual diagram, and brief descriptions are given below.

1. **Inlet**: This is where water enters the wetland. The inlet can be a swale, a pipe, a diverter box, sheet flow, or other method of transporting water to the wetland.

2. **Deep Pool:** This zone consists of permanent deep pools of water that retain water even during drought. Deep pools in a stormwater wetland are one of two types:

a. *Forebay:* The forebay is a deep pool that directly follows the inlet provides two important functions: (1) dissipates runoff velocity and energy and (2) collects gross solids and sediment to ease maintenance of the BMP. The forebay essentially acts as a pretreatment device for the stormwater wetland. The water flows out of the forebay and into the wetland. The entrance to the forebay is deeper than the exit of the forebay. This design will dissipate the energy of the water entering the system, and will also ensure that large solids settle out.

b. *Non-Forebay Deep Pools*: Other deep pools in the wetland are always full of water and are areas where rooted plants do not live. Submerged and floating plants may be used in this area, except around the wetland outlet device. The deep pool at the outlet should be non-vegetated to prevent clogging. Deep pools provide additional pollutant removal and storage volume as well as habitat for aquatic wildlife such as the mosquito-eating fish. Include a deep pool next to the outlet structure to allow for proper drawdown.

3. **Shallow water, “low marsh”**: Shallow water includes all areas inundated by the permanent pool to a depth of 3″-6″ with occasional drying during periods of drought. The shallow water zone provides a constant hydraulic connection between the inlet and outlet structure of the stormwater wetland. The top of the shallow water zone represents the top of the permanent pool elevation (PPE). Herbaceous plants, listed in Table 1, are recommended for this area because they are more efficient in the pollutant removal process and less likely to encourage mosquito growth.

4. **Shallow land, “high marsh” or “temporary inundation zone”**: This zone provides the temporary storage volume of the stormwater wetland. The top of the shallow land zone represents the top of the temporary pool elevation (TPE). The shallow land is wet only after a rain event, and rooted plants live in this zone. (See Table 1 at the end of this section for plant selection.) Shallow land in a wetland provides pollutant uptake, shade, and wildlife habitat and should be planted with vegetation able withstand irregular inundation and occasional drought.

5. **Upland**: These areas are never wet, are not a required element of wetland design, and can be eliminated if space is of concern. They may serve as an amenity or provide access for maintenance. Some wetlands have upland areas as an island in the center of the wetland.

6. **Outlet**: The outlet structure consists of a drawdown orifice placed at the top of the shallow water elevation so that stormwater accumulating in the shallow land area will be able to slowly draw down from the wetland. The outlet structure may also be designed to pass larger storm events, which will have a higher flow outlet at the proper elevation.

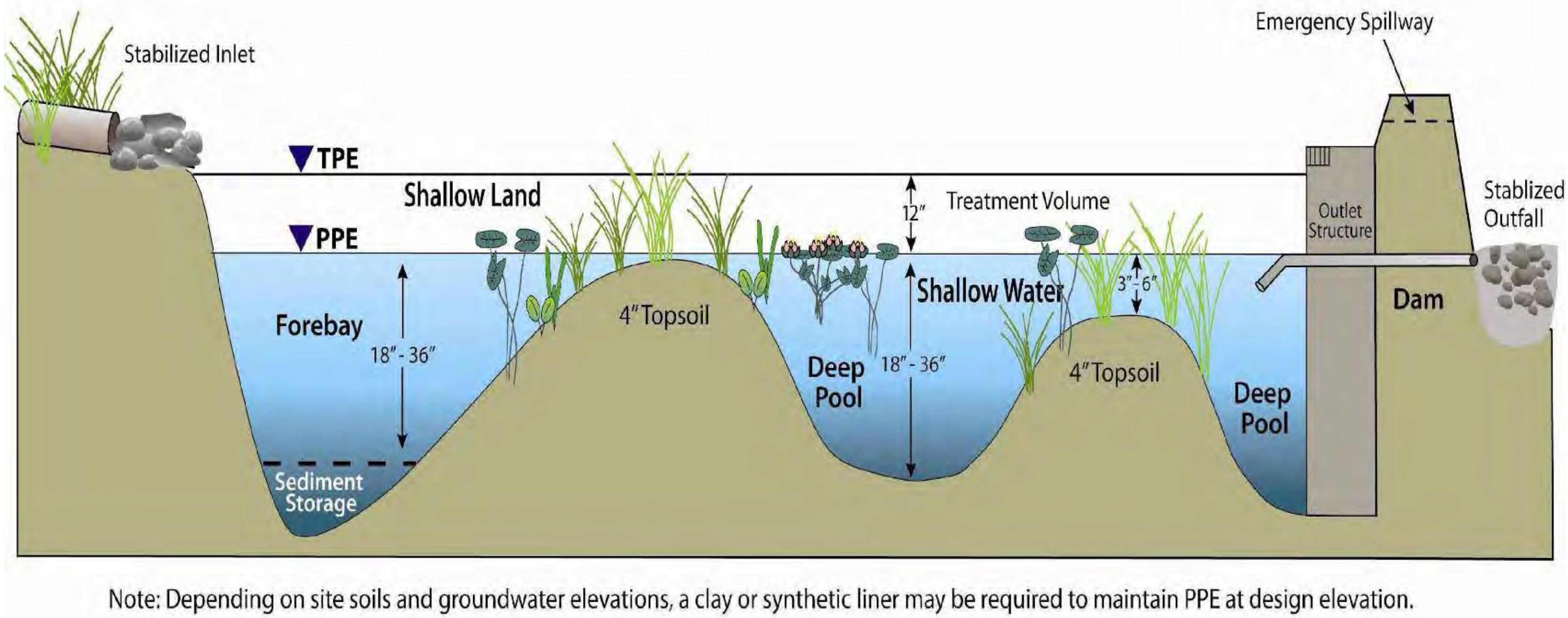


Figure 2 Constructed Stormwater Wetland Conceptual Diagram

Step 2: Determine the Volume of Water to Treat

Water Treatment Volume

A wetland is intended to treat the first flush (1″-1.5″) of a particular design storm. The Simple Method in Appendix A details the volumetric calculation.

Contributing Drainage

There is no minimum or maximum for the drainage area. Instead, any drainage area that contributes a minimum volume of 3,630 cubic feet is allowed. Smaller volumes will be allowed on a case-by-case basis, though supporting calculations such as a water balance or other justification will be required.

Siting Issues

Stormwater wetlands should not be located within existing jurisdictional wetlands or constructed as in-stream impoundments. If there are industrial or commercial land uses in the drainage area, accumulated pollutants may eventually increase environmental risk to wildlife (such as algae blooms). Typical pollutant loads found in residential and commercial settings are unlikely to cause this problem.

Pretreatment Options

Wetlands and pond/wetland systems require the use of a forebay for pretreatment.

Step 3: Determine Surface Area and Depth of Each Wetland Zone

Flow paths from inlet to outlet points within stormwater wetlands should be maximized. Internal berms and irregular shapes are often used to achieve recommended flow paths. The minimum length-to-width ratio shall be 1.5:1; however, 3:1 is highly recommended. Narrow, deep-water zones should be constructed at the wetland inlet and outlet to evenly distribute flow. Inlets also may incorporate pipe manifolds to enhance flow distribution. Deep-water zones perpendicular to the flow direction, and internal berms parallel to the flow, can also be used to reduce the potential for short-circuiting.

The total surface area of the deep-pool topographic zone should be broken into several micropools that are well dispersed throughout the wetland so that the distance for fish to travel within the shallow water zone to reach the entire wetland is minimized. One deep pool should be located at the entrance of the wetland, and one should be located at the exit. Other deep pools can be dispersed throughout the wetland.

The geometric calculations for wetlands are provided below. As opposed to many other types of BMP designs, the permanent volume of water contained in the stormwater wetland is not part of the design calculations, but is merely a result of the breakdown of natural or engineered hydrologic zones and their respective depths.

a. Determine Required Surface Area of Entire Wetland and Each Wetland Zone:

Two factors determine the surface area:

1) The watershed runoff volume that is to be contained (Q_{Volume}), and

2) The depth of water that plants can sustain for several days in the shallow land area (D_{Plants}), the depth of the temporary pool, up to 12 inches (Hunt and Doll, 2000).

The total surface area of the wetland is determined by the quotient of these variables. The surface area of each wetland zone is a percentage of the total required surface area.

Calculations for determining the surface areas of the various wetland zones are provided below.

• *Surface Area*: The total surface area of the wetland is

$$\frac{Q_{Volume}(ft^3)}{D_{Plants}(ft)} = \_\_\_ \text{ (SF)}$$

(Note: D_{Plants} can be up to 12 inches.) This surface area, in square feet (SF), is distributed to the various wetland zones as outlined below:

- Deep Pools: Ideally, several deep pools should be provided throughout the wetland.
  - Non-Forebay: 5-10% of wetland surface
  - Forebay: 10% of wetland surface
- Shallow Water (low marsh): 40% of wetland surface.
- Shallow Land (high marsh): 30-40% of wetland surface (maximize if pathogens are target pollutant).
- Upland: This is an optional design element. If upland area is included, it will not replace any of the required calculated surface area.

b. Design Depth of Each Wetland Zone: Determine the appropriate depth for each wetland zone. The following depths are recommended for each wetland zone as illustrated in Figure 2:

- Deep Pools:
  - Non-Forebay: 18-36" (include one at the outlet structure for proper drawdown).
  - Forebay: 18-36" plus additional depth for sediment accumulation (deepest near inlet to dissipate energy, more shallow near the exit).
- Shallow Water (low marsh): 3-6". A primary cause of wetland failure is designing this layer to be too deep.
- Shallow Land (high marsh): Up to 12". This is the depth, D_{Plants}, used in the surface area calculation, and is also the depth of the temporary pool.
- Upland: Up to 4 feet above the shallow land zone.

c. Double Check the Volume: Ensure that the volume of the shallow land section can accommodate the treatment volume necessary for the wetland (as was calculated in Step 2). The shallow land zone acts as the temporary pool and contains the treatment volume after a rain event.

Step 4: Select the Soil Media Type

A soil analysis should be conducted within the stormwater facility area to determine the viability of soils to ensure healthy vegetation growth and to provide adequate infiltration rates through the topsoil. For wetlands designed to utilize a clay or synthetic liner, at least four (4) inches of quality topsoil shall be added to the top of the liner to support plant growth. Imported or in situ soils may be amended with organic material, depending on soil analysis results, to enhance suitability as a planting media.

Step 5: Select the Appropriate Outlet Structure

The outlet design must be accessible to operators, easy to maintain, and resistant to fouling by floating or submerged plant material or debris. Wetlands should have both low- and high-capacity outlets. High-capacity outlets, such as weir boxes or broadcrested spillways, should be provided unless bypasses are provided for storms in excess of the first flush volume. The low-capacity outlet is typically a drawdown orifice and should be able to draw down the temporary pool within 2-5 days. Multiple-outlet structures are often used to balance the volume control requirements and maintenance needs. Additionally, designers can choose to install manual drawdown valves or flashboard risers (also called sliding weir plates) so that maintenance personnel can drain the wetland for maintenance purposes. If installed, drawdown valves should be secured so that only intended personnel can access them. Also, trash racks are recommended on the outlet structure to keep floating plants from clogging the outlet.

An ideal outlet structure should contain the following features:

- High-capacity weir box overflow;
- Low-capacity drawdown sized to draw down the temporary pool (shallow land zone) in 2-5 days; and
- Easy accessibility for operation and maintenance.

Overflow Structure Maintenance Considerations

Stormwater wetland maintenance must be considered when designing outlet structures. Occasionally, wetlands may require complete drawdown. The structures in Figure 3 show the low-capacity drawdown orifice, the high-capacity overflow, and a manually operated valve for maintenance purposes. Alternatively, a flashboard riser can be used to draw water down for maintenance, as shown in Figure 4.

Figure 3 Outlet Structures with Manual Drawdown Valve for Maintenance

Figure 4 Outlet Structure with Flashboard Riser for Maintenance (Photos Courtesy of NC State Science House & BAE)

One method to help ensure that the drawdown orifice does not clog is to turn the orifice downward below the normal pool as shown in Figure 5. This prevents floating debris or vegetation from clogging the orifice. The site in Figure 5 has been drained for maintenance.

Figure 5 Outlet Structure with Down-Turned Drawdown Orifice

The overflow structure should be located near the edge of the wetland so that it can be accessed easily for maintenance, as shown in Figure 6.

Figure 4 Outlet Structure Near Wetland Edge, Orifice Easily Accessible for Maintenance

Overflow structures that are several feet into the wetland, as shown in Figure 7, are difficult to reach and likely will not be maintained.

Figure 5 Outlet Structure Not Near Wetland Edge, Orifice *Not* Easily Accessible for Maintenance

Step 6: Select Plants

High pollutant-removal efficiencies in a stormwater wetland depend on a dense cover of emergent plant vegetation. Although various plant types differ in their abilities to remove pollutants from the water column, in general, the specific plant species do not appear to be as important for stormwater wetland functioning as plant growth survival and plant densities (Kadlex and Knight, 1996). In particular, species should be used that have high colonization and growth rates, can establish large areas that continue through the winter dormant season, have a high potential for pollutant removal, and are very robust in continuously or periodically flooded environments. Non-invasive species should be used. Native species are preferred.

Shrubs and wetland plants should be designed to minimize solar exposure of open water areas. A landscape plan should be prepared by a qualified design professional that outlines the methods to be used for maintaining wetland plant coverage.

A stormwater wetland facility consists of the area of the wetland, including bottom and side slopes, plus maintenance/access buffers around the wetland. Minimum elements of a stormwater wetland landscape plan include:

- Delineation of planting (pondscaping) zones;
- Selection of corresponding plant species;
- A minimum of ten (10) different species total, of which at least five (5) are emergent species, with no more than 30% of a single species;
- Buffers are recommended as centipede grass;
- Minimum plant quantities and sizes per 200 ft^2 of shallow water area: 50 herbaceous plants of at least 4-cubicinch container (equivalent to 2 ft on center minimum; 1.5 ft on center recommended)
- Minimum plant quantities and plant sizes per 200 ft^2 of shallow land area:

  50 herbaceous plants of at least 4-cubic inch container, OR

  8 shrubs of at least 1-gallon container (equivalent to 5 ft on center minimum; 3 ft on center recommended), OR

  1 tree of at least 3-gallon container and 40 grass-like herbaceous plants of at least 4-cubic inch container
- Source of plant materials (wetland seed mixes are not allowed);
- Planting layout;
- Sequence and timing for preparing wetland bed (including soil amendments, initial fertilization, and watering, as needed);
- Growing medium specifications (soil specifications); and
- Specification of supplementary plantings to replenish losses.

Soil bioengineering techniques, such as the use of fascines, stumps or logs, and coconut fiber rolls, can be used to create shallow land cells in areas of the stormwater wetland that may be subject to high flow velocities. The landscape plan should also provide elements that promote greater wildlife and waterfowl use within the wetland and buffers, as well as aesthetic considerations.

Five (5) or more species of emergent wetland plants should be selected in order to optimize treatment processes as well as to promote ecological mosquito control (i.e., attract a variety of predator insects for natural mosquito control). Use of trees and shrubs should be limited if mosquitoes are of concern, and these are best planted around the perimeter of the wetland. Cattails shall not be planted, as they can quickly take over and choke out other plants in the wetland, which will limit biodiversity and ultimately lead to mosquito infestation.

Plant recommendations are listed in Table 1. The listing of plant species is not exhaustive, and additional wetland plant species may be suitable that are not shown below. There are many excellent plant references in publication as well as recommendations from wetland scientists and landscape architects.

Table 1: Wetland Plant Recommendations

DEEP POOL

Botanical Name	**Common Name**
Floating Aquatic Plants	
Lemna spp.	Duckweed
Nelumbo lutea	American lotus
Nuphar lutea ssp. *polysepala*	Rocky Mtn Pond-lily
Nuphar lutea ssp. *advena*	Yellow Pond-lily
Submerged Aquatic Plants	
Eleocharis acicularis	Needle spikerush
Eleocharis quadrangulata	Squarestem spikerush
Elodea canadensis	Canadian waterweed
Elodea nuttallii	Western waterweed

SHALLOW WATER

Botanical Name	**Common Name**
Herbaceous Plants	
Acorus subcordatum	Sweetflag
Alisma subcordatum	Water plantain
Hydrolea quadrivalvis	Waterpod
Iris virginica	Blue flag iris
Juncus effusus var. pylaei or solutus	Soft rush
Ludwigia spp.	Primrose willow
Peltandra virginica	Arrow arum
Pontederia cordata	Pickerelweed
Sagittaria latifolia	Duck Potato
Sagittaria lancifolia	Bulltongue
Saururus cernuus	Lizard's tail
Schoenoplectus tabernaemontani	Soft stem bulrush
Schoenoplectus americanus	Three-square bulrush
Schoenoplectus pungens var. pungens	Common threesquare
Scirpus cyperinus	Woolgrass
Zizaniopsis miliacea	Giant cutgrass

SHALLOW LAND

Botanical Name	**Common Name**
Herbaceous Plants	
Asclepias incarnata	Swamp Milkweed
Carex tenera	Quill sedge
Chelone glabra	White Turtlehead
Eupatoriadelphus dubius	Dwarf Joe Pye Weed
Eupatoriadelphus fistulosus	Joe Pye Weed
Eupatoriadelphus maculatus	Spotted trumpetweed
Hibiscus coccineus	Scarlet rose mallow
Hibiscus laevis	Halberdleaf rosemallow
Kosteletzkya virginica	Seashore Mallow
Lobelia cardinalis	Cardinal flower
Lobelia elongata	Longleaf lobelia
Lobelia siphilitica	Great blue Lobelia
Rhynchospora colorata	Starrush whitetop
Saccharum baldwinii	Narrow plumegrass
Shrubs	
Aronia arbutifolia	Red Chokeberry
Cephalanthus occidentalis	Common Buttonbush
Clethra alnifolia	Sweet pepperbush
Cornus amomum	Silky dogwood
Cyrilla racemiflora	TiTi
Gordonia lasianthus	Bushy St. Johnswort
Hypericum densiflorum	Possumhaw
Ilex deciduas	Inkberry
Ilex glabra	InkberryVirginia Sweetspire
Itea virginica	Swamp Rose
Rosa palustris	Creeping Blueberry
Vaccinium crassifolium	Possumhaw
Viburnum nudum var. nudum	Loblolly Bay

Design Variations

There are several variations of the wetland design. The designs are characterized by the volume of the wetland in deep pool, high marsh, and low marsh, and whether the design allows for detention of small storms above the wetland surface.

Shallow Marsh

In the shallow marsh design, most of the wetland volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage to this design is that, since the pool is very shallow, a large amount of land is typically needed to store the water quality volume (i.e., the volume of runoff to be treated in the wetland).

Extended Detention Wetland

This design is the same as the shallow marsh, with additional storage above the surface of the marsh. Stormwater is temporarily ponded above the surface in the extended detention zone for 12 to 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate wet and dry periods should be specified in the extended detention zone.

Pond/Wetland System

The pond/wetland system combines the wet pond design (see *Wet Pond Practice*) with a shallow marsh. Stormwater runoff flows through the wet pond and into the shallow marsh. Like the extended detention wetland, this design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (i.e., 6-8 feet) pond.

Pocket Wetland

This design is very similar to the pocket pond (see *Wet Pond Practice*). In this design, the bottom of the wetland intersects the groundwater, which helps to maintain the permanent pool. Some evidence suggests that groundwater flows may reduce the overall effectiveness of stormwater-management practices (Brown and Schueler, 1997). This option may be used when there is not significant drainage area to maintain a permanent pool.

Gravel-Based Wetlands

In this design, runoff flows through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the rocks and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave like wet ponds with differences in grading and landscaping, gravel-based wetlands are more similar to filtering systems.

Construction Considerations

The wetland must be stabilized within 14 days of construction. Consider construction sequencing so that vegetation can be planted and the wetland brought online within 14 days. Plants may need to be watered during this time if the device is not brought online the same day. Stabilization may be in the form of final vegetation plantings or a temporary means until the vegetation becomes established. A good temporary means of stabilization is a wet hydroseed mix. For rapid germination, scarify the soil to a half-inch prior to hydroseeding.

Inlet and outlet channels should be protected from scour that may occur during periods of high flow. Standard erosion-control measures should be used. *Volume 1 - Erosion and Sediment Control Manual* can provide information on erosion- and sediment-control techniques.

The stormwater wetland should be staked at the onset of the planting season. Water depths in the wetland should be measured to confirm the original planting zones. At this time, it may be necessary to modify the planting plan to reflect altered depths or the availability of wetland plant stock. Surveyed planting zones should be marked on an "as-built" or record design plan and located in the field using stakes or flags.

The wetland drain should be fully opened for no more than 3 days prior to the planting date (which should coincide with the delivery date for the wetland plant stock), to preserve soil moisture and workability.

The most common and reliable technique for establishing an emergent wetland community in a stormwater wetland is to transplant nursery stock obtained from local aquatic plant nurseries. The optimal period for transplanting extends from early April to mid-June so that the wetland plants will have a full growing season to build the root reserves needed to survive the winter. However, some species may be planted successfully in early fall. Contact your nursery well in advance of construction to ensure that they will have the desired species available.

Post-nursery care of wetland plants is very important in the interval between delivery of the plants and their subsequent installation because they are prone to desiccation. Stock should be frequently watered and shaded.

Safety Considerations

The permanent pool of water presents an attractive play area to children and thus may create safety problems. Engineering design features that discourage child access are recommended. Trash racks and other debris-control structures should be sized to prevent entry by children. Other safety considerations include using fences around the spillway structure, embankment, and stormwater wetland slopes; using shallow safety benches around the stormwater wetland; and posting warning signs.

Fencing of stormwater wetlands is not generally aesthetically pleasing but may be required by the local review authority. A preferred method is to engineer the contours of the stormwater wetland to eliminate drop-offs and other safety hazards as discussed above. Riser openings must restrict unauthorized access. Endwalls above pipe outfalls greater than 48 inches in diameter must be fenced to prevent falls.

Common Problems

The landscape professional managing the wetland must understand the biological requirements of the plants and manage water levels appropriately to provide for their needs. For example, growing conditions are most critical during seed germination and early establishment. However, optimum conditions are not always required once the vegetated community becomes established.

Although wetland plants require water for growth and reproduction, they can be killed by drowning in excessively deep water. Usually, initial growth is best with transplanted plants in wet, well-aerated soil. Occasional inundation, followed by exposure of the majority of the vegetation to air, enables the plants to obtain oxygen and grow optimally. Conversely, frequent soil saturation is important for wetland plant survival.

If a minimum coverage of 70 percent is not achieved in the planted wetland zones after the second growing season, supplemental planting should be completed. Coverage of 90 to 95 percent is desirable.

Dramatic shifts can occur as plant succession proceeds. The plant community reflects management and can indicate problems or the results of improvements. For example, a requirement of submerged aquatic plants, such as pondweed (*Potamogeton* spp.), is light penetration into the water column. The disappearance of these plants may indicate inadequate water clarity. The appearance of invasive species or development of a monoculture is also a sign of a problem with the aquatic/soil/vegetative requirements. For instance, many invasive species can quickly spread and take over a wetland. If cattails become invasive, they can be removed by a licensed aquatic pesticide applicator by wiping aquatic glyphosate, a systemic herbicide, on the cattails.

Unlike maintenance requirements for wet or dry stormwater ponds, sediment should only be selectively removed from stormwater wetlands, primarily from the forebay. Sediment removal disturbs stable vegetation cover and disrupts flow paths through the wetland. The top few inches of sediment should be stockpiled so that it can be replaced over the surface of the wetland after the completion of sediment removal to re-establish the vegetative cover using its own seed bank. Accumulated sediment should be removed from around inlet and outlet structures.

Maintenance

- Immediately following construction of the stormwater wetland, bi-weekly inspections will be conducted and wetland plants will be watered bi-weekly until vegetation becomes established (commonly six weeks).
- No portion of the stormwater wetland will be fertilized after the first initial fertilization that is required to establish the wetland plants.
- Stable groundcover will be maintained in the drainage area to reduce the sediment load to the wetland.
- Once a year, a dam safety expert should inspect the embankment.

Dry Detention Pond

Practice Description

As the name of this BMP implies, these basins are typically dry between storm events. A low-flow outlet slowly releases water retained over a period of days. This BMP can be applied in residential, industrial, and commercial developments where sufficient space is available. The primary purpose of dry extended detention basins is to attenuate and delay stormwater runoff peaks. They are appropriate where water quality issues are secondary to managing peak runoff, since the overall pollutant removal efficiency of dry extended detention basins is low. Dry extended detention basins are not intended as infiltration or groundwater recharge measures

Planning Considerations

Dry detention ponds have traditionally been one of the most widely used stormwater best management practices. In some instances, these ponds may be the most appropriate best management practice. However, they should not be used as a “one size fits all: solution. If pollutant removal efficiency is an important consideration, dry detention ponds may not be the most appropriate choice. Dry detention ponds require a large amount of space to build. In many instances, smaller sized best management practices are more appropriate alternatives (see *Grassed Swales, Infiltration Basin, Infiltration Trench, Pervious Asphalt Pavement*, *Bioretention (Rain Gardens), Permeable Interlocking Concrete Paving,* or *Green Roofs*).

Design Criteria

Converting Sediment and Erosion Control Devices

Sediment basins that are used during construction can be converted into dry extended detention basins after the construction is completed. If used during construction as a sediment basin, the basin must be completely cleaned out, graded, and vegetated within 14 days of completion of construction.

Siting Considerations

Designers need to ensure that the dry detention pond is feasible at the site in question. This section provides basic guidelines for siting dry detention ponds.

Drainage Area

Dry extended detention basins can be utilized on very large sites, but often reach limitations around 25 acres or more. The most common limitation is the bottom of the basin approaching groundwater.

Slope

Dry detention ponds can be used on sites with slopes up to about 15 percent. The local slope needs to be relatively flat, however, to maintain reasonably flat side slopes in the practice. There is no minimum slope requirement, but there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that flow can move through the system.

Soils/Topography

Dry detention ponds can be used with almost all soils and geology, with minor design adjustments for regions of karst topography or in rapidly percolating soils such as sand. In these areas, extended detention ponds should be designed with an impermeable liner to prevent groundwater contamination or sinkhole formation.

Ground Water

Except for the case of hot spot runoff, the only consideration regarding groundwater is that the base of the extended detention facility should not intersect the groundwater table. A permanently wet bottom may become a mosquito breeding ground. Research in southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produced more mosquitoes than other pond systems, particularly when the facilities remained wet for more than 3 days following heavy rainfall.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Some features, however, should be incorporated into most dry extended detention pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

A forebay is highly recommended at the inlet of a dry extended detention basin to trap incoming sediment if the design flow to the facility is over 10 acre-inches. A forebay is recommended on all other dry detention basins. With heavy, coarse sediment confined to the forebay area, maintenance is made simpler and less costly and the life of the BMP is extended.

To prevent resuspension of trapped sediment and scour during high flows, the energy of the influent flow must be controlled. This can be in the form of a forebay as mentioned above, a plunge pool, riprap, or other energy-dissipating and erosion-control measures.

Treatment

Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. Designing dry ponds with a high length-to-width ratio (i.e., at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short-circuit the pond. Designing ponds with relatively flat side slopes can also help to lengthen the effective flow path. Finally, the pond should be sized to detain the volume of runoff to be treated for between 12 and 48 hours.

Length, Width, Depth and Geometry

The volume of a dry extended detention basin is driven exclusively by the volume of stormwater that is required to be captured. Once that volume is calculated, the dimensional aspect of the basin is mostly site driven. Below are some dimensional and layout requirements:

- The maximum depth shall be 10 feet.

- A minimum of 1 foot of freeboard shall be provided between the design flow pool elevation and the emergency overflow invert.

- The minimum flow length-to-width ratio shall be 1.5:1, but 3:1 is recommended. The basin width should preferably expand as it approaches the outlet.
- Side slopes of the basin shall be no steeper than 3H:1V if stabilized by vegetation.
- In addition to detention volume, design must provide for sediment storage equal to 25 percent of detention volume. If it is known that the upstream drainage basin will contribute high sediment loads (e.g. construction) over several years, then additional sediment storage should be provided.

By causing turbulence and eddies in the flow, flow short-circuiting can interfere with the function of the basin outlet system and should therefore be minimized. The most direct way of minimizing short-circuiting is to maximize the distance between the riser and the inlet. Larger length-to-width ratios should be used if sedimentation of particulates during low flows is desirable. Irregularly shaped basins appear more natural. If a relatively long, narrow facility is not suitable at a given site, baffles constructed from gabions or other materials can be placed in the basin to lengthen the flowpath.

A sinuous low-flow channel should be constructed through the basin to transport dry-weather flows and minor storm flows. Preferably, the channel would be grass lined and sloped at approximately 2 percent to promote drainage of the basin between storms. The entire bottom of the basin should drain toward the low-flow channel.

Conveyance

Conveyance of stormwater runoff into and through the dry pond is a critical component. Stormwater should be conveyed to and from dry ponds safely in a manner that minimizes erosion potential. The outfall of pond systems should always be stabilized to prevent scour. To convey low flows through the system, designers should provide a pilot channel. A pilot channel is a surface channel that should be used to convey low flows through the pond. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate the warming of water at the outlet channel, designers should provide shade around the channel at the pond outlet.

Outlet Design

In addition to meeting specific hydraulic requirements for runoff detention and peak attenuation, outlets also must be functionally simple and easy to maintain. Below are design requirements and guidelines for dry extended detention basin outlets:

- Basin design should include a small permanent pool near the outlet orifice to reduce clogging and keep floating debris away from the outlet.
- Basin design must include a drain that will completely empty the basin for clean-out.

- Durable materials such as reinforced concrete or plastic are preferable to corrugated metal in most instances.
- The riser should be placed in or at the face of the embankment to make maintenance easier and prevent flotation problems.
- Erosion protection measures should be used at the basin discharge point.
- To prevent piping and internal erosion problems around the spillway/outlet conduit through an embankment system, a filter diaphragm and drainage system is recommended.

Maintenance Reduction

Regular maintenance activities are needed to maintain the function of stormwater practices. In addition, some design features can be incorporated to ease the maintenance burden of each practice. In dry detention ponds, a “micropool” at the outlet can prevent resuspension of sediment and outlet clogging. A good design includes maintenance access to the forebay and micropool.

Another design feature that can reduce maintenance needs is a non-clogging outlet. Typical examples include a reverse-slope pipe or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and determines the water elevation of the micropool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.

Landscaping

When choosing vegetation for a dry extended detention basin, consideration must be given to the wildflowers or grasses specified because of the frequent inundations, warm and cold seasons, as well as salt and oil loading. Additionally, the plants should not be fertilized except for a one-time application after seeding. Mowing should be minimal. It has been found that a wet meadow mix or Bermuda grass typically performs well in those locations with the climate able to support it.

The dry extended detention basin must be stabilized within 14 days after the end of construction. The stabilization might be the final vegetation or a temporary stabilization measure until the vegetation becomes established.

Design Variations

Tank Storage

Another variation of the dry detention pond design is the use of tank storage. In these designs, stormwater runoff is conveyed to large storage tanks or vaults underground. This practice is most often used in the ultra-urban environment on small sites where no other opportunity is available to provide flood control. Tank storage is provided on small areas because underground storage for a large drainage area would generally be costly. Because the drainage area contributing to tank storage is typically small, the outlet diameter needed to reduce the flow from very small storms would very small. A very small outlet diameter, along with the underground location of the tanks, creates the potential for debris being caught in the outlet and resulting maintenance problems. Since it is necessary to control small runoff events (such as the runoff from a 1-inch storm) to improve water quality, it is generally infeasible to use tank storage for water quality and generally impractical to use it to protect stream channels.

Common Problems

Although dry detention ponds are widely applicable, they have some limitations that might make other stormwater management options preferable:

- Dry detention ponds have only moderate pollutant removal when compared to other structural stormwater practices, and they are ineffective at removing soluble pollutants.
- Dry extended detention ponds may become a nuisance due to mosquito breeding if improperly maintained or if shallow pools of water form for more than 7 days.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home.
- Dry detention ponds on their own only provide peak flow reduction and do little to control overall runoff volume, which could result in adverse downstream impacts.

Maintenance

– The drainage area will be managed to reduce the sediment load to the dry extended detention basin.

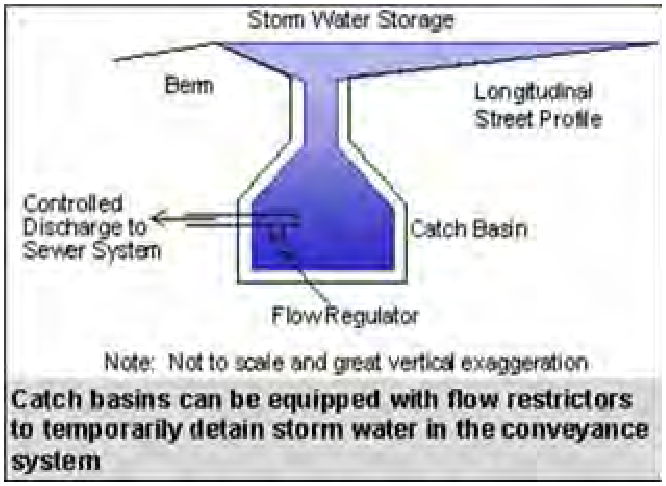
– Immediately after the dry extended detention basin is established, the vegetation will be watered twice weekly, if needed, until the plants become established (commonly six weeks).

– No portion of the dry extended detention pond will be fertilized after the first initial fertilization that is required to establish the vegetation.

– The vegetation in and around the basin should be maintained at a height of approximately six inches.

– Once a year, a dam safety expert will inspect the embankment.

In-Line Storage



Source: EPA

Practice Description

In-line storage refers to a number of practices designed to use the storage within the storm drain system to detain flows. While these practices can reduce storm peak flows, they are unable to improve water quality and offer limited protection of downstream channels. Hence, the U.S. Environmental Protection Agency does not recommend using these practices in many circumstances. Storage is achieved by placing devices in the storm drain system to restrict the rate of flow. Devices can slow the rate of flow by backing up flow, as in the case of a dam or weir, or through the use of vortex valves (devices that reduce flow rates by creating a helical flow path in the structure). A description of various flow regulators is included in Urbonas and Stahre (1990).

Planning Considerations

In-line storage practices serve a similar purpose as traditional detention basins (see *Dry Detention Ponds Practice*). These practices can act as surrogates for aboveground storage when little space is available for aboveground storage facilities.

Design Criteria

Flow regulators cannot be applied to all storm drain systems. In older cities, the storm drain pipes may not be oversized, and detaining stormwater within them would cause upstream flooding. Another important issue in siting these practices is the slope of the pipes in the system. In areas with very flat slopes, restricting flow within the system is likely to cause upstream flooding because introducing a regulator into the system will cause flows to back up a long distance before the regulator. In steep pipes, on the other hand, a storage flow regulator cannot utilize much of the storage available in the storm drain system.

Common Problems

In-line storage practices only control stormwater quantity and are not efficient at improving runoff water quality.

Without proper design, these practices often cause upstream flooding.

Maintenance

Flow regulators require very little maintenance because they are designed to be “self-cleaning,” much like the storm drain system. In some cases, flow regulators may be modified based on downstream flows, new connections to the storm drain, or the application of other flow regulators within the system. For some designs, such as check dams, regulations will require only moderate construction in order to modify the structure’s design.

Wet Pond

Practice Description

Wet ponds (a.k.a. stormwater ponds, wet retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). In wet detention basins, a permanent pool of standing water is maintained by the riser—the elevated outlet of the wet detention basin. Water in the permanent pool mixes with and dilutes the initial runoff from storm events. Wet detention basins fill with stormwater and release most of the mixed flow over a period of a few days, slowly returning the basin to its normal depth.

Runoff generated during the early phases of a storm usually has the highest concentrations of sediment and dissolved pollutants. Because a wet detention basin dilutes and settles pollutants in the initial runoff, the concentration of pollutants in the runoff released downstream is reduced. Following storm events, pollutants are removed from water retained in the wet detention basin. Two mechanisms that remove pollutants in wet detention basins include settling of suspended particulates and biological uptake, or consumption of pollutants by plants, algae, and bacteria in the water. However, if the basin is not adequately maintained (e.g., by periodic excavation of the captured sediment), storm flows may re-suspend sediments and deliver them to the stream.

Planning Considerations

Wet detention basins are applicable in residential, industrial, and commercial developments where enough space is available. Wet detention basins are sized and configured to provide significant removal of pollutants from the incoming stormwater runoff. The permanent pool of water is designed for a target total suspended solids removal efficiency according to the size and imperviousness of the contributing watershed. Above this permanent pool of water, wet detention basins are also designed to hold the runoff volume required by the stormwater regulations, and to release it over a period of 2 to 5 days. As a result, most of the suspended sediment and pollutants attached to the sediment settle out of the water. In addition, water is slowly released so that downstream erosion from smaller storms is lessened.

Design Criteria

Converting Erosion- and Sediment-Control Devices

Wet detention basins are typically part of the initial site clearing and grading activities and are often used as sediment basins during construction of the upstream development. Volume 1 contains design requirements for sediment basins required during construction. A sediment basin typically does not include all the engineering features of a wet detention basin, and the design engineer must ensure that the wet detention basin includes all the features identified in this section, including the full sizing as a wet detention basin. If the wet detention basin is used as a sediment trap during construction, all sediment deposited during construction must be removed, erosion features must be repaired, and the vegetated shelf must be restored, before operation as a stormwater BMP begins.

Siting Considerations

Because large storage volumes are needed to achieve extended detention times, wet detention basins require larger land areas than many other BMPs. Wet detention basins may not be suitable for projects with very limited available land. Permanent retaining walls may be used to obtain the required design volumes while reducing the footprint that would otherwise be required for earthen construction. Retaining walls utilized to contain the permanent pool must not reduce the required 10′ width of the vegetated shelf, and must not extend to a top elevation above the lowest point of the vegetated shelf. Retaining walls utilized to contain the temporary pool must not reduce the required 10′ width of the vegetated shelf, and must not be in contact with the stormwater stored up to the temporary pool elevation. Two retaining walls may be used, as shown in Figure 1. Or, the design may be altered to contain only one of the two shown.

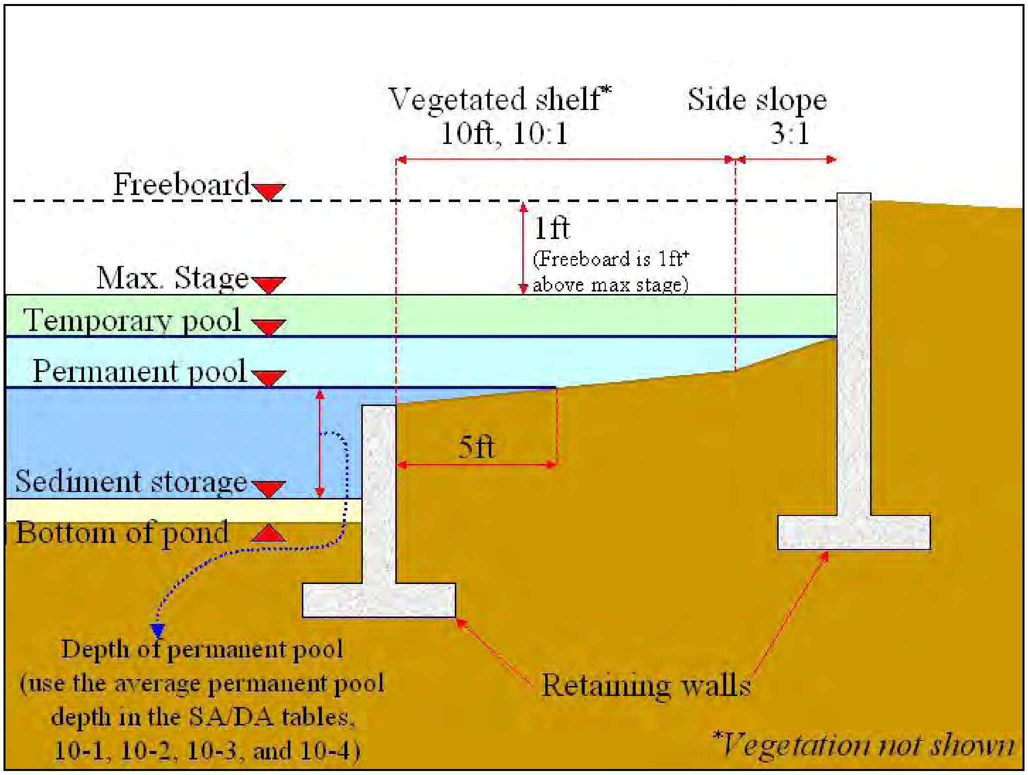


Figure 1 Alternative Wet Pond Design: Retaining Wall Option

Drainage Area

Wet ponds need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall. BMPs that focus on source control, such as bioretention, should be considered for smaller drainage areas.

Slope

Wet ponds can be used on sites with an upstream slope up to about 15 percent. The local slope should be relatively shallow, however. Although there is no minimum slope requirement, there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system.

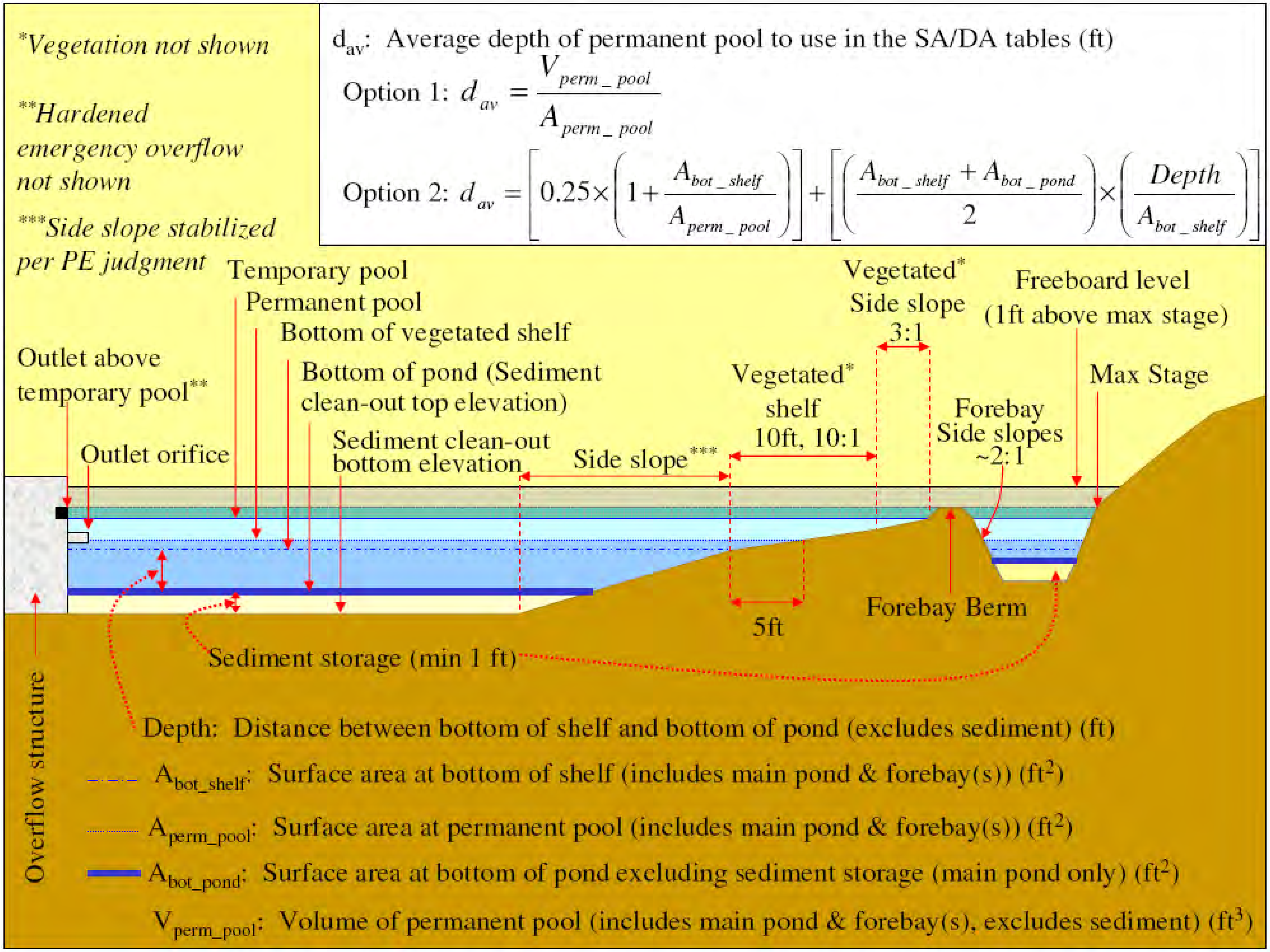


Figure 2 Basic Wet Detention Basin Elements: Cross Section

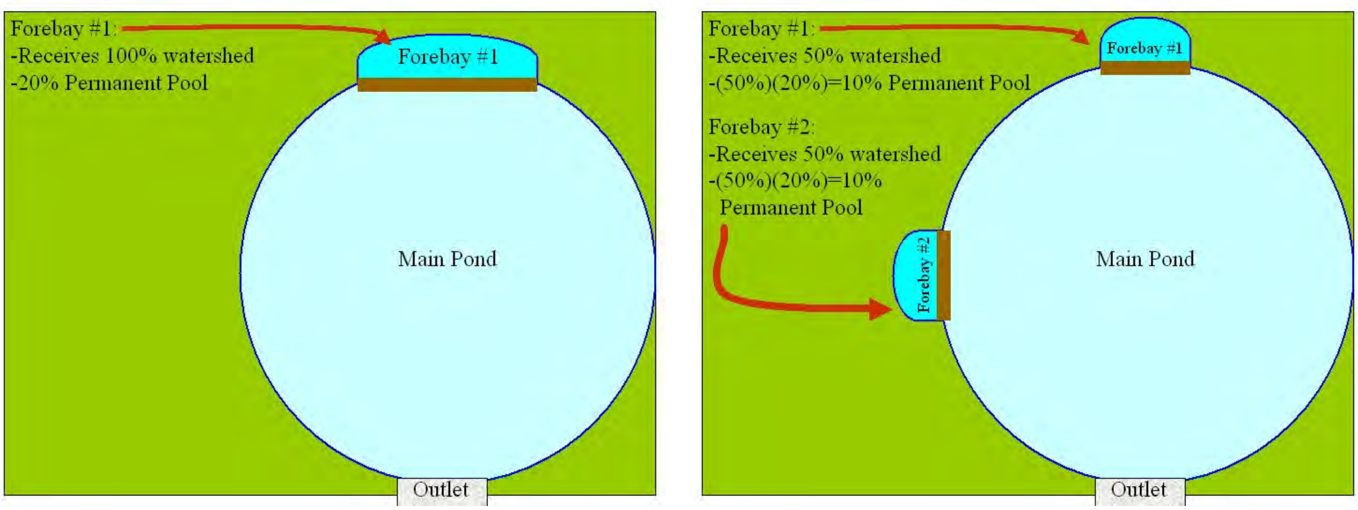
Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wet pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Forebays are highly recommended on all inlets to a wet detention basin. A properly engineered forebay can concentrate large particle-size sediment for easier removal, and can dissipate the incoming flow energy prior to the stormwater entering the main part of the BMP. The dissipation of incoming flow energy reduces re-suspension of settled material in the main pool, and it reduces the likelihood of erosion features within the BMP. Also, the forebay itself should be configured for energy dissipation within the forebay to avoid re-suspension of large-particle settled material previously captured in the forebay. One of several engineering means of energy dissipation is to have the inlet pipe submerged below the permanent forebay pool level, provided that the inlet placement does not serve to re-suspend previously captured sediment.

It is recommended that the design volume for the forebay be approximately 20% of the total calculated permanent pool volume. The main pool of the permanent pool would then account for approximately 80% of the design volume. If the pond has more than one forebay, the total volume of the forebays should equal 20% of the permanent pool volume. In this case, each forebay should be sized as in Figures 3–5.



Figures 3–4 Forebay Sizing Examples (continued)

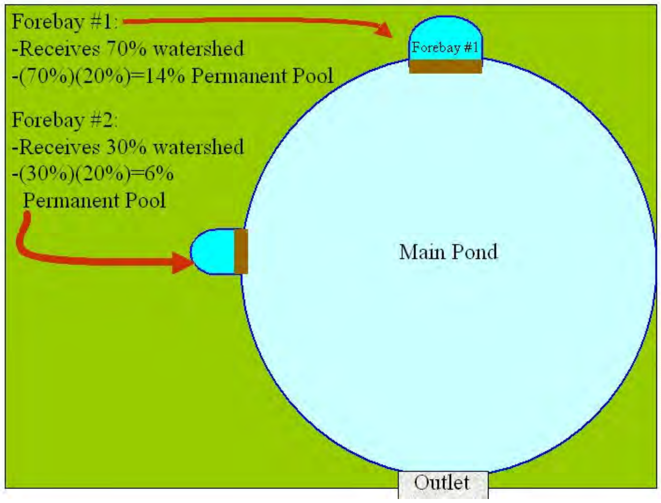


Figure 5 Forebay Sizing Examples (concluded)

Treatment

Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. The purpose of most of these features is to increase the amount of time that stormwater remains in the pond.

One technique of increasing the pollutant removal of a pond is to increase the volume of the permanent pool. Typically, ponds are sized to be equal to the water quality volume (i.e., the volume of water treated for pollutant removal). Designers may consider using a larger volume to meet specific watershed objectives, such as phosphorus removal in a lake system. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that sufficient inflow is available to maintain the permanent pool.

Other design features do not increase the volume of a pond, but can increase the amount of time stormwater remains in the practice and eliminate short-circuiting. Ponds should always be designed with a length-to-width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer route through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat stormwater. Another feature that can improve treatment is to use multiple ponds in series as part of a “treatment train” approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system. Additionally, a vegetated buffer with shrubs or trees around the pond area should provide shading and consequent cooling of the pond water.

If designers of wet ponds are anticipating ponds that stratify in the summer, they might want to consider installing a fountain or other mixing mechanism. This will ensure that the full water column remains oxic.

Conveyance

Length, Width (Area), Depth, Geometry

Depth is an important engineering design criterion because most of the pollutants are removed through settling. Very shallow basins may develop currents that can re-suspend materials; on the other hand, very deep wet detention basins can become thermally stratified and/or anoxic and release pollutants back into the water.

The engineering design of a wet detention basin must include a 10-foot-wide (minimum) vegetated shelf around the full perimeter of the basin. The inside edge of the shelf shall be no deeper than 6″ below the permanent pool level, and the outside edge shall be 6″ above the permanent pool level. For a 10′ wide shelf, the resulting slope is 10:1. With half the required shelf below the water (maximum depth of 6 inches), and half the required shelf above the water, the vegetated shelf will provide a location for a diverse population of emergent wetland vegetation that enhances biological pollutant removal, provides a habitat for wildlife, protects the shoreline from erosion, and improves sediment trap efficiency. A 10′ wide shelf also provides a safety feature prior to the deeper permanent pool.

Short-circuiting of the stormwater must be prevented. The most direct way of minimizing short-circuiting is to maximize the length of the flow path between the inlet and the outlet: basins with long and narrow shapes can maximize the length of the flow path. Long and narrow but irregularly shaped wet detention basins may appear more natural and therefore may have increased aesthetic value. If local site conditions prohibit a relatively long, narrow facility, baffles may be placed in the wet detention basin to lengthen the stormwater flow path as much as possible. Baffles must extend to the temporary pool elevation or higher. A minimum length-to-width ratio of 1.5:1 is required, but a flow path of at least 3:1 is recommended. Basin shape should minimize dead storage areas and, where possible, the width should expand as it approaches the outlet.

Although larger wet detention basins typically remove more pollutants, a threshold size seems to exist above which further improvement of water quality by sedimentation is negligible. The permanent pool volume within a wet detention basin is calculated as the total volume beneath the permanent pool water level, and above the sediment storage volume, including any such volume within the forebay.

Outlet Design

The outlet device shall be designed to release the temporary pool volume (minimum required treatment volume as calculated by the Simple Method) over a period of 48 to 120 hours (2 to 5 days). Longer detention times typically do not improve settling efficiency significantly, and the temporary pool volume must be available for the next storm. In addition, prolonged periods of inundation can adversely affect the wetland vegetation growing on the vegetated shelf.

In addition to being designed to achieve the 2- to 5-day drawdown period, outlets also must be functionally simple and easy to maintain. One possible configuration option of the outlet piping that simplifies maintenance and reduces the potential for obstruction is the submerged orifice arrangement shown in Figure 6.

Durable materials, such as reinforced concrete, are preferable to corrugated metal in most instances. The riser should be placed in or at the face of the embankment. By placing the riser close to the embankment, maintenance access is facilitated and flotation forces are reduced. The design engineer must present flotation force calculations for any outlet design subject to flotation forces.

Emergency overflow spillways must be designed with hardened materials at the points where extreme conditions might compromise the integrity of the structure.

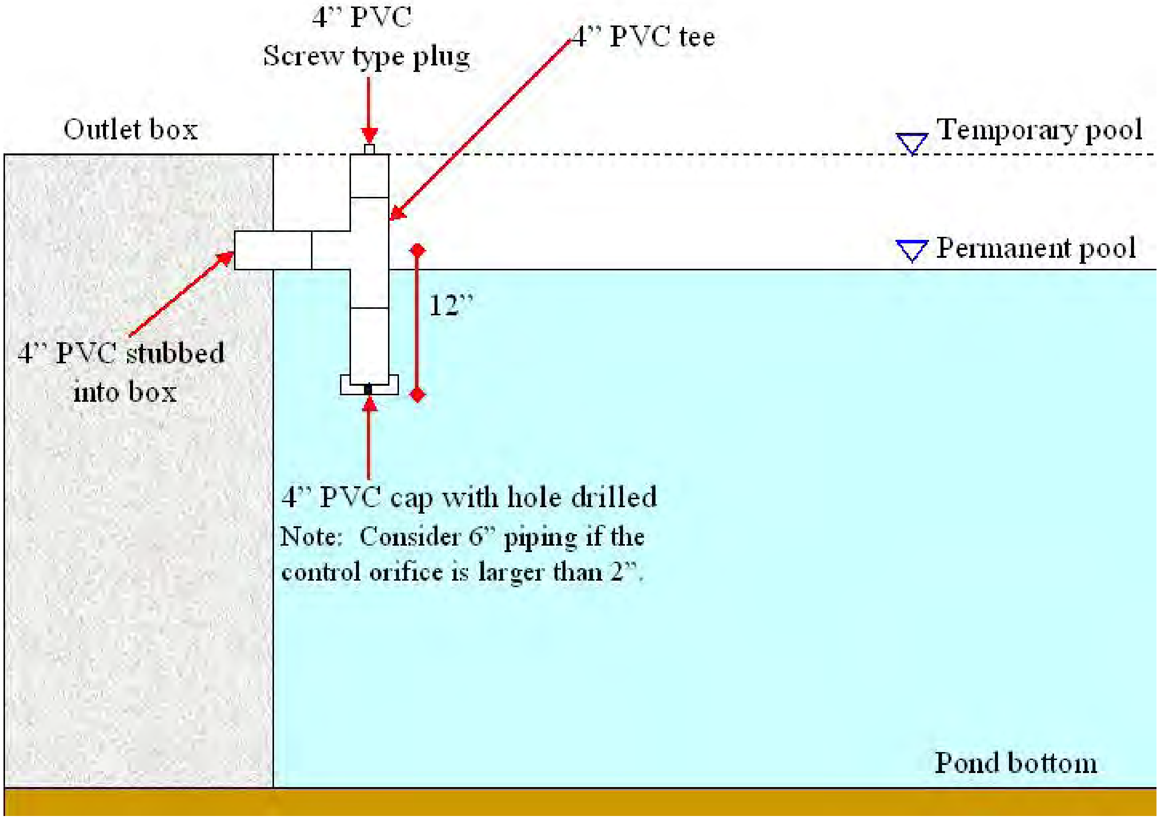


Figure 6

Typical Submerged Orifice Outlet Configuration

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of stormwater practices, some design features can be incorporated to ease the maintenance burden of each practice. In wet ponds, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wet ponds is clogging of the outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. (Smaller orifices are more susceptible to clogging.)

Design features are also incorporated to ease maintenance of both the forebay and the main pool of ponds. Ponds should be designed with maintenance access to the forebay to ease this relatively routine (5.7 year) maintenance activity. In addition, ponds should generally have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the pond.

Fountains in the Wet Pond

Fountains are optional, decorative wet pond amenities. If they are included, they shall be designed as follows:

1. Ponds smaller than 30,000 ft^3 cannot have a fountain.
2. The fountain must draw its water from less than 2′ below the permanent pool surface.
3. Separated units (where the nozzle, pump and intake are connected by tubing) may be used only if they draw water from the surface in the deepest part of the pond.
4. The falling water from the fountain must be centered in the pond, away from the shoreline.
5. The maximum horsepower for the fountain's pump is based on the permanent pool volume, as described in Table 1. As an example, if the pond's volume is 350,000 cubic feet, the maximum pump horsepower for the fountain is 1.

Table 1
Fountain Pump Power Requirements

Minimum Pond Volume (ft^3)	Max Pump HP
30,000	1/8
40,000	1/6
60,000	1/4
80,000	1/3
125,000	1/2
175,000	3/4
250,000	1
450,000	2
675,000	3

Landscaping

Landscaping of wet ponds can make them an asset to a community and can also enhance the pollutant removal of the practice. A vegetated buffer should be preserved around the pond to protect the banks from erosion and provide some pollutant removal before runoff enters the pond by overland flow. In addition, ponds should incorporate an aquatic bench (i.e., a shallow shelf with wetland plants) around the edge of the pond. This feature may provide some pollutant uptake, and it also helps to stabilize the soil at the edge of the pond and enhance habitat and aesthetic value.

Construction Considerations

Even moderate rainfall events during the construction of a wet detention basin can cause extensive damage to it. Protective measures should be employed both in the contributing drainage area, and at the wet detention basin itself. Temporary drainage or erosion control measures should be used to reduce the potential for damage to the wet detention basin before the site is stabilized. The control measures may include stabilizing the surface with erosion mats, sediment traps, and diversions. Vegetative cover and the emergency spillway also should be completed as quickly as possible during construction.

The designer should address the potential for bedding erosion and catastrophic failure of any buried outlet conduit. A filter diaphragm and drain system should be provided along the barrel of the principal spillway to prevent piping. There has been an evolution in standard practice, and the accumulated evidence suggests that, in most circumstances, filter diaphragms are much superior to anti-seep collars in preventing piping. Filter diaphragms are preferred over the older design anti-seep collar.

If reinforced concrete pipe is used for the principal spillway, “O-ring” gaskets (ASTM C361) should be used to create watertight joints and should be inspected during installation.

Safety Considerations

The permanent pool of water presents an attractive play area to children and thus may create safety problems. Engineering design features that discourage child access are recommended. Trash racks and other debris-control structures should be sized to prevent entry by children. Other safety considerations include using fences around the spillway structure, embankment, and wet detention basin slopes; using shallow safety benches around the wet detention basin; and posting warning signs.

Fencing of wet detention basins is not generally aesthetically pleasing but may be required by the local review authority. A preferred method is to engineer the contours of the wet detention basin to eliminate drop-offs and other safety hazards as discussed above. Riser openings must not permit unauthorized access. End walls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent falls.

Design Variations

There are several variations of the wet pond design. Some of these design alternatives are intended to make the practice adaptable to various sites and to account for regional constraints and opportunities.

Wet Extended Detention Pond

The wet extended detention pond combines the treatment concepts of the dry extended detention pond and the wet pond. In this design, the water quality volume is split between the permanent pool and detention storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 12 to 48 hours. This design has similar pollutant removal to a traditional wet pond and consumes less space. Wet extended detention ponds should be designed to maintain at least half the treatment volume of the permanent pool. In addition, designers need to carefully select vegetation to be planted in the extended detention zone to ensure that the selected vegetation can withstand both wet and dry periods.

Water Reuse Pond

Some designers have used wet ponds to act as a water source, usually for irrigation. In this case, the water balance should account for the water that will be taken from the pond. One study conducted in Florida estimated that a water reuse pond could provide irrigation for a 100-acre golf course at about one-seventh the cost of the market rate of the equivalent amount of water ($40,000 versus $300,000).

Common Problems

Limitations of wet ponds include:

- If improperly located, wet pond construction may cause loss of wetlands or forest.
- Wet ponds are often inappropriate in dense urban areas because each pond is generally quite large.
- Wet ponds may pose safety hazards.

Maintenance

– Immediately after the wet detention basin is established, the plants on the vegetated shelf and perimeter of the basin should be watered twice weekly, if needed, until the plants become established (commonly six weeks).

– No portion of the wet detention pond should be fertilized after the first initial fertilization that is required to establish the plants on the vegetated shelf.

– Stable groundcover should be maintained in the drainage area to reduce the sediment load to the wet detention basin.

- If the basin must be drained for an emergency or to perform maintenance, the flushing of sediment through the emergency drain should be minimized to the maximum extent practical.

- Once a year, a dam safety expert should inspect the embankment.

Additional Recommended Design Criteria, Specifications and Methodologies

The following criteria, specifications, and methodologies are recommended for stormwater management systems that are not specified by applicable regulatory requirements of federal, state or local jurisdictions.

Wet Detention Systems: These systems collect and temporarily store stormwater in a permanently wet impoundment in such a manner as to provide for treatment through physical, chemical, and biological processes with subsequent gradual release of the stormwater. These systems should be designed to meet the following requirements:

1. Required volume: First 0.5 inch of runoff or 1.5 inches of runoff from impervious area.

2. Return time: Outfall structure must discharge one half (½) volume of stormwater within 48 to 72 hours. No more than one half (½) the volume will be discharged within 48 hours.

3. Permanent pool: Provide average residence time at least 14 days during wet season

4. Littoral zone design:

    a. Sloped (4:1 or flatter) to a depth of at least 2 feet below control elevation; approximately 30 percent of the wet detention system surface area should be littoral zone (ratio of vegetated littoral zone to surface area of the pond at the control elevation).
    b. The treatment volume should not cause pond level to rise more than 18 inches above the control elevation, unless the littoral zone vegetation can survive at greater depths.
    c. Eighty percent coverage of the littoral zone vegetation should be established within the first 24 months. Portions of the littoral zone may be established by placement of wetland topsoils (at least a four-inch depth) containing a seed source of desirable native plants. To utilize this alternative, the littoral zone must be stabilized by mulching or other means.

5. A forebay should be established at the pond inflow points to capture larger sediment particles and be 4 to 6 feet deep. The forebay volume should equal about 20% of the total basin volume. Multiple inlets may require additional volume. Direct maintenance access should be a minimum of 15 feet wide, with a maximum slope of 5:1.

6. Mean depth of the permanent pool should be between 2 and 8 feet. The maximum depth should not exceed 12 feet below the invert of the outlet device, unless the deeper depths will not inhibit physical, chemical, and biological treatment processes or cause re-suspension of pollutants into the water column due to anaerobic conditions in the water column.

7. Flow path through pond should have an average length-to-width ratio of at least 2:1. The alignment and location of inlets and outlets should maximize flow paths in the pond. If short flow paths are unavoidable, the effective flow path should be increased by adding diversion barriers such as islands, peninsulas, or baffles to the pond. Inlet structures should be designed to dissipate the energy of water entering the pond.

8. Outlet devices incorporating dimensions smaller than three inches minimum width or less than 20 degrees for “v” notches should include a device to eliminate clogging. Examples include baffles, grates, and pipe elbows.

9. Outlet structure invert elevations should be at or above the estimated post-development normal groundwater table elevation. If the proposed structure is set below this elevation, groundwater inflow must be considered in the drawdown calculations, calculation of average residence time, estimated normal water level in the pond, and pollution removal efficiency of the system.

10. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system (including the pond, littoral zone, inlets, and outlet) should be established.

Dry Retention Systems: These systems are designed to collect and temporarily store stormwater in a normally dry basin with subsequent gradual release of the stormwater. Dry detention is recommended as an off-line system, but if the design calls for an in-line system, additional volume may be required. Additional volume may be required for on-line systems. These systems should be incorporated as a best management practice in a treatment train approach, which includes other best management practices including, but not limited to, grassed swales, level spreaders, filter strips, buffer zones, bioretention, and skip curbs—all with water flow lengths less than 300 feet. Dry retention systems are not recommended for use in areas that require piped water conveyance systems. These systems should be designed to meet the following requirements:

1. Required volume: first 1.0 inch of runoff or 2.5 inches from impervious areas, whichever is greater.

2. Return Time: Discharge one-half the appropriate treatment volume of stormwater specified above between 24-30 hours following a storm event.

3. Discharge structures should include a device to prevent the discharge of accumulated sediment, minimize exit velocities, and prevent clogging. A perforated riser enclosed in a gravel jacket and perforated pipes enclosed in sand or gravel is a good example.

4. Contain areas of standing water for no more than 3 days following a storm event.

5. Stabilize with permanent native vegetative cover.

6. Average flow path through the basin should have a length-to-width ratio of at least 3:1. The alignment and location of inlets and outlets should be designed to maximize flow paths in the basin. If short flow paths are unavoidable, the effective flow path should be increased by adding diversion barriers such as baffles.

7. Inlet structures should be designed to dissipate the energy of water entering the basin.

8. A maintenance schedule is recommended for removal of sediment and debris on at least a bi-monthly basis, as well as mowing and removal of grass clippings.

9. Basin floor should be level or uniformly sloped (1-2% maximum) toward the outfall structure.

10. Basin floor should be at least three feet above the seasonal high groundwater table elevation. Sumps may be placed up to one foot below the control elevation.

11. Permanent maintenance easements or other acceptable legal instruments should be in place to allow for access to and maintenance of the system. The easement or other acceptable instrument should cover the entire stormwater system.

<u>Constructed Wetland Systems</u>: Wetland systems collect and temporarily store stormwater in a permanently wet impoundment and provide treatment through physical, chemical, and biological processes. These systems should be designed to meet the following requirements.

1. Required volume: First 1.0 inch of runoff or 2.5 inches of runoff from impervious area.

2. Inflow of water must be greater than infiltration.

3. Designed for an extended detention time of 24 hours for the 1-year storm event.

4. Protection against blockage should be installed around outlets vulnerable to blockage from plant material or other debris that will enter the basin with stormwater runoff. Reverse slope pipes are recommended.

5. Surface area of the wetland should account for a minimum 3% of the area of the watershed draining into it.

6. The length-to-width ratio should be at least 3 to 1.

7. Deeper area of the wetland should include the outlet structure so that the outflow from the basin is not impeded by sediment buildup.

8. A forebay should be established at the pond inflow points to capture larger sediment particles and be 4 to 6 feet deep. The forebay volume should equal about 20% of the total basin volume. Multiple inlets may require additional forebay volume. Direct maintenance access should be a minimum of 15 feet wide, with a maximum slope of 5:1.

9. In cases where water velocities exceed 0.5 ft/s, energy dissipation devices should be installed.

10. Pre- and post-grading pondscaping design should be used to create both horizontal and vertical diversity and habitat.

11. Approximately 30 to 50 percent of the shoulder area (12 inches or less) of the basin should be planted with native wetland vegetation.

12. A 25-foot buffer, for all but pocket wetlands, should be established and planted with native riparian and upland vegetation.

13. Surrounding slopes should be stabilized by planting in order to minimize sediment and pollutants from entering the wetland.

14. A written maintenance plan should be provided and adequate provision made for ongoing inspection and maintenance. Maintenance should be scheduled more often during the first three years after construction.

15. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system are recommended. The easement or other acceptable instrument should cover the entire stormwater system.

<u>Swale Systems</u>: These systems are man-made trenches that filter and treat stormwater runoff as part of a treatment train approach. Swale system criteria may vary depending on its place in the treatment train. However, at a minimum, these systems should be designed to meet the following requirements:

1. Required volume should be designed for a 6-month, 24-hour design storm event.

2. No contiguous areas of standing or flowing water within 72 hours following storm event.

3. Peak discharges should be 5 to 10 cfs.

4. Water velocity should be 1.0 to 1.5 ft/s.

5. Maximum design flow depth should be 1 foot.

6. Swale slopes:
   a. Graded as close to zero as possible and still permit drainage
   b. Should not exceed 2%

7. Must have a top width–to-depth ratio of greater than 6:1, or cross-section side slopes of 3:1 (horizontal:vertical) or flatter.

8. Swale length should be at least 100 feet per acre of drainage area.

9. Underlying soils should have high permeability.

10. Swales must be planted with or have stabilized native vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake.

11. Soil erodibility, soil percolation, slope, slope length, and drainage area must be taken into account, in order to prevent erosion and reduce pollutant concentration of any discharge.

12. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system are recommended. The easement or other acceptable instrument must cover the entire stormwater system.

<u>Manufactured Stormwater Treatment Systems</u>: These systems are recommended for use in commercial and industrial developments. The manufactured systems should satisfy the following conditions:

1. Field test data from the southeastern United States should be available. The test data should be from an area with similar rainfall distribution as the project area.

2. Field test data should provide the following results:
   a. Removal of 70-80% of total suspended solids (TSS)
   b. Particle size distribution for TSS removal rates
   c. Conditions under which TSS removal is obtained (storm event, rainfall intensity, etc.)

3. Maintenance information should include how often the system should be serviced.

4. Manufactured systems should be structurally sound and designed for acceptable municipal and commercial traffic loadings.

5. Manufactured systems should not allow inflow or infiltration.

6. Weirs, openings, and pipes should be sized to pass, as a minimum, the storm drain system design storm.

7. Manholes should be provided to each chamber to provide access for cleaning.

8. Treatment train approach incorporating the use of other appropriate best management practices is recommended because efficiency will be increased and maintenance reduced.

9. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system are recommended.

Detention Practice Criteria: These criteria are recommended when post-construction runoff volumes should be kept to pre-construction values in order to prevent downstream degradation and flooding. Detention basins and associated outflow structures should be designed to address the 2-year, 5-year, 10-year, 25-year, and 50-year, 24-hour storm events.

Runoff volumes and rates may be calculated using the SCS Runoff Curve Number Method (see Appendix Volume, Appendix A, A-16).

Detention storage may be determined using the Short Cut Floodrouting Method for determining drainage areas and runoffs that fall with the method's limits. If drainage areas and runoffs fall outside the method's limits, other detention sizing methodologies should be used.

Erosion and Sediment Control Calculations for Estimated Reductions: The effect of BMPs may be calculated using the USLE methodology (see Appendix Volume, Appendix A, A-2). During construction, the BMP plan should demonstrate the ability to keep sediment yield to 115% of the pre-disturbance sediment yield (15% increase in sediment above pre-disturbance conditions). This is known as performance-based planning. A performance-based plan can demonstrate that selected practices may meet the desired results.

Effectiveness of Erosion and Sediment Control BMPs: An estimate of the effectiveness of selecting the more common erosion and sediment control BMPs may be found on Page A-11 (in the Appendix Volume). These estimates can help in performance-based planning.