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FDM 10-1-1 Purpose and Objectives
February 18, 2020

1.1 Originator

The Environmental Services Section is the Originator of this chapter. Questions and comments on the content of this chapter should be sent to the Statewide Stormwater Quality Engineer at (608) 266-0279 or DOTStormwater@dot.wi.gov.

1.2 Purpose

The purpose of this chapter is to provide information and guidance to designers on erosion control and storm water management. This guidance is provided so WisDOT projects will comply with all applicable laws and regulations. See FDM 10-1-2 for a summary of these laws and regulations.

1.3 Chapter Organization

The chapter is divided into two parts, Part A and Part B (see table below). Part A, which applies statewide, provides guidance for developing construction site erosion control plans as required by TRANS 401 and the WisDOT/DNR Cooperative Agreement. Part B provides guidance for developing permanent storm water management measures to protect water quality, primarily when dealing with WisDOT drainage facilities that are located within municipalities regulated by Chapter NR216, Wis. Adm. Code. In areas of the state not covered by NR216, the use of "Best Management Practices", as defined in Part B, may be applicable, especially where water quality concerns are an issue, such as near high quality waters.

Chapter 10	
Part A - Erosion Control	**Part B - Water Quality**
Who Does It Apply to: - applies statewide to any DOT administrated construction site	Who Does It Apply to: - applies to DOT transportation facilities located within municipalities permitted under the authority of Chapter NR 216 Wis. Adm. Code
What is Required: - must develop and implement construction site erosion control plans (see FDM 10-5-55)	What is Required: - must fulfill requirements of DOT/DNR Memorandum of Understanding - must implement storm water quality best management practices

1.4 Glossary

A glossary of key words used in this chapter is located in FDM 10-15-1.

FDM 10-1-2 Applicable Laws and Permits
November 30, 2018

2.1 Federal, State, and Local Laws and Regulations

As a result of the National Environmental Policy Act of 1969 and the Clean Water Act of 1972, numerous state and federal regulations governing land disturbing activities have been developed. In addition, various permits are being required (Section 404, Section 402 of the Federal Water Pollution Control Act, and Sections 9 and 10 of the Rivers and Harbor Act) by a number of agencies such as the Army Corps of Engineers, Environmental Protection Agency (EPA) and Fish and Wildlife Service.

A more recent regulation is EPA's National Pollution Discharge Elimination System (NPDES), requirement of which EPA has delegated the Wisconsin Department of Natural Resources (WDNR) to administer. Under WDNR's authority, these regulations are known as the Wisconsin Pollution Discharge Elimination System (WPDES) requirements and are authorized under Chapter 283 of the Wisconsin Statues. The WPDES requirements are designed to regulate the quality of storm water being discharged into the waters of the United States to include surface and ground waters.

The following Wisconsin statutes and administrative codes are applicable:

1. WisDOT/WisDNR Cooperative Agreement

   https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx

2. Cooperative Agreement Memorandum of Understanding of Erosion Control

   https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx

3. Chapter 30.12(4) Wis. Stats. DOT Activities; exemption; interdepartmental coordination of environmental protection measures.
4. Trans 401 Wis. Administrative Code, relating to WisDOT construction site erosion control procedures.
5. NR 216 Wis. Admin. Code - Administrative rule on Storm Water Discharges and Permits.
6. Chapter 283 Wis. Stats. Wisconsin Pollution Discharge Elimination system.
7. Section 281.31 Wis. Stats. Construction Site Erosion Control and Storm Water Management.

2.2 Transportation Construction General Permit

WDNR has issued a general permit authorizing WisDOT to discharge storm water associated with land disturbing construction activity. This general WPDES permit is issued pursuant to ss. 283.33(4m), and 283.35(1) Wis. Stats.

Coverage under the Transportation Construction General Permit is required for WisDOT directed and supervised projects with one acre or more of land disturbing construction activity.

To obtain permit coverage, a complete Notice of Intent (NOI) must be submitted to the WDNR. The NOI should be submitted after WisDOT requests WDNR final concurrence, typically around 90% final design. After submission of the NOI, WDNR will review and grant permit coverage if warranted. Verification of permit coverage will be received with the WDNR final concurrence letter in the form of a certificate.

Directions for submitting the NOI are available at:

http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/erosion-ctrl-drainage.aspx

2.2.1 Area of Land Disturbance

Permit coverage is required for projects with an acre or more of land disturbance. Land disturbance is defined as: any man-made alteration of land surface resulting in a change in topography or existing vegetative or non-vegetative soil cover that may result in storm water runoff and lead to increased soil erosion and movement of sediment into waters of the state.

Land disturbing construction activity includes, but is not limited to, clearing and grubbing, demolition, excavating, pit trench dewatering, filling and grading activities. The following are common areas of land disturbance:

- Any area where subsoils are exposed or vegetation has been removed or disturbed, including areas within your slope intercepts, or areas outside your slopes intercepts that you anticipate will be disturbed to perform the work or topsoil storage areas.
- Underground utility work including pipe culverts and storm sewer installations.
- Grading associated with beam guard replacement or upgrading of end terminals.
- Ground disturbance at select sites and contractor staging areas not permitted separately are to be added to the project total. This will need to be estimated based on the scope of the project. One way to estimate would be to assume a depth at the select site. i.e. if a project is estimated to require 27,000 CY of borrow, and the assumed depth is 6 ft., the ground disturbance would be 121,500 sf. (the assumed depth of 6 ft. can be adjusted to account for site conditions.)

$$\left(27{,}000\ CY \times 27\frac{CF}{CY} \div 6ft\ deep = 121{,}500\ SF\right)$$

- Staging area where existing vegetation will be disturbed.
- It is understood all estimates for ground disturbance are estimates only. Please be more detailed if a project will be close to 1 acre.

Once determined, the area of land disturbance should be included in the plan set, on the Runoff Coefficient Table (refer to FDM 10-5-60).

2.3 Transportation Separate Storm Sewer System Permit

WDNR has issued a general permit authorizing WisDOT to discharge storm water from the transportation separate storm sewer system. This general WPDES permit is issued pursuant to ss. 283.33(4m) Wis. Stats.

Coverage under the TS4 permit is required for WisDOT storm sewer system discharge located within a United States Environmental Protection Agency (USEPA) designated Urbanized Area (Appendix A, Table 1) and the area of any incorporated municipality separate from an Urbanized Area requiring an MS4 permit from WDNR (Appendix A, Table 2). WisDOT is not responsible for a separate storm sewer system that drains a connecting highway. WisDOT is only responsible for storm water discharges of runoff that originate within the WisDOT right-of-way (ROW). Both tables are in the TS4 permit available on line.

https://dnr.wi.gov/topic/stormwater/documents/WPDES-WI-S066800-1.pdf

Contact WisDOT Central Office storm water quality engineer for specific guidance to meet storm water pollutant load reduction requirements.

2.4 Wis. Adm. Code, Chapter Trans 401

Trans 401 was created to establish and implement erosion control and storm water management standards for airport, railroad, highway, and bridge projects which are administered by WisDOT.

Trans 401 establishes minimum performance standards which all projects administered by WisDOT should meet. An erosion control plan and an erosion control implementation plan are also required under Trans 401. Erosion control and storm water management measures should be maintained and inspected prior, during and after construction or maintenance of a transportation facility.

2.5 Administration Rules for Erosion and Sediment Control on Highway Construction Projects

The Federal Highway Administration (FHWA) has adopted the American Association of State Highway and Transportation Officials (AASHTO) Highway Drainage Guidelines, Vol. III, "Erosion and Sediment Control in Highway Construction," 1992. The FHWA has adopted these guidelines to be followed on all construction projects funded under title 23, United States Code. These guidelines are not intended to preempt any requirements made by or under State law if such requirements are more stringent.

To develop standards and practices of erosion and sediment control on Federal-aid construction projects, each State should apply the AASHTO guidelines or apply its own guidelines, if its own guidelines are more stringent.

To be consistent with the requirements of section 6217 (g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), some certain states should follow specific management measures of erosion and sediment non-point source pollution control. Highway construction projects funded under title 23, United States Code, located in States with federally approved coastal zone management programs should utilize "Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters," U.S. EPA, January 1993.

FDM 10-1-3 Erosion Control Plan *January 24, 1997*

The design erosion control (EC) plan includes all erosion and sediment control considerations made during the planning, location, and project development phases and is found in the contract plans, specifications, and special provisions.

In general, the design EC plan should accomplish three objectives:

1. Limit off-site effects to acceptable levels;

2. Facilitate project construction and minimize overall costs;
3. Comply with federal, state and local laws and regulations.

Once the project is let, the design EC plan is used by the contractor to develop an "Erosion Control Implementation Plan", (ECIP). The ECIP is a narrative and pictorial plan based on the contractor's schedule of operations. It differs from the design EC plan in that it outlines a general timetable of when each erosion control device or set of devices is expected to be installed by the contractor before, during and after construction based on the estimated schedule of operations.

3.1 Limit Off-Site Effects

Off-site effects are defined in relation to the levels of sediment that may cause damage to the environment and/or customer sensitive areas.

An evaluation of each site for possible actions and their consequences is central to the development of an effective erosion and sediment control plan. Designers should analyze the probable effects to be expected from both the implementation of the control measures as well as their omission; the location of the effects; whether or not potential damage is acceptable; and the cost effectiveness of the chosen action.

Proper planning and scheduling of the construction operations are major factors in controlling anticipated erosion and sediment problems. The contract documents should require that the work be performed in a manner which will cause minimum soil disturbance. Designers should consider including, in the contract documents, a limitation on the amount of erodible surface area which may be exposed at any one time, especially when working near sensitive areas as defined in FDM 10-5-10 and FDM 10-5-15.

3.2 Facilitate Construction and Minimize Cost

To help minimize overall costs, control measures should be effective and safe in their operation, simple to construct, afford as little interruption to normal construction procedures as practicable, and be reachable to ensure proper maintenance.

Care should be taken to avoid the "shot-gun approach." Much is lost when the designer attempts to achieve total control of both erosion and sediment by calling for rigorous or inflexible design plan measures of questionable effectiveness. The design EC plan should be flexible enough to allow construction to be able to adjust the control measures to field conditions when necessary.

3.3 Laws & Regulations

See FDM 10-1-2 for a summary of applicable laws and regulations.

FDM 10-1-5 The Erosion Process *January 24, 1997*

Soil erosion is the process by which the land's surface is worn away by the action of wind, water, ice and gravity. Natural, or geologic erosion has been occurring at a relatively slow rate since the earth was formed, and is a tremendous factor in creating the earth as we know it today. Except for some cases of shoreline and stream channel erosion, natural erosion occurs at a very slow and uniform rate and remains a vital factor in maintaining environmental balance.

Water-generated erosion is unquestionably the most severe type of erosion, particularly in construction areas. It is, therefore, the main problem addressed in this chapter. 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 its motion as it runs off the land surface. The force of falling raindrops is applied vertically, and force of flowing water is applied horizontally. Although the direction of the forces created is different, they both perform work in detaching and moving soil particles.

Water-generated erosion can be broken down into the following types:

Raindrop erosion is the first effect of a rainstorm on the soil. Raindrop impact dislodges soil particles and splashes them into the air. These detached particles are then vulnerable to the next type of erosion.

Sheet erosion is the erosion caused by the shallow flow of water as it runs off the land. These very shallow moving sheets of water are seldom the detaching agent, but the flow transports soil particles which are detached by raindrop impact and splash. The shallow surface flow rarely moves as a uniform sheet for more than a few feet on land surfaces before concentrating in the surface irregularities.

Rill erosion is the erosion which develops as the shallow surface flow begins to concentrate in the low spots and irregular contours of the surface. As the flow changes from the shallow sheet flow to deeper flow in these low areas, the velocity and turbulence of flow increase. The energy of this concentrated flow is able to both detach and transport soil material. This action begins to cut small channels of its own. Rills are small but well- defined channels which are, at most, only a few inches in depth. They are easily obliterated by harrowing or other surface treatments.

Gully erosion occurs as the flow in rills comes together in larger channels. The major difference between gully and rill erosion is the order of magnitude. Gullies are too large to be repaired with conventional tillage equipment and usually require heavy equipment and special techniques for stabilization.

Channel erosion occurs as the flow cases movement of the stream bed and bank materials. Wind can have similar erosive effects as water and should be considered in the design and construction phases.

FDM 10-1-10 Basic Principles of Erosion and Sediment Control *January 24, 1997*

An effective erosion and sediment control plan originates in the project planning stage. When conscientiously and expeditiously applied, these planned measures should result in a project that facilitates construction without environmental degradation.

In general, the following basic principles apply to all projects:

1. Plan the highway project to fit the particular topography, soils, drainage patterns and natural vegetation as much as practicable. Designers should take special precautions in areas with steep slopes and highly erosive soils. When possible, these areas should be avoided.
2. Minimize the extent and duration of erodible surface area. The contract should require that the work be performed in a manner which will cause minimum soil disturbance. When working near sensitive areas, the designer should consider including, in the contract, a limitation on the amount of erodible surface area which may be exposed at any one time during construction of the project. In addition, because projects may need to be "buttoned up" over the winter, the designer should provide adequate quantities and special provisions to prevent erosion through the spring thaw.

   Grading should be completed as soon as possible after it has begun and the phases or stages of construction should be planned to minimize this exposure. Once completed, permanent vegetative cover should be established in the area. As cut slopes are made and fill slopes are brought up to finished grade, areas should be revegetated as the work progresses.

   If it is not possible to bring the area to final grade within a reasonable period of time as determined by the engineer, the use of temporary devices such as temporary seed should be considered. In any event, the contractor should not be allowed to delay in bringing the grading to final stages.
3. Utilize erosion and sediment control practices to prevent erosion and protect sensitive areas. This third principle involves using temporary and permanent best management practices. These practices should be judiciously planned and implemented so as to prevent sediment from entering environmental and customer sensitive areas. Practices include utilizing:
   - Flat side slopes rounded and blended to the natural terrain with adequate right-of-way or temporary easements for construction equipment to perform the work;
   - Drainage channels that are designed with due regard to width, depth, gradient, side slopes, alignment, energy dissipation, and protection treatment;
   - Protective ground covers such as vegetation, mulch, erosion mat or riprap to help prevent erosion from occurring;
   - Diversion measures such as dikes and intercepting embankments to help divert sheet flow away from disturbed areas;
   - Slope drains or flumes for channeling runoff to appropriate locations;
   - Sediment control devices such as traps, basins, stone or rock ditch checks, erosion bales or silt fence (not to be used in channels) to help filter out sediment;
   - Located and spaced facilities for ground water interception;
   - Special grading methods such as roughening a slope on the contour or tracking with a cleated dozer to reduce runoff velocities and allow sediments to settle out;
   - Available technical assistance.
4. Apply perimeter control practices, as needed, to protect the disturbed area from off-site runoff and prevent sediment from leaving the construction site. This principle relates to using practices that effectively isolate the construction site from surrounding properties in order to prevent sediment damage. Generally, sediment can be retained by two methods: (1) filtering runoff as it flows through an area, and, (2) impounding the sediment-laden runoff for a period of time so that the soil particles settle

out.

5. Keep runoff velocities low. The removal of existing vegetative cover and the resulting increase in impermeable surface area during construction will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control. Keeping slope lengths short and gradients low, and preserving natural vegetative cover can limit erosion hazards. Runoff from the construction site should be safely conveyed to a stable outlet using storm or slope drains, diversions, stable channels or similar measures. Conveyance systems should be designed to withstand the velocities of projected peak discharges and should be operational as soon as practicable.
6. Stabilize disturbed areas as soon as possible after final grade has been attained. Permanent structures, temporary or permanent vegetation, mulch, stabilizing emulsions, or a combination of these measures, should be employed as quickly as possible after the land is disturbed. If a delay is anticipated in obtaining the finished grade, temporary measures should be implemented immediately after rough grading is completed.
7. Establish and implement a thorough maintenance and follow-up program. This last principle is vital to the success of the six other principles. A site cannot be effectively controlled without thorough, periodic checks of the erosion and sediment control practices. The practices must be maintained just as construction equipment must be maintained, and material checked and inventoried. It is recommended that a routine "end of the day check" be made to ensure that all control devices and measures are functioning properly. Designers should schedule a time to meet with the construction project engineer in the field to evaluate and obtain feedback.

In general, limiting the time of exposure and judiciously selecting control practices will help minimize erosion and sediment loss.

FDM 10-5-1 Communication and Coordination

January 24, 1997

An effective erosion and sediment control plan spans the entire planning, design construction and maintenance stages of a project. To be successful, it is imperative that communication be established and maintained throughout each stage of development to ensure a coordinated effort. This effort should include both internal and external feedback from those affected within and outside the Department.

1.1 Internal Communication and Coordination

Internal communication and coordination for the designer includes that which needs to be established and maintained within the Department in order for the design erosion control (EC) plan to be carried out effectively. Therefore, designers should obtain information from or relay information to:

1. Planning Section, on budget needs or adjustments.
2. Real Estate Section, on erosion or sediment control land acquisition requirements or information on property owners.
3. Construction Section, on whether the desired EC practice is constructable.
4. Maintenance Section, to see if there are any existing erosion and sediment control problems that need to be addressed.
5. Soils Engineer on the types of soil in the area or whether soil stabilization measures will be required.
6. Central Office Landscape Section for special seed mixtures or landscape planning assistance.

In addition to obtaining technical assistance, designers and planners must be aware of what is practical, reasonable and achievable during construction as well as over the life of the project when selecting design features and control criteria for use in developing the design EC plan.

1.2 External Communication and Coordination

1.2.1 With the Department of Natural Resources (DNR)

To help define the coordination effort needed between the DOT and the DNR, the "Cooperative Agreement Between Wisconsin Department of Transportation and the Department of Natural Resources" as well as the "Memorandum of Understanding on Erosion Control", was developed in 1987 (see https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx) environmental concerns can provide information and requirements regarding existing stream and impoundment quality classifications, their present and potential use, and the impact that differing levels of sediment input may produce.

In addition, the U.S. Geological Survey (USGS) and the DNR are primary sources for stream sediment and sediment related data.

FDM 10-5-5 Planning and Location Considerations

January 24, 1997

If damage from erosion and sediment is considered during the planning and location stages of the project development process, the cost of solving problems can be minimized. Therefore, it is important that the following be identified as early as possible:

1. Sensitive locations including environmental and customer sensitive areas as well as those with highly erosive soils. Where possible, these areas should be avoided (see FDM 10-5-10 and FDM 10-5-15).
2. Drainage patterns and quantity of water coming to the project site.
3. Potential soil loss given the amount of grading or soil disturbance involved. Where possible, existing vegetation should be preserved and a limitation on the amount of erodible surface area which may be exposed at any one time should be considered near sensitive areas.

Erosion control costs should be estimated for each of the route alternatives under study, as well as the risks associated should the measures not be implemented. Costs can be minimized if the site design can be adapted to existing on-site conditions and if good soil conservation principles are used.

FDM 10-5-10 Erosion Sensitive Areas

January 24, 1997

Some soil types are known to be more erosive than others and their identification is a valuable aid in route selection. Areas with unstable or troublesome soils such as landslide areas, loess soils, alluvial fans, and some glacial deposits, are potential problem areas when disturbed.

Information on soil erodibility can be obtained from WisDOT's soil engineers, as well as:

1. geological maps,
2. local agricultural offices,
3. local Soil Conservation Service (SCS) offices,
4. WisDOT maintenance and local highway personnel familiar with previous work in particular soil types.
5. Local elected officials and property owners.

The natural drainage pattern and subsurface flows should be examined for each alternative route considered. Steep gradient channels present a greater erosive potential than flatter gradients. Subsurface flows, if left unmanaged, can present slope stability problems especially in areas requiring extensive cut sections. Therefore, designers should consult with their soils engineer for appropriate soil stabilization measures.

Climatic conditions such as rainfall and snow melt, wind intensity, and temperature extremes should be taken into account when evaluating use of various EC items. In addition, soil loss should be evaluated given the amount of soil to be disturbed and the duration of exposure. Erosion and sediment control measures should be implemented to protect the project as needed.

FDM 10-5-15 Environmental and Customer Sensitive Areas

January 24, 1997

Federal and State regulations, as well as the Department's policy dictate the need for careful evaluation and protection measures. To help ensure this effort, environmental and customer sensitive areas should be identified early in the planning and design process. There are two general types of sensitive areas that must be protected from erosion and sedimentation. They are:

<u>Environmentally Sensitive Areas</u>: Areas that must be protected as mandated by law and enforced by state and federal regulatory agencies.

<u>Customer Sensitive Areas:</u> Areas that must be protected as a matter of being a good neighbor.

Environmentally Sensitive Areas	Customer Sensitive Areas

• Water resources such as Lakes, Streams, or Wetlands.
• Other areas that are potentially environmentally sensitive are:
  • Unique wildlife habitat areas especially those that preserve rare and endangered wildlife species.
  • Unique vegetation like prairies, endangered plants and trees
  • Drainage ways
  • Water supply sources
  • Public lands and parks
	• Farmland
	• Residential areas
	• Driveways and roadways
	• Industrial and commercial areas
	• Drainage districts and other drainage systems
	• Parklands

Designers should utilize the guidance in this Chapter to protect these areas with both temporary and permanent erosion and sediment control devices. In addition, contract provisions should consider limiting the amount of surface area exposed at any one time around these sensitive areas and provide for over winter and spring-thaw protection measures.

FDM 10-5-20 Soils Investigation

January 24, 1997

Soil properties such as natural drainage, depth to bedrock, depth to seasonal water table, permeability, shrink-swell potential, texture, and erodibility should exert a strong influence on design decisions. These properties can be found in the project's soils report.

The request for a soils investigation and report should be submitted as early in the project's data gathering stage as possible. Designers should submit this request to their soil's engineer, and, once received, investigate alternatives for resolving any potential problem areas. Also, see Section IX of FDM 10-5 Attachment 60.1 for groundwater and permanent infiltration system requirements.

FDM 10-5-25 Geometric Considerations

January 24, 1997

25.1 Introduction

Geometrics can be used to an advantage in minimizing erosion and soil loss. The alignment, grade and cross section, as well as, stream crossings and encroachments are geometric features which may have a range of flexibility. Adjustments can often reduce potential damage due to erosion and considerably lessen the cost of control measures. In general, the following geometric considerations should be used where possible:

1. Obtain adequate right-of-way or temporary easements for such purposes as avoiding steep, unstable slope angles and providing detention ponds or other sediment trapping devices. When adequate right-of-way or slope easements for rounding and blending are obtained, appearance is also improved. The initial cost of additional right-of-way should be weighed against the long term costs of construction and maintenance.
2. Use a smooth grade line with gradual changes to avoid numerous breaks, minimize the number of cut-to-fill runouts, and avoid short lengths of grade.
3. Preserve the natural and existing drainage patterns to the greatest extent possible. Avoid placing low points of vertical curves in cut sections. Avoid low grade lines requiring ditch sections in areas of high water table or wetlands.
4. Avoid or minimize earthwork balancing that requires dirt to be hauled across streams. Avoid the need for placement of sediment-generating haul roads in stream areas.
5. Leave stabilized steep slopes of rock debris, soil or stream banks undisturbed, where possible. If the project is "short of dirt", it is generally better to obtain borrow than disturb these critical areas. If it is impossible to obtain borrow, purchase additional right-of-way or temporary easements in order to lay back the slopes.
6. Use independent alignments on divided highways to fit the highway to the terrain and better adjust grades.
7. Set construction limits that provide for slope rounding, preserve trees and shrubs, and prevent over-clearing, unless, they interfere with clear zone requirements.
8. Avoid irregular ditch profiles and steep ditch gradients. Adjust gradients with special ditch grades. If steep ditches are necessary, the steep section should be located at the head of the ditch, not at the outlet.
9. Provide vegetated ditches and drainage channels with wide, rounded cross sections that reduce the erosion potential.
10. Minimize channel changes. When channel changes are required, adjust the new channel cross section, alignment, or length to maintain the existing flow velocity.
11. Locate and align culverts to avoid erosion at the inlet and outlet. Place structures as close as possible to the natural flow line and in line with the flow direction to allow direct entrance and exit conditions. Avoid placing outlets at curved sections or channels or where the outflow can drop and cause scour.
12. Leave an undisturbed, vegetated buffer strip between disturbed soil and sensitive areas when possible.
13. Utilize "toe" ditches at the bottom of fill slopes as a means of protecting sensitive areas. To be effective, these ditches should be moved away from the fill intercept point, approximately 6 to 8 feet (1.8 to 2.4 m), by means of a minimum 6:1 ditch slope (see typical section detail in Channel Matrix, FDM 10-5-35).
14. Maximize the use of natural materials such as soils, sod, seed, mulch, and riprap. By so doing, costs will be reduced and permanent erosion control can be achieved. The use of open metal, concrete, or asphaltic concrete flumes should be avoided. These structures are costly to install, subject to undermining, deteriorate with freezing and thawing, and frequently fail over time.
15. Review the plans by watershed and/or sensitive area. Coordinate "Mobilizations for Erosion Control"

in these areas as grading is completed.

16. Evaluate the grade line and cross sections for possible erosion problems especially in ditches, cut runouts, at low points of the vertical curves, and any other area where water may concentrate.

17. Request and make use of available technical assistance. A quick detail review with additional Department input can save hours of costly changes and minimize problems.

25.2 Topography

The primary topographic considerations effecting erosion potential are slope steepness and slope length. Because of the effect of accumulated runoff, erosion potential is greater on long, steep slopes especially when the slopes are left bare.

Slope gradients for bare soils can be grouped into three general ranges of soil erodibility:

0-7%	- Low erosion hazard
7-15%	- Moderate erosion hazard
> 15%	- High erosion hazard

With these slope gradient ranges, the erosion hazard becomes greater as the slope length increases. Therefore, in determining potential critical areas, the site planner should be aware of excessively long slopes. As a general rule, the erosion hazard will become critical if the bare slope exceeds the following criteria: (2)

0-7%	- 300 feet **(92 m)**
7-15%	- 150 feet **(46 m)**
> 15%	- 75 feet **(23 m)**

NOTE: The above information is based on bare soils. Since WisDOT recommends using seed and mulch on all disturbed areas, the erosion potential is minimized. Other erosion control devices can be used in addition to or in combination with seed and mulch to provide additional protection (refer to FDM 10-5-35).

25.3 Alignment and Grade

Alignment and grade of a highway are important to successful erosion control and their careful selection may be an option available to the designer. The alignment may be shifted to eliminate or minimize encroachment into a surface water environment. A change in grade may be used to avoid intrusion into known erodible soil strata. Alignment and grade alternatives must be consistent with highway safety criteria and should be blended and fitted to the natural landscape to minimize cut and fill sections and to reduce erosion and costly maintenance. These geometric features should be selected so that both ground and surface water can pass through the highway right-of-way or be intercepted with minimum disturbance to streams and without causing serious erosion problems.

Whenever practical, stream crossings should be made at stable reaches of a stream, avoiding meanders that are subject to rapid shifting and channel profiles that are degrading or aggrading. The direction and amount of flood flow at various stages must be considered in the location of hydraulic openings to avoid undue scour and erosion. To reduce the potential for problems every effort should be made to minimize the number of stream crossings and encroachments.

25.4 Cross Sections

Good landscaping and drainage design are compatible with both erosion control and vehicle safety. Slopes of the roadway cross section should be as flat as practicable and consistent with soil stability, climatic exposure, geology, proposed landscape treatment, and maintenance procedures. The cross section should be varied, if necessary, to minimize erosion and to be consistent with safety and drainage requirements. Designers should refer to FDM 13-30 to calculate flow depths in the channel based on the amount of water (discharge) being directed to the area, as well as, how to design channel sections.

Severe erosion of earth slopes is usually caused by a concentration of surface water flowing from the area at the top of cut or fill slopes. Diversion dikes and ditches, either temporary or permanent, should be included in the cross section to intercept and convey the runoff to a suitable outlet.

25.5 Proper Shaping for Erosion Control

Proper design features and natural materials or methods are the most effective means of erosion control. One of the most important erosion prevention items is proper shaping and/or contouring (refer to Attachment 25.1). Proper shaping means slope and ditch rounding, cut-to-fill blending, built-in gully elimination, and feathering cuts. Edges of slopes where cuts or fills intersect the natural ground line should be round. Slope angles should be constructed that will ensure slope stability. Existing vegetation and topographic features should be conserved and perpetuated to reduce erosion.

The solution to some erosion problems depends on avoidance. Sidehill locations where steep, deep cuts are required should be avoided. These steep, deep cuts are difficult areas to stabilize, especially in rock cuts with loose sloughing overburden, in water bearing soils, and/or in soils high in silt content. Before slopes can be stabilized, the foundation soils and/or geologic formations must be stable. In general, the degree of slope designed must be flatter than the natural angle of the weakest soils or rock formation encountered in the slope. Vegetation can only stabilize and control surface erosion (erosion normally contained to the top 1-ft (300 mm) of soil). Revegetation is directly dependent on slope stability. If slope angles are constructed to ensure stability, plant establishment can usually follow. Side slopes may vary with the height-of-fill or cut and right of way limits. At times, the designer may make adjustments to flatten the slope angle or shorten the length of slope.

25.6 Cut-To-Fill Transitions (Cut Runouts)

Cut-to-fill transition areas are highly susceptible to erosion. The erosion problem generally starts at the cut-to-fill transition and extends down along the toe of the embankment slope to the low point (refer to Attachment 25.2 and Attachment 25.3).

There are two conditions which affect the shape of the drainage channel at the toe of the fill.

1. The natural ground is level or slopes away from the fill;
2. The natural ground slopes toward the fill.

If the natural ground slopes toward the fill, a special ditch gradient should be constructed along the toe of the slope to reduce the erosion potential and to provide the desired rounded cross section. The designer should determine whether or not channel protection is required to convey runoff quantities down the cut-run-out ditch. Flumes are frequently necessary to convey drainage down the special ditch grades and to prevent erosion. The runoff to be conveyed down the flume will have to be determined.

If it is determined that a flume is inadequate for the runoff flow quantities to be conveyed down the special ditch, an enclosed pipe down drain should be considered.

When the natural ground slopes away from the fill, ditches are not necessary. However, attention should be paid to natural drainage courses and nearby sensitive areas which may receive sediment from the fill slope.

25.7 Culverts

Culverts generally constrict flood flows and increase velocities, giving a much higher than normal erosion potential for a particular site. In many instances, erosion and scour at culvert crossings are damaging to either the highway embankment, the structure itself, or the downstream channel if not designed and protected properly. A good indication of the need for outlet protection at culverts is the performance of other culverts in the area.

The culvert size, location, grade, and the provision of any necessary outlet protection are important design considerations in determining the erosive potential of a culvert crossing site.

Culverts should be located to minimize channel changes where practicable. Consideration should be given to constructing culverts on skewed alignments to minimize channel relocation and erosion.

The invert grade of the culvert should closely match that of the natural channels. A thorough evaluation of culvert invert grade alternatives will help identify which alternative will result in the least erosion and scour both during and following construction. Cantilevered outlets should be avoided unless they discharge onto a rock foundation or other protected outlet provisions.

LIST OF ATTACHMENTS

Attachment 25.1	Erosion Control Prevention
Attachment 25.2	Erosion Control At Cut To Fill Transition
Attachment 25.3	Transition From Cut of Fill

FDM 10-5-30 Drainage Guidance For Erosion Control

January 24, 1997

30.1 Natural Drainage

Early in the data gathering stage, it is important for planners and designers to review and take pictures of the project during, or shortly after, it rains to:

1. Identify or confirm existing drainage patterns.

2. Identify and record existing drainage problem areas.

The existing drainage patterns, which consist of overland flow, swales and depressions, and natural watercourses, should be identified in order to plan around critical areas where water will concentrate. Where 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 can become part of the erosion problem if they are not properly designed and constructed. Care should also be taken to be sure that the increased runoff from the site will not erode or flood the existing natural drainage system. Possible sites for storm water detention should be located at this time. Where possible, the natural drainage system of a site should be preserved.

30.2 Adjacent Areas

An analysis of adjacent properties should focus on areas down slope from the construction project. Of major concern should be watercourses which will receive direct runoff from the site. The potential for sediment pollution of these watercourses should be considered as well as the potential for downstream channel erosion due to increased volume, velocity and peak flow rate of storm water runoff from the site. The potential for sediment deposition on adjacent properties due to sheet and rill erosion should also be analyzed so that appropriate sediment trapping measures can be planned and installed prior to any land-disturbing activity.

30.3 Local Input

To gain an understanding of existing drainage problems or concerns, designers should gather information from those who are familiar with the project area such as maintenance personnel, nearby property owners, farmers, town officials or administrators, drainage district offices and the district DNR liaison.

30.4 Storm Design Guidance and Channel Capacity

In general, designers should use the following storm design guidance when designing for temporary and permanent erosion control measures:

1. For permanent roadside channel linings, a 10-year, 24 hour frequency storm is considered cost effective unless the risk associated with failure would warrant a larger frequency. Risks should be weighed against the cost and erosion control measures designed accordingly.
2. For temporary roadside channel linings and temporary devices such as silt fence and erosion bales, a 2-year, 24 hour frequency storm is considered cost effective unless as noted in #1 above.
3. Emergency spillways for detention basins are to be designed for the 100 year, 24 hour frequency storm.

NOTE: If environmental or customer sensitive areas are impacted, a longer frequency may be needed.

FDM 13-10 Attachment 1.1 requires roadside and median channels to have enough capacity for a 25-year, 24 hour design storm. However, designing channels to prevent erosion given the 25-year storm would produce very expensive channels. Therefore, it is recommended that designers provide:

1. Appropriate measures to minimize channel erosion during the 10-year, 24 hour storm, yet,
2. Enough channel capacity for the 25-year, 24 hour storm (refer to Chapter 13 for further information on hydraulic and channel capacity design).

If the permanent lining is to be a vegetative lining and a temporary lining is to be used during the establishment period, the mean annual flood (2.33-year recurrence interval, approximately 2 years) should be used for the design of the temporary lining. This is because the temporary lining is only required for a short period of time, and if the lining is damaged, repairs are usually inexpensive.

30.5 Storm Water Runoff

Runoff calculations must be done to determine the effect of the highway on the existing hydrologic system. To determine how runoff will travel over the site, divide the site into drainage areas and consider how erosion and sedimentation can be controlled in each small drainage area. Once the smaller sites have been evaluated, the entire site can then be reviewed to see how the erosion control measures fit together.

Designers should refer to Chapter 13 when calculating runoff and contact the locality, where applicable, to see if they have adopted more stringent runoff requirements.

Where existing conditions are being maintained, and there is no significant alteration to existing drainage patterns or areas, such as on 3R projects, or where the drainage area is small, the designer may rely upon the use of empirical design methods. A working system does not need to be altered or redesigned unless problems have been identified.

FDM 10-5-35 Channel and Slope Matrics February 27, 2004

Attachment 35.1 and Attachment 35.2 were developed for use as a guide to identify where to apply erosion and sediment control devices, given a specific set of parameters. These parameters are typically slope and slope length. In addition, they can be used as a tool to evaluate whether the project's channel or slope design will need to be modified to provide the required protection. The matrices are only a guide and should not replace critical engineering judgment or the need for careful design consideration.

These matrices were developed with information obtained from the American Association of State Highway Transportation Officials (AASHTO), Department of Natural Resources (DNR), Soil Conservation Service (SCS), data from the WisDOT PAL (found at: https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/pal/default.aspx), other states, district offices and past practices. Each device is shown to the limit where it could function if used alone. Consider using a combination of these devices when developing an effective erosion control plan.

The channel matrix is based on the Department's typical section as shown in FDM 11-15-1. The use of the matrix does not mean that designers are restricted from using larger flows. However, if larger flows are used the channel section and/or erosion measures will need to be adjusted accordingly to protect the channel from erosion. One method for calculating the appropriate channel cross section and erosion measures is known as the "tractive force" or "shear stress" method (see FDM 10-5-40 for guidance.) Designers should also refer to FDM 13-30 on how to calculate flow depths based on the amount of water (ie., discharge) being directed to the area, as well as, how to design alternate channel section.

Costly erosion and sediment control measures can be minimized if the site design can be adapted to existing on-site conditions and if good conservation principles are used. Where possible, existing vegetation should be preserved. Costs should be estimated for each alternative under study and the risks analyzed should the measures not be implemented.

LIST OF ATTACHMENTS

FDM 10-5-40 Calculating Shear Stress in Channels January 24, 1997

To help determine the appropriate channel liner, designers can refer to the channel matrix in FDM 10-5-35. However, for channels not conforming to the typical section shown in the channel matrix or having a depth of flow greater than 6 inches (150 mm), the designer will need to design for an appropriate channel liner. One way to do this is to use the "tractive force" method presented in FHWA's Hydraulic Engineering Circular (HEC) No. 15. This method requires that the CALCULATED MAXIMUM SHEAR STRESS of a channel is not to exceed the PERMISSIBLE SHEAR STRESS of the channel liner.

To use this method, permissible shear stress values are stated next to each device listed in the channel matrix. Calculated shear stress values can be determined using the formula:

Calculated Shear Stress = (Unit Weight of Water)(d)(S)

Where:

- Calculated Shear Stress is in lbs/ft^2 or Pascals *
- Unit Weight of Water = 62.4 lbs/ft^3 (9800 Newtons/m^3)
- d = Depth of Flow in Channel (feet or meters)
- S = Channel Gradient (feet/foot or meters/meter)

* Note: 1 Pascal is defined as 1 Newton/m^2

If the calculated maximum shear stress exceeds the permissible shear stress of the mat being considered, the channel or channel liner must be adjusted. This may involve one or more of the following:

1. CHANNEL LINER: Use a stronger channel liner, either flexible or rigid, to meet the drainage requirements of the channel.
2. CHANNEL CROSS SECTION: Modify the channel's cross section such as widening the ditch bottom to decrease the depth of flow in order to reduce the stresses on the liner (refer to Chapter 13).

Once vegetation is established, the permissible shear stress of the channel increases. Engineering judgement should be used given the sensitivity of the area prior to vegetation establishment as well as long term performance requirements.

Caution: Even though the calculated shear stress may be less than the permissible shear stress, designers should still use their engineering judgement to decide whether the channel liner is appropriate based upon the project conditions. For example, if the calculated shear stress value falls just under the permissible shear stress for the channel liner selected, it may be appropriate to go to a different channel liner if the area is adjacent to a critical environmental or customer sensitive area.

In addition:

1. When riprap or grouted riprap is to be used, designers should refer to FDM 10-10-19 and FDM 13-30 for design guidance.
2. For steep slopes or critical channel sections, designers should refer to FDM 13-30 and consult with their Hydraulic or Soils Engineer.
3. Another method for designing channel liners is to compare the calculated velocity of the channel to the permissible velocity of the channel liner. For further information on this method, refer to FDM 13-30.

Sample Problem

Given: A 300 ft long triangular ditch with a 6:1 inslope, 4:1 backslope and a channel gradient of 4% (S=0.04). The ditch must handle a flow (Q) of 20 cfs.

Determine: An appropriate channel liner.

Discussion: Based on FDM 10-5 Attachment 35.1 there are several options available if the depth of flow does not exceed 6 inches. If this depth may be exceeded then the following procedure should be followed.

1. Assume a depth of flow (da) for the channel. Say 1 ft. (Caution: Avoid having the depth of flow equal to the ditch depth. There should be some freeboard.)
2. Pick a potential channel liner and determine its n value from Manning's Roughness Coefficients Table (refer to Attachment 40.1). For this example try a Class II, Type B, a "Straw with Net" erosion mat. From the table, n = 0.033 based on the assumed depth of 1 foot.
3. Use the nomograph in Attachment 40.2 to determine the actual depth of flow (d). Since the channel slopes are not the same, calculate "z" using the formula z = T/da where "T" is the width of the flow in the channel at the assumed depth.

   For an assumed depth of 1 ft, T = 10 ft and z = 10/1 = 10. The z/n ratio is then 10/0.033 or 303. Connect the z/n ratio of 303 with slope (S) of 0.04 on the nomograph. From the turning point draw a line through the discharge value of 20 cfs and extend the line to the far right depth of flow scale. The reading on this scale (d) is approximately 0.8 ft.
4. Check this revised depth against Attachment 40.1 to see if it still falls within the depth range originally selected for the Manning's roughness coefficient. If so, continue. If not then select a different channel liner with a different n value. In this example d = 0.8 ft which falls in the 0.5 ft - 2.0 ft range for the chosen channel liner. Therefore, the n value is the same as for the assumed depth of 1.0 ft and there is no need to choose another liner option.
5. Check if the channel liner selected meets the shear stress requirements of the channel. This is done using the formula from page 1:

   Calculated Maximum Shear Stress
   $= (62.4\ \text{lbs/ft}^3)(d)(S)$
   $= (62.4\ \text{lbs/ft}^3)(0.8\ \text{ft})(0.04)$
   $= 2.00\ \text{lbs/ft}^2$

   This equals the permissible shear stress of the Class II, Type B channel liner as shown in FDM 10-5 Attachment 35.1 therefore, the chosen option is acceptable.

If the calculated shear stress is greater than the permissible shear stress of the chosen channel liner, then a stronger liner would be needed. If another liner is used it should be checked using the procedure described above.

LIST OF ATTACHMENTS

Attachment 40.1	Manning's Roughness Coefficients Table
Attachment 40.2	Nomograph for Flow in Triangular Channels

FDM 10-5-45 Analyzing Costs
January 24, 1997

45.1 Cost vs. Effectiveness

The cost of implementing erosion and sediment control practices is highly variable and dependent upon many factors including regional cost trends, availability and proximity of materials, time of year, prevailing labor rates, maintainability, etc.

Those preparing a design erosion control (EC) plan must pay careful attention to the selection of each practice. The practice with the least expensive initial cost may require a great deal of maintenance over the length of a project. Accessibility for maintenance can often be a factor that determines effectiveness. Silt fence for instance, requires regular maintenance. If it is placed in a location that is difficult to reach or in a location that drains a large disturbed area, maintenance may become a problem, increasing the potential for failure. In such a case, a diversion dike leading to a sediment trap may be a better selection. The dike and trap are more suitable to handle larger runoff volume and would require less day-to-day maintenance, if installed properly.

Once installed, the costs associated with a particular erosion control installation can be kept to a minimum when maintenance is performed on a regular basis. Once a practice fails, the replacement cost can be double the initial cost of the practice. Regular maintenance also decreases the likelihood of damage to downslope property.

FDM 10-5-50 Estimating Erosion Control Quantities
April 27, 2011

In order for erosion control items to be successful they must be available in adequate quantities. When determining adequate quantities of these items, designers should include an extra amount of each item as "Undistributed" to provide for unforeseen circumstances and provide for any necessary repair work. Approximately 25% of the calculated quantity should be used as the undistributed amount. For example, if the calculated plan quantity for Class I, Type B erosion mat is 1000 yd2, the undistributed quantity would be 250 yd2, for a total of 1250 yd2. If the quantities are small to begin with or if the project will span more than one construction season, a higher percentage should be used for the undisturbed quantity.

50.1 Mobilization for Erosion Control

For the bid item of "Mobilizations Erosion Control", the designer should estimate how many times an erosion control or landscaping contractor may need to be mobilized given the type of work and environmental or customer sensitivity in the project area. It is important to provide adequate quantities for this item commensurate with applicable environmental requirements.

Practice indicates that landscapers are mobilized up to 5 times for small bridge projects. For example:

1. Install silt fence prior to earthwork.
2. Install temporary ditch checks.
3. Install turbidity barrier prior to abutment or pier work.
4. Bring erosion control measures up to the Q2 elevation after the substructure work is complete but prior to work on the superstructure.
5. Perform final restoration and landscaping.

Some examples of estimating Mobilizations Erosion Control are;

1. Three mobilizations for each earthwork balance point,or
2. Three mobilizations for each construction staging sequence,or
3. One mobilization for each 2-3 weeks of contract duration, or
4. One mobilization for each ¼ to ½ mile of project length, or

Use whichever method provides the most mobilizations. If there are environmental or site restrictions on how much area can be exposed at one time, include additional quantities of Mobilizations Erosion Control.

50.2 Emergency Mobilization for Erosion Control

For the bid item of "Mobilizations Emergency Erosion Control", the designer must estimate how many times it may be necessary to mobilize for emergency situations. A “rule of thumb” is to include one emergency mobilization for every 4-5 weeks of contract duration at a minimum, and more if any of the following are applicable:

1. The project is erosion sensitive (refer to FDM 10-5-10),

2. Environmental or customer sensitive areas are located within or nearby the project (refer to FDM 10-5-15),
3. The project will be constructed during normally wet months,
4. The project will span more than one construction season, thereby making it susceptible to spring runoff erosion.

FDM 10-5-55 Erosion Control Plan Preparation *January 24, 1997*

55.1 Introduction

Erosion control during construction is highly dependent on the temporary and permanent measures contained in the design erosion control (EC) plan. The design EC plan includes all erosion and sediment control considerations made during the planning, location, and project development phases and is found in the construction plans, specifications and special provision's. To be effective, it must contain sufficient measures and adequate quantities.

The Department is required to meet the substantive legal requirements of the Wisconsin Pollution Discharge Elimination System (WPDES) as well as the terms and conditions presented in the WisDOT/WisDNR Cooperative Agreement (refer to https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx). By doing so, the Department is considered to be in compliance with the WPDES permit program requirements.

To meet the substantive requirements of the WPDES and the WisDOT/WisDNR Cooperative Agreement, designers should refer to FDM 10-5-60 for a checklist of erosion control plan requirements.

55.2 Special Provisions

The special provisions should contain a statement which explains any special erosion and sediment control measure, environmental protection measures and references to sensitive areas. It should contain information concerning existing site conditions, construction schedules, and other pertinent items. It should also indicate sensitive areas on the project and any special considerations for those areas.

When working near sensitive areas, designers should consider including, in the contract documents, a limitation on the amount of erodible surface area which may be exposed at any one time. In addition, projects should be evaluated to see whether they may be left uncompleted and carried over the winter. In such cases, these projects should be "buttoned up" by providing adequate quantities in the plans and include special provisions sufficient enough to prevent erosion and maintain devices through the spring-thaw season.

55.3 Construction Plans

Erosion and sediment control measures for a construction project should be detailed and quantified in the construction plans. Information required to be on the design EC plan, or for reviewing the design EC plan, is located in the:

1. TITLE SHEET: Indicates the general location of the construction activity.
2. GENERAL NOTE SHEET: Includes general plan information.
3. CONSTRUCTION DETAIL SHEETS: Includes non-standard details of erosion and sediment control devices that are needed for the project.
4. PROJECT OVERVIEW SHEET/MAP: May be used to show nearby receiving waters such as lakes, rivers, and wetlands.
5. ESTIMATE OF QUANTITIES: Lists the total quantity of each erosion and sediment control device used on the project.
6. MISCELLANEOUS QUANTITY SHEETS: Contains information on the specific location of erosion and sediment control devices.
7. EROSION CONTROL PLAN DETAIL SHEETS: Illustrates the location of all pertinent erosion and sediment control devices as well as other relevant information such as drainage patterns, slope intercepts and environmental and customer sensitive areas. Topographic features such as tree-lines, nearby buildings, parking lots and driveways, are also desirable.

   For complex projects, separate plan sheets are recommended in order to avoid clutter and allow the contractor to find the information as quickly as possible. For less complex projects, it may be appropriate to illustrate the location on the "Plan and Profile" sheets. In some cases, it may be appropriate to show the devices by station and location on the miscellaneous quantity sheets. Again, the object being to not clutter the plan.

8. STANDARD DETAIL DRAWINGS: Included for all erosion or sediment control devices applicable to the project.
9. CROSS SECTION SHEETS: Contains valuable information on existing and proposed drainage features such as channel and slope grades, culvert pipe locations & elevations, slope intercepts and intercepting embankments.

An erosion and sediment control plan must contain sufficient information to ensure that the problems of erosion and sedimentation have been adequately addressed for a proposed project. The length and complexity of the plan should be commensurate with the size of the project, the severity of site conditions, and the potential for off-site damage.

Plans for projects undertaken on flat terrain will generally be less complicated than plans for projects constructed on steep slopes where erosion potential is greater. The greatest level of planning and detail should be evident on plans for projects which are directly adjacent to sensitive areas.

FDM 15-1 Attachment 5.10 shows an example of an erosion control detail sheet.

FDM 10-5-60 Checklist for Erosion Control Plans *December 5, 2017*

A design erosion control plan is required on all projects having a potential to cause the discharge of sediments. The checklist in Attachment 60.1 summarizes the items that need to be included throughout the contract documents for a given project. The checklist was developed to:

1. Help designers meet the federal and state regulations
2. Improve statewide consistency in the development of erosion control plans

Most of the requirements are not new for WisDOT P.S.& Es. Those that are new are shown in bold type. For information only, items that need to be included in the soils report to meet the requirements are also given.

LIST OF ATTACHMENTS

Attachment 60.1	Erosion Control Plan Checklist
Attachment 60.2	Runoff Coefficient Table

FDM 10-5-65 Construction Considerations *January 24, 1997*

All erosion and sediment control considerations made during the planning, location, and plan development phases should be contained in the design erosion control (EC) plan. The design EC plan contains the erosion and sediment control plans and contract provisions necessary for the contractor and construction personnel to perform the work.

The control of soil erosion is an essential consideration in construction operations. The contract documents should require that the work be performed in a manner which will cause minimum soil disturbance. When working near sensitive areas, the designer should consider including, in the contract documents, a limitation on the amount of erodible surface area which may be exposed at any one time during the performance of the work.

The designer should also anticipate whether the project might be left uncompleted and carried over the winter. Adequate quantities and special provisions should be provided to "button up" the project sufficient enough to prevent soil loss.

Once the project is let, the design EC plan is used by the contractor to develop an "Erosion Control Implementation Plan", (ECIP). The ECIP is a narrative and pictorial plan based on the contractor's schedule of operations. It differs from the design EC plan, in that, it outlines a general timetable of when erosion control devices are expected to be installed by the contractor before, during and after construction based on the estimated schedule of operations. In addition, it includes all Wisconsin Pollution Discharge Elimination System (WPDES) requirements for borrow and waste site areas (refer to FDM 10-1-1).

Proper planning and scheduling of the construction operations are major factors in controlling anticipated erosion and sediment problems. The schedule should consider the probable weather conditions and the potential occurrence of storms, particularly if work in or adjacent to sensitive areas is involved.

This plan should be available to the construction project engineer prior to the pre-construction conference. For further information regarding the ECIP, see the Construction and Materials (C&M) manual, the Wisconsin Standard Specifications for Road and Bridge Construction and/or supplemental specifications.

It is now the contractor's and project engineer's responsibility to not only carry out the explicit contract plan provisions for erosion and sediment control, but also to adapt, adjust, add, and implement the measures through the different phases of construction to achieve an acceptable level of erosion and sediment control.

The construction project engineer and inspection staff must become thoroughly familiar with the erosion and sediment sensitive areas of the project and the control measures contained in the plans. This information should be reviewed with the contractor at the pre-construction meeting to facilitate the implementation of the design EC and ECIP plans.

The designer should attend the pre-construction conference and be ready to answer any questions pertaining to the project.

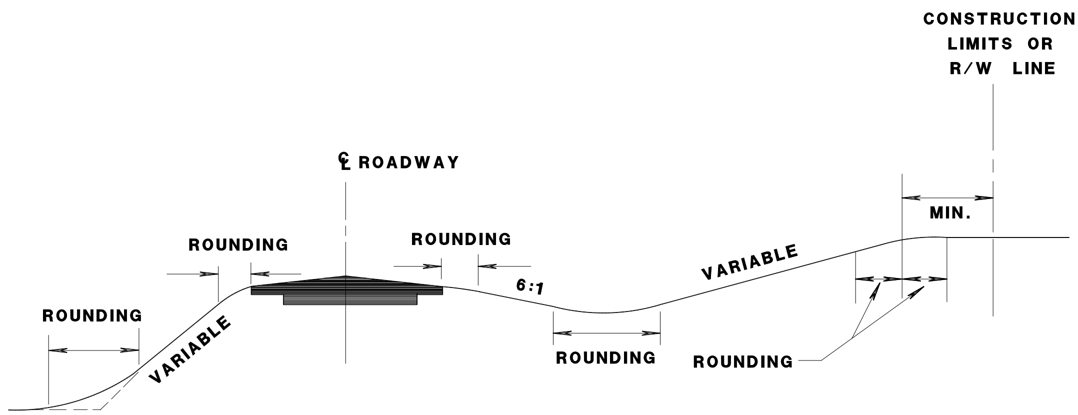
Periodic field reviews and inspections by the design and construction engineers to correct deficiencies and improve control procedures are highly recommended. The designer should try to schedule a time to meet with the construction project engineer in the field to evaluate the design and obtain feedback.

FDM 10-5-70 Maintenance Considerations *January 24, 1997*

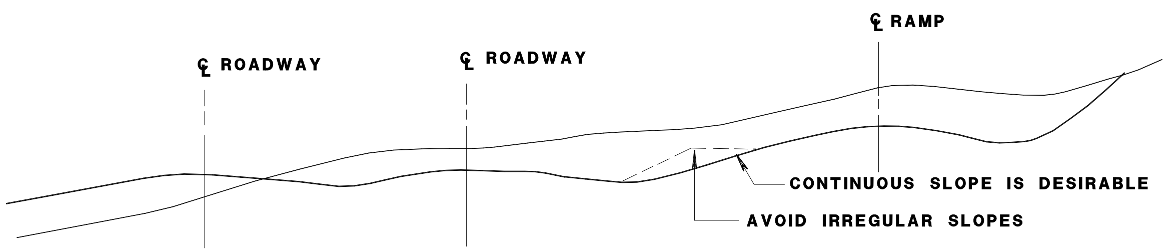
The need for continual maintenance of temporary erosion and sediment control devices as well as the need for maintenance of permanently installed measures is as important as the initial installation. Access for future maintenance purposes must be considered when specifying devices.

Temporary sediment control devices such as silt fences, sediment traps and ditch checks, usually require frequent and periodic cleanout of accumulated sediment. To effectively control erosion on construction sites during extended periods of inactivity such as during winter months, it is essential that the designer consider maintenance in the contract special provisions and estimated quantities.

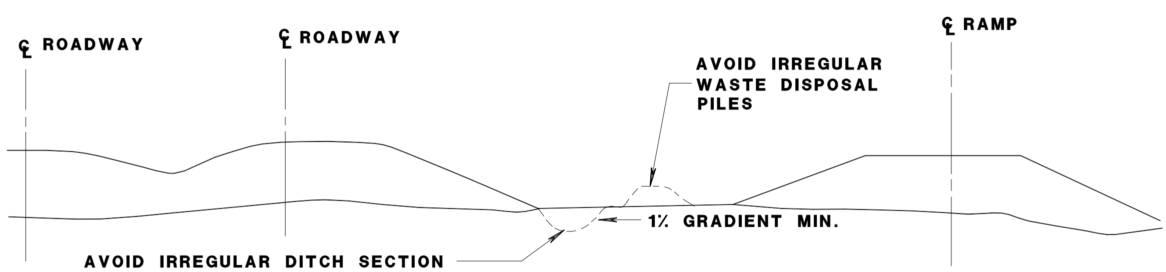
In addition, once the contractor has completed the project and the new vegetation has been firmly established, the project should be checked to see that all remaining temporary erosion and sediment control devices are removed if no longer needed.



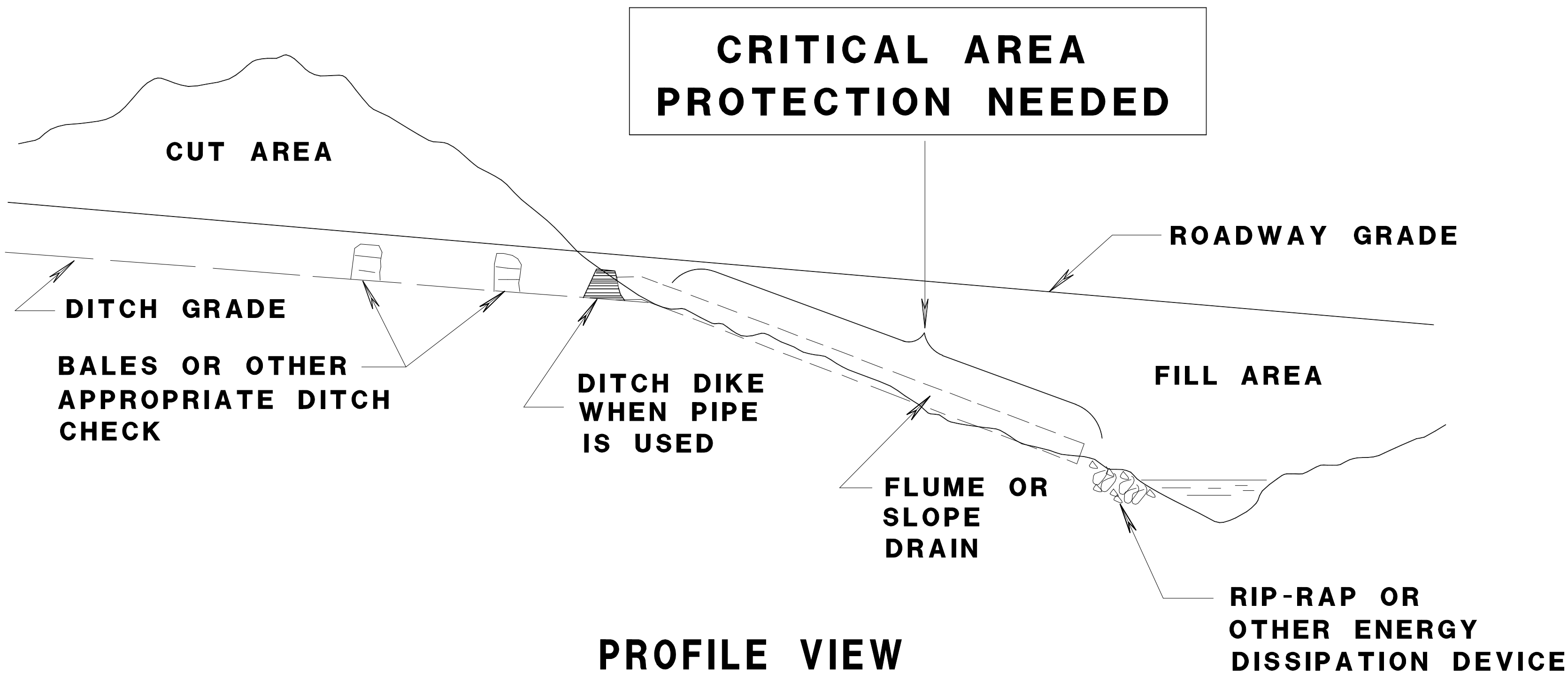
TYPICAL SECTION - ROUNDING FOR EROSION CONTROL



INTERCHANGE CUT

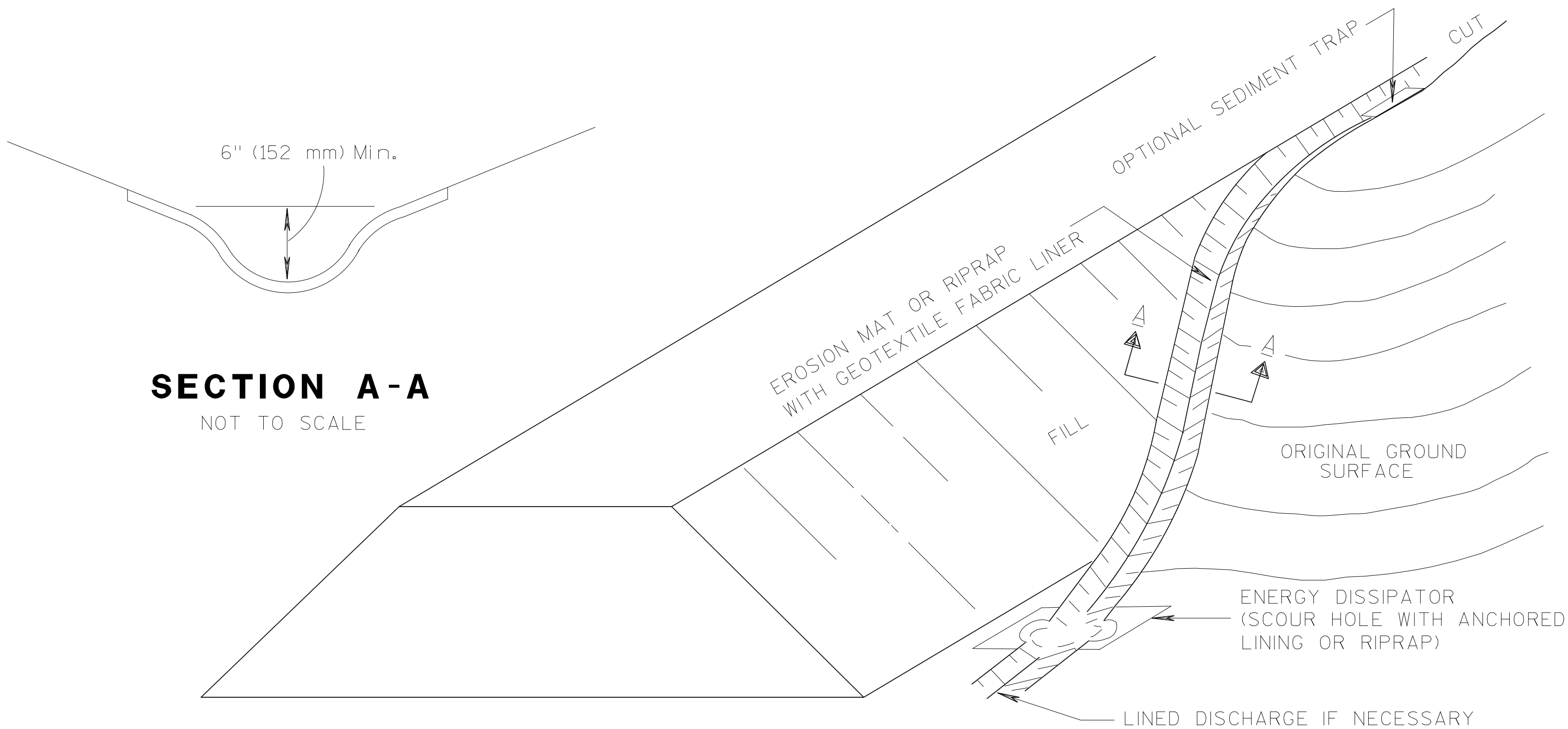


INTERCHANGE FILL



PROFILE VIEW

EROSION CONTROL AT CUT-TO-FILL TRANSITION



TRANSITION FROM CUT TO FILL

CHANNEL EROSION CONTROL MATRIX

(Concentrated Flow Application)

TYPE OF EROSION CONTROL DEVICE	PERMISSIBLE SHEAR LBS/S.F.	DITCH GRADE															REMARKS
		< 2%			2% - 4%			4% - 6%			6% - 9%*			9% - 12%*			
		Max. Length (ft.)			Max. Length (ft.)			Max. Length (ft.)			Max. Length (ft.)			Max. Length (ft.)			
		300	600	1200	300	600	1200	300	600	1200	300	600	1200	300	600	1200	
Seed with properly anchored mulch	0.6	—	—														Anchor mulch per specifications.
Sod ditch checks with seed and mulch	N/A	—	—	—	—	C											Install one ditch check for every 1 foot of drop. Sod stakes required.
Temporary ditch checks (hay bales or approved manufactured alternatives lisited in the WisDOT PAL)	N/A	—	—	—	—	—	—										Install one ditch check for every 2 feet of drop. Maximum 200' spacing. Not recommended for slopes less than 1%.
Sod ditch liner	1.0	—	—	—													Upstream end must be buried. Additional sod stakes required.
Double netted light duty (WisDOT Class I Type B) erosion mat	1.5	—	—	—	—	—	—	—									Only mat type products allowed.
Sod reinforced with a double netted jute (WisDOT Class II Type A) erosion mat	1.5	—	—	—	—	—											Upstream end must be buried. Additional sod stakes required. Two bid items needed.
Stone or rock ditch checks, or Rock-Filled Filter Bags	N/A	▪▪▪	▪▪▪	▪▪▪	—	—	—	—	—	—							Use No. 2 coarse aggregate, railroad ballast, or breaker run. Install one ditch check for every 2 feet of drop. Use in conjunction with a channel lining.
Medium duty coconut erosion mat (WisDOT Class II Type B or C)	2.0	▪▪▪	▪▪▪	▪▪▪	—	—	—	—	—	⊗	—						
Heavy duty synthetic (WisDOT Class III Type A) erosion mat or turf reinforcement mat (WisDOT Class III Type B)	2.0	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	—	—	—	—						Germination may be a problem with Class III Type A mats. An ECRM is required for initial erosion protection for Class III Type B mats.
Heavy duty synthetic turf reinforcement (WisDOT Class III Type C) mat	3.5	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	—	—	—	—			An ECRM is required for initial erosion protection. Contact manufacturer if higher shears are needed.
Riprap ditch checks	N/A	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	—	—	—	—	—		Place top of downstream ditch check level with bottom of upstream ditch check. Use in conjunction with a channel lining.
Heavy duty synthetic turf reinforcement (Class III Type D) mat	5	▪▪▪	▪▪▪	▪▪▪	▪▪▪	—	—	—	—	—	—	—	—	—	—	—	An ECRM is required for initial erosion protection. Contact manufacturer if higher shears are needed.
Light riprap	4	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	—	—	—	—		Outfalling, overtopping and scour need to be addressed. Use 2' minimum ditch depth.
Medium riprap	5	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	—	
Heavy riprap	8	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	

Riprap measures apply to all ditch types. Use of these measure requires engineering judgement and design.

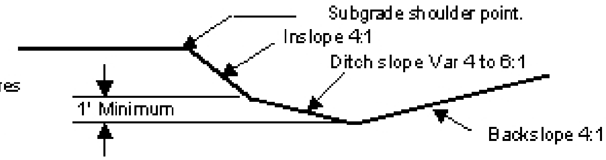
CHANNEL EROSION CONTROL MATRIX (cont.)

(Concentrated Flow Application)

TYPE OF EROSION CONTROL DEVICE	PERMISSIBLE SHEAR LBS/S.F.	DITCH GRADE < 2% Max. Length (ft.) 300	< 2% 600	< 2% 1200	2% - 4% Max. Length (ft.) 300	2% - 4% 600	2% - 4% 1200	4% - 6% Max. Length (ft.) 300	4% - 6% 600	4% - 6% 1200	6% - 9%* Max. Length (ft.) 300	6% - 9%* 600	6% - 9%* 1200	9% - 12%* Max. Length (ft.) 300	9% - 12%* 600	9% - 12%* 1200	REMARKS
Grouted rip rap	N/A	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	Address outfalling, overtopping and scour. Line with Grotextile fabric Type "HR", (see Chap. 10, Const. Detail and special provision). Use 2' minimum ditch depth.
Articulated Concrete Block Type A	5	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	▬▬▬	▬▬▬	▬▬▬	▬						ACBs apply to all ditch types. Use of these measures requires engineering judgement and design.
Articulated Concrete Block Type B	10	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	▬▬▬	▬▬▬	▬▬▬	▬▬▬			
Articulated Concrete Block Type C	15	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	▬▬▬	▬▬▬	
Articulated Concrete Block Type D	20	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	
Articulated Concrete Block Type E	30	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	

Standard Ditch Section

Erosion control for ditches not conforming to the typical at right, that complies with FDM procedures 11-15-1 Figures 6 & 7, should be designed according to FDM Chapter 13.



KEY

Effective range of device for Sandy or Clayey Soil: ▬▬▬

Device applicable, may not be cost effective: ■ ■ ■ ■ ■ ■ ■ ■

" C " effective for clayey soil only

Not applicable. Use in conjunction with other BMPs: ⊗

ECRM - Erosion control revegetation mat. All Class I and II mats are ECRMs.
TRM - Turf reinforcement mat.
FDM - WisDOT Facilities Development Manual
BMP - Best Management Practice
PAL - See Note 6

* For ditch grades over 9% special design considerations may be required.
** Soils that are not sandy should be treated as clay soils.

NOTES

1) Ditch flow rates used to develop bar chart are based on a 60 ft. right of way from pavement centerline and a 2-Yr. rainfall event for temporary liners or a 25-Yr. rainfall event for permanent (Class III mat or riprap) liners. If the drainage area extends outside the 60 foot right of way or unusual flows are expected, use the shear stress column values to determine the suitablity of a liner. See FDM procedures in Chapter 10 and in Section 13-30-10.
2) Erosion mats shall extend upslope 1.0 ft. min. vertically from the ditch bottom or 6" higher than the design flow depth. There shall be no joints within 18" of the low point.
3) Cost shall be a consideration in the selection of these devices.
4) Add sediment traps at the bottom of channel slopes.
5) Refer to FDM Chapter 10 for any channels exceeding the limits shown.
6) Approved materials for erosion products are referenced from the Wisconsin Department of Transportation Erosion Control Product Acceptability Lists (PAL), found at https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/pal/default.aspx
7) On long or steep channels that require a higher class mat, use the appropriate lower class mat for the first 300 ft to 600 ft of the channel.
8) Effective erosion control involves minimizing the amount of time soil is exposed and the selection of a combination of practices, and not reliance on just one practice.

SLOPE EROSION CONTROL MATRIX

TYPE OF EROSION CONTROL	SLOPE																		REMARKS
	6:1 or flatter (7)			4:1			3:1			2.5:1			2:1			1:1			
	SLOPE LENGTH			SLOPE LENGTH			SLOPE LENGTH			SLOPE LENGTH			SLOPE LENGTH			SLOPE LENGTH			
	0 - 30'	30 - 60'	60 - 120'	0 - 30'	30 - 60'	60 - 120'	0 - 30'	30 - 60'	60 - 120'	0 - 30'	30 - 60'	60 - 120'	0 - 30'	30 - 60'	60 - 120'	0 - 30'	30 - 60'	60 - 120'	
Seed with properly anchored mulch	━	━	━	━	━	━	━	━											
Single netted light duty (WisDOT Class I Type A) erosion mat	┅	┅	┅	┅	┅	┅	━	━	━	━	━								
Light duty single netted 100% biodegradeable (WisDOT Urban Type A) erosion mat	━	━	━	━	━	━													Use only 100% biodegradeable anchors for urban mats.
Light duty double netted 100% biodegradeable (WisDOT Urban Type B) erosion mat	┅	┅	┅	━	━	━	━	━	━	━									Use only 100% biodegradeable anchors for urban mats.
Bonded Mulch (WisDOT Type A Soil Stabilizer)	┅	┅	┅	━	━	━	━	━											May be applied over Class III Type B, C, or D mats in place of erosion control revegetation mats.
Polymer (WisDOT Type B Soil Stabilizer)	Used in conjunction with other BMPs effective up to a 2:1 slope. Not effective in sand. When used alone effective up to a 3:1 slope. Stand alone use appropriate for earthen stock piles, temporary, and late season applications																		
Double netted light duty (WisDOT Class I Type B) erosion mat	┅	┅	┅	┅	┅	┅	━	━	━	━	━	⊗	━						
Sod	┅	┅	┅	┅	┅	┅	━	━	━	━	━	⊗	━						
Medium duty coconut erosion mat (WisDOT Class II Type B or C)	┅	┅	┅	┅	┅	┅	┅	┅	━	━	━	━	━	━					
Sod reinforced with a double netted jute (WisDOT Class II Type A) erosion mat	┅	┅	┅	┅	┅	┅	┅	┅	━	━	━	⊗	━	━					Sod stakes required. Two bid items needed.
Heavy duty synthetic erosion control revegetation mat (WisDOT Class III Type A)	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	━	━	━				Germination may be a problem with Class III Type A mats
Riprap	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	━	━	━				Angle of repose must be considered, see FDM Chapter 13.
Heavy duty synthetic turf reinforcement (WisDOT Class III Type B or C) mat	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	━	━	━	━			A soil stabilizer or ECRM will be required for initial erosion protection.
Heavy duty synthetic turf reinforcement (WisDOT Class III Type D) mat	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	━	━	━	━	━	━	A soil stabilizer or ECRM will be required for initial erosion protection.
Slope paving or grouted riprap	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	┅	Consider clear zone requirements. Only use in limited circumstances such as overflow areas near bridges.

SLOPE EROSION CONTROL MATRIX (cont.)

Benches	Consider benches when cuts exceed 20', bench at approximately 15' vertical intervals to collect and drain water. Treat benches as channels (ditches). Adjust elevations to provide drainage. Consider flumes at transitions.
Intercepting embankments	Used to intercept runoff from abutting lands. Flumes may be necessary to direct runoff.
Silt fence	Used at toe of slopes to intercept and detain small amounts of sediment.
Temporary ditch checks or Erosion bales	Used at toe of slopes to intercept and detain small amounts of sediment.
Slope drains/flumes	May be necessary on slopes (see channel matrix for design guidance).
Sediment traps	Used to trap sediment laden runoff. Could be used at the inlet or outlet end of slope drain.

KEY:

Not applicable. Use in conjunction with other BMPs:

Effective range of device for Sandy or Clayey Soil:

Device applicable, may not be cost effective:

* Soils that are not sandy should be treated as clay soils.

ECRM - Erosion control revegetation mat. All Class I and II mats are ECRMs.

TRM - Turf reinforcement mat.

FDM - WisDOT Facilities Development Manual

PAL - See Note 5

NOTES

1) Cost shall be a consideration in the selection of these devices.
2) Designers should review FDM Chapter 10 prior to selection of erosion mats.
3) Install intercepting ditches to limit slope lengths to 15' vertical intervals. (See FDM Chapter 10)
4) Refer to FDM Chapter 10 for any slopes exceeding the limits shown.
5) Approved materials for erosion products are referenced from the Wisconsin Department of Transportation Erosion Control Product Acceptability Lists (PAL), found at the https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/pal/default.aspx
6) On steeper slopes that require a higher class mat, use the appropriate lower class mat or seed and mulch for the first 30 ft to 60 ft of the slope.
7) Unless project conditions require otherwise, seed and mulch all slopes that are flatter than a 5% grade, regardless of length. If practicable, bench the slopes.
8) Effective erosion control involves minimizing the amount of time soil is exposed and the selection of a combination of practices, and not reliance on just one practice.

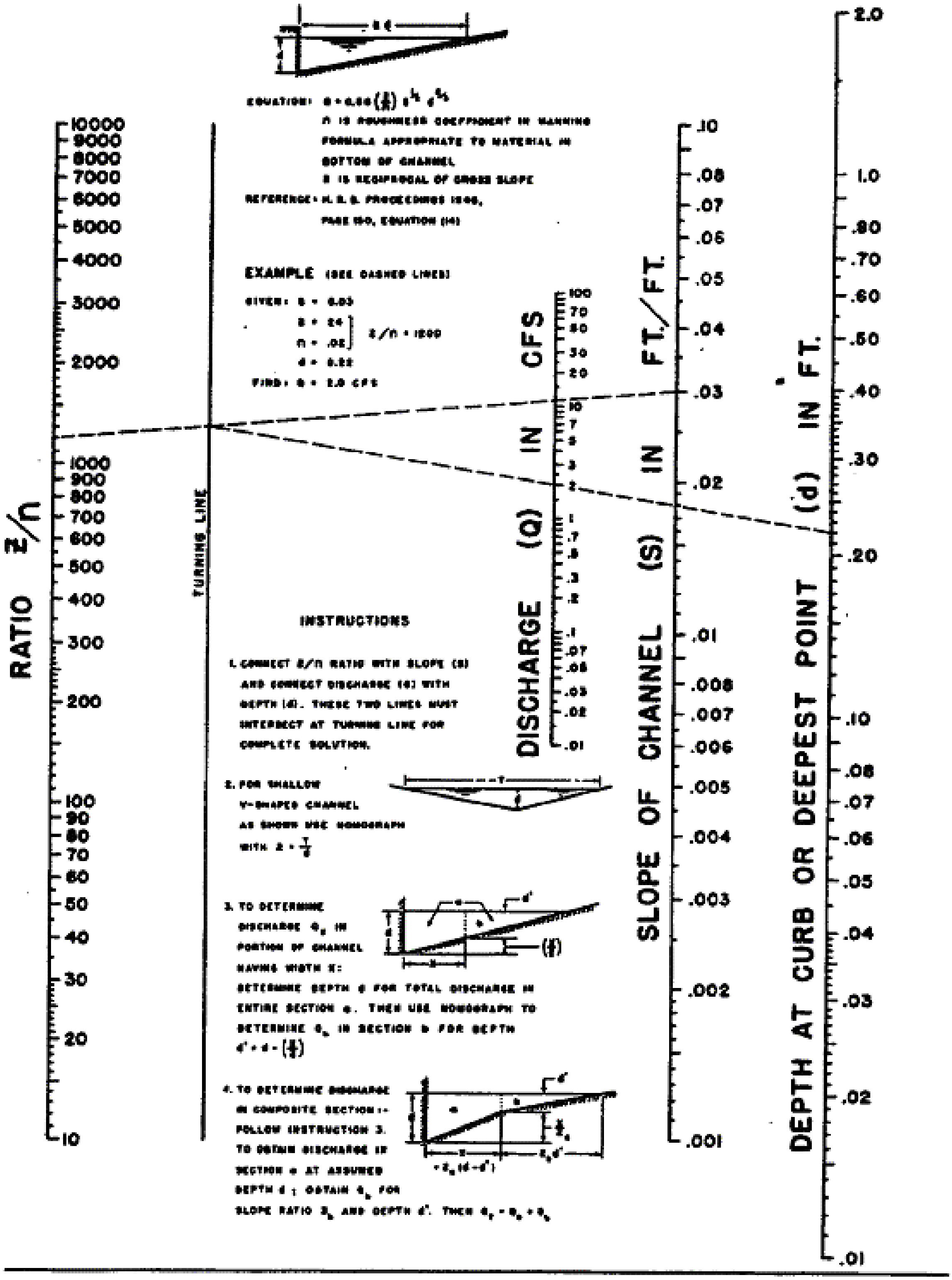
Manning's Roughness Coefficients Table

		n - value		
		Depth Ranges		
Lining Category	Lining Type	0 - 0.5 ft **(0 - 150mm)**	0.5 - 2.0 ft **(150-600mm)**	> 2.0 ft **(> 600mm)**
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Temporary*	Jute Net	0.028	0.022	0.019
	Straw with Net	0.065	0.033	0.025
	Curled Wood Mat	0.066	0.035	0.028
	Synthetic Mat	0.036	0.025	0.021
Gravel Riprap	1-inch (25mm)D_{50}	0.044	0.033	0.030
	2-inch (50mm)D_{50}	0.066	0.041	0.034
Rock Riprap	6-inch (150mm)D_{50}	0.104	0.069	0.035
	12-inch (300mm)D_{50}	--	0.078	0.040

Note: Values listed are representative values for the respective depth ranges. Manning's roughness coefficients, n, vary with the flow depth.

* Some temporary linings become permanent when buried.

(FHWA Hydraulic Engineering Circular No: 15).



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

Source: FHWA Hydraulic Design Series No. 3

Erosion Control Plan Checklist

I. CONTRACT PROPOSAL

_____ A. Provide a description of the project.
(Contract Proposal cover sheet and General special provision)

_____ B. Explain the nature of the construction activity.
(Contract Proposal cover sheet and Scope of Work special provision)

_____ C. Include any special erosion control requirements, such as scheduling or staging of construction that must be relayed to the contractor. See the Environmental Protection and/or Erosion Control special provisions in FDM 19-15-55 and FDM 19-15-60 respectively.

_____ D. Describe the sensitive areas on or near the project and any special considerations for those areas.
(Environmental Protection special provision)

_____ E. Include any limitations to the amount of erodible surface area which may be exposed at any one time.
(Erosion Control special provision)

_____ F. Describe the interim and permanent stabilization practices to be used on the site. Include over-winter and maintenance measures.
(Erosion Control special provision)

_____ G. Describe the structural practices to be used on the site such as those used to divert flow away from exposed soils, store flows, or limit runoff and the discharge of pollutants. Unless otherwise specifically approved in writing by the DNR, structural measures are to be installed on upland sites.
(Erosion Control special provision)

II. STANDARD BID ITEMS

_____ A. The following standard bid items should be included, as a minimum, on all grading projects, unless otherwise justified:

Item 627.0200 or 627.0205 - Mulching

Item 628.1140 - Erosion Bales

Item 628.1504 - Silt Fence

Item 628.1520 - Silt Fence, Maintenance

Item 628.1905 - Mobilizations, Erosion Control

Item 628.1910 - Mobilizations, Emergency Erosion Control

Item 628.2004 - Erosion Mat, Class I, Type B *

Item 629.0205 or 629.0210 - Fertilizer, Type A or B, respectively (depends on the project)

* Other types of erosion mat may be substituted when appropriate.

III. TITLE SHEET

_____ A. Indicate the quarter, quarter-quarter, section, township, range and the county in which the project is located, unless otherwise shown on the right-of-way plat or erosion control plan sheet(s).

_____ B. List the location of the erosion control plan sheets on the "Order of Sheets".

Example 1: When erosion control plans are on a separate plan sheet:

ORDER OF SHEETS
Section No. __2___ Typical Sections and Details
(includes erosion control plans)

Example 2: When erosion control plans are included in the Plan and Profile Sheets:

ORDER OF SHEETS
Section No.__5___ Plan and Profile
(includes erosion control plans)

IV. GENERAL NOTE SHEET

_____ A. Include in the Standard Detail List all pertinent erosion control standard detail drawings.

_____ B. List the name, address, and phone number of the district DNR area liaison. DNR liaison staff: http://dnr.wi.gov/topic/sectors/transportation.html.

V. CONSTRUCTION DETAIL SHEETS

_____ A. Include all non-standard erosion control construction detail drawings.

VI. EROSION CONTROL PLAN SHEETS

_____ A. Illustrate the location of all erosion and sediment control devices. Separate plan sheets are recommended in order to:

1. Avoid cluttering the plan and profile sheets.
2. Make it easier for the contractor or subcontractor to understand and implement the plan. The use of separate plan sheets is especially important for complex projects or when grading is to be done near sensitive areas. For less complex projects, it may be appropriate to illustrate the location of the devices on the plan and profile sheets.

   In some cases (such as for very small, less complex projects) it may be appropriate to show only those less pertinent devices by station and location on the miscellaneous quantity sheets. Again, the object being to not clutter the plan. When this alternative is chosen, a general note indicating which erosion control devices are located on the miscellaneous quantity sheets should be noted on the plan.

_____ B. Include a north arrow on all plan drawings.

_____ C. Indicate right-of-way, easements, slope intercepts and construction limits.

_____ D. Include velocity dissipation devices at discharge locations and along the length of any outfall channel, as necessary, to provide a non-erosive flow from the structure to a water course.

_____ E. Include a legend on each erosion control plan sheet identifying the erosion control symbols or other symbols used. However, when the erosion control measures are shown on the plan and profile sheets, then the erosion control symbols should be included with the legend on the Title Sheet.

_____ F. Show topographic features such as buildings, roads, tree lines and driveways.

_____ G. Show the abutting boundaries of and label all environmentally sensitive areas such as lakes, streams and wetlands.

_____ H. Include the name of the immediate receiving water from the United States geological service 7.5 minute series, topographic maps or another appropriate source. If desired, this information can be placed on the Project Overview Sheet instead.

_____ I. Show existing and proposed drainage patterns. This may be indicated by the use of drainage arrows, contour mapping or spot elevations on topographic mapping. It is particularly important that existing drainage be indicated where overland flows enter or leave the highway right-of-way.

_____ J. Show drainage devices such as storm sewer inlets, culverts, bridges and detention ponds.

_____ K. Identify the locations where storm water is discharged to a surface water or wetland.

_____ L. Include the runoff coefficient of the site before and after construction. To satisfy this requirement, FDM 10-5 Attachment 60.2 of this procedure should be included as a detail on the erosion control plan sheet. This figure can be accessed via CADDS for plan preparation purposes. See FDM 10-15 Attachment 5.1.

_____ M. Estimate the total area of the project and the total area expected to be disturbed by construction activities. The total area of the project is typically the area bounded by the project and right-of-way limits. The total area expected to be disturbed is typically the area where bare soil is exposed. On the bottom of the CADDS detail, discussed in Item VI (L) above, space has been allocated for listing the total area and total disturbed area of the project. As an alternative, however, designers could include this information as a general note on the erosion control plan sheet.

VII. MISCELLANEOUS QUANTITY SHEETS

_____ A. List the location and estimate the quantities needed for the erosion control measures identified in the plan. See Section II for items that should be specified on all grading projects. When using these items, up to an additional 25% of the total estimated quantity should be included as "Undistributed" (does not apply to mobilization items).

VIII. CROSS SECTION SHEETS

_____ A. Show all existing and proposed drainage features such as channel and slope sections, intercepting embankments, culvert pipes and other drainage structures, as well as, slope intercepts, right-of-way and easement lines.

IX. SOILS REPORT

_____ A. Include existing data describing the surface soil as well as the subsoils.

_____ B. Include depth to groundwater, as indicated by soil conservation service soil information, where available. When permanent infiltration systems are used the depth to groundwater shall be identified as outlined in items C and/or D below. Contact the DNR liaison to help determine locations where this information is needed. *

____ C. When permanent infiltration systems are used, appropriate on-site testing shall be conducted to determine if seasonal high water (groundwater) is within 5 feet of the bottom of the proposed infiltration system. *

* Items IX B, C and D can be supplied as a separate document.

_____ D. If permanent infiltration structures are to be used and there is a municipal well within 400 feet or a non-public well within 100 feet, the groundwater flow must be identified in accordance with the provisions specified in either ch. NR 110 or 214 (DNR Administrative Code). *

* Items IX B, C and D can be supplied as a separate document.

RUNOFF COEFFICIENT TABLE

	Hydrologic Soil Group											
	A			B			C			D		
	Slope Range (Percent)			Slope Range (Percent)			Slope Range (Percent)			Slope Range (Percent)		
Land Use:	0 - 2	2 - 6	6 & Over	0 - 2	2 - 6	6 & Over	0 - 2	2 - 6	6 & Over	0 - 2	2 - 6	6 & Over
Row Crops	.08 .22	.16 .30	.22 .38	.12 .26	.20 .34	.27 .44	.15 .30	.24 .37	.33 .50	.19 .34	.28 .41	.38 .56
Median Strip Turf	.19 .24	.20 .26	.24 .30	.19 .25	.22 .28	.26 .33	.20 .26	.23 .30	.30 .37	.20 .27	.25 .32	.30 .40
Side Slope Turf			.25 .32			.27 .34			.28 .36			.30 .38
Pavement												
Asphalt	.70 - .95											
Concrete	.80 - .95											
Brick	.70 - .80											
Drives, Walks	.75 - .85											
Roofs	.75 - .95											
Gravel Roads, Shoulders	.40 - .60											

Total Project Area = ________________ Acres

Total Area Expected To Be Disturbed By Construction Activities = ________________________ Acres

File Name:	de_hwys_std:erosionc.cel
Cell Name:	RCCHRT

FDM 10-10-1 Devices and Measures Available April 27, 2011

1.1 Introduction

Various geometric measures can be implemented to minimize erosion and sediment loss. Erosion control during construction is dependent on the timely installation of the temporary and permanent devices. By placing sod, mulch, and seed promptly as the project progresses, the length of time that areas are left unprotected and the amount of area exposed is reduced.

Erosion control devices such as vegetation or erosion mat hold the soil in place and act as protective covers shielding the soil from wind and water forces. Sediment control devices such as erosion bails, silt fences, sediment traps and basins, trap sediment only after the soil has eroded. A combination of both sediment and erosion control devices should be used when designing an effective erosion control plan.

Temporary devices must be used during construction to contain and control erosion until the permanent measures are firmly established. This includes sufficient measures to carry the project through the winter and the spring-thaw season.

In general, control measures can be categorized into three areas of effort:

1. Erosion control
2. Sediment control
3. Runoff diversion

1.2 Devices Available

1.2.1 Erosion Control Devices

Erosion control devices provide direct protection to the soil surface therefore, are considered one the best measures for preventing erosion. They blanket the soil, protecting it from wind and water forces. The devices include ground covers and channel liners such as:

1. Vegetation (see FDM 10-10-3, FDM 10-10-6, FDM 10-10-8, FDM 10-10-9 and FDM 10-10-10).
2. Mulch (see FDM 10-10-13).
3. Erosion mat (see FDM 10-10-15).
4. Riprap (see FDM 10-10-19).

Vegetation is the most cost-effective form of erosion control. In addition, vegetation helps to improve water quality by helping to slow down the velocity of runoff, thereby, removing sediment particles. Methods for quickly revegetating exposed soils include using temporary seed, permanent seed and sod. Where possible, existing vegetation should be preserved.

Using vegetation to stabilize the soil will be effective only if the site is stable and engineered properly (see FDM 10-5-25). Other devices may be needed to initially stabilize the soil until vegetation becomes established. Therefore, designers should become familiar with these other devices and how they should be used.

1.2.2 Sediment Control Devices

Sediment control devices help remove sediment by filtering or slowing the velocity of the sediment laden water to such an extent that it can no longer keep the particles in suspension. Examples of sediment control devices include:

1. Temporary Ditch Checks (see FDM 10-10-22 and SDD 8E8).
2. Silt fence (see FDM 10-10-23 and SDD 8E9).
3. Stone or rock ditch checks (see FDM 10-10-25).
4. Sediment traps and basins (see FDM 10-10-51).

Sediment traps and basins, when designed properly, are one of the most effective measures for trapping sediment and improving water quality. When possible, designers should try to incorporate them into their project.

1.2.3 Runoff Diversion Devices

Runoff diversion devices are used to keep off-site runoff from entering a construction area or to redirect on-site runoff to an acceptable area. Examples of such devices are listed below.

1. Channels/ditches (see FDM 10-5-25, FDM 10-5-30 and FDM 13-30.
2. Diversion dikes/intercepting embankments (see FDM 10-10-37).
3. Slope drains (see FDM 10-10-57).
4. Flumes (see FDM 10-10-57).

These devices are typically used in combination, such as the use of intercepting embankments with slope drains or sod flumes to divert sheet runoff. They are considered to be very economical. Once diverted, the sediment-laden runoff should be discharged to a safe outlet structure, energy dissipation device and/or sediment trapping facility.

1.3 Devices Required on All Grading Projects

To help avoid change orders and give the construction project engineer the necessary bid items to address ever changing field conditions, the following seven bid items are required on all grading projects unless deemed inappropriate.

1. Temporary seed (see FDM 10-10-6).
2. Permanent seed (see FDM 10-10-6).
3. Fertilizer (see FDM 10-10-12).
4. Mulch (see FDM 10-10-13)
5. Erosion mat (see FDM 10-10-15)
6. Temporary ditch checks (see FDM 10-10-22)
7. Silt Fence (see FDM 10-10-23)
8. Soil Stabilizer Type B (see FDM 10-10-47)
9. Erosion Control Mobilizations
10. Emergency Erosion Control Mobilizations

Note: Sod was not included in the above list due to problems with adaptability on certain soil types. Use as appropriate.

1.4 Temporary vs. Permanent Measures

1.4.1 Temporary Measures

Many of the erosion and sediment control devices are used as temporary measures until permanent protection is firmly established. Due to their high potential for erosion during construction, temporary erosion protection is of particular concern for projects with the following characteristics:

1. In steep rolling topography.
2. Where most of the drainage from the highway construction limits enters directly into streams, lakes, ponds, water courses and adjacent land.
3. With highly erosive soils.

Ground covers are one of the best measures for preventing erosion. Temporary ground covers frequently used are vegetation, mulch, or a combination of the two. They are generally used:

1. On disturbed areas that are not to final grade and will be exposed for a period of time.
2. In areas where seasonal limitations or a delay in final construction preclude permanent seeding.

A common type of temporary vegetative cover is a combination of a quick growing native grass such as rye, with a straw or hay mulch to provide protection to the surface and seeds until the permanent vegetation is established (see FDM 10-10-6). In some instances, a heavy application of mulch such as wood chips, wood fibers, or cellulose is used in conjunction with the seeding as a temporary protective cover. To be effective, these ground covers must be routinely inspected to ensure that they are functional and in good repair.

In order for temporary erosion control items to be successful, they must be available in adequate quantities and must be used in a timely manner. When determining adequate quantities, designers should include an extra amount, known as an "undistributed quantity", to each of the devices. Undistributed quantities should be provided for use by the contractor as directed by the engineer. This undistributed quantity is usually 25% of the total bid item quantity.

1.4.2 Permanent Measures

Permanent control measures are those design features that are incorporated into a project to reduce long-term sediment yield. They include, but are not limited to:

1. Vegetation (see FDM 10-10-3, FDM 10-10-6 and FDM 10-10-9).
2. Special slope designs such as benching (see FDM 10-10-39).
3. Geometric features such as rounding and blending with the natural terrain (see FDM 10-5-25).
4. Special channel linings such as riprap or the higher classes of erosion mat (see FDM 10-10-19, FDM 10-10-15).
5. Subsurface drains to intercept groundwater (see FDM 10-10-33).

Timely implementation of permanent measures may reduce or eliminate the need for temporary actions.

Attachment 1.1 is a summary of advantages and disadvantages of various erosion control measures addressed in this section. Attachment 1.2 is a list of applications for these devices. Attachment 1.3 is an example of how a combination of erosion control measures can work together.

LIST OF ATTACHMENTS

FDM 10-10-3 Vegetation

May 15, 2019

Vegetation is the most cost-effective form of erosion control and includes items such as grass, legumes, grains, trees, shrubs and flowers. Since effective erosion control is a form of risk management, to reduce that risk it is important to make every effort to revegetate sites as quickly as possible. Where possible, existing vegetation should be preserved.

Since vegetation helps prevent erosion, it is considered an erosion control device as opposed to a sediment control device. Vegetation reduces erosion by:

1. Having an extensive root system that binds the soil particles together with the roots;
2. Reducing runoff by increasing water infiltration into the soil;
3. Transpiring water back into the atmosphere, thereby reducing the possibility for over saturation of the soil;
4. Absorbing the energy from falling rain;
5. Decreasing runoff velocities.

Using vegetation to stabilize the soil will be effective only if the site is engineered properly (see FDM 10-5-25) and if atmospheric conditions (temperature, moisture, sunlight) will support growth.

Embankment slopes adjacent to streams, rivers, etc., should be adequately protected against erosion. Where practical, a protective buffer of undisturbed vegetative cover should be left or established between the highway embankment and adjacent watercourse along with other erosion control measures or devices as necessary.

In the absence of adequate rainfall, watering is needed until a good root system develops.

FDM 10-10-6 Seeding

May 15, 2019

6.1 Definition

Seeding is the establishment of vegetative cover on disturbed areas by planting seed.

6.1.1 Temporary Seed

Temporary seeding is the establishment of a temporary vegetative cover on disturbed areas by seeding with an annual herbaceous plant, which is quick to germinate.

6.1.2 Permanent Seed

Permanent seeding is the establishment of a perennial vegetative cover; this cover can include grasses and forbs.

6.1.3 Native Seed

Native seeding is the establishment of permanent vegetative cover using seeds of species that are native to the region, thus are more adapted to the regional growing conditions. Native plants tend to have much stronger, deeper and more fibrous root systems that help hold the topsoil and subsoil in place and allow better percolation of water into the soil.

6.1.4 Borrow Pit Seed

Borrow pit seeding is the establishment of perennial vegetative cover on areas that have been used as borrow or waste sites on grading projects.

6.1.5 Dormant Seed

Dormant seeding is a method of seeding using any non-native seed mix where the seed is applied when soil temperatures will remain consistently below 53 degrees Fahrenheit. The seed will not germinate until the soil temperatures rise in the spring. This method does not provide immediate erosion protection but does prepare the seed to germinate in the spring.

6.2 Application

6.2.1 Temporary Seeding:

1. Disturbed areas that will not have construction activity for more than 14 days.
2. Other disturbed areas where quick vegetation is desired such as sides of sediment basins, temporary road banks, intercepting embankments, stockpiles, etc.

6.2.2 Permanent Seeding:

1. Disturbed areas where permanent, long-lived vegetation cover is needed to stabilize the soil.
2. Rough-graded areas that will not be brought to final grade for a year or more.

6.2.3 Native Seeding:

1. The soils would benefit from a deeper root structure.
2. Native vegetation is requested for aesthetic purposes.
3. Adjacent land has an existing native vegetative stand.
4. Is required as part of the environmental documentation process.

6.2.4 Borrow Pit Seeding:

1. Disturbed areas including the borrow pits and the haul routes for the borrow location.
2. Material disposal sites and the haul routes for the disposal site.

6.3 Design Guidance

6.3.1 Temporary Seeding

Measured quantities should be included for temporary applications even though it is more difficult to estimate since it depends on the contractor’s methods and schedule of operations. Designers should communicate with other sections if necessary and use their engineering judgment and/or experience to estimate this temporary seeding quantity as it will vary depending on the length of the contract and project conditions. Seeding rates can be found in section 630 of the standard specifications.

In addition to measured quantities, undistributed quantities should also be called for in the plan to aid in unforeseen circumstances. A rule of thumb in estimating the undistributed quantity is to add approximately 25% of the calculated temporary seeding quantity to use as the undistributed amount (small quantities may require larger percentages).

Temporary seeding should be fertilized and mulched. Designers should refer to FDM 10-10-12 to determine the type of fertilizer to be used. Depending on the site conditions, erosion mat may be needed instead of mulch (see FDM 10-5-35).

In the absence of adequate rainfall (approximately 1-inch per week), watering may be needed until a good root system develops.

The temporary seed mixes can be found in Standard Spec 630.

6.3.2 Permanent Seeding

Permanent seeding should be included on all projects where exposed soils are expected, or revegetation is required.

In addition to measured quantities, undistributed quantities of permanent seed should also be called for in the plan to aid in unforeseen circumstances. A rule of thumb in estimating the undistributed quantity is to take approximately 25% of the calculated permanent seeding quantity to use as the undistributed amount (small quantities may require larger percentages).

The use of salt tolerant seed or sod should be considered in urban median areas, between the curb and the sidewalk and within the first 5 feet behind the curb, especially if the outer lane is a traffic lane on a high volume rural roadway. The designer should contact WisDOT's landscape architect (see FDM 27-1-1 for contact information) for guidance.

Permanent seeding should be fertilized, mulched, and watered as necessary. Designers should refer to FDM 10-10-12 to determine the type of fertilizer to use. Depending on the site conditions, other erosion control devices such as soil stabilizer or erosion mat may be needed in place of mulch (see FDM 10-5-35).

Proper preparation and maintenance of the seedbed is needed to help ensure germination. Special preparation may be desired for areas where lawn type turf is to be established. For more guidance refer to Standard Specifications and FDM 10-10-11.

In the absence of adequate rainfall (approximately 1-inch per week), watering is needed until a good root system develops.

Though wildflowers are desirable in erosion control seed mixes, they do not develop as fast or initially provide as much soil protection as grasses. They should not be used on steep slopes or where grass seed and fertilizer application is heavy, as this will promote grass competition. Since special care needs to be taken to ensure their growth, the designer should contact WisDOT's landscape architect for additional guidance. Also, refer to FDM 27-25-15.

Permanent seed mixes and their appropriate uses can be found in WisDOT’s Standard Specifications for Highway and Structure Construction, section 630. If a specialty mix is required/desired the WisDOT landscape architect can assist in developing one.

6.3.3 Native Seeding

Native seed can offer a more sustainable vegetative cover than other non-native permanent seed mixtures due to their much deeper root structures. They should be specified in areas not subject to routine mowing.

Seed mixtures 75 and 80 should be specified where a cost-effective mixture of natives is desirable for erosion control. These mixtures contain native grasses only.

Seed mixtures 70 and 70A should be specified in areas where it is desirable to incorporate wild flowers into the mix, however keep in mind that these mixtures are much more costly and should be specified only where conditions warrant.

Consult with the Regional Stormwater Engineer or department landscape architect before specifying the native seed mixtures. There is an established period associated with native seed mixes, refer to the Standard Specifications for Highway and Structure Construction for timelines.

Also refer to FDM Chapter 27 Planting and Aesthetic Design for further guidance.

6.3.4 Borrow Pit Seeding

Borrow pit seeding should be included on all grading projects having borrow or waste as a bid item. The designer should incorporate sufficient quantities of borrow pit seed mixtures to cover the approximate area anticipated.

In addition to measured quantities, undistributed quantities of permanent borrow pit seed should also be called for in the plan to aid in unforeseen circumstances. A rule of thumb in estimating the undistributed quantity is to take approximately 25% of the calculated permanent seeding quantity to use as the undistributed amount (small quantities may require larger percentages).

Borrow pit seeding should be fertilized and mulched. Designers should refer to FDM 10-10-12 to determine the type of Fertilizer to be used. Depending on the site conditions, other erosion control devices such as soil stabilizer or erosion mat may be needed in place of mulch (see FDM 10-5-35).

FDM 10-10-8 Water

May 15, 2019

8.1 Definition

Water can be used as an erosion control bid item to help maintain or establish vegetation.

8.2 Application

Application of water should be considered on all areas that utilize seed or sod. Consider factors such as watering equipment accessibility especially in sensitive areas, typical material and equipment storage locations such as on bridge projects which can preclude access, height of slopes (how far the water can be sprayed), etc., in the use of this item.

8.3 Design Guidance

Water is used in the compaction of embankments, base aggregates and controlling dust. Include the bid item for water (item 624.0100 Water) when these tasks are anticipated. Refer to FDM 14-5-1.1 for guidance on including water when placing base aggregates. For additional information on dust control, refer to FDM 10-10-41. Also, “Watering Plant Materials” is used in the standard specifications to describe watering of plants such as trees and is incidental to the plant bid item.

To properly estimate and bid other erosion control watering items, with different types of equipment and operator hours, it is necessary to use bid items unique to the given type of watering.

8.3.1 Seed Water

The bid item “Seed Water” should be included on all projects that have a seed bid item. Sufficient quantity of water should be included to maintain soil moisture for 30 days after the seed has germinated.

8.3.2 Sod Water

Watering sod is incidental to the item of “sod” for a period of 30 days if the contract does not include the bid item “631.0300 Sod Water”. If the project is in a sandy area it may be desirable to water sod for longer than the required 30 days by including the “Sod Water” bid item. Note that if this item is included it will cover payment for all sod watering, including the first 30 days.

8.4 Estimating Quantities

For estimating the quantity of water for either sod or seeded areas, provide the equivalent of one inch of rain per week for 2 to 4 weeks depending upon the time of year that the work will be ongoing. Use 2 weeks as a minimum for spring and fall, and 4 weeks for the summer. Since designers often are unable to determine exact letting dates or when this work will be done, error on the safe side if unsure. The construction project manager can adjust as necessary to meet varying construction schedules or weather conditions.

The following is an example that can be used to calculate quantities of Seed or Sod Water;

- $Quantity\ of\ Seeded\ Area\ (SY)\ X\ 1\ \frac{inch}{week}\ X\ \frac{0.0278\ yard}{1\ inch} = \frac{XX\ CY\ Water}{1\ Week}$
- $\frac{XX\ CY\ Water}{1\ Week}\ X\ \frac{201.97\ Gal}{1\ CY}\ X\ \frac{1\ Mgal}{1000\ Gal} = \frac{XX\ Mgal}{1\ Week}$
- $\frac{XX\ Mgal}{1\ Week}\ X\ \#\ of\ weeks = XXX\ Mgal\ Water$

FDM 10-10-9 Sodding

April 27, 2011

9.1 Definition

Sod is a thin cut layer of grass-covered topsoil that is held together by matted roots and used to stabilize fine graded disturbed areas.

9.2 Application

Conditions where sod is generally used are:

1. In urban or suburban settings for boulevard or terrace areas, or adjacent to residential or commercial

lawns where quick use is desired.

2. In disturbed areas requiring immediate vegetative cover, or where sod is preferred to other means of grass establishment.
3. Sod reinforced with Class II Type A (jute) erosion mat may be used in:
   - Channels with intermittent flows.
   - Behind inlet grates.
   - At culvert inlets and outlets.

9.3 Design Guidance

1. The use of sod should generally be limited to urban or suburban areas where an immediate turf cover and an aesthetic appearance are desired. It is generally more costly compared to other means of vegetative cover.
2. Requires additional maintenance effort to establish and maintain growth by the contractor, adjacent property owner, or municipality.
3. Requires additional effort and cost to repair areas that do not establish.
4. Sod is usually limited in the blends of turf grass that it is comprised of and can be more susceptible to disease.

Sod for special purposes, such as salt tolerant sod, or upland sod is available in some areas and may be an alternate to what is normally used. The use of salt tolerant sod should be considered in urban median areas, between the curb and sidewalk or within the first 5 feet behind the curb, especially if the outer lane is a traffic lane on a high-volume roadway. Upland sod may be desirable in rural sandy applications as it is more drought tolerant. Designers should contact WisDOT's landscape architect (refer to FDM 27-1-1 for contact information) for guidance.

In addition to measured quantities, undistributed quantities should also be called for in the plan to aid in unforeseen circumstances. Since measured quantities should be relatively well defined for urban and suburban areas, the undisturbed amount can normally be limited to 5 - 10% of the computed sod quantity. For example, given a sod quantity of 2000 yd2, at 10%, the undistributed quantity would be 200 yd2, for a total of 2200 yd2.

Sod requires fertilizer but not mulch. Designers should see FDM 10-10-12 for the recommended fertilizer type given the project's soil conditions.

When necessary, sod may need to be reinforced with Class II Type A (jute) erosion mat (see FDM 10-5-35). Lightweight plastic netting should be avoided for use over sod since it increases the risk of small animals being caught and causes damage to maintenance equipment.

Proper ground preparation and maintenance are needed to ensure that the sod will be firmly rooted in the soil. Until such time that a good root system becomes developed, watering should be required for a specified period of days (20 to 30 days suggested) to maintain moist soil. Watering may be the responsibility of the contractor, property owner, or municipality. Designers need to ensure, through bid items, public involvements, or project agreements, that the proper entity is fully aware of that responsibility.

9.4 Limitations

Sod requires more maintenance to establish than seeded areas due to its need for water during the establishment period when the roots are going down into the topsoil. It is also more susceptible to winter damage the first year. The designer should ensure that sodded areas will be adequately maintained through the use of public involvement or project agreements.

FDM 10-10-10 Mowing

April 27, 2011

10.1 Definition

Mowing vegetation is a method used to help establish dense permanent vegetation and control invasive plant species.

10.2 Application

Applicable for larger projects where mowing can be accomplished in stages under contract or for other projects where invasive species are present on the areas to be striped for salvaged topsoil.

10.3 Design Guidance

Mowing can aid in the establishment of desirable turf species along roadways by cutting the initial growth of temporary grain seed “nurse crop” vegetation that has served to protect the permanent seed during germination but can overly shade that permanent growth if not cut.

Mowing also helps control invasive plant species that germinate on projects from the existing seed bank found in the salvaged topsoil. The designer, with assistance from the environmental coordinator or landscape architect, should asses the existing vegetation in areas that will be striped for salvaged topsoil. Where that vegetation contains a high percentage of invasives, including a bid item for mowing may be desirable.

If mowing is determined to be used on the project, it is necessary to use a special provision and bid item. Mowing height should be specified as between 6 and 8 inches.

10.4 Considerations

Consider factors such as the duration of the project and if the slopes may be too steep on parts of the project for mowing equipment to safely reach.

10.5 Estimating Quantities

To estimate the quantity for mowing, use the quantities obtained for topsoil, or salvaged topsoil, and adjust for areas where access to steep slopes is a factor.

FDM 10-10-11 Topsoil

April 27, 2011

11.1 Definition

Topsoiling is a method of preserving and using the surface layer of undisturbed soil, often enriched in organic matter, to obtain a more desirable planting and growth medium. It should be noted that for purposes of this subject, topsoiling refers to the bid items of Topsoil or Salvaged Topsoil.

11.2 Application

In areas where permanent vegetation is to be established, WisDOT requires topsoil on all disturbed areas unless other protective measures, such as riprap or other hand non-erodible surfaces are specified. Compost incorporated with subsoil may be utilized as a substitute for topsoil.

11.3 Design Considerations

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the major zone of root development, carrying much of the nutrients available to plants, and supplying a large share of the water used by plants.

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

1. Salvage native topsoil to the extent possible since topsoil is a natural resource. Designers should consult the soils report for existing topsoil depths.
2. Determine if there is there an adequate volume of native topsoil on the site. Topsoil should be spread to a minimum depth of 4 inches in rural areas and a minimum depth of 6 inches in urban areas.
3. Preliminary underground utility work may impact available salvageable topsoil, thereby increasing the need for the use of the “topsoil” bid item.
4. By supporting vegetation topsoil can be used to help improve water quality and reduce the amount of runoff. Topsoil should not be wasted if possible. Where excess topsoil exists, designers should discuss possible uses with the stormwater or soils engineer. Unless otherwise specified in the special provisions, excess topsoil can be used by the contractor in the outer fill slopes of the roadway or disposed of as waste.
5. Consider agricultural limestone for soils having a low pH level. Check the soils report or consult with the Regional stormwater engineer or Department landscape architect regarding the pH level and limestone application rates.
6. In areas where a lawn type turf is desired, it may be beneficial to include special provisions to enhance the topsoil preparation requirements.

FDM 10-10-12 Fertilizer

April 27, 2011

12.1 Definition

Fertilizing is a method of adding nutrients to established vegetation or to a prepared seed bed, or sod bed, to aid in the establishment of vegetation. Generally, WisDOT only applies fertilizer during the initial seed/sod bed preparation and establishment.

12.2 Application

In areas where permanent vegetation is to be established, WisDOT uses fertilizer on all disturbed areas in conjunction with permanent seeding. Follow section 629 of the Standard Specifications for Highway and Structure Construction for application methods and rates.

To minimize nutrient entry into surface and groundwater resources it is important to follow proper application methods and guideline

12.3 Design Considerations

WisDOT uses two types of fertilizer, Type A and Type B. They differ by the amount of potash included and should be specified based on the soil region in which the project is located and a soil test. Consult the regional soils engineer to determine the project soil type and in turn the recommended fertilizer type.

1. Consider agricultural limestone for soils having a low pH level. Check the soils report or consult with the regional soils engineer regarding the pH level and limestone application rates.
2. In areas where a lawn type turf is to be established or next to sensitive areas where the resulting runoff could add nutrients to waterways, it may be beneficial to include special provisions to utilize a slow release turf type fertilizer.
3. Consider using a phosphorous free fertilizer alternative where restricted by local ordinance, unless soil testing indicates otherwise.
4. Do not apply fertilizer to saturated soils, wetlands, surface waters, frozen ground, or impervious surfaces.
5. Do not apply fertilizer within 20 feet of a water body or wetland.
6. Do not apply fertilizer when a runoff event is expected within 24 hours.

FDM 10-10-13 Mulching

April 27, 2011

13.1 Definition

Mulch is a degradable, protective ground cover usually composed of straw, hay, woodchips, or wood fibers. It is used in conjunction with seeding to prevent erosion by protecting the soil surface from raindrop impact. In addition, it helps to foster the growth of vegetation by increasing available moisture and providing insulation against extreme heat and cold.

13.2 Application

Mulch should be applied:

1. To all disturbed areas, unless another cover such as erosion mat is used, including borrow pits and waste areas, which are seeded with either temporary or permanent seed. Seeded areas should be mulched immediately following seeding.
2. In areas that cannot be seeded because it is too late or early in the season mulch may be able to provide some protection to the soil surface depending on the site conditions (see FDM 10-5-35). The application of a Soil Stabilizer Type B along with mulch is recommended for late season stabilization (see FDM 10-10-47). If applicable, organic mulch should be used and the area over seeded as soon as weather or seasonal conditions permit, or dormant seeded if it is past the germination date.
3. Together with plantings of trees, shrubs, or certain ground covers which do not provide adequate soil stabilization by themselves.
4. At the recommended rates per the specifications.

13.3 Design Considerations

Mulches are applied to the soil surface to prevent erosion and to promote plant growth. Surface mulch can be one of the most effective means of controlling runoff and erosion on disturbed land.

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination. Organic mulch materials have been found to be the most effective.

The choice of materials for mulching depends on site conditions, season and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and on steep slopes and southern slope exposures.

If wood chips, wood fibers or similar materials are used for mulching, treat areas with one pound of available nitrogen per 1000sf either before or after applying the mulch, because decomposing wood fiber uses and thereby decreases available nitrogen in the soil.

Certified weed seed free mulch is available but should be reserved for mulching next to native areas due to cost. The certification is through the Wisconsin Crop Improvement Association. When used this should be a separate bid item.

The use of mulch behind curb and gutter areas is not recommended when adjacent to live traffic lanes due to turbulence from the traffic that displaces the mulch. Consider the use of erosion mat or sod as an alternative.

There are three approved methods of anchoring mulch; netting, tacking, and crimping. These are at the option of the contractor unless otherwise specified. Details can be found in Chapter 627 of the Standard Specifications for Highway and Structure Construction.

Tackifiers are used to bind organic mulches together to prevent displacement. They are generally spray applied and act like glue over the mulch, holding it in place. In areas where lawn type turf will be established, the use of tackifiers is the preferred anchoring method and should be specified. Crimping will tend to leave an uneven surface and plastic netting can become entangled in mowing equipment.

Crimping the mulch into the soil is the most common method chosen by contractors. It is done with a pull behind crimper that looks like a disc with teeth and crimps the mulch to a depth of at least 1 ½ inches.

Placing netting, like erosion mat netting, over the mulch is the least common method chosen.

FDM 10-10-15 Erosion Mat *April 27, 2011*

15.1 Definition

Erosion mat is a general term for any rolled protective soil covering mat or soil retention blanket that is installed on a prepared planting area of a slope, channel or shoreline. Erosion mats are made from straw, wood, coconut, or synthetic fibers, and are held together by plastic or biodegradable netting on one or both sides, and/or stitched together. They have varying life spans depending upon the type of fiber used.

An "Erosion Control Revegetative Mat" (ECRM), is a blanket-like covering laid on top of a prepared seed bed to protect the soil and seed from the erosive forces of nature.

A "Turf Reinforcement Mat" (TRM), helps to permanently stabilize the soil by acting as reinforcement for the roots of the vegetation. This open-weaved, synthetic mat is installed on top of soil and then filled with topsoil and seeded. As the vegetation grows, the roots intertwine into the mat, "reinforcing the turf." In vegetated channels, this reinforcement helps to raise the channel's maximum permissible shear stress.

In addition to this procedure, designers should refer to FDM 10-5-35 and Chapter 13 for further guidance on placement and design considerations.

15.2 Application

Many of the permanent erosion mats are cost effective when compared with structural channel lining. For slope protection applications, erosion mats are excellent in preventing the loss of topsoil, thereby reducing surface erosion and promoting a rapid establishment of permanent grass cover on cut or fill slopes.

Conditions warranting the application of erosion mat are:

1. On vegetated channels where additional reinforcement is necessary. See FDM 10-5 Attachment 35.1.
2. On steep slopes or roadway embankments where the erosion potential is high, and planting is likely to be too slow in providing adequate protective cover. Erosion mat should be considered to help stabilize and revegetate sensitive slopes steeper than 3:1. See FDM 10-5 Attachment 35.2.
3. On stream banks or channels where moving water is likely to wash out new plantings. Refer to Chapter 13 and consult with the Hydraulic, Stormwater or Soils Engineer when designing for these conditions.

4. In areas where the forces of wind or traffic turbulence prevent standard mulching practices from remaining in place until vegetation becomes established.
5. Whenever typical revegetation measures do not provide the desired degree of erosion control or revegetation emphasis.
6. As an alternative to slope paving or structural channel linings. Note: With the exception of bridge applications, slope paving and paved channels are not recommended since they promote rapid runoff, are prone to undermining and are susceptible to frost heave.

See FDM 10-15 Attachment 5.10 and FDM 10-15 Attachment 5.11 for illustrations of the proper application of erosion mat.

15.3 Design Guidance

Erosion mats should be selected so that they last long enough for the grass or other vegetation to become densely established.

Use Urban grade erosion mats in locations where shortly mowed turf or lawn grasses are to be established. These mats do not have plastic netting that can wrap around the blades of lawn mowers, or snag in the shoes and trip pedestrians.

Consider using Class I Urban Type A, Class I Urban Type B, or Class II Type C mats in or next to sensitive areas where the plastic netting on other categories of mat may trap small animals, snakes, or frogs. Select the type based on calculated shear values. Since Class II Type C mats tend to be expensive, they should only be specified for environmentally sensitive areas where Class I Urban mats do not have sufficient shear values for the site.

Class III mats may be appropriate as a replacement for riprap as a channel liner especially in areas where infiltration is desired or there are clear zone concerns. Check the shear stress criteria for the channel to determine mat applicability.

It may be difficult to establish permanent vegetation and adequate erosion protection in a channel with continuous flow. Consider using riprap, articulated concrete blocks (ACB’s), or wetland species with a coconut or synthetic ECRM.

Because of the variety of erosion mats available on the market, installation varies depending on the mat used. As per the Product Acceptability List, prior to actual installation of the mats, contractors will be required to provide the construction project engineer with one full set of the manufacturer's literature and installation instructions for each erosion mat product selected. This information will be used to verify conformance with the Department's approved materials list and for use by the construction erosion control inspector.

For channels not conforming to the typical section showed in FDM 10-5 Attachment 35.1 or those having a depth of flow greater than 6 inches the designer must compare the CALCULATED MAXIMUM SHEAR STRESS of their channel to the PERMISSIBLE SHEAR STRESS of the erosion mat. See FDM 10-5-40 for the Procedure and an example of its application.

If the calculated maximum shear stress exceeds the permissible shear stress of the mat being considered, the design should be adjusted. This may involve one or more of the following:

1. Specify a higher class or type of erosion mat.
2. Modify the channel's cross section, e.g., widen the ditch bottom to decrease the depth of flow.
3. Choose another device such as riprap or articulated concrete block.

Once vegetation is established, the permissible shear stress of the channel increases. Engineering judgment should be used based on the sensitivity of the area prior to vegetation establishment as well as long term performance requirements.

When erosion mat is the desired alternative for flexible channel lining and the calculated maximum shear stress is greater than 5.0 lbs/ft2, the designer should contact the regional erosion control specialist, stormwater or drainage engineer to assist in the design. FDM 19-1-5 should be used to specify the product in a special provision. With high stress values, there is no substitute for a thorough understanding of the manufacturer's instructions and recommendations. In addition, a site visit by the designer, soils engineer, and manufacturer is recommended to verify the product's appropriateness.

Caution: Even though the calculated shear stress may be less than the permissible shear stress, designers should still use their engineering judgment to decide whether the mat is appropriate given their project-specific conditions. For example, if the calculated shear stress value falls just under the permissible shear stress for the mat, it may be appropriate to use a higher-class mat or a different type of channel liner, if the project is adjacent to a critical environmental or customer sensitive area such as a wetland or residential property.

Erosion mats that are made out of organic materials will degrade after a period of time, leaving a naturally vegetated channel. Organic erosion mats are used in channels that are expected to withstand a shear stress not exceeding 2.0 lbs/ft2.

Erosion mats made of synthetic materials generally do not degrade and often remain as a permanent element within the drainage channel. Synthetic materials are generally used in channels that are expected to withstand shear stresses greater than 2.0 lbs/ft2 or on unstable or highly erodible slopes of 1:1 or flatter.

Costs should be analyzed to compare the erosion mat selected to other erosion and sediment control devices that would perform similarly. This analysis should be weighed against the risks associated should another device be chosen.

15.4 Erosion Mat Classes and Types

There are eleven erosion mat types listed below which fall under three different classes. These erosion mat classes are also outlined in Attachment 15.1. When erosion mat is the preferred alternative, care must be taken to choose the type of mat which is most appropriate for the specific needs of the project. For additional guidance in determining the location of these devices, designers should refer to FDM 10-5-35.

15.4.1 Class I

Class I erosion mats are light-duty, organic ECRM mats. Non-organic, photodegradable or biodegradable netting is allowed for the non-urban mats. They are short term in duration (6-month minimum duration). There are four types of Class I erosion mats.

Type A (Minimum Permissible Shear Stress: 1.0 lbs/ft2: For use on slopes 2½:1 and flatter with a C factor from the Revised Universal Soil Loss Equation of 0.20 or less. Not to be used in channels.

Type B (Minimum Permissible Shear Stress: 1.5 lbs/ft2: This is a double netted product for use on slopes 2:1 or flatter with a C factor from the Revised Universal Soil Loss Equation of 0.20 or less, or in channels where the calculated shear stress is 1.5 lbs/ft2 or less.

15.4.1.1 Class I Urban

In addition to the requirements under Class I, the urban mats must be 100% organic and biodegradable, this shall include parent material, stitching, and netting. Urban mats are to be used where mowing may need to be accomplished within two weeks with little or no snagging of the netting or mat. *Recommended for use in environmentally sensitive areas that have a high probability of entrapping animals in plastic netting such as near streams or wetlands.* Not to be used in channels.

*Urban, Type A (*No Minimum Permissible Shear Stress Required for netted products, Minimum Permissible Shear Stress: 1.0 lbs/ft^2 for non-netted products): For use on slopes 4:1 and flatter with a C factor from the Revised Universal Soil Loss Equation of 0.20 or less.

Urban, Type B (Minimum Permissible Shear Stress: 1.0 lbs/ft^2): For use on slopes 2.5:1 and flatter with a C factor from the Revised Universal Soil Loss Equation of 0.20 or less.

15.4.2 Class II

Class II erosion mats are long lasting (3 years minimum), organic ECRMs. Class II Type B and C mats are intended for use on slopes 2:1 or flatter or in channels where the calculated shear stress does not exceed the permissible shear stress. Slopes steeper than 2:1 may have to consider other alternatives such as using the mat in combination with other erosion control devices or measures, modifying the slope, etc.

Type A: 100% jute fiber mats used for reinforcing sod. This item shall confirm to Section 628.2.2 of the Standard Specifications, no products are identified in the Product Acceptability List.

Type B (Minimum Permissible Shear Stress: 2.0 lbs/ft2): These are intended for use on slopes 2:1 or flatter or where vegetation may be slower to establish such as shady locations.

Type C (Minimum Permissible Shear Stress: 2.0 lbs/ft2): Type C erosion mats are high-strength, 100% organic fiber mats which include the coconut fiber mats. Woven mats are allowed with a maximum opening of ½ inch. *Recommended for use in environmentally sensitive areas that have a high probability of entrapping animals in plastic netting such as near streams or wetlands.*

15.4.3 Class III

Class III erosion mats are synthetic mats that are primarily used to stabilize steep channels or slopes permanently. Compared to Classes I and II, they have the greatest strength and survivability. They do, in many instances, offer a cost-effective alternative to structural devices such as riprap or grouted riprap. Class III mats area required to provide a C factor from the Revised Universal Soil Loss Equation of 0.20 or less.

Type A (Minimum Permissible Shear Stress: 2.0 lbs/ft2): This is an ECRM mat for use on slopes 2:1 or flatter or in channels where the calculated shear stress does not exceed the permissible shear stress. Class III, Type A mats tend to be quite dense. In addition, because they are a synthetic mat, they do not decompose. Decomposition helps to promote good grass germination by creating additional void space as the grass begins to grow. Therefore, designers should use caution when selecting these mats since they may be slow in producing vegetation.

Type B (Minimum Permissible Shear Stress: 2.0 lbs/ft2): This is a TRM for use on slopes 2:1 or flatter or in channels where the calculated shear stress does not exceed the permissible shear stress.

Type C (Minimum Permissible Shear Stress: 3.5 lbs/ft2): This is a TRM for use on slopes 2:1 or flatter or in channels where the calculated shear stress is less than the permissible shear stress.

Type D (Minimum Permissible Shear Stress: 5.0 lbs/ft2): This is a TRM for use on slopes 1:1 and flatter or in channels where the calculated shear stress is less than the permissible shear stress.

Class III, Types B, C and D mats are open weaved TRMs installed prior to seeding. The voids are then filled with soil. Though their open weave allows grass to germinate, this openness can create a tendency for some initial soil loss which interferes with the establishment of vegetation. To prevent this, the specification requires either the application of an approved soil stabilizer type A or ECRM over the TRM on slopes, or an ECRM over the TRM in channels, after installation is complete. Installed in this manner, these mats provide superior erosion protection and offer long-term turf reinforcement

Compared to Class I and II mats, conditions that may benefit from the use of Class III mats include:

1. Unstable soils.
2. Highly erodible soils.
3. Areas where vegetation may be difficult to establish such as in shady areas.
4. In some constant flow conditions. Depending on the velocity of flow and/or wave action, alternative measures such as heavy riprap, interlocking cells, gabions or structural devices may be necessary.

Designers should refer to Chapter 13 and consult with the Stormwater, Hydraulic and/or Soils Engineers to help determine appropriate stabilization measures.

15.5 General Performance Measures

The following general performance measures are included for information purposes only.

15.5.1 Maximum Acceptable Sediment Loss Standards

All approved erosion mats are tested to meet the minimum product C factor in the Revised Universal Soil Loss Equation as specified for each category of mat in WisDOT's Product Acceptability List (PAL).

15.5.2 Minimum Acceptable Vegetation Density Standards

All approved erosion mats in the PAL are required to allow vegetation to achieve the following minimum vegetation density standards.

- Clay Soils: 80%
- Sandy Soils: 70%

Density is compared to undisturbed areas within one year from the date of installation.

15.5.3 Netting

All plastic-netted products listed in the PAL are to be bonded sufficiently to prevent separation of the net from the parent material for the life of the product. This is particularly important as the vegetation starts to grow. If not sufficiently bonded, the net tends to "float" or “tent” which causes damage to maintenance equipment when slopes are mowed and increases the risk of small animals being caught.

LIST OF ATTACHMENTS

Attachment 15.1	Erosion Mat

FDM 10-10-17 Interlocking Cells

April 27, 2011

17.1 Definition

Interlocking cells (cellular confinement structures and articulated concrete blocks) are manufactured cellular devices which are usually filled with a granular material. They consist of two main types, cellular confinement structures, and articulated concrete blocks.

17.2 Application

These devices would generally be used as a replacement for riprap but are not cost effective for large areas. Cellular confinement systems generally have lower shear capabilities than articulated concrete blocks. They have merit in certain situations:

1. To protect erodible slopes or channels that are subject to vehicular or pedestrian traffic.
2. On some streambanks or in channels where constant flow conditions may wash out new plantings.

Designers should consult with their stormwater, hydraulic or soils engineer, as well as contact various manufacturers for product literature, when designing for these conditions.

Due to their cost, careful consideration should be given to the location, placement, and design of these measures as compared to other devices.

17.3 Design Guidance

As with many erosion control-type products, there is no substitute for a thorough understanding of the manufacturer's literature and recommendations. Therefore, it is recommended that guidance be obtained from various manufacturers of the product to help assist in the design of this device. In addition, a site visit by the designer, soils engineer, and manufacturers should be made in order to verify the product's appropriateness.

Interlocking cells are broken down into two main categories:

1. Cellular Confinement Structures.
2. Articulated Concrete Blocks.

17.3.1 Cellular Confinement Structures (Plastic or Fabric Pavers)

Cellular Confinement Structures are interconnected, grid-like structures usually made from a high-density polyethylene or 9-ounce non-woven polyester. Once expanded, they have dimensions of approximately 4 feet wide, 20 feet long and 3 inches high. These cells need to be bonded together in a consistent orientation in order to keep them from separating. The cells are placed over a subgrade layer and filled with aggregate. When subjected to heavy loads, they help reduce the stress exerted on the subgrade.

17.3.2 Articulated Concrete Blocks

Articulated concrete block revetment systems are a flexible manufactured erosion control system that is able to expand and contract with the subgrade. The systems are made of individual concrete block units, which are physically integrated through mechanical interlock, cables, grids, or other means to produce an erosion resistant lining. They are available in both open and closed cell types. The open cell types are designed to be filled with gravel or topsoil and be vegetated.

Articulated concrete block systems are particularly useful where vehicles or bicycles need to cross intermittent streams, or for sediment removal access areas of stormwater ponds, because of their pavement like surface.

They are organized into 5 types based on shear stress. Refer to the Erosion Control Product Acceptability List for additional information on these products.

The articulated concrete block system must be approved by the department and listed on the Erosion Control Product Acceptability List and be approved by the engineer prior to the start of mat fabrication.

FDM 10-10-19 Riprap or Grouted Riprap

January 24, 1997

19.1 Definition

Riprap is a flexible lining having a loose assemblage of relatively large rocks or stones that vary in size.

Grouted riprap is a rigid lining which consists of riprap with all or part of the voids filled with portland cement.

19.2 Application

Riprap and grouted riprap are used:

1. To protect the soil from the erosive forces of concentrated runoff.
2. To slow the velocity of water.
3. To protect embankments that are subject to current or wave actions such as those adjacent to a stream or a lake.
4. To dissipate energy at the outlet end of culverts or rigid channel linings.
5. To stabilize slopes or channels with seepage problems or non-cohesive soils.

For advantages and disadvantages of flexible versus rigid linings, see FDM 13-30-10.

See FDM 10-15 Attachments 5.12 – 5.24 for examples of the proper use of riprap.

19.3 Riprap

Riprap is considered a flexible lining since it can adjust to foundation changes. This flexibility eliminates many of the hydrostatic pressure problems associated with rigid linings. It is also porous, allowing infiltration and exfiltration of the protected soil. As water passes over the riprap, sediment fills the voids and, over time, vegetation may begin to grow, giving the channel or embankment a more natural appearance.

While rock riprap can be an effective erosion resistant lining, it does have limitations of use and is susceptible to damage due to:

1. Displacement of individual stones by the forces of water or ice.
2. Loss of foundation stability by leaching of the underlying soil through the riprap layer.
3. Undermining by scour.

The size of the individual riprap stones is important in combating displacement damage. Of as much importance as the individual stone size is the provision of a well-graded, interlocking mass of stone. This multi-stone contact and interlock within the layer provides greater resistance of the mass to displacement than could be provided by the individual stones. Thus, it is important that riprap stone be sized to resist displacement and also be well-graded within the selected size range. A well-graded, interlocking mass of riprap stone will also present fewer voids through which the flow can attack the foundation soil.

For design information on how to size riprap, designers should consult Chapter 13.

In some situations, such as reservoir shore protection, steep graded ditches, or highly erosive foundation soils, a loss of foundation stability by leaching of the underlying soil through the riprap layer can occur. The most common methods of providing protection against this leaching action are one or a combination of the following:

1. Increase the thickness for the riprap layer.
2. Provide a stone filter blanket between the riprap and underlying soil.
3. Place a geotextile under the riprap stone to serve as a filter.
4. Grout the riprap with portland cement concrete.

For stream and lakeshore protection - velocity, wave height, soil type, and slope should be considered along with FDM 13-30-25, when determining whether, and to what extent, riprap or heavy riprap should be used. Riprap should extend from the streambed to two feet (600 mm) above high water, the minimum requirements being three feet (900 mm) below normal water to two feet (600 mm) above high-water elevation. Refer to environmental website (https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx) for guidance on 404 permit requirements for riprap placed below ordinary high water.

19.4 Grouted Riprap

Grouted riprap can take the place of riprap when velocity, soil and climate conditions make it necessary to have a rigid channel lining. Leaving the upper portion of the riprap ungrouted has proven successful in enhancing the riprap's ability to act as an energy dissipater. Though grouted riprap is less prone to movement in severe situations, it is more susceptible to frost heave damage due to its inflexibility to move with the soil.

19.5 Design Guidance

Caution: Clear zone requirements must be examined and the possibility of damage by vandals throwing stones evaluated when considering these devices.

To determine the minimum channel and riprap (grouted or ungrouted) size that will be stable under flow conditions, designers should see FDM 13-30-10.

To help prevent slippage, riprap for channel or slope stabilization should be designed so that the natural angle of repose of the stone mixture is greater than the gradient being stabilized (see FDM 13-30-10).

A lining of geotextile filter fabric should be placed between the riprap or grouted riprap and the underlying soil surface to prevent soil movement into or through the riprap. Designers should refer to the Wisconsin Standard Specifications for Road and Bridge Construction for the types of filter fabric needed for a given size. However, filter fabric may encourage slippage on steep slopes, especially on those greater than 1.5:1. Designers should consult with their Soils Engineer for guidance.

FDM 10-10-21 Erosion Bale Barriers *April 27, 2011*

21.1 Definition

Erosion bale barriers are temporary sediment barriers consisting of a row or rows of entrenched and anchored straw or hay bales.

21.2 Application

When properly installed and maintained, erosion bale barriers can provide effective, temporary erosion control protection during grading operations.

Erosion bales are used:

1. To intercept and detain small amounts of sediment from disturbed areas.
2. At the base of a slope.
3. Along a street or sidewalk to prevent silt from reaching the pavement.
4. Next to wetlands where silt fence may not stand due to soft soils.

21.3 Limitations

1. Not to be used in intermittent or perennial stream channels.
2. Not to be used on rock or other areas where the barrier cannot be entrenched as required and firmly anchored.

21.4 Design Guidance

A single or double row of erosion bales can be used for sheet flow application.

To be effective, erosion bale barriers need to be spaced at intervals not exceeding one barrier for every 25 feet for 10 to 33% slopes, every 50 feet for 5 to 10% slopes, and 100 feet for 2% slopes.

For sheet flow applications, erosion bales can be used as an alternative to silt fence at perimeter locations such as the base of a disturbed slope. As with silt fence, an effort should be made to locate them at least 5 to 7 feet from the base of the slope. Sometimes erosion bales are used along the contours of a slope to catch the sediment before it reaches the bottom. However, other measures such as mulch, erosion mat, intercepting embankments, slope drains, etc., may be more effective.

The ends of the barrier should be extended up the slope to help ensure that sediment-laden runoff will be maintained in the barrier and not flow around the ends.

21.5 Estimating Quantities

Erosion bales are paid for by “each” bale.

To estimate the quantity of erosion bales, first determine the total length of slope where bales are needed. Then, based on an average length of 3 feet per bale, determine the number of bales needed.

Since the estimated useful life of erosion bales is 3 months, the bales will require replacement depending on the length of the contract. Therefore, designers should provide enough quantity for adequate maintenance.

FDM 10-10-22 Temporary Ditch Checks *April 27, 2011*

22.1 Definition

Temporary Ditch Checks are temporary sediment barriers, for use in channels.

22.2 Application

When properly installed and maintained, temporary ditch checks can provide effective, temporary erosion control protection during grading operations through the time of permanent vegetative cover. Sufficient quantities of these devices should be provided.

Temporary ditch checks are used:

1. To intercept and detain small amounts of sediment from disturbed areas in channelized flows,
2. To decrease the velocity of low volume channel flows.

Unless otherwise specified in the contract, either temporary ditch check products approved and listed in the departments Erosion Control Product Acceptability List, or straw or hay erosion bales, may be used for this bid item.

Log-type manufactured products (wattles) shall be entrenched a minimum of 2 inches and staked per manufacturers recommendations. All other installation requirements, including stakes, shall be as per SDD 8E8.

22.3 Limitations

1. Not to be used in intermittent or perennial stream channels.
2. Not to be used on rock or other areas where the barrier cannot be entrenched as required and firmly anchored.

22.4 Design Guidance

If erosion bales are used by the contractor a double row of bales is required per SDD 8E8. The maximum flow for a double row channel application is 3 ft^3/sec.

To be effective, Temporary Ditch Checks need to be spaced at intervals not exceeding one ditch check for every two feet drop in elevation in the channel, with a maximum spacing of 200 feet. (see FDM 10-5-35, for additional information).

The barrier should extend up the slope to such a length that the bottoms of the end barriers are higher in elevation than the top of the lowest middle barrier to help assure that sediment-laden runoff will flow either through or over the barrier but not around it (see SDD 8E8).

Temporary ditch checks need to be designed to fit the cross-section of the ditch to allow for proper installation and help prevent a washout from occurring. If the bales cannot be designed to fit the cross-section of the channel, another control measure should be used.

22.5 Estimating Quantities

Temporary ditch checks are paid for by the linear foot measured across the ditch. If the contractor uses erosion bales for this item a double row of bales is required however only the total length across the ditch is measured for the basis of payment, not the length of each row, therefore the designer only needs to adequately estimate the total linear feet needed for the ditch checks.

To estimate the quantity of temporary ditch checks, the designer should first determine the average ditch cross section dimension needed for the ditch checks, then how many ditch checks will be needed based on using one ditch check for every two feet drop in elevation in the channels.

Since the estimated useful life of these products is 3 months, the ditch checks will require replacement depending on the length of the contract. Therefore, designers should provide enough quantity for adequate maintenance.

FDM 10-10-23 Silt Fence

April 27, 2011

23.1 Definition

Silt fence is a temporary sediment control barrier consisting of a geotextile filter fabric that is stretched across supporting posts and entrenched or sliced into the ground. Its purpose is to:

1. Intercept and detain small amounts of sediment from disturbed areas during construction operations.
2. Decrease the velocity of sheet flows.

23.2 Application

1. Below disturbed areas where erosion would occur in the form of sheet or rill erosion such as the base of a slope.
2. A round or downslope of soil piles, stock piles, topsoil piles, etc..

3. Where effectiveness is required for one year or less.

23.3 Limitations

Due to its low permeability, silt fence has a damming effect which often causes the fence to collapse in concentrated flow conditions. This damming effect can also cause soil saturation problems during construction, especially around inlets.

Limit to conditions in which only sheet or overland flows are expected where the maximum contributing runoff area does not exceed ¼ acre per 100 ft. of silt fence.

Improper placement, installation, and maintenance will significantly decrease the effectiveness. Silt fence should only be placed in areas where it is applicable. Use other devices, determined by the Erosion Control Matrix, in channels or areas of concentrated flow where silt fence is not the appropriate BMP.

Silt fence should not be used;

1. In locations where the natural overland flow is from an undisturbed area onto disturbed areas of the project in which case the silt fence would be at a higher elevation than the disturbed area and serve no value.
2. Parallel to the direction of flow down a slope since this will promote gullies to form along the fence. Place silt fence along the contour of slopes.
3. For storm sewer inlet protection.
4. As an intercepting embankment to divert flows.
5. In areas where rock or another hard surface prevents full and uniform depth anchoring of the barrier.
6. Closer to tree trunks than the drip line of the tree. Care should be taken to minimize damage to tree roots when possible.
7. In areas where the silt fence serves to protect neither an environmental nor customer sensitive area.
8. To "gift wrap" the project. Silt fence should be placed only in areas where it is applicable, not for “looks” or as a perimeter/safety fence.

23.4 Design Guidance

A common misconception is that silt fence actually “filters” suspended particles from runoff. The effectiveness of silt fence is primarily derived from its ability to pond water behind the silt fence. This ponding action allows particles to settle out on the uphill side of the fence.

Proper installation methods can improve performance and reduce failures. Water must not be allowed to flow under, around, or over the silt fence. In sheet flow applications, such as installation at the base of a slope, sufficient quantities are needed so that the ends of the silt fence can be extended 1 to 2 feet up the slope to help ensure that the sediment laden runoff does not flow around the barrier.

Parallel fences may be needed on steep or long slopes. Since silt fence is a sediment control device, effectiveness is increased when used in conjunction with other upslope erosion control practices.

Attempt to locate silt fence at least 5 to 7 feet beyond the base of disturbed slopes. This allows the sediment to settle out behind the fence and reduce the stress on the fence. When this is not possible, reinforcement measures such as a combination of silt fence and erosion bales may be necessary. Sensitive areas may require additional protection.

23.5 Estimating Quantities

Estimate the quantities of silt fence by looking at the cross sections to determine locations where sheet flow will leave the right of way. Areas with ditches generally do not require silt fence installation.

Estimate "Silt Fence, Maintenance" to occur at least once every 30 days that the silt fence is to be in place.

FDM 10-10-24 Heavy Duty Silt Fence — *August 16, 2022*

24.1 Definition

Heavy duty silt fence is a temporary sediment control device that is typically used for perimeter erosion control purposes. It is a composite fence system that is assembled on site by the contractor and consists of a fencing fabric, steel fence posts, and geotextile fabric type HR.

24.2 Application

Heavy Duty Silt Fence is a type of silt fence that is intended to provide more robust protection of sensitive environmental resources compared to standard silt fence. This protection is provided through an increased fence height and stabilizing the fence by backing the geotextile fabric with a metal fence fabric. These combine to allow the heavy duty silt fence to capture and contain greater amounts of sediment compared to standard silt fence. While standard silt fence fabric acts more in a damming effect to allow particles to settle out, the HR fabric allows for sediment filtering as water passes through it.

The support system of the heavy duty silt fence is the steel fence posts and fence fabric. The fence fabric may consist of a variety of different types of fencing material, including woven wire, chain link, or welded wire. In an effort to encourage the use of recycled materials and reduce construction costs, the specification allows for the use of salvaged fence fabrics provided it is free of rust and other structural defects. New fence fabrics may be used as well. The fence fabric is secured to the steel fence posts with at least three ties at each post.

The filtering element of heavy duty silt fence is the geotextile fabric type HR. Once the fence fabric is erected and secured to the steel fence posts, a layer of geotextile fabric type HR is draped over the fence fabric and secured by ties to the fence fabric and/or steel posts. It is important that the geotextile fabric is properly secured to minimize damage or displacement by wind and/or wave actions. To simplify construction, the specification allows for excess geotextile fabric to be draped over the backside of the fence system. The contractor may elect to cut this to the required dimensions.

Similar to standard silt fence, the performance of heavy duty silt fence is predicated on being properly anchored to the ground to prevent undermining. This can be done through trenching in the HR fabric at least six inches and backfilling the trench with the spoils from the trenching operation. In wet conditions, such as standing water, trenching may not be possible and an alternative anchoring method using a continuous line of rock or sand bags may be necessary. In a wet application, it is important to provide a continuous line of bags to properly secure the geotextile fabric through continuous fabric to ground contact. It is the contractor’s responsibility, with consultation of the project staff, to determine which anchoring method will be used.

24.3 Design Guidance

Heavy duty silt fence is recommended in areas where environmental resources are in close proximity to the work site and there is an elevated risk of runoff and overtopping of standard silt fence. Designers may propose the use of this item based on a risk assessment of the work to be performed on the site – the mere presence of a waterway or wetland does not necessarily warrant a need for this item.

Some considerations for the use of heavy duty silt fence:

- Height of embankment construction
- Slope length and steepness
- Soil type(s)
- Size of the drainage area
- Distance from slope intercept to the environmental resource
- Project schedule and exposure risk
- Types of other erosion/sediment control measures to be used in the area

Since the cost of heavy duty silt fence is significantly higher than standard silt fence, this item should be limited to areas necessary to properly protect the environmental resource. In most cases, standard silt fence will be used and then transitioned to the heavy duty silt fence for the areas of higher risk.

Designers should consult with the regional Stormwater and Erosion Control Engineer (SWECE) for project specific guidance related to the use of this item.

If using in marsh or wetland areas, the designer should review soil characteristics to determine proper applicability of this product. Marsh and wetland areas can present challenges related to the stability of fence posts or depth necessary to provide adequate support of the heavy duty silt fence system. In these cases, the specification may need to be modified. Consider requiring longer posts with deeper embedment, closer post spacing, or alternative post options. Other erosion control devices, or combinations of devices, may be more effective in these situations.

All projects using the Silt Fence Heavy Duty item shall also include the Silt Fence Heavy Duty Maintenance item in the contract. Since installed quantities are likely to be limited, it is recommended that the entire fence length be included as an undistributed quantity for maintenance purposes. Consider increasing this amount further when the fence will be in place for extended periods of time or over winter months, when there is high risk of erosion, or when other environmental factors present increased risk for maintenance.

FDM 10-10-25 Stone or Rock Ditch Checks *January 24, 1997*

25.1 Definition

Stone or rock ditch checks are temporary or permanent stone dams constructed across a swale or drainage ditch. They may be constructed from coarse aggregate, riprap, breaker run, or railroad ballast.

25.2 Application

Stone or rock ditch checks are limited to open channels or swales. They should not be used in streams or live watercourses. Some typical applications for stone or rock ditch checks are:

1. To reduce the velocity of concentrated storm water flows in swales or channels.
2. To trap sediment generated from adjacent areas or from the ditch itself by ponding the storm water runoff.
3. To protect temporary ditches or swales which, because of their short length of service, cannot receive a non-erodible lining but still need protection to reduce erosion.
4. To protect permanent ditches or swales when a permanent, non-erodible lining cannot be placed because, for example, the seed bed is not prepared, or final shaping is not completed.
5. To protect grass linings in either temporary or permanent ditches and swales during the establishment period.
6. To aid in the sediment trapping strategy for a construction site.

See FDM 10-15 Attachment 5.27 and FDM 10-15 Attachment 5.28 for examples of these applications.

25.3 Design Guidance

When constructed of a porous material, such as coarse aggregate #2, stone or rock ditch checks perform more effectively in filtering sediment than other ditch checks (i.e., erosion bales or sod ditch checks) and are commonly referred to as "filter berms".

On channels removed from traffic and under severe flow conditions and erodible soils, these ditch checks are extremely effective. However, since they may pose a traffic hazard, clear zone requirements should be evaluated and alternative measures used, such as continuous sod or erosion mat, where necessary.

If ditch checks are used in grass-lined channels which will be mowed, care should be taken to remove all the stone when the dam is removed. This should include any stone which has washed downstream.

"Breaker Run" is a type of rock that is sometimes used to construct ditch checks. Due to its fracture count, it has proven to be less susceptible to shifting than riprap. However, because of the fines present, it tends to be somewhat dirty. Therefore, it may not be desirable where water quality is a concern, such as near a lake or stream.

Some other design factors that need to be considered are:

1. The drainage area of the ditch or swale being protected should not exceed 2 acres (8100 m2) when filter berms are used alone and should not exceed 10 acres (4.05 hectares or 40,500 m2) when riprap is used. An effort should be made to extend the stone to the top of channel banks.
2. The maximum height of the dam should not exceed 3.0 feet (900 mm).
3. The center of the ditch check should be at least 6 inches (150 mm) lower than the outer edges. Field experience has shown that many dams are not constructed to promote this "weir" effect. Storm water flows are then forced to the stone-soil interface, thereby promoting scour at that point and subsequent failure of the structure to perform its intended function. Regular inspections should be made to ensure that the center of the ditch check is lower than the edges. Erosion caused by high flows around the edges of the dam should be corrected immediately.
4. For added stability, the base of the ditch check should be keyed into the soil approximately 6 inches (150 mm).

5. The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
6. Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges.
7. Geotextile may be used under the stone to provide a stable foundation and to facilitate the removal of the stone. Geotextile may also be used over the stone to provide filtration and facilitate maintenance.
8. Ditch checks should be considered permanent whenever practical so as to prevent further disturbance of the soil.
9. Ditch Checks should be inspected for sediment accumulation after each runoff-producing storm event, especially when trying to establish vegetation. If submergence after rainfall is too long or silting is excessive, vegetation may be killed off. Sediment should be removed when it reaches one half of the original height of the ditch check.

FDM 10-10-27 Storm Drain Inlet Protection — April 27, 2011

27.1 Definition

A temporary barrier installed around a storm drain inlet, drop inlet or curb inlet to reduce sediment from entering storm drains before stabilizing the contributing drainage area.

27.2 Application

This practice applies where runoff from construction sites enters conveyance system structures such as drain inlets, drop inlets, and curb inlets. Inlet protection devices should be considered the last line of defense against sediment transport. Other BMPs should be installed up-gradient from the inlet.

27.3 Design Guidance

This section establishes the minimum standards for design, installation and performance requirements.

The appropriate type of inlet protection barrier shall be installed once the drain, drop, or curb inlet can receive runoff. The device shall remain in place and be maintained until the contributing drainage area is stabilized.

Designers should be aware that more than one type of inlet protection is generally required for each inlet as the job progresses. For example Inlet Protection Type A is generally required in the initial phases of construction, while the same inlet may require Type B, C, or D in the later stages.

Storm drain inlet protection consists of several types of inlet filters and traps and should be considered as only one element in an overall erosion control plan. Each type differs in application with selection dependent upon site conditions and inlet type. Not all designs are appropriate in all cases. The user must carefully select a design suitable for the needs and site conditions.

Use WisDOT's SDD 8E10 for inlet protection.

27.3.1 General Criteria Applicable to All Inlet Protection Devices

1. Ponding water to settle sediment is encouraged; however, ponding shall not interfere with the flow of traffic, create a safety hazard, or cause property damage.
2. The contributing drainage area to the inlet protection device shall be one acre or less. In instances where a larger contributing drainage area exists, runoff shall be routed through a properly designed sediment trapping or settling device upstream of inlet.
3. Other than Type D inlet protection devices, no gaps shall be left in the material used that would allow the flow of water to bypass the inlet protection device.
4. All fabrics used as part of an inlet protection device must be selected from the list of approved fabrics certified for inlet protection, Geotextile, Type FF in the current addition of the WisDOT Product Acceptability List (PAL).

27.3.2 Criteria Applicable to Unpaved Areas or the Pre-Paving Phase of Construction

1. Inlet Protection Barriers include, but are not limited to straw bales, sandbags, other material filled bags and socks, and stone weepers. These devices can be used to either settle sediments or divert flows.

   Manufactured bags shall be durable enough to last the intended life of the BMP and allow for removal without breakage.

2. Inlet protection Types A & B are applicable to the pre-paving phase of construction.

   Inlet protection Type A devices shall be utilized around inlets in unpaved areas until permanent stabilization methods have been established. Type A devices shall be utilized on inlets prior to installation of curb and gutter or pavement, and where safety considerations are not compromised on the site.

   Type B may be utilized for yard or parking lot drains after the casting and grate are in place.

27.3.3 Criteria Applicable to Post-Paving/Curbing Phase of Construction

Inlet Protection Types B, C and D are applicable to post paving construction.

1. Type B shall be utilized on inlets without a curb box such as for yard or parking lot drains.
2. Type C shall be utilized on street inlets with curb heads.
3. Type D shall be utilized in areas where other types of inlet protection are identified as incompatible with roadway and traffic conditions, causing possible safety hazards when ponding occurs at the inlet.

   Type D inlet protection shall have a three-inch space between the bag and the sides of the inlet to prevent the inlet sides from blocking the overflow and shall only be used in inlets deeper than 30 inches from the top of grate to bottom of the inlet. If clearance is not available, cinch or tie the sides of the bag (with rope or ties) to provide clearance.

FDM 10-10-29 Culvert Inlet Protection — *May 15, 2019*

29.1 Definition

Culvert inlet protection usually involves placing a sediment filter or excavated impoundment area at the inlet end of culverts.

29.2 Application

Culvert inlet protection is used to prevent sediment from entering, accumulating in and being transferred by a culvert and associated drainage system prior to permanent stabilization of a disturbed project area. It is also used to provide sediment control protection when elevation or drainage patterns are changing due to construction operations.

29.3 Design Guidance

Like drop and curb inlets, culverts which are made operational prior to stabilization of the associated drainage areas can convey large amounts of sediment to natural drainageways. In cases of extreme sediment loading, the pipe or pipe system itself may clog and lose a major portion of its capacity.

The following measures can help prevent sediment from entering the culvert:

1. Culvert Inlet Sediment Trap: Runoff storage requirements should be in accordance with information outlined under FDM 10-10-51. The maximum area draining to this practice should not exceed 3 acres. This practice has a maximum expected useful life of approximately 18 months.
2. Culvert Pipe Checks: Rock filled bags can also help pond runoff water and trap sediment in front of the culvert pipe inlet. Typical installation would include one layer of rock filled bags placed across the inlet end of culvert or culvert apron endwall. Culvert pipe checks are not recommended in pipes that convey large quantities of water.

The inlet protection devices should be constructed in a manner that will facilitate clean out and disposal of trapped sediment while minimizing interference with construction activities. They should also be constructed such that any ponding of storm water will not cause excessive inconvenience or damage to the structure or adjacent areas.

FDM 10-10-31 Outlet Protection — *April 27, 2011*

31.1 Definition

Outlet protection involves placing an energy dissipating device at the outlets of pipes or channel sections.

31.2 Application

Outlet protection devices are used to:

1. Prevent scour at storm water outlets.

2. Minimize the potential for downstream erosion by reducing the velocity and energy of concentrated storm water flows.

31.3 Design Guidance

The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater which is transported through man-made conveyance systems at design capacity generally reaches a velocity which exceeds the capacity of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

Where flow is excessive for the economical use of a structurally lined apron, excavated sediment basins may be used (see FDM 10-10-51).

The design of structurally lined aprons at the outlets of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% should not be protected using just outlet protection given the reconcentration and large velocity of flow encountered as the flow leaves the structural apron. Designers should use a combination of devices and engineering practices to slow down and dissipate this energy.

FDM 10-10-33 Subsurface Drains

January 24, 1997

33.1 Definition

Subsurface drains are perforated conduits such as pipe, tubing or tile installed beneath the ground to intercept and convey ground water.

33.2 Application

Subsurface drains are used to:

1. Prevent sloping soils from becoming excessively wet and sloughing.
2. Improve the quality of the growth medium in excessively wet areas by lowering the water table.
3. Drain stormwater detention areas or structures.

33.3 Design Guidance

Subsurface drainage systems are of two types, relief drains and interceptor drains.

Relief drains are used either to lower the water table or to remove surface water. They are installed along a slope and drain in the direction of the slope. They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern.

Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout.

To install an effective subsurface drainage system, the soil must be deep and permeable enough. If a gravity outlet is not available, pumping must be provided. Designers should obtain assistance from their Soils Engineer in the design of these devices.

In addition, the following criteria should be met:

Location: Tree roots can often clog subsurface drain systems. Consequently, sub-surface drains should be located such that there are no trees within 50 feet (15 m) of the drains.

Relief drains should be located through the center of wet areas. They should drain in the same direction as the slope.

Interceptor drains should be located on the uphill side of wet areas. They should be installed across the slope and drain to the side of the slope.

Outlets: Subsurface drain outlets should empty into a channel or some other watercourse and should be above the mean water level in the receiving channel. Protection is needed from erosion, undermining, damage from periods of submergence, and the entry of small animals into the drain.

Material: Strength and durability of the pipe should be considerations since crushing of the pipe can occur if the pipe is subjected to heavy vehicle loads such as utility vehicles and maintenance mowing equipment.

Maintenance: Subsurface drains should be checked periodically to ensure that they are free-flowing and not clogged with sediment. The outlet should be kept clean and free of debris. Inlets should be kept open and free of sediment and other debris. Trees located too close to a subsurface drain can often clog the system with their roots. If a drain becomes clogged, the drain should be relocated, or the trees removed. Where drains are crossed by heavy vehicles, the line should be checked to ensure that it is not crushed.

FDM 10-10-37 Diversion Dikes/Intercepting Embankments *January 24, 1997*

37.1 Definition

A diversion dike is a ridge of compacted soil constructed at the top or base of a sloping disturbed area and may be either temporary or permanent.

An intercepting embankment is a type of permanent diversion dike, which is used only along the top of back slopes in cut areas to prevent the adjacent lateral drainage from flowing over or down the back slope.

37.2 Application

Diversion dikes and intercepting embankments can be used whenever storm water runoff must be diverted to protect disturbed areas and slopes or to retain sediment on site during construction. They are considered economical because they use material available on the project site and can usually be constructed with equipment needed for site grading. Their useful life can be extended by stabilizing the dike or embankment with vegetation. They are preferable to silt fence because they are more durable, less expensive, and require less maintenance when constructed properly. Along with a temporary sediment trap or basin they become a logical choice for a control measure once the control limits of the silt fence or erosion bale barrier have been exceeded.

37.3 Design Guidance

Diversion dikes and intercepting embankments are often used as perimeter controls on moderate to large construction sites. Intercepting embankments are highly recommended in areas of large cuts since the embankment prevents severe erosion of the slope and aids in the establishment of a good turf cover.

Note: Diversion dikes and intercepting embankments are generally paid for under the grading bid items. As such they should be shown on the plan cross sections.

To protect adjacent and downstream areas, dikes and embankments should divert overland sheet flow to a stabilized outlet or sediment-trapping facility.

It is very important that temporary or permanent vegetation be installed as soon as possible after construction of the dike or embankment to prevent these devices from eroding. If installed properly and in the first phase of grading, maintenance costs are very low. Often, the cleaning of the sediment-trapping facility is the only associated maintenance requirement. The dike or embankment should have a positive grade to assure drainage. However, if the gradient is too great, precautions must be taken to prevent erosion created from high-velocity channel flows.

Flumes should be used at critical locations on back slopes to carry water from intercepting embankments to roadside ditches. These flumes are normally constructed of erosion mat or sod, but large volumes of water over steep slopes may require the use of riprap or slope drains. Flumes should be spaced so as to prevent large concentrations of water. Refer to SDD 8E5 for sodded back slope flume and intercepting embankment details.

FDM 10-10-39 Benching *January 24, 1997*

39.1 Definition

Benching is a series of permanent, deep cuts that are constructed in steep backslopes in order to:

1. Reduce runoff velocity by reducing the effective slope length.
2. Detain sediment.
3. Provide access to slopes for seeding, mulching and maintenance.

39.2 Application

Benches are an effective method of preventing erosion on large cut slopes. They help to reduce and collect sheet flow so that standard erosion control measures can protect the slope.

39.3 Design Guidance

Benches should be considered whenever cuts exceed 20 feet in depth and required where cuts exceed 25 feet unless other stabilization methods are utilized (see Attachment 39.1).

Therefore, they need to be planned in the early design stages because they increase right-of-way requirements. If right-of-way costs are not prohibitive, they are an effective erosion and sediment control measure.

Special erosion control measures, such as using erosion mat to cover the slope, are an alternative to benches but they do not provide the long-term protection or maintenance benefits that benches provide.

Benching should be done at approximately 15 ft. vertical intervals to collect and channel sheet flow. Benches should slope downward into the slope as to provide a "ditch" and should be a minimum of 8 feet wide for ease of constructability. Treat benches as ditches by using the appropriate channel erosion control treatment. Adjust the elevations of the benches to provide proper drainage. Flumes or slope down drains need to be considered at the termini of these sections.

LIST OF ATTACHMENTS

FDM 10-10-41 Dust Control

April 16, 2015

41.1 Definition

Dust control includes measures such as:

- water / irrigation
- vegetative cover
- mulch
- surface treatments (spray-on adhesives or chemicals).

They are used to reduce surface and air movement of dust during land disturbing, demolition and construction activities.

41.2 Application

Construction activities inevitably result in the exposure and disturbance of soil. Therefore, dust control measures should be available for use on all construction sites to help reduce the presence of airborne substances that may present health hazards or traffic safety problems.

41.3 Design Guidance

Dust is brought about by excavation, demolition, vehicle traffic and other human activity, as well as wind erosion over the exposed earth surfaces. Large quantities of dust are typically generated in heavy construction activities that disturb significant areas of the soil surface. Construction site research has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earth-moving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control, limiting the amount of soil disturbance at any one time should be a key objective. Therefore, phased clearing and grading operations and utilizing temporary stabilization can significantly reduce dust emissions. It is recommended that the contract documents include a limitation on the amount of erodible surface area that may be exposed at any one time when working near sensitive areas.

Some of the temporary dust control measures that should be considered are:

1. Water / Irrigation: Water application/irrigation is the most commonly used dust control practice and should be included on all projects. In addition to protecting the construction site, it offers fast protection for haul roads and other heavy traffic routes
2. Vegetative Cover: In areas subject to little or no construction traffic, a stabilized, vegetative surface can aid in reducing dust emissions. Where possible, existing vegetation should be preserved. Undisturbed vegetative buffers, having a 50 foot minimum width, are recommended between graded areas and protected areas.
3. Mulch: When properly applied, mulch offers a fast, effective means of controlling dust. However, it is not recommended for areas within heavy traffic pathways. Binders or tackifiers are often used to stabilize organic mulches when wind erosion is the key issue.
4. Surface treatments: Many chemicals have been developed to control dust on construction sites. Standard Spec 623 lists two: calcium chloride and magnesium chloride. Both products should provide

good dust control results when applied properly.

FDM 10-10-42 Tracking Pads April 27, 2011

42.1 Definition

A stabilized pad of stone aggregate, located at any point where construction vehicles will egress a construction site. It is intended to minimize tracking of mud and sediment by vehicle tires. The tires of vehicles traveling across the tracking pad are cleaned by the rolling motion and large aggregate scraping the tires.

42.2 Application

Applicable on projects where construction vehicles enter a paved roadway with live traffic and for waste or borrow sites and tracking of sediment onto the roadway is either a safety or environmental concern. Environmentally, this is of particular concern on urban projects where sediment runoff could run directly into a storm sewer.

42.3 Design Guidance

In most cases the designer will not be able to identify locations where tracking pads will be installed prior to bidding, since each contractor will likely have different locations.

The following design guidance applies and should be incorporated in the specifications:

1. Tracking pads shall be installed prior to any traffic leaving the site.
2. The aggregate for tracking pads shall meet the requirements of Select Crushed Material in Section 312 of the Standard Specifications for Highway and Structure Construction.
3. The aggregate shall be placed in a layer at least 18 inches thick. Stone tracking pads shall be underlain with a WisDOT Type R geotextile to prevent migration of underlying soil into the stone.
4. The tracking pad shall be the full width of the egress point. The tracking pad shall be a minimum of 50 feet long.
5. Surface water must be prevented from passing through the tracking pad. Flows shall be diverted away from tracking pads or conveyed under and around them by using a variety of practices, such as culverts, diversions, or other similar practices.

42.4 Considerations

The locations of tracking pads will be identified on the contractors ECIP. Therefore, the designer will only be able to estimate a rough quantity based on points of egress into live traffic and anticipated borrow or waste site locations.

Rural projects where the roadway is paved, but closed to traffic, thereby not posing safety issues, may not require tracking pads if runoff sediment is contained and cannot enter a waterway.

42.5 Estimating Quantities

To estimate the quantity of tracking pads, the designer should estimate one tracking pad for every balance point or one for every 20,000 square yards of borrow or waste, whichever is less. Each tracking pad will be paid as "each".

The final plan quantity will be determined upon approval of the ECIP.

FDM 10-10-43 Silt Screen January 24, 1997

43.1 Definition

Silt screen is a floating geotextile material used to minimize sediment transport within a body of water. Unlike "Turbidity Barriers", they do not touch the bottom of the watercourse. Instead, silt screens float from the surface of the water to approximately 2 feet (600 mm) above the water bed.

43.2 Application

Silt screens are used in watercourses:

1. That are adjacent to or near up-slope land disturbance activities.
2. When dredging and filling is occurring within the watercourse.

See FDM 10-15 Attachment 5.34 for an example of a silt screen application.

43.3 Design Guidance

Soil loss into a watercourse can result in suspended sediments. In time, the suspended sediment may travel long distances and could affect wide-spread areas. Silt screens and turbidity barriers are designed to deflect and contain sediment within a limited area. They provide time for soil particles to fall out of suspension and help prevent these particles from being transported to other areas.

It is imperative that the erosion and sediment control plan provide sufficient measures to keep sediment out of the watercourse. However, silt screens or turbidity barriers provide an excellent "last line of defense" and, therefore, are essential when land disturbing activities are adjacent to or near the watercourse.

It is seldom practical to extend a silt screen or turbidity barrier lower than 10 to 12 feet (3.0 - 3.6m) below the surface, even in deep water. If installed deeper, the force of the water will place strain on the screen materials and mooring system.

Designers should consider the velocity of water and the direction of flow. Silt screens and turbidity barriers are not to be installed perpendicular to channel flows, unless currents are extremely slow or non-existent.

Soil particles trapped by silt screens or turbidity barriers should always be allowed to settle for a minimum of 6 to 12 hours prior to their removal by equipment or prior to removal of the device. However, it is recommended that the sediment only be removed if there has been a significant change in the original contours of the affected area in the watercourse since sediment removal may create more of a sediment problem by resuspending the particles. In addition, accidental dumping of the material by the equipment may occur.

In addition, silt screens:

1. Are not recommended where currents exceed 1.65 ft/second (0.5 meters/second).
2. Should never touch the bottom of the waterway. Instead, a minimum 2-foot (600 mm) "gap" should exist between the weighted lower end of the screen and the waterbed. Movement of the lower skirt over the bottom due to current or wind and wave action on the floatation system may fan and stir sediments already settled out.
3. Have a tendency to "billow up" towards the surface under the pressure of the moving water. This results in an effective depth which is significantly less than the skirt depth. Therefore, when sizing the length of the floating silt screen, allow an additional 10% to 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.

For additional guidance on turbidity barriers, see FDM 10-10-45.

FDM 10-10-45 Turbidity Barrier — *April 27, 2011*

45.1 Definition

Turbidity barriers are fence-like structures that are placed within a body of water to barricade sediment from being transported. A geotextile material is stretched on posts from the bottom of the waterbed to an elevation 2 feet above the anticipated high-water mark for the time of year the barrier is to be placed.

45.2 Application

Turbidity barriers are used in watercourses:

1. That are adjacent to or near up-slope land disturbing activities.
2. Where dredging or filling is taking place within the watercourse.

Refer to FDM 10-15 Attachment 5.35 for an example of a turbidity barrier application.

45.3 Design Guidance

Turbidity barriers are not recommended where currents exceed 5 ft/second. If currents exceed these limits, other measures should be considered to divert the water away from the area being worked on or disturbed. This may be accomplished by using diverters such as portable cofferdams, sheet piling, or jersey barrier. Designers should consult with the Hydraulic, Stormwater or Soils Engineer and their DNR liaison when using these other methods.

Barriers are one of the "last lines of defense" and should be used as part of an overall erosion and sediment control plan to help prevent sediment from entering the waterway.

Care should be taken when removing the barrier due to the release of sediment. When possible, the barrier should be released when flow rates are low. Consultation with the DNR liaison and Army Corps of Engineers is recommended.

FDM 10-10-47 Soil Stabilizer, Type B (Land Application of Polymers) April 27, 2011

47.1 Definition

The land application of products containing water-soluble polymers as temporary soil binding agents to reduce erosion on construction sites.

47.2 Application

This practice is intended for direct soil surface application. This may be used in conjunction with permanent seed and mulch, to sites where the timely establishment of vegetation may not be feasible, or where vegetative cover is absent or inadequate. Such areas include construction sites where land disturbing activities or winter shutdown prevent establishment or maintenance of a vegetative cover.

Soil Stabilizer, Type B is effective at preventing construction site erosion. This may be especially important where cold weather will likely prevent seed germination, and the site needs to be protected during the winter. This type of application is generally done in conjunction with dormant permanent seeding, followed by an application of mulch. However, if the site will be re-disturbed in the spring the permanent seed application is not warranted.

47.3 Design Guidance

On large grading and land disturbing projects the designer should include this bid item. To estimate the bid quantity application area, include any area that the designer expects to be unvegetated for more than 30 days or estimate how much disturbed area will likely be unvegetated going into winter, and include adequate quantity to cover those areas with soil stabilizer, type B. One way to determine the quantity is to look at the number and anticipated date of mobilizations for erosion control estimated for the project and includes all areas with mobilizations after September 15th. Include all dormant seeded areas in the quantity computation.

Adding mulch to areas treated with Soil Stabilizer, Type B increases the effectiveness. Since Soil Stabilizer, Type B neither increases nor decreases seed germination characteristics, mulch should always be considered a requirement on permanent seed areas, because mulch serves primarily to protect seed from the effects of wind and sun.

Application of Soil Stabilizers, Type B may be particularly effective in the following situations:

- During rough grading operations
- Phased construction projects
- Stockpiles
- After final grading and before paving or final seeding and planting.
- Sites having a winter shutdown.
- Sites receiving final landscaping, but where adequate vegetation cannot be established prior to winter.
- Applied with mulch.

For additional guidance see WisDNR conservation practice standard 1050, Erosion Control Land Application of Polymers. These standards may be found at http://dnr.wi.gov/topic/stormwater/documents/dnr1051.pdf.

Operation and Maintenance

Maintenance should consist of reapplying Soil Stabilizer, Type B to areas subsequently disturbed or graded, to eroded areas, to areas subjected to vehicle traffic, or any other disturbance that breaks the thin protective layer that this practice provides. Soil Stabilizer, Type B may lose its effectiveness in two to six months depending upon weather conditions and ultraviolet light exposure.

FDM 10-10-48 Water Application of Polymers April 27, 2011

48.1 Definition

The application of products containing polymers in, or prior to sediment control structures to settle out or remove suspended sediment from water.

48.2 Application

This practice is generally considered incidental to other items of work such as dewatering or would be employed via change order to provide some corrective action to waters contaminated by a construction project. Therefore, a bid item has not been created. In rare cases it could be a special bid item.

This practice shall be used on an emergency or temporary basis with self-contained sediment control structures or settling basins, to restore or improve the sediment removal efficiency of the sediment control structure.

48.3 Design Guidance

Only products meeting the WisDNR conservation practice standard 1051 approval requirements may be used. For questions regarding which products have met these requirements, contact the WisDNR Urban Stormwater Engineer in the Runoff Management Section (http://dnr.wi.gov/topic/stormwater/documents/dnr1051.pdf).

If designers elect to use this as a special bid item, reference must be made to the above approval requirements.

Contractors may only use products receiving a use restriction in Wisconsin by the WisDNR. All materials accepted on the job site shall be accompanied by a copy of the DNR use restriction letter and performance test letter.

In all cases, since this is a practice applied to waterways contact the WisDNR Liaison prior to application.

Where polymer mixtures are used with sediment control structures in a waterway, such as turbidity barrier during bridge construction, the sediment control structure should not be removed until the water is clarified. If the resulting sediment is more than 6 inches deep it may need to be removed.

Where the sediment control structure is not part of a waterway, such as for sedimentation ponds, sediment levels on the bottom should be monitored to measure the loss of storage capacity over time due to the enhanced sedimentation from the polymer mixture.

For additional guidance see WisDNR conservation practice standard 1051, Water Application of Polymers. This standard may be found at http://dnr.wi.gov/topic/stormwater/documents/dnr1051.pdf.

FDM 10-10-49 Intermittent Channels

January 24, 1997

49.1 Definition

Intermittent channels are temporary or permanent waterways that are shaped, sized, and lined with appropriate vegetation or structural material to safely convey stormwater runoff.

49.2 Application

Intermittent channels are usually man-made channels, such as highway ditches, that are constructed or modified to accommodate flows generated by land development. These channels, whether natural or man-made, are usually the most economical means of collecting and disposing of runoff when concentration of flows cannot be avoided.

49.3 Design Guidance

A well-designed stable channel carries storm water without erosion, does not present a hazard to traffic, and provides the lowest overall construction and maintenance cost.

The size and geometric shape of a channel are important features in determining erodibility.

The design of a channel cross-section and lining is based primarily upon the volume and velocity of flow expected in the channel. Besides the primary design considerations of capacity and velocity, other important factors such as land availability, compatibility with land use and surrounding environment, safety, maintenance requirements, outlet conditions, and the soil erodibility factor should be taken into account when selecting a cross-section and lining.

Designers should refer to FDM 13-30 on how to calculate flow depths based on the amount of water (i.e. discharge) being directed to the area, as well as, how to design alternate channel sections.

The capacity of the channel must be sufficient to convey the 10-year, 24-hour frequency design storm without overtopping the banks. Designers should refer to FDM 13-30 when determining channel capacity and/or the riprap size that will be stable under various flow conditions.

Channels should be designed so that the calculated shear stress of the channel does not exceed the permissible shear stress of the channel lining being used (see FDM 10-5-30 and FDM 10-5-35). Another method that can be used is to design the channel so that the velocity of flow expected from a 2-year, 24-hour design storm does not exceed the permissible velocity for the type of lining used. Permissible velocities for grass-lined channels can be found in FDM 13-30-15.

Roadside ditches generally conform to a standard size and shape that minimizes the shock or impact to errant vehicles and provide a traversable section. Geometric features, such as flat slopes and rounded transitions, help to reduce the erosion potential. Wide channels, such as trapezoidal or parabolic ditches, will generally provide better erosion protection since flow depths are shallower. However, because of their size, right-of-way costs will need to be considered.

Where the quantity of water is relatively small, "V" shaped ditches can be effective. However, because of their shape, flows tend to be more concentrated which causes the channel to be more sensitive to erosion (see FDM 10-5-35).

Grass-lined channels provide good protection against erosion and provide an aesthetic setting for conveyance of runoff. However, the velocity that grass linings can handle are much lower than that which can be withstood other liners such as riprap channel liners. If riprap is chosen, filter fabric should be used to act as a separator and stabilizer between the stone and the earth.

The use of concrete channel liners is not recommended. Concrete channels have a poor maintenance history and are susceptible to damage by undercutting, hydrostatic uplift, freeze/thaw and erosion along the interface between the lining and the natural channel surface.

Outlet protection for all channels must be considered (see FDM 10-10-31). This is particularly important when transitioning from a man-made lining, such as riprap, to vegetation or non-vegetative lining. Appropriate measures must be taken to dissipate the energy of the flow to prevent scour of the receiving channel.

FDM 10-10-51 Sediment Traps and Basins *January 24, 1997*

51.1 Definition

Sediment traps and basins are storage areas provided by either excavation or the provision of a dam or barrier. They are constructed for the primary purpose of trapping and storing sediment and are usually constructed in channels and drainageways on, or downslope, from construction sites. They range in size from small excavated traps with a volume of one cubic yard (0.76 m3) or less to large impoundments with volumes measured in acre-feet (hundreds of m3).

51.2 Application

The location and design of sediment basins is determined by the expected sediment-laden runoff and the degree of downstream protection required. Additional information on design criteria can be found in the applicable chapters of AASHTO's Model Drainage Manual. See FDM 1-1-1 for guidance on ordering AASHTO publications.

See the following attachments in FDM 10-15-5 for example applications.

FDM 10-15 Attachment 5.33 and FDM 10-15 Attachment 5.36, Sediment Trap

FDM 10-15 Attachment 5.37 and FDM 10-15 Attachment 5.38, Sediment Basin

51.3 Design Guidance

51.3.1 Sediment Traps

While some sediment traps can be included in the project erosion and sediment control plans, most are located by the construction project engineer and contractor to meet specific needs that develop during grading operations. The contract documents should ensure that the engineer and contractor have this flexibility. Permanent sediment traps should be bid by standard "excavation" bid items.

These small basins are excavated pits, and they are used effectively in many locations. Common sites are:

1. Around drop inlets.
2. In swales and small ditches.
3. At the outlet of temporary slope drains.
4. In conjunction with ditch checks.

Many applications do not require an outlet drain. Trapped water is removed by evaporation or percolation into the adjoining soil. This percolation must be anticipated and considered in areas where soil saturation could present stability problems. Therefore, in order to protect the structural integrity of the roadway, the use of this type of device is discouraged in close proximity to fill slopes or in areas designated for future pavement.

The length, width and depth of the trap can be varied according to project conditions. However, sediment traps should be limited to drainage areas of 15 acres (6 hectares) or less. In severe areas, a series of traps may be placed. Spacing should be a minimum of 300 feet (91 m) between traps when placed in a series. All traps may be fenced to prevent unwanted access. Questions and a review of the adequacy of proposed installations at critical or sensitive locations should be referred to the District Soils Engineer and/or the District Environmental Section.

These small traps should be located as near the source of sediment-laden waters as possible since they are not designed for large flows. Small basins become filled quite rapidly and must be inspected and maintained after each rainfall.

51.3.2 Sediment Basins

Sediment basins serve the same functions as sediment traps but do so on a larger scale. Sediment basins have a longer design life (the length of the construction project or in some cases are permanent) and, therefore, benefit from individual design effort and good construction practices. These designs usually provide flow control section details utilizing durable construction materials. Basins are located where they will not be affected by later phases of construction and are also designed to be cleaned out as required. In some cases, permanent basins may be converted into small recreational lakes and, therefore, may have to be designed with reference to other agency's specifications.

The location of large sediment basins requiring a dam and spillway structure are generally included in the project plans since they are designed for a specific site and usually require additional right-of-way. These structures can be quite costly, and their need and cost effectiveness must be evaluated. This determination begins in the planning stage with the identification of sediment sensitive downstream conditions. It also involves the evaluation of the use of other measures within the construction area that may be more cost effective.

If a large basin is justified, the site must be reviewed for the most effective placement. This would include consideration of access for necessary cleanout and maintenance of the dam and spillway, disposal of the removed sediment, and a reasonable adaptability of a dam and impoundment to the site.

Large impoundments should be designed with public health, safety, and nuisance abatement in mind. This criterion assumes greater importance when locating a basin in or close to a developed area.

There are three general areas of consideration in the design of sediment basins:

1. Adequate storage volume for expected sediment.
2. Adequate retention to allow settlement of suspended particles.
3. A dam and spillway to accommodate expected flows.

Storage volume requirements can best be determined from past experience at similar sites. It is generally not cost-effective to provide a volume sufficient to contain the total expected sediment runoff from an area during the entire construction life of a project. Therefore, a reasonable length of time between cleanouts should be established and a volume chosen to accommodate this period. This volume must be sufficient to provide for a chosen storm event. In most instances, if the basin provides sufficient retention based on a minimum surface area requirement, an adequate volume is established. The shape and location of the basin must be such to facilitate cleanout and disposal of materials.

Required retention time of a basin is dependent on sediment particle size and the desired percent of removal. It is generally acceptable and practicable to remove 70 to 90 percent of particles larger than the very fine sands having diameters greater than 0.062 mm. Silt and clay-sized particles require excessive retention time, so it is generally not feasible to design a trap to remove them, unless costly chemical flocculent is added. Widely used methods of determining suitable size for retention basins are based on particle settling times or a set runoff volume. The use of baffles in the basin to increase the travel path of particles has met with some success in increasing basin settlement efficiency.

While retention determinations are based on small inflows in the range of a mean annual 25-year event, the spillway must be designed to accommodate a much larger event, since failure could result in release of considerable quantities of stored sediment. Spillway design should be based on an economic assessment of potential damages.

Large sediment basins should be inspected after each storm event to determine if any maintenance is required. This inspection should include a review of the outlet structure and emergency spillway to assure that they are free of debris and functioning properly.

FDM 10-10-55 Safety Fence

January 24, 1997

55.1 Definition

A safety fence is a protective barrier installed to prevent access to an erosion control measure.

55.2 Application

Safety fences are applicable whenever any erosion or sediment control measure or series of measures is considered unsafe because of its potential to be accessed by the public.

55.3 Design Guidance

The safety of the public must always be considered at both the planning and implementation phases of a land-disturbing activity. If there is any question concerning the risk of a particular erosion control measure to the general public, the measure should be relocated to a safer area, or an appropriate safety fence should be installed to prevent undesired access. Plastic (polyethylene) fence is used in situations when a temporary barrier is needed.

Many times, the danger posed by a control may not be easily seen by plan designers and reviewers. Therefore, the on-site contractor or inspector needs to be aware of such situations in the field.

Properly designed and installed safety fences prevent people from trespassing into potentially dangerous areas, (e.g. children using a sediment basin or a storm water retention structure as play areas).

Safety fences should be located so as to create a formidable barrier to undesired access, while allowing for the continuation of necessary construction operations. They are usually installed when constructing sediment traps, basins or dams. In use with those structures, safety fences should be located far enough beyond the outer toe of the embankment to allow for the passage of maintenance vehicles. Fences should not be installed across the slope of a dam or dike.

A standardized special provision is available for safety fence (refer to standardized special provisions web site (https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/stsp.aspx). The fence should never be so short as to become an attraction for children to climb over it.

Signs noting potential hazards such as "DANGER-QUICKSAND" or "HAZARDOUS AREA-KEEP OUT" should be posted where they can be easily seen by anyone approaching the protected areas.

FDM 10-10-57 Other Devices

May 15, 2006

57.1 Pipe Down Drains

Pipe down drains, also referred to as "slope drains", and are used to help direct runoff down a slope at a specific location. They are usually used in conjunction with diversion dikes, intercepting embankments, or temporary fill diversions. Also, they are used in place of paved ditches; on long, steep runs in sandy soil; or in cut to fill transition sections. Corrugated metal pipe should be used, with collars (cut-off walls) placed at intervals along the pipe to prevent piping and/or slippage. Endwall protection should be provided at both entrance and discharge ends. In addition, an energy dissipater is necessary at the outlet end to protect the area from erosion and scour.

See FDM 10-15 Attachment 5.39 for an example of a slope drain.

57.2 Preformed Apron Endwalls

Preformed apron endwalls should be used on all culvert pipes, except for special cases. Endwalls are used on both ends of cross drains, side road drains, median drains, and private entrances. For details on preformed apron endwalls for culvert pipes and pipe arches, see the standard detail drawings, https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/rdwy/sdd.aspx.

57.3 Mortar Rubble Masonry or Concrete Masonry

Mortar rubble masonry or concrete masonry should be used for end protection on cattle passes and for special cases such as multiple pipe installations or on pipes where preformed endwalls would not provide the proper inlet or discharge characteristics. For mortar rubble masonry details, see the standard detail drawings.

57.4 Anti-Seepage Collar

Anti-seepage collars are used to prevent the movement of water along the outside of the culvert and the failure by washout of the fill next to the culvert. They are used in sandy fills where the culvert is under high head.

Collars are located at the midpoint and upper quarter on long box culverts. If only one collar is used, it is located far enough from the inlet to prevent seepage over the top of the collar.

A typical collar applicable to all single and twin box structures and corrugated metal pipes is shown in the Bridge Manual 8.4.

An alternate method of preventing seepage would be to use a minimum one-foot thick impervious soil blanket around the culvert inlet, extending five feet over the undisturbed embankment. The same effect can be obtained by designing seepage protection into the endwalls.

57.5 Weep Holes

The need for weep holes should be investigated for clay type soils with high fills and should be eliminated in other cases.

If weep holes are necessary, alternate layers of fine and coarse aggregate should be placed around the holes, starting with coarse aggregate next to the hole.

57.6 Scour Hole

Since it is difficult to estimate the erosion potential at the outlets of proposed culverts, it is best to do a field inspection of the proposed site. This site inspection, along with soil information and maintenance histories of existing structures in similar environments, can be used to estimate the local scour potential.

The U.S. Army Corps of Engineers has developed a method for computing the size of a scour hole when the downstream streambed is composed of easily erodible sand. This is an extreme erosion case, which may be used as a yardstick for evaluating the erosion potential at a culvert outlet. For further details on evaluating the erosion potential at a culvert outlet, see FHWA's Hydraulic Engineering Circular (HEC) No. 14, "Hydraulic Design of Energy Dissipaters for Culverts and Channels", 1975.

57.7 Flumes

Flumes are used at critical locations on back slopes to carry water from intercepting embankments to roadside ditches. These flumes are normally constructed of sod, but large volumes of water over steep slopes may require the use of erosion mat or grouted riprap, or pipe down drains. Flumes should be spaced so as to prevent large concentrations of water.

See FDM 10-15 Attachment 5.6 – 5.9 for examples of flumes.

Refer to the standard detail drawing for sodded back slope flume and intercepting embankment details.

57.8 Gabions

Gabions are large, multi-celled, rectangular wire mesh boxes filled with rock to form flexible monolithic building blocks. They are used as erosion control structures in channels, revetments, retaining walls, abutments, check dams, etc. Erosion control construction design should ensure the following:

1. The foundations are properly prepared to receive gabions.
2. The gabion structure is securely "keyed" into the foundation and abutment surfaces.
3. The rock used is durable and adequately sized to be retained by the baskets.

Maintenance entails periodic inspections of the transition areas for evidence of undercutting or inordinate erosion.

57.9 Bin Type Retaining Walls

Bin type retaining walls are a system of closed-face bins filled with soil to act as a gravity type retaining wall. They are used to construct roadways within narrow rights-of-way, to protect stream and lakeshores from erosion, to construct wingwalls on bridge abutments or headwalls for large drainage structures, etc.

57.10 Sheeting

Sheeting is a lining of wood or steel driven into the subsoil and used to support an embankment or the walls of an excavation. It may be used as a permanent or temporary installation. Some typical applications for sheeting include shore protection, trench protection, low retaining walls, check dams, wash checks, jetties, lagoon baffles, and wingwalls.

57.11 Structure Protection

57.11.1 Surface Drains

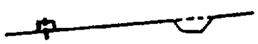
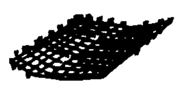
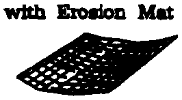
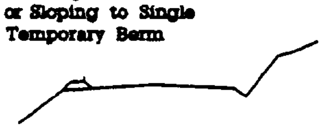
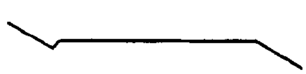
Runoff from bridge decks can cause serious erosion of earth embankments around abutments. Normal protection consists of a concrete surface drain inlet to carry the deck runoff to a corrugated metal pipe buried under the embankment. This pipe carries the water down the slope and discharges it onto a concrete, mortar rubble, or riprap apron at the toe of the slope. The apron is generally designed to act as an energy dissipater.

See FDM 10-15 Attachment 5.40 for an example of a surface drain.

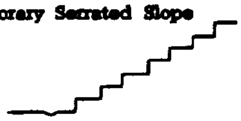
57.11.2 Slope Paving

Slopes under grade separation structures are usually protected with either cast-in-place slope paving or concrete, asphalt-treated, gravel or crushed stone slope paving in accordance with the bridge standard drawings in the Bridge Manual.

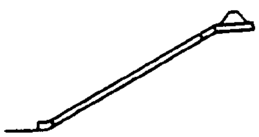
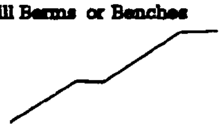
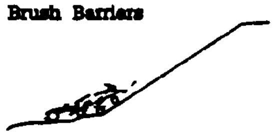
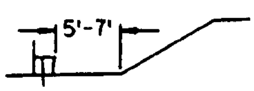
EROSION CONTROL MEASURES

TREATMENT PRACTICE	ADVANTAGES	DISADVANTAGES
ROADWAY DITCHES		
Check Dams 	Maintain low velocities Catch sediment Can be constructed of logs, rock, lumber, masonry or concrete	Close spacing on steep grades Require clean-Out Unless keyed at sides and bottom, erosion may occur
Sediment Traps/ Erosion Bale Combination 	Can be located as necessary to collect sediment during construction Clean-out often can be done with on-the-job equipment Simple to construct Top of lowest bale must be lower than bottom of end bale. See S.D.D.	Little direction on spacing and size Sediment disposal may be difficult Must be periodically cleaned. May require seeding or sodding when removed during final cleanup.
Sodding 	Easy to place with a minimum of preparation Can be repaired during construction Immediate protection May be used on sides of ripraped ditches to provide increased capacity.	Requires water during first few weeks Sod not always available Will not withstand high velocity or severe abrasion from sediment load May not be salt tolerant. May not work well on sandy soils.
Seeding with Mulch 	Usually least expensive Effective for ditches with very low velocity. Easily placed in small quantities with inexperienced personnel	Will not withstand higher velocities.
Seed with Erosion Mat 	Three classes of mat available. Higher classes are able to withstand greater velocities. Cost effective alternative to riprap or rigid liners. Easily placed.	Requires proper installation. Initial cost greater than seed and mulch.
Riprap, Grouted Riprap	Effective for high velocities May be part of the permanent erosion control effort	Cannot always be placed when needed because of construction traffic and final grading and dressing Initial cost is high
ROADWAY SURFACE		
Crowning to Ditch or Sloping to Single Temporary Berm 	Directing the surface water to a prepared or protected ditch minimizes erosion	None - should be part of good construction procedures
Compaction	The final lift of each day's work should be well compacted and bladed to drain to ditch or berm section. Loose or uncompacted material is more subject to erosion	None - should be part of good construction procedures
Crushed Aggregate Cover 	Minimizes surface erosion Permits construction traffic during adverse weather May be used as part of permanent base construction	Requires reworking and compaction if exposed for long periods of time Loss of surface aggregates can be anticipated
Seed/Mulch	Minimizes surface erosion	Must be removed or is lost when construction of pavement is commenced.

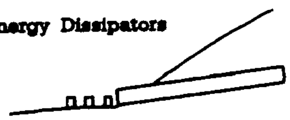
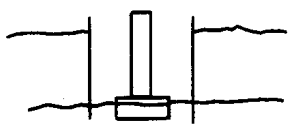
EROSION CONTROL MEASURES (Continued)

TREATMENT PRACTICE	ADVANTAGES	DISADVANTAGES
CUT SLOPES		
Intercepting Embankment (Permanent Berm at top of cut) 	A permanent device Diverts water from cut Collects water for slope drains/ditches May be constructed before grading is started	Access to top of cut Difficult to build on steep natural slope or rock surface Concentrates water and may require channel protection or energy dissipation devices Can cause water to enter ground, resulting in sloughing of the cut slope
Diversion Dike 	May be either temporary or permanent Collects and diverts water at a location selected to reduce erosion potential May be incorporated in the permanent project drainage	Access for construction May be continuing maintenance problem if not paved or protected Disturbed material or berm is easily eroded
Slope Benches 	Slows velocity of surface runoff Collects sediment Provides access to slope for seeding, mulching and maintenance Collects water for slope drains or may divert water to natural ground	May cause sloughing of slopes if water infiltrates Requires additional ROW Not always possible due to rotten material etc. Requires maintenance to be effective Increases excavation quantities
Slope Drains or Flumes 	Prevents erosion on the slope Can be temporary or part of permanent construction Can be constructed or extended as grading progresses	Requires berms to collect water. Permanent construction is not always compatible with other project work Usually requires some type of energy dissipation
Seeding/Mulching or Erosion Mat 	The end objective is to have a completely grassed slope. Early placement is a step in this direction. The mulch provides temporary erosion protection until grass is rooted. Temporary or permanent seeding may be used. Mulch should be anchored. Larger slopes can be seeded and mulched with smaller equipment if stage techniques are used. For steep slopes erosion mat may be used in place of mulch.	Difficult to schedule high production units for small increments Time of year may prevent seeding. May require supplemental water Contractor may perform this operation with untrained or unexperienced personnel and inadequate equipment if stage seeding is required
Sodding 	Provides immediate protection Can be used to protect adjacent property from sediment and turbidity	Difficult to place until cut is complete Sod not always available May be expensive
Slope Pavement, Riprap 	Provides immediate protection for high risk areas and under structures May be cast in place or off site	Expensive Difficult to place on high slopes May be difficult to maintain
Temporary Cover	Plastics or geotextile fabrics are available in wide rolls and large sheets that may be used to provide temporary protection for cut or fill slopes Easy to place and remove Useful to protect high risk areas from temporary erosion	Provides only temporary protection Original surface usually requires additional treatment when plastic is removed Must be anchored to prevent wind damage
Temporary Serrated Slope 	Lowers velocity of surface runoff Collects sediment Holds moisture Minimizes amount of sediment reaching roadside ditch	May cause minor sloughing if water infiltrates Construction compliance

EROSION CONTROL MEASURES (Continued)

TREATMENT PRACTICE	ADVANTAGES	DISADVANTAGES
FILL SLOPES		
Temporary Fill Diversion (Berms at Top of Embankment) 	Prevent runoff from embankment surface from flowing over face of fill Collect runoff for slope drains or protected ditch Can be placed as a part of the normal construction operation and incorported into fill or shoulders	Cooperation of construction operators to place final lifts at edge for shaping into berm Failure to compact outside lift when work is resumed Sediment buildup and berm failure Can cause water to enter embankment resulting in sloughing of the slope.
Diversion Dike 	May be either temporary or permanent Collects and diverts water at a location selected to reduce erosion potential May be incorporated in the permanent project drainage	Access for construction May be continuing maintenance problem if not paved or protected Disturbed material or berm is easily eroded
Slope Drains or Flumes 	Prevent fill slope erosion caused by embankment surface runoff Can be constructed of full or half section pipe, asphalt, metal, concrete, plastic or sod Can be extended as construction progresses May be either temporary or permanent	Permanent construction as needed may not be considered desirable by contractor Removal of temporary drains may distrurb growing vegetation Energy dissipation devices are required at the outlets Consider salt tolerant sod for flumes.
Fill Berms or Benches 	Slows velocity of slope runoff Collects sediment Provides access for maintenance Collects water for slope drains	Requires additional fill material if waste is not available May cause sloughing Additional ROW may be needed
Seeding/Mulching or Erosion Mat	Timely application of mulch and seeding decreases the period a slope is subject to severe erosion Mulch that is cut in or otherwise anchored will collect sediment. The furrows made will also hold water and sediment For steep slopes erosion mat may be used in place of mulch.	Time of year may prevent seeding. Watering may be necessary Steep slopes or locations with low velocities may require supplemental treatment
PROTECTION OF ADJACENT PROPERTY		
Brush Barriers 	Use slashing and logs from clearing operation Can be covered and seeded rather than removed Eliminates need for burning or disposal off ROW	May be considered unsightly in urban areas
Erosion Bale Barriers 	Bales are readily available in many areas When properly installed, they filter sediment and some turbidity from runoff	Require removal Subject to vandal damage Flow is slow through straw requiring considerable area
Sediment Traps 	Collects most of the sediment spill from fill slopes and storm drain ditches Inexpensive Can be cleaned and expanded to meet need	Does not eliminate all sediment and turbidity during construction Space is not always available Must be periodically cleaned
Retention/Detention Ponds 	Can be designed to handle large volumes of flow Both sediment and turbidity are removed May be incorporated into permanent erosion control plan	Requires prior planning, additional ROW and/or flow easement If removal is necessary, can present a major effort during final construction stage Clean-out volumes can be large Access for clean-out not always convenient

EROSION CONTROL MEASURES (Continued)

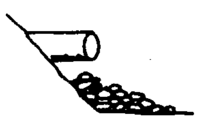
TREATMENT PRACTICE	ADVANTAGES	DISADVANTAGES
PROTECTION OF ADJACENT PROPERTY (continued)		
Energy Dissipators 	Slows velocity to permit sediment collection and to minimize channel erosion Can be constructed of concrete, rock, wood or other suitable materials.	Collects debris and requires cleaning. Requires special design and construction.
PROTECTION OF LAKES OR STREAMS		
Construction Dike 	Usually constructed of earth. Permits work to continue during normal stream stages Controlled flooding can be accomplished during periods of inactivity	Usually requires pumping of work site water into sediment pond Subject to erosion from stream and from direct rainfall on dike
Sheet Piling Cofferdam 	Work can be continued during most anticipated stream conditions Clear water can be pumped directly back into stream No material deposited in stream Good for heavy flow conditions.	Expensive May cause sediment release into waterway when removed.
Temporary Stream Channel Change or Diversion Channel	Temporary channel to keep flows away from construction Good for heavier flows when cofferdams cannot be used	New channel usually will require protection Stream must be returned to old channel and temporary channel refilled
Riprap or Grouted Riprap	Easy to stockpile and place Can be installed in increments as needed Grouted riprap is a rigid liner and can withstand higher velocities.	Expensive
Temporary Culverts for Haul Roads 	Eliminates stream turbulence and turbidity Provides unobstructed passage for fish and other water life Capacity for normal flow can be provided with storm water flowing over the roadway	Space not always available without conflicting with permanent structure work May be expensive, especially for larger sizes of pipe Subject to washout
Rock-lined Low-Level Crossing 	Minimizes stream turbidity Inexpensive May also serve as ditch check or sediment trap	May not be fordable during rainstorms During periods of low flow, passage of fish may be blocked
Silt Screen	Minimizes sediment transport into water. See detail drawing.	Not to be used where current exceeds 1.65 ft./sec. (0.5 m/sec.) Do not place perpendicular to flow.
Turbidity Barrier	Eliminates sediment transport into water. See detail drawing.	Not to be used where current exceeds 4.95 ft./sec. (1.5 m/sec.). Do not place perpendicular to flow.

SUMMARY OF CONTROL MEASURE APPLICATIONS

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL					
		CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Temporary and permanent planting of exposed soils 	To stabilize soils by absorbing the impact of raindrops, reducing velocity of runoff, and allowing precipitation to enter the soil.	●	●	●			●
Temporary and permanent grass protection of waterways, swales and dikes 	To protect drainageways by lowering water velocity over the soil surface and by binding soil particles with roots.				●	●	●
Intercepting embankment 	To intercept storm runoff from small upland areas and divert it to an outlet.	●					●
Temporary fill diversion 	To intercept storm runoff and divert it to a stable outlet or sediment-trapping device, or to prevent runoff from entering a disturbed area and to direct sediment-laden runoff leaving the distrubed area.	○	●	●			●
Temporary grade stabilization structure 	To convey concentrated, high-velocity runoff down slopes without causing erosion.	●	●				

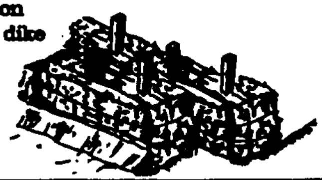
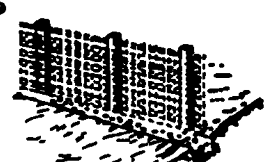
KEY: ● Preferred control measure ○ Alternative but less effective control measure.

SUMMARY OF CONTROL MEASURE APPLICATIONS (con't)

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL					
		CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Check dam 	To reduce the velocity of concentrated stormwater flows in swales or ditches draining small areas.				●	●	●
Diversion dike (1) 	To prevent runoff from entering a disturbed area and sediment-laden runoff from leaving the disturbed area. Diversion dike can be placed at either position 1 or 2.		●				●
Riprap or grouted riprap 	To protect a soil surface, drainageway or outlet from the erosive forces of water.	○			●	●	●
Culvert pipe 	To convert pipe flow to channel flow and reduce water velocity.				●	●	○
Permanent subsurface drain 	To remove runoff from and prevent water movement into a wet area, to regulate the water table and groundwater flow to improve plant growth and to dewater a sediment basin.	○	○	○			○

KEY: ● Preferred control measure ○ Alternative but less effective control measure.

SUMMARY OF CONTROL MEASURE APPLICATIONS (con't)

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL					
		CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Retention/Detention ponds 	To collect and hold runoff to allow suspended sediment to settle out.	●	●	●			●
Sediment trap 	To intercept small quantities of sediment-laden runoff and trap the sediment.	○	○	●			●
Temporary stabilized construction entrance 	To reduce the tracking or flowing of sediment onto public rights-of-way.						●
Erosion bale dike 	To intercept and detain small amounts of sediment from small unprotected areas.			○			○
Silt fence 	To intercept and detain the sediment in runoff from small erodible areas while decreasing the velocity of the runoff.			○			○

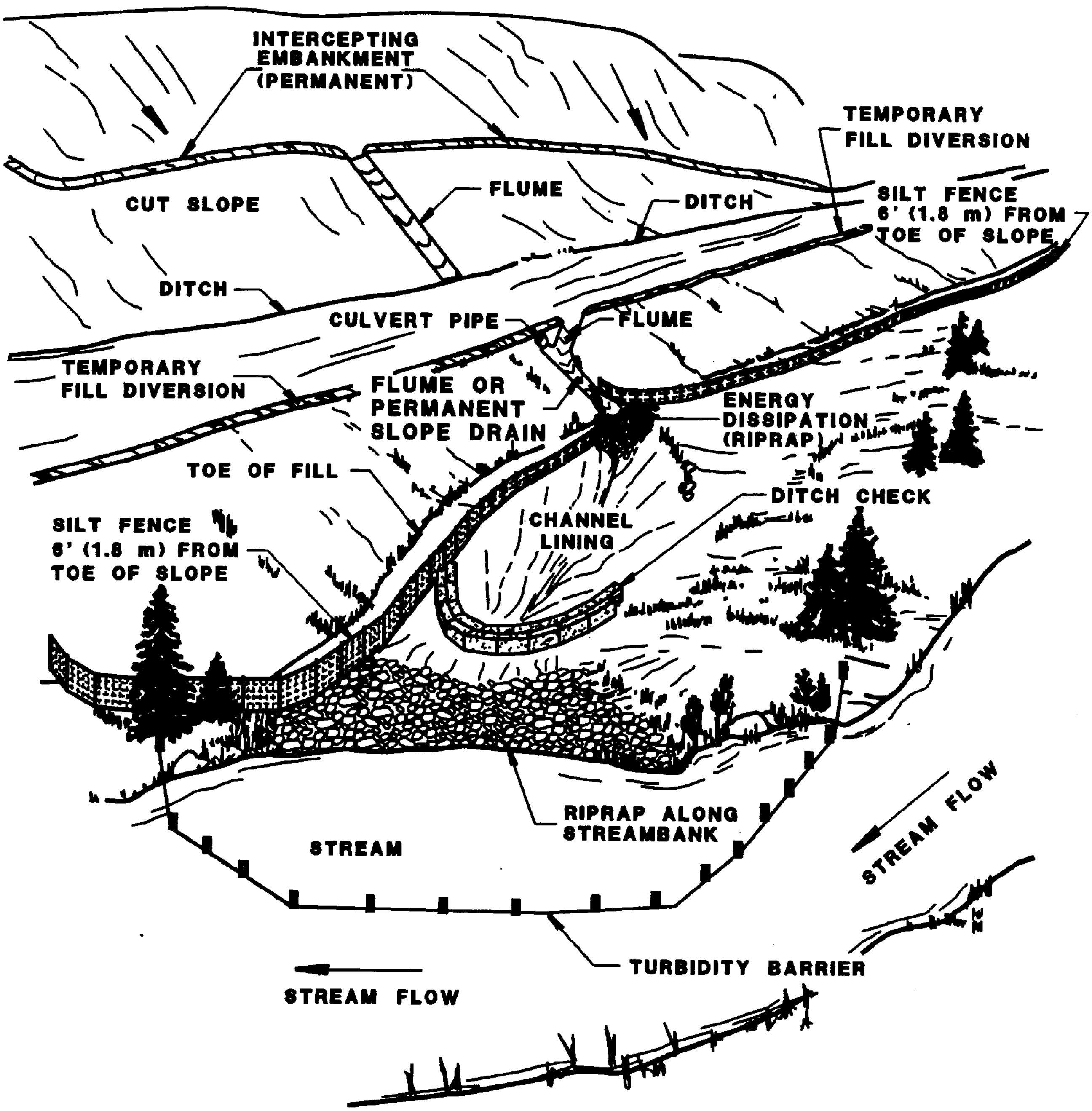
KEY: ● Preferred control measure ○ Alternative but less effective control measure.

SUMMARY OF CONTROL MEASURE APPLICATIONS (con't)

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL					
		CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
General land grading practices for minimizing erosion 	To provide for erosion control and plant establishment on areas where topography is to be re-shaped by grading	●	●	●			●

KEY: ● Preferred control measure ○ Alternative but less effective control measure.

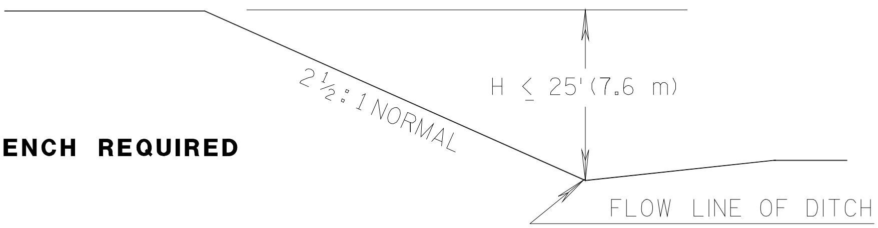
EXAMPLE OF SELECTED CONTROL MEASURES USED IN COMBINATION



EROSION MAT

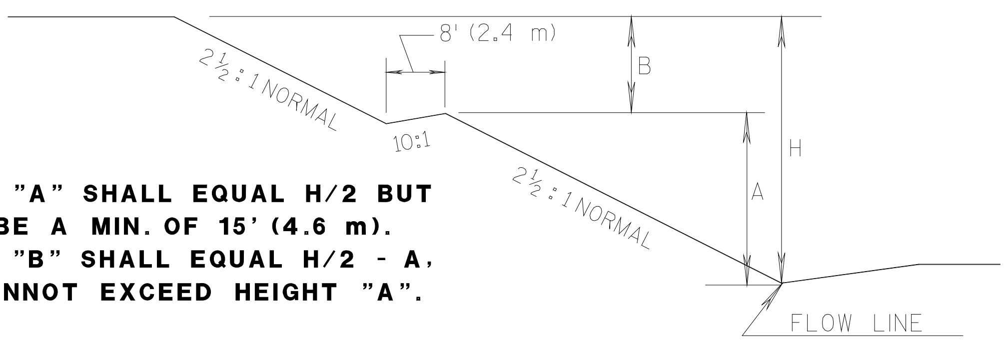
CLASS I SHORT TERM ORGANIC	CLASS II MODERATE TERM ORGANIC	CLASS III PERMANENT SYNTHETIC
TYPE A SHEAR 1.0 SLOPES UP TO 2 1/2:1	TYPE A JUTE FOR SOD REINFORCEMENT	TYPE A SHEAR 2.0 ECRM MAT SLOPES UP TO 2:1 CHANNEL LINER
TYPE B SHEAR 1.5 SLOPES UP TO 2:1 LIGHT DUTY CHANNEL LINER	TYPE B SHEAR 2.0 SLOPES UP TO 2:1 MEDIUM DUTY CHANNEL LINER SYNTHETIC NETTING ALLOWED	TYPE B SHEAR 2.0 TRM MAT SLOPES UP TO 2:1 CHANNEL LINER
	TYPE C SHEAR 2.0 SLOPES UP TO 2:1 MEDIUM DUTY CHANNEL LINER 100% ORGANIC FIBER REQUIRED	TYPE C SHEAR 3.5 TRM MAT SLOPES UP TO 2:1 HEAVY DUTY CHANNEL LINER
		TYPE D SHEAR 5.0 TRM MAT SLOPES UP TO 1:1 HEAVY DUTY CHANNEL LINER

CONDITION 1: SLOPES LESS THAN 25' (7.6 m) IN HEIGHT H ≤ 25' (7.6 m)



NO BENCH REQUIRED

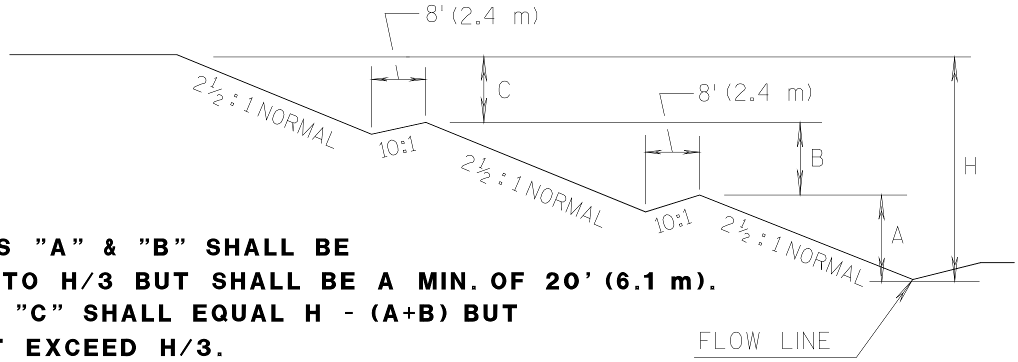
CONDITION 2: SLOPES WITH 25' (7.6 m) < H AND ≤ 50' (15.2 m)



HEIGHT "A" SHALL EQUAL H/2 BUT SHALL BE A MIN. OF 15' (4.6 m). HEIGHT "B" SHALL EQUAL H/2 - A, BUT CANNOT EXCEED HEIGHT "A".

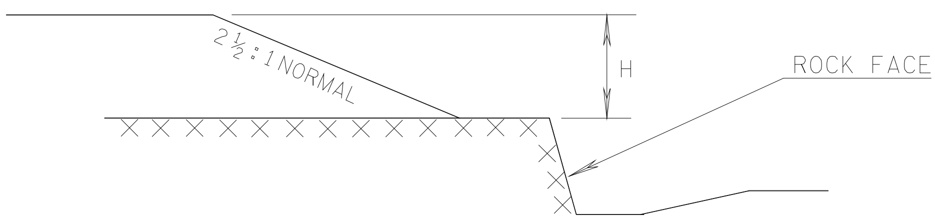
BENCHED SLOPE EXAMPLES
(SLOPES IN UNCONSOLIDATED MATERIAL)

CONDITION 3: SLOPE WITH H > 50' (15.2 m)



HEIGHTS "A" & "B" SHALL BE EQUAL TO H/3 BUT SHALL BE A MIN. OF 20' (6.1 m). HEIGHT "C" SHALL EQUAL H - (A+B) BUT CANNOT EXCEED H/3.

CONDITION 4: SLOPES ABOVE ROCK CUTS



CONDITIONS 1, 2 & 3 SHALL APPLY BUT HEIGHT "H" SHALL BE TAKEN AS THE HEIGHT ABOVE THE EXPOSED ROCK FACE.

BENCHED SLOPE EXAMPLES
(SLOPES IN UNCONSOLIDATED MATERIAL)

FDM 10-15-1 Glossary

January 24, 1997

The list of terms that follows is representative of those used by public works officials, planners and other urban specialists, water pollution specialists, engineers, developers, soil scientists and conservationist planners. Not all the terms are necessarily used in the chapter, but they are in common use in urban conservation and environmental matters.

Glossary

Absorption	The act or process of taking in water by inflow of atmospheric vapor, hygroscopic absorption, wetting, infiltration, influent seepage and gravity flow of streams into sinkholes or other large openings.
Abstraction	That portion of rainfall which does not become runoff. It includes interception, infiltration, and storage in depression. It is affected by land use, land treatment and condition, and antecedent soil moisture.
Abutment	The support at either end of a bridge: usually classified as spill-through or vertical.
Accretion	1. A process of accumulation by flowing water whether of silt, sand, pebbles, etc. Accretion may be due to any cause and includes alleviation. 2. The gradual building up of a beach by wave action. 3. The gradual building of a channel bottom, bank, or bar due to silting or wave action.
Acre-Foot	The amount of water that will cover 1 acre to a depth of 1 foot. Equals 43,560 cubic feet (**1233.5 m^3**). Abbreviated AF.
Aggradation	General and progressive upbuilding of the longitudinal profile of a channel by deposition of sediment.
Allowable Headwater	The depth or elevation of impounded water at the entrance to a hydraulic structure beyond which flooding or some other unfavorable result could occur.
Alluvial Channel	A channel wholly in alluvium, no bedrock exposed in channel at low flow or likely to be exposed by erosion during major flow.
Alluvium	Unconsolidated clay, silt, sand, or gravel deposited by a stream in a channel, flood plain, fan or delta.
Anabranched Stream	A stream whose flow is divided at normal and lower stages by large islands or, more rarely, by large bars. The width of individual islands or bars is greater than three times water width.
Annual Flood	The highest peak discharge in a water year.
Annual Series	A frequency series in which only the largest value in each year is used, such as annual floods.
Annual Yield	The total amount of water obtained in a year from a stream, spring, artesian well, etc. Usually expressed in inches depth, acre-feet, millions of gallons, or cubic feet.
Antecedent Moisture Conidition (AMC	The degree of wetness of a watershed at the beginning of a storm.
Anti-seepage Collar	A device attached to the outside of a culvert to prevent failure by washout of the fill next to the culvert.
Area Rainfall	The average rainfall over an area, usually as derived from, or discussed in contrast with, point rainfall.

Armor	Artificial surfacing of channel beds, banks, or embankment slopes to resist scour and lateral erosion.
Armoring	Armoring is the concentration of a layer of stones on the bed of the stream which are of a size larger than the transport capability of the recently experienced flow.
Avulsion	A sudden change in the course of a channel, usually by breaching of the banks during a flood.
Aquifer	A porous, water-bearing geologic formation. Generally restricted to materials capable of yielding an appreciable supply of water.
Artesian	Pertains to groundwater that is under pressure and will rise to a higher elevation if given an opportunity to do so.
B	Barrel width, ft.
Backwater	The increase in water-surface profile, relative to the elevation occurring under natural channel and flood-plain conditions, induced upstream from a structure, bridge, or culvert, that obstructs or constricts a channel. It also applies to the water surface profile in a channel or conduit.
Baffle	A structure built on the bed of a stream to deflect or disturb the flow. Also a device used in a culvert to facilitate fish passage.
Bank	Lateral boundaries of a channel or stream, as indicated by a scarp, or on the inside of bends, by the streamward edge of permanent vegetal growth.
Bar	An elongated deposit of alluvium, not permanently vegetated, within or along the side of a channel.
Base Flood	The 100-Year flood.
Base Flow	Stream discharge derived from groundwater sources. Sometimes considered to include flows from regulated lakes or reservoirs. Fluctuates much less than storm runoff.
Basin, Drainage	The area of land drained by a watercourse.
Basin Lag	The amount of time from the centroid of the rainfall hyetograph to the hydrograph peak.
Bed (of a channel	The part of a channel not permanently vegetated, bounded by banks, or stream)over which water normally flows.
Bed Load	Sediment that is transported in a stream by rolling, sliding, or skipping along the bed or very close to it; considered to be within the bed layer.
Bed Material	Sediment consisting of particle sizes large enough to be found in appreciable quantities at the surface of a streambed.
Bed Shear	The force per unit area exerted by a fluid flowing past a stationary (tractive force)boundary.
Benching	Benching is a series of permanent, deep cuts that are constructed in steep backslopes.
Berm	A narrow shelf or ledge; also a form of dike.
Braided Stream	A stream whose surface is divided at normal stage by small mid-channel bars or small islands. The individual width of bars and islands is less than three times the water width. A braided stream has the aspect of a single large channel within which are subordinate channels.
Bridge	A structure including supports erected over a depression or an obstruction and having a tract or passageway for carrying traffic or moving loads, and having an opening measured along the center of the roadway of more than 20 feet **(6.0 m)** between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than

	half of the smaller contiguous opening. Also a structure designed hydraulically using the principles of open channel flow to operate with a free water surface, but may be inundated under flood conditions.
Breakers	The surface discontinuities of waves as they break-up. They may take different shapes (spilling, plunging, surging). Zone of break-up is called surf zone.
Bridge Opening	The cross-sectional area beneath a bridge that is available for conveyance of water.
Bridge Waterway	The area of a bridge opening available for flow, as measured below a specified stage and normal to the principal direction of flow.
Broken-Back Culvert	A culvert comprising two or more longitudinal structure profiles. Such culverts are sometimes effective in reducing outflow velocities by the energy dissipation of a hydraulic jump.
By-Pass	Flow which bypasses an inlet on grade and is carried in the street or channel to the next inlet downstream. Also called carryover.
Capacity	A measure of the ability of a channel or conduit to convey water.
Catch Basin	A structure with a sump for inletting drainage from a gutter or median and discharging the water through a conduit. In common usage it is a grated inlet with or without a sump.
Catchment	The watershed. (Implying all physical characteristics.)
Catchment Area	The area tributary to a lake, stream, or drainage system.
CFS	Abbreviation for cubic feet per second. A unit of water flow. Sometimes called "second feet."
Channel	(1) The bed and banks that confine the surface flow of a natural or artificial stream. Braided streams have multiple subordinate channels, which are within the main stream channel. Anabranched streams have more than one channel. (2) The course where a stream of water runs, or the closed course or conduit through which water runs, such as a pipe.
Channel Lining	The material applied to the bottom and/or sides of a natural or manmade channel. Material may be concrete, sod, grass, rock, or any of several other types.
Channel Routing	The process whereby a peak flow and/or its associated streamflow hydrograph is mathematically transposed to another site downstream.
Check Dam	A low structure, dam or weir, across a channel for the control of water stage, or velocity, or to control channel erosion.
Check Flow	A flow, larger or smaller than the design flow, which is used to assess the performance of the facility.
Chute	An open or closed channel used to convey water, usually situated on the ground surface.
Coast Line (shore line)	The line forming the boundary between the land and water.
Coastal Zone	The strip of land that extends inland to the first major change in terrain (lake shore)features.
Coefficient Of Discharge	The coefficient used for orifice flow processes.
Combination Inlet	Drainage inlet usually composed of two or more inlet types, e.g., curb-opening and a grate inlet.
Conduit	An artificial or natural channel; usually a closed structure such as a pipe.
Conjugate Depth	The alternate depth of flow involved with the hydraulic jump.
Continuity Equation	Discharge equals velocity times cross-sectional area. ($Q = V \times A$)

Control Section	A cross section, such as a bridge crossing, reach of channel, or dam, with limited flow capacity, in which the discharge is related to the upstream water-surface elevation.
Contraction	The effects of a channel constriction on flow.
Contraction Scour	The response of a river to the change in its bed load requirement as a result of a contraction of flow. The flow contraction is due to an encroachment of either the main channel or the flood plain by a natural constriction or the highway embankment.
Controlled Spillways	A reservoir outlet works wherein the outflow is controlled by tainter gates or some similar device.
Conveyance	A measure, K, of the ability of a stream, channel, or conduit to convey water. In Manning's formula $K = (1.49/n)AR^{2/3}$.
Corrosion	The deterioration of pipe or structure by chemical action.
Cover	The extent of soil above the crown of a pipe or culvert. The vegetation, or vegetational debris such as mulch, that exists on the soil surface. In some classification schemes fallow or bare soil is taken as the minimum cover class.
Critical Depth	The depth at which water flows over a weir; this depth being attained automatically where no backwater forces are involved. It is the depth at which the energy content of flow is a minimum.
Cross Drainage	The runoff from contributing drainage areas both inside and outside the highway right-of-way and the transmission thereof from the upstream side of the highway facility to the downstream side.
Cross-Section	The shape of a channel, stream, or valley, viewed across its axis. In watershed investigations it is determined by a line approximately perpendicular to the main path of water flow, along which measurements of distance and elevation are taken to define the cross-sectional area.
Culvert	A structure which is usually designed hydraulically to take advantage of submergence to increase hydraulic capacity. A structure used to convey surface runoff through embankments. A structure, as distinguished from bridges, which is usually covered with embankment and is composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert. Also, a structure which is 20 feet (**6.0 m**) or less in centerline length between extreme ends of openings for multiple boxes.
Culvert Inlet	Usually is the placing of a sediment filter or excavated impoundment Protectionarea at the inlet end of storm sewer culverts.
Curb-Opening Inlet	Drainage inlet consisting of an opening in the roadway curb.
Cumulative	A tabulation or graphical plot of the accumulated measures of Conveyance conveyance; proceeding from one stream bank to the other.
Cutoff Wall	A wall that extends from the end of a structure to below the expected scour depth, or scour-resistant material.
D	Culvert diameter or barrel depth.
D_{50}	Median size of rip rap. The particle diameter at the 50 percentile point on a size weight distribution curve.
D_{16}	The particle diameter at the 16 percentile point on a size weight distribution curve.
D_{85}	The particle diameter at the 85 percentile point on a size weight distribution curve.
d_c	Critical depth of flow, ft.
Debris	Material transported by the stream, either floating or submerged, such as logs or brush.

Degradation	General and progressive lowering of the longitudinal profile of a channel by erosion.
Deposition	The settling of material from the stream flow onto the bottom.
Depression Storage	Rainfall which is temporarily stored in depressions within a watershed.
Depth-Area Curve	A graph showing the change in average rainfall depth as size of area changes.
Design Discharge Or Flow	The rate of flow for which a facility is designed.
Design Flood	The recurrence interval that is expected to be accommodated without Frequencycontravention of the adopted design constraints. The return interval (recurrence interval or reciprocal of probability) used as a basis for the design discharge.
Design Highwater	The maximum water level that a bridge opening is designed to Elevationaccommodate without contravention of the adopted design constraints. The usual term used to describe the estimated water surface elevation in the stream at the project site for the design discharge.
Design Flood	A flood that does not overtop the roadway.
Design Storm	A given rainfall amount, areal distribution, and time distribution, used to estimate runoff. The rainfall amount is either a given frequency (25-year, 50-year, etc.) or a specific large value.
Detention Basin	A basin or reservoir incorporated into the watershed whereby runoff is temporarily stored, thus attenuating the peak of the runoff hydrograph.
Dike	An impermeable linear structure for the control or confinement of overbank flow. River training structure used for bank protection.
Direct Runoff	The water that enters the stream channels during a storm or soon after, forming a runoff hydrograph. May consist of rainfall on the stream surface, surface runoff, and seepage of infiltrated water (rapid subsurface flow).
Discharge	The rate of the volume of flow of a stream per unit of time, usually expressed in cfs.
Diversion Dike	A ridge of compacted soil constructed at the top or base of a sloping disturbed area and may be either temporary or permanent.
Drainage Area	The area draining into a stream at a given point. The area may be of different sizes for surface runoff, subsurface flow, and base flow, but generally the surface flow area is used as the drainage area.
Drop Inlet	Drainage inlet with a horizontal or nearly horizontal opening.
Dust Controls	Measures such as vegetative cover, mulch, irrigation or spray-on adhesives that are used to reduce surface and air movement of dust during land disturbing, demolition and construction activities.
Effective Duration	The time in a storm during which the water supply for direct runoff is produced. Also used to mean the duration of excess rainfall.
Effective Particle	The diameter of particles, spherical in shape, equal in size and arranged Sizein a given manner, of a hypothetical sample of granular material that would have the same transmission constant as the actual material under consideration.
Emergency Spillway	A rock or vegetated earth waterway around a dam, built with its crest above the normally used principal spillway. Used to supplement the principal spillway in conveying extreme amounts of runoff safely past the dam.
End Section	A concrete or metal structure attached to the end of a culvert for purposes of retaining the embankment from spilling into the waterway, appearance, anchorage, etc.
Energy Dissipation	The phenomenon whereby energy is dissipated or used up.

Energy Grade Line	A line joining the elevation of energy heads; a line drawn above the hydraulic grade line a distance equivalent to the velocity head of the flowing water at each section along a stream, channel or conduit.
Energy Gradient	Slope of the line joining the elevations of total energy along a conduit of flowing water.
Ephemeral Stream	A stream or reach of a stream that does not flow continuously for most of the year.
Equalizer	A culvert or opening placed where it is desirable to equalize the water head on both sides of the embankment.
Equivalent Cross-to Slope	An imaginary straight cross-slope having conveyance capacity equal that of the given compound cross-slope.
Erosion Mat	A general term for any protective covering mat or soil retention mat this is installed on a prepared planting area of a slope, channel, or shoreline. A <u>protective covering mat,</u> also referred to as an "Erosion Control Revegetative Mat" (ECRM), is a blanket-like covering laid on top of a prepared seed bed to protect the soil and seed from the erosive forces of nature. A <u>soil retention mat</u>, also referred to as a "Turf Reinforcement Mat" (TRM), helps to permanently stabilize the soil by acting as a reinforcement for the vegetation. This open weaved, synthetic mat is installed on top of a prepared seed bed and then filled with topsoil or granular material such as pea grave (ie., Course Aggregate No. 4 or 5). As the vegetation grows, the roots intertwine into the mat, 'reinforcing the turf". In vegetated channels, this reinforcement helps to raise the channel's maximum permissible shear stress.
Erosion Bale	Temporary sediment barriers consisting of a row or rows of entrenched and anchored straw or hay bales.
Erosion	The wearing away or scouring of material in a channel, opening, or outlet works caused by flowing water.
Evapotranspiration	Plant transpiration plus evaporation from the soil. Difficult to determine separately, therefore used as a unit for study.
Excess Rainfall	Direct runoff.
Exfiltration	The process by which stormwater leaks or flows to the surrounding soil through openings in a conduit.
Fetch	The distance the wind blows over water in generating waves.
Filter	A device or structure for removing solid or colloidal material from stormwater or preventing migration of fine-grained soil particles as water passes through soil. The water is passed through a filtering medium; usually a granular material or finely woven or non-woven cloth.
Filter Berms	See "Stone or Rock Ditch Checks".
Filtration	The process of passing water through a filtering medium consisting of either granular material of filter cloth for the removal of suspended or colloidal matter.
Flanking Inlets	Inlets placed upstream and on either side of an inlet at the low point in a sag vertical curve. The purposes of these inlets are to intercept debris as the slope decreases and to act as relief of the inlet at the low point.
Flared Inlet	A specially fabricated pipe appurtenance or a special feature of box culverts. This type of inlet is effective in reducing the calculated headwater.
Flared Wingwalls	The part of a culvert headwall which serves as a retaining wall for the highway embankment. The walls form an angle to the centerline of the culvert.
Flood	In common usage, an event that overflows the normal banks. In technical usage, it refers to a given discharge based, typically, on a statistical analysis of an annual series of events.

Flood Frequency	The average time interval, in years, in which a given storm or amount of water in a stream will be exceeded.
Flood Of Record	Reference to the maximum estimated or measured discharge that has occurred at a site.
Floodplain	The alluvial land bordering a stream, formed by stream processes, that is subject to inundation by floods.
Flood Pool	Floodwater storage elevation in a reservoir. In a floodwater retarding reservoir, the temporary storage between the crests of the principal and emergency spillways.
Flood Routing	Determining the changes in a flood hydrograph as it moves downstream through a channel or through a reservoir (called reservoir routing). Graphic or numerical methods are used.
Floodwater	A dam, usually with an earth fill, having a flood pool where incoming Retarding
Flow-Control	A structure, either within or outside a channel, that acts as a Structurecountermeasure by controlling the direction, depth, or velocity of flowing water.
Flow Concentration	A preponderance of the streamflow.
Flow Distribution	The estimated or measured spatial distribution of the total streamflow.
Flume	An open or closed channel used to convey water.
Ford	A location where a highway crosses a river or wash by allowing flow over the highway. Often with cut-off walls and markers.
Freeboard	The vertical distance between the level of the water surface, usually corresponding to design flow and a point of interest such as a low chord of a bridge beam or specific location on the roadway grade.
Free Outlet	Those outlets whose tailwater is equal to or lower than critical depth. For culverts having free outlets, lowering of the tailwater has no effect on the discharge or the backwater profile upstream of the tailwater.
Frequency	In analysis of hydrologic data, the recurrence interval is simply called frequency.
Froude Number	A dimensionless number that represents the ratio of inertial forces to gravitational forces. High froude numbers are indicative of high flow velocity and high potential for scour.
Frontal Flow	The portion of flow which passes over the upstream side of a grate.
Functional Values	Characteristics of surface water and wetlands. These include terrestrial and aquatic wildlife habitat, flood control, groundwater recharge, aesthetics, shore and bank line geometry, and water quality.
g	The acceleration of gravity. At sea level it is 32 ft/sec^2 or 9.8 m/sec^2.
Gabion	Large, multi-celled, rectangular wire mesh boxes filled with rock to form flexible monolithic building blocks. They are used as erosion control structures in channels, revetments, retaining walls, abutments and check dams.
General Scour	Scour involving the removal of material from the bed and banks across or most of the width of a channel and is not localized at an element such as a pier, abutment or other obstruction to flow. Also termed contraction scour.
Graded Filter	An aggregate filter which is proportioned by particle size to allow water to pass through at a specified rate while preventing migration of fine-grained soil particles without clogging.
Grate Inlet	Drainage inlet composed of a grate in the roadway section or at the roadside in a low point, swale, or ditch.

Groin	A structure in the form of a barrier placed oblique to the primary motion of water, designed to control movement of bed load. Groins are usually solid, although they may be constructed with openings to control elevations of sediments.
Groundwater	Subsurface water occupying the saturation zone, from which wells and springs are fed. A source of base flow in streams. In a strict sense the term applies only to water below the water table. Also called phreatic water.
Grouted Riprap	A rigid lining which consists of riprap with all or part of the voids filled with portland cement.
Guide Banks	Embankments built upstream from one or both abutments of a bridge to guide the approaching flow through the waterway opening.
H	Total energy head loss, ft.
H_E	Entrance head loss, ft.
Head	Potential energy expressed as the height of water above a datum.
Head Cutting	Channel degradation associated with abrupt changes in the bed elevation (headcut), that migrates in an upstream direction.
Headloss	A loss of energy in a hydraulic system.
Headwall	The structural appurtenance usually applied to the end of a culvert to control an adjacent highway embankment and protect the culvert end.
Headwater, H_w	That depth of water impounded upstream of a culvert due to the influence of the culvert constriction, friction, and configuration.
H_f	The friction headloss, ft.
Highwater	The water surface elevation that results from the passage of flow. It may Elevationbe "observed highwater elevation" as a result of an event, or "calculated highwater elevation" as part of a design process.
Historical Flood	A past flood event of known or estimated magnitude.
h_o	The height of the hydraulic grade line above the outlet invert, ft.
Hydraulic Grade	A profile of the piezometric level to which the water would rise in Linepiezometer tubes along a pipe run. In open channel flow, it is the water surface.
Hydraulic Gradient	The slope of the hydraulic grade line.
Hydraulic Head	The height of the free surface of a body of water above a given point.
Hydraulic Jump	A hydraulic phenomenon, in open channel flow, whereby supercritical flow is converted to subcritical flow. This can result in an abrupt rise in the water surface.
Hydraulic Radius	A measure of the boundary resistance to flow, computed as the quotient of cross-sectional area of flow divided by the wetted perimeter. For wide shallow flow, the hydraulic radius can be approximated by the average depth.
Hydraulic Roughness	Is a composite of the physical characteristics which influence the flow of water across the earth's surface, whether natural or channelized. It affects both the time response of a watershed and drainage channel as well as the channel storage characteristics.
Hydraulics	The characteristics of fluid mechanics involved with the flow of water in or through drainage facilities.
Hydrograph	A graph showing, for a given point on a stream or for a given point in any drainage system, the discharge, stage, velocity or other property of water with respect to time.
Hydrologic Soil-Cover Complex	A combination of a hydrologic soil group and a type of cover.

Hydrologic Soil	A group of soils having the same runoff potential under similar storm Groupand cover conditions.
Hydrology	The study of the occurrence, circulation, distribution, and properties of the waters of the earth and its atmosphere.
Hyetograph	A graphical representation of average rainfall, rainfall-excess rates or volumes over specified areas during successive units of time during a storm.
Impermeable Strata	A strata in which texture is such that water cannot move perceptibly through it under pressures ordinarily found in subsurface water.
Impervious	Impermeable to the movement of water.
Improved Inlet	Flared, depressed or tapered culvert inlets which decrease the amount of energy needed to pass the flow through the inlet and thus increase the capacity of culverts.
Infiltration	That part of rainfall that enters the soil. The passage of water through the soil surface into the ground. Used interchangeably herein with the word: percolation.
Infiltration Rate	The rate at which water enters the soil under a given condition. The rate is usually expressed in inches per hour, feet per day, or cubic feet per second.
Inflow	The rate of discharge arriving at a point (in a stream, structure, or reservoir).
Initial	When considering surface runoff, Ia is all the rainfall before runoff begins.
Interlocking Cells	Manufactured cellular devices which are usually filled with a granular material.
Abstraction (Ia)	When considering direct runoff, Ia consists of interception, evaporation, and the soil-water storage that must be exhausted before direct runoff may begin. Sometimes called "initial loss."
Inlet	A structure for capturing concentrated surface flow. May be located
Inlet Efficiency	The ratio of flow intercepted by an inlet to the total flow.
Inlet Time	The time required for stormwater to flow from the most distant point in a drainage area to the point at which it enters a storm drain.
Intensity	The rate of rainfall upon a watershed, usually expressed in inches per hour.
Interception	Precipitation retained on plant or plant residue surfaces and finally absorbed, evaporated, or sublimated. That which flows down the plant to the ground is called "stemflow" and not counted as true interception.
Intercepting	A type of permanent diversion dike, which is used along the top of Embankmentbackslopes in cut areas to prevent the adjacent lateral drainage from flowing over or down the backslopes.
Intermittent	Temporary or permanent waterways that are shaped, sized, and lined Channelswith appropriate vegetation or structural material to safely convey stormwater runoff.
Invert	The flow line in a channel cross-section, pipe, or culvert.
Inverted Syphon	A structure used to convey water under a road using pressure flow. The hydraulic grade line is above the crown of the structure.
Isohyet	A line on a map, connecting points of equal rainfall amounts.
Jetty	An elongated obstruction projecting into a stream to control shoaling and scour by deflection of currents and waves. They may be permeable or impermeable.
Lag Time, T_L	The difference in time between the centroid of the excess rainfall (that rainfall producing runoff) and the peak of the runoff hydrograph. Often estimated as 60 percent of the time of concentration ($T_L = 0.6T_c$)

Levee	A linear embankment outside a channel for containment of flow.
Littoral Transport	The movement of sediments in the near shore zone by waves and currents. The movement can be parallel to the shore (long shore transport) or perpendicular to the shore (onshore-offshore transport).
Local Scour	Scour in a channel or on a flood plain that is localized at a pier, abutment or other obstruction to flow. The scour is caused by the acceleration of the flow and the development of a vortex system induced by the obstruction to the flow.
Manhole	A structure by which one may access a drainage system.
Manning's "n"	A coefficient of roughness, used in a formula for estimating the capacity of a channel to convey water. Generally, "n" values are determined by inspection of the channel.
Mass Inflow Curve	A graph showing the total cumulative volume of stormwater runoff plotted against time for a given drainage area.
Maximum Probable	The greatest flood that may reasonably be expected, taking into Flood
Mean Daily	The average of mean discharge of a stream for one day. Usually given Dischargein cfs.
Meanders	The changes in direction and winding of flow which are sinuous in character.
Migration, Channel	Change in position of a channel by lateral erosion of one bank and simultaneous accretion of the opposite bank.
Mulch	A degradable, protective ground cover usually composed of woodships or wood fibers, and used in conjunction with seeding to prevent erosion by protecting the soil surface from raindrop impact. In addition, it helps to foster the growth of vegetation by increasing available moisture and providing insulation against extreme heat and cold.
Natural Scour	Scour which occurs along a channel reach due to an unstable stream, no exterior causes.
Normal Stage	The water stage prevailing during the greater part of the years.
One-Dimensional Water Surface Profile	An estimated water surface profile which accommodates flow only in the up-stream-downstream direction.
Ordinary High	The line on the shore established by the fluctuations of water and Waterindicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of liter and debris, or other appropriate means that consider the characteristics of the surrounding areas.
Outfall	The point location or structure where drainage discharges from a channel, conduit or drain.
Outlet Protection	The placing of an energy dissipating device at the outlets of pipes or channel sections.
Overland Flow	Runoff which makes its way to the watershed outlet without concentrating in gullies and streams (often in the form of sheet flow).
Partial-Duration	A list of all events, such as floods, occurring above a selected base, Serieswithout regard to the number, within a given period. In the case of floods, the selected base is usually equal to the smallest annual flood, in order to include at least one flood in each year.
Peak Discharge	Maximum discharge rate on a runoff hydrograph.
Percolation	The movement or flow of water through the interstices or the pores of a soil or other porous medium. Used interchangeably herein with the word "infiltration."
Permeability	The property of a material that permits appreciable movement of water through it when it is saturated and movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water.

Permanent Seeding	The establishment of perennial vegetative cover on disturbed areas by planting seed. This cover can include grasses, legumes and/or wildflowers.
Perennial Stream	A stream or reach of a stream that flows continuously for all or most of the year.
Pervious Soil	Soil containing voids through which water will move under hydrostatic pressure.
pH	The reciprocal of the logarithm of the Hydrogen ion concentration. The concentration is the weight of hydrogen ions, in grams, per liter of solution. Neutral water has a pH value of 7.
Pipe Down Drains	Also referred to as "slope drains", are used to help direct runoff down a slope at a specific location. They are usually used in conjunction with diversion dikes, intercepting embankments, or temporary fill diversions.
Point Rainfall	Rainfall at a single rain gage.
Precipitation	The process by which water in liquid or solid state falls from the atmosphere.
Principal Spillway	Conveys all ordinary discharges coming into a reservoir and all of an extreme discharge that does not pass through the emergency spillway.
Rainfall Excess	The water available to runoff after interception, depression storage, and infiltration have been satisfied.
Rainfall Intensity	Amount of rainfall occurring in a unit of time, converted to its equivalent in inches per hour at the same rate.
Rating Curve	A graphical plot relating stage to discharge.
Reach	A length of stream or valley, selected for purpose of study.
Recession Curve	The receding portion of a hydrograph, occurring after excess rainfall has stopped.
Recharge	Addition of water to the zone of saturation from precipitation or infiltration.
Recharge Basin	A basin excavated in the earth to receive the discharge from streams or storm drains for the purpose of replenishing groundwater supply.
Regional Analysis	A regional study of gaged watersheds which produces regression equations relating various watershed and climatological parameters to discharge. Use for design of ungaged watershed with similar characteristics.
Regulatory Flood	The 100-year flood, which was adopted by the Federal Emergency Management Agency (FEMA), as the base flood for flood plain management purposes.
Regulatory	The floodplain area that is reserved in an open manner by Federal, State, Floodwayor local requirements, i.e., unconfined or unobstructed either horizontally or vertically, to provide for the discharge of the base flood so that the cumulative increase in water surface elevation is no more than a designated amount.
Reservoir Routing	Flood routing of a hydrograph through a reservoir.
Retard	A structure designed to decrease velocity and induce silting or accretion. Retard type structures are permeable structures customarily constructed at and parallel to the toe of a slope.
Retention Basin	A basin or reservoir wherein water is stored for regulating a flood. It does not have an uncontrolled outlet. The stored water is disposed by a means such as infiltration, injection (or dry) wells, or by release to the downstream drainage system after the storm event. The release may be through a gate-controlled gravity system or by pumping.
Revetment	A rigid or flexible armor placed on a bank or embankment as protection against scour and lateral erosion.

Riprap	A flexible lining having a loose assemblage of relatively large rocks or stones that vary in size.
Roughness	The estimated measure of texture at the perimeters of channels and conduits. Usually represented by the "n-value" coefficient used in Manning's channel flow equation.
Runoff	That part of the precipitation which runs off the surface of a drainage area after all abstractions are accounted for.
Runoff Coefficient	A factor representing the portion of runoff resulting from a unit rainfall. Dependent on terrain and topography.
Safety Fence	A protective barrier installed to prevent access to an erosion control measure. Typically used around detention basins.
Saturated Soil	Soil that has its interstices or void spaces filled with water to the point at which runoff occurs.
Scour	The result of the erosive action of running water, excavating and carrying away material from the bed and banks of streams.
Scupper	A vertical hole through a bridge deck for the purpose of deck drainage. Sometimes a horizontal opening in the curb or barrier is called a scupper.
Sediment Pool	Reservoir storage provided for sediment, thus prolonging the usefulness of floodwater or irrigation pools.
Sedimentation	The deposition of soil particles which have been carried by flood waters.
Sedimentation Basin	A basin or tank in which stormwater containing settleable solids is retained to remove by gravity or filtration a part of the suspended matter.
Sediment Traps or Basins	Storage areas provided by either excavation or the provision of a damor a barrier for the purpose of trapping and storing sediment.
Sheeting	A lining of wood or steel driven into the subsoil and used to support an embankment or the walls or an excavation. It may be used as a permanent or temporary installation.
Silt Fence	A temporary sediment control barrier consisting of a synthetic filter fabric that is stretched across supporting posts and entrenched at the bottom. It is limited to conditions in which only sheet or overland flows are expected and is not recommended for use in channels.
Silt Screen	A floating geotextile material used to minimize sediment transport within a body of water. Silt screens float from the surface of the water to approximately 2 feet **(600 mm)** above the water bed.
Skew	A measure of the angle of intersection between a line normal to the roadway centerline and the direction of the streamflow at flood stage on the lineal direction of the main channel.
Skewness	The curvature observed in a plot of data on log-normal paper.
Slotted Drain Inlets	Drainage inlets composed of a continuous slot built into the top of a pipe which serves to intercept, collect and transport the flow.
Sod	A grass-covered surface soil that is held together by matted roots and used to stabilize fine graded disturbed areas.
Soffit	The inside top of the culvert or storm drain pipe.
Soil Porosity	The percentage of the soil (or rock) volume that is not occupied by solid particles, including all pore space filled with air and water.
Soil-Water-Storage	The amount of water the soils (including geologic formations) of a watershed will store at a given time. Amounts vary from watershed to watershed. The amount for a given watershed is continually varying as rainfall or evapotranspiration takes place.

Splash-Over	That portion of frontal flow at a grate which splashes over the grate and is not intercepted.
Spread	The accumulated flow in and next to the roadway gutter. This water often represents an interruption to traffic flow during rainstorms. The lateral distance, in feet, of roadway ponding from the curb.
Spur	A structure, permeable or impermeable, projecting into a channel from the bank for the purpose of altering flow direction, inducing deposition, or reducing flow velocity along the bank.
Spur Dike	A dike placed at an angle to the roadway for the purpose of shifting the erosion characteristics of stream flow away from a drainage structure. Often used at bridge abutments.
Stage	Height of water surface above a specified datum.
Stage-Discharge	Sometimes referred to as the Rating Curve of a stream cross-section. A - Relationshipcorrelation between stream flow rates and corresponding water surface elevations.
Stilling Basin	An energy dissipator placed at the outlet of a structure.
Stone or Rock Ditch Checks	Temporary or permanent dams constructed across a swale or drainage ditch. They may be constructed from course aggregate, riprap, breaker run, or railroad ballast and are commonly referred to as "filter berms".
Storage-Indication Method	A flood-routing method, also often called the modified Puls method.
Storm Drain	The water conveyance elements (laterals, trunks, pipes) of a storm drainage system. Extend from inlets to an outlet.
Storm Duration	The period or length of storm.
Stream Contraction	A narrowing of the natural stream waterway. Usually in reference to Constrictiona drainage facility installed in the roadway embankment.
Stream Reach	A length of stream channel selected for use in hydraulic or other computations.
Submerged Inlets	Inlets of culverts having a headwater greater than about 1.2 D.
Submerged Outlets	Submerged outlets are those culvert outlets having a tailwater elevation greater than the soffit of the culvert.
Subsurface Drains	Perforated conduits such as pipe, tubing or tile installed beneath the ground to intercept and convey ground water.
Superflood	Flood used to evaluate the effects of a rare flow event; a flow exceeding the 100-year flood. It is recommended that the superflood be on the order of the 500-year event or a flood 1.7 times the magnitude of the 100-year flood if the magnitude of the 500-year flood is not known.
Surface Runoff	Total rainfall minus interception, evaporation, infiltration, and surface storage, and which moves across the ground surface to a stream or depression.
Surface Storage	Stormwater that is contained in surface depressions or basins.
Surface Water	Water appearing on the surface in a diffused state, with no permanent source of supply or regular course for a considerable time; as distinguished from water appearing in water courses, lakes, or ponds.
Synthetic Hydrograph	A hydrograph determined from empirical rules. Usually based on the physical characteristics of the basin.
Swale	A slight depression in the ground surface where water collects.
Tailwater, TW	The depth of flow in the stream directly downstream of a drainage facility. Often calculated for the discharge flowing in the natural stream without the highway constriction.

	Term is usually used in culvert design and is the depth measured from the downstream flow line of the culvert to the water surface.
Temporary Fill Diversions	Channels with a supporting ridge of soil on the lower side, constructed along the top of an active earth fill in order to divert storm water runoff away from an unprotected fill slope to a stabilized outlet or sediment-trapping facility.
Temporary Seeding	The establishment of a temporary vegetative cover on disturbed areas by seeding with an annual herbaceous plant, usually grass, that is quick to germinate.
Thalweg	The line connecting the lowest flow points along the bed of a channel. The line does not include local depressions.
Time Of Concentration, T_c	The time it takes water from the most distant point (hydraulically) to reach a watershed outlet. T_c varies, but often used as constant.
Topsoiling	A method of preserving and using the surface layer of undisturbed soil, often rich in organic matter, in order to obtain a more desirable planting and growth medium.
Trash Rack	A device used to capture debris, either floating, suspended, or rolling along the bed, before it enters a drainage facility.
Travel Time	The average time for water to flow through a reach or other stream or valley length.
Turbidity Barriers	Fence-like structures that are placed within a body of water to "barricade" sediment from being transported. A geotextile material is stretched on posts from the bottom of the waterbed to an elevation 2 feet **(600 mm)** above the anticipated high water mark for the time of year the barrier is to be placed.
Tributaries	Branches of the watershed stream system.
Uncontrolled Spillway	A facility at a reservoir at which flood water discharge is governed only by the inflow and resulting head in the reservoir. Usually the emergency spillway is uncontrolled.
Ungaged Stream Sites	Locations at which no systematic records are available regarding actual stream-flows.
Uniform Flow	Flow of constant cross-section and average velocity through a reach of channel during an interval of time.
Unit Hydrograph	A hydrograph of a direct runoff resulting from 1 inch of effective rainfall generated uniformly over the watershed area during a specified period of time or duration.
Unsteady Flow	Flow of variable cross-section and average velocity through a reach of channel during an interval of time.
Watercourse	A channel in which a flow of water occurs, either continuously or intermittently, with some degree of regularity.
Watershed	The catchment area for rainfall which is delineated as the drainage area producing runoff. Usually it is assumed that base flow in a stream also comes from the same area.
Water Table	The upper surface of the zone of saturation, except where that surface is formed by an impermeable body (perched water table).
Water Year	The 12-month period, October 1 through September 30. It is designated by the calendar year in which it ends.
Weir Flow	Free surface flow over a control surface which has a defined discharge vs. depth relationship.
Wells	Shallow to deep vertical excavations, generally with perforated or slotted pipe backfilled with selected aggregate. The bottom of the excavation terminates in pervious strata above the water table.
Wet Well Sump	The feature in a pump station in which runoff waters are temporarily stored.

Wetted Perimeter	The boundary over which water flows in a channel, or culvert, taken normal to flow.

FDM 10-15-5 Erosion Control CADD Cells

February 27, 2004

This procedure contains illustrations of many of the erosion control features described previously in this chapter. They are grouped here in order to create a library of graphics which are available to designers for use in their project plans. All the attachments have a CADD cell name and most have a reference to other procedures in this chapter where design guidance can be found.

Cells can be viewed at the following address:

https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/tools/cad/default.aspx

LIST OF ATTACHMENTS

Attachment 5.31	Curb Inlet Sediment Barrier (Sandbag Type)
Attachment 5.32	Coarse Aggregate Sediment Filter For Drop Inlets
Attachment 5.33	Culvert Inlet Sediment Trap
Attachment 5.34	Silt Screen Detail
Attachment 5.35	Turbidity Barrier Detail
Attachment 5.36	Typical Excavated Sediment Trap
Attachment 5.37	Sediment Basin & Outlet Detail
Attachment 5.38	Silting Pond Detail
Attachment 5.39	Temporary Flexible Slope Drain
Attachment 5.40	Concrete Surface Drain
Attachment 5.41	Split Concrete Block Wall
Attachment 5.42	Typical Section of Temporary Channel Change
Attachment 5.43	Detail for Split concrete Block Retaining Wall

FDM 10-15-10 References *January 24, 1997*

The following references were used in the development of this chapter.

1. American Association of State Highway and Transportation Officials, INC; "Highway Drainage Guidelines, Volume III, AASHTO Guidelines for Erosion and Sediment Control in Highway Construction. "1992; Model Drainage Construction." 1992; "Model Drainage Manual" 1991".
2. "Virginia Erosion and Sediment Control Handbook, third edition" 1992.
3. Storm Water Pollution Prevention Plan Handbook, State of California, Department of Transportation", October 1992.
4. "Road Design Manual, Design Policy and Criteria, Chapter Eight, Drainage Design and Erosion Control" Minnesota Department of Transportation, January 31, 1992.
5. "Statewide General Special Specification 1225, Soil Retention Blankets" Texas Department of Transportation, February 1993.
6. "Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas" United States Department of Agriculture, Soil Conservation Service.
7. "Soil Erosion and Sedimentation Control Measures" Michigan Department of Transportation, 1991.
8. "Wisconsin Construction Site Best Management Practice Handbook", Wisconsin Department of Natural Resources, April 1989.
9. "Design of Roadside Channels with Flexible Linings" United States Department of Transportation, Federal Highway Administration.
10. National Cooperative Highway Research Program Reports; 18 "Erosion Control on Highway Construction"; 221 "Erosion Control During Highway Construction, Manual on Principles and Practices."
11. "Silt Curtains to Control Sediment Movement on Construction Sites" Research and Development Branch, Ontario Ministry of Transportation.
12. "Erosion Control Manual" Colorado Department of Transportation. 1978.
13. Department of the Army, Waterways

    Experiment Station, Corps of Engineers, Transmittal of Technical Report D-78-39. Subject Silt Curtains and Turbidity Barriers.

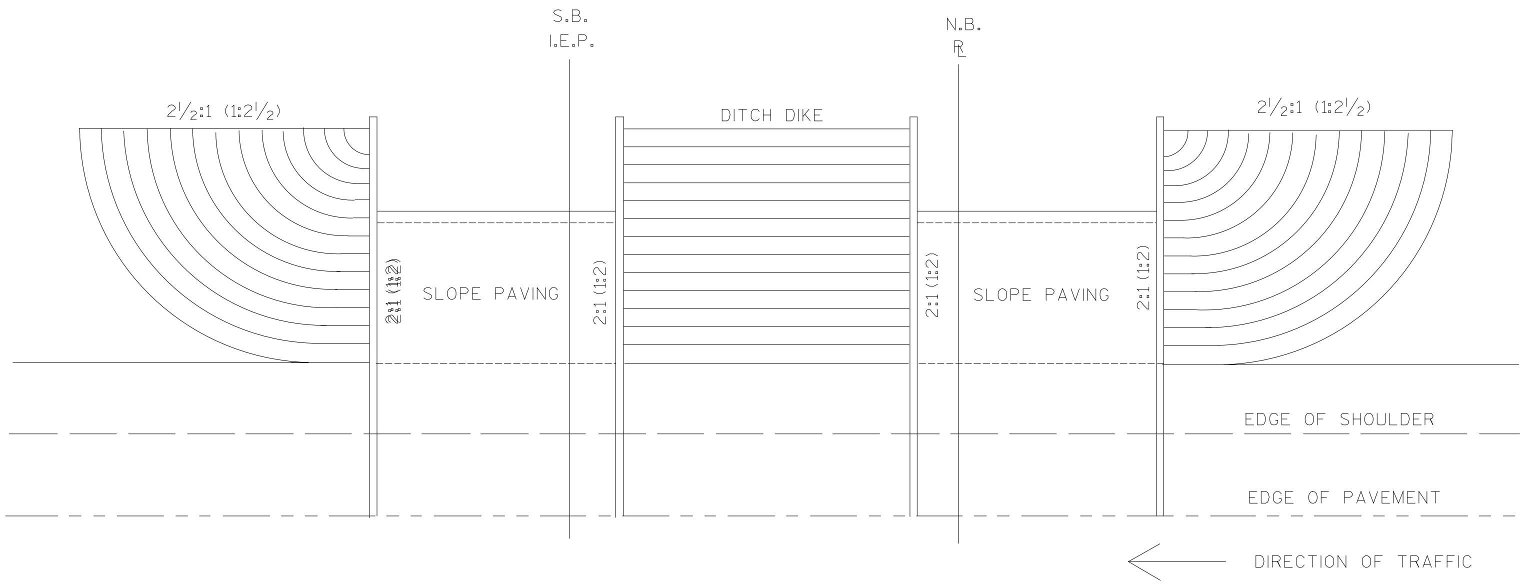
RUNOFF COEFFICIENT TABLE

	HYDROLOGIC SOIL GROUP											
	A			B			C			D		
	SLOPE RANGE (PERCENT)			SLOPE RANGE (PERCENT)			SLOPE RANGE (PERCENT)			SLOPE RANGE (PERCENT)		
LAND USE:	0-2	2-6	6 & OVER	0-2	2-6	6 & OVER	0-2	2-6	6 & OVER	0-2	2-6	6 & OVER
ROW CROPS	.08 .22	.16 .30	.22 .38	.12 .26	.20 .34	.27 .44	.15 .30	.24 .37	.33 .50	.19 .34	.28 .41	.38 .56
MEDIAN STRIP-TURF	.19 .24	.20 .26	.24 .30	.19 .25	.22 .28	.26 .33	.20 .26	.23 .30	.30 .37	.20 .27	.25 .32	.30 .40
SIDE SLOPE-TURF			.25 .32			.27 .34			.28 .36			.30 .38
PAVEMENT:												
ASPHALT	.70 - .95											
CONCRETE	.80 - .95											
BRICK	.70 - .80											
DRIVES, WALKS	.75 - .85											
ROOFS	.75 - .95											
GRAVEL ROADS, SHOULDERS	.40 - .60											

TOTAL PROJECT AREA = _________ ACRES (HECTARES)
TOTAL AREA EXPECTED TO BE DISTURBED BY CONSTRUCTION ACTIVITIES = ________ACRES (HECTARES)

CELL NAME: RCCHRT

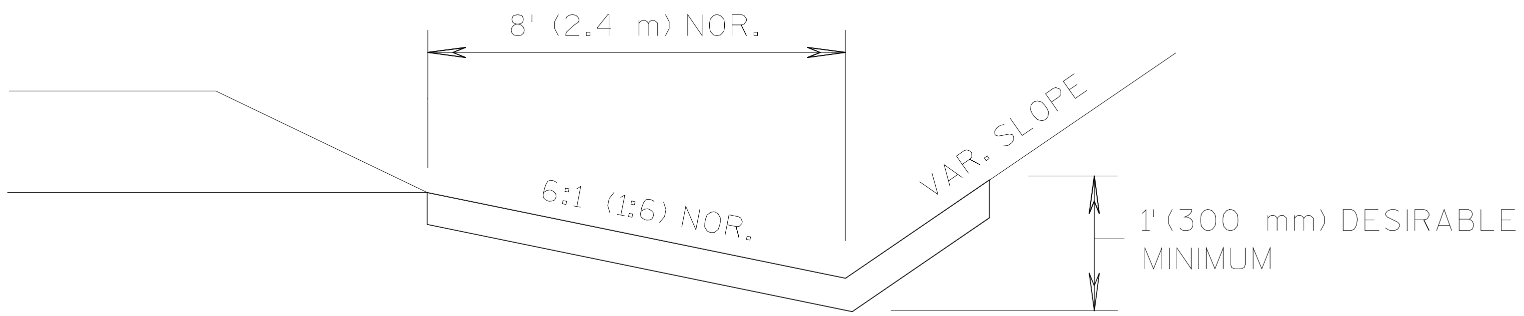
REFERENCE: SEE FDM PROCEDURE 10-5-60,FIG.1,SECTION VI(L)



DETAIL OF SOD SLOPES AT STRUCTURES

CELL NAME: SDSLP

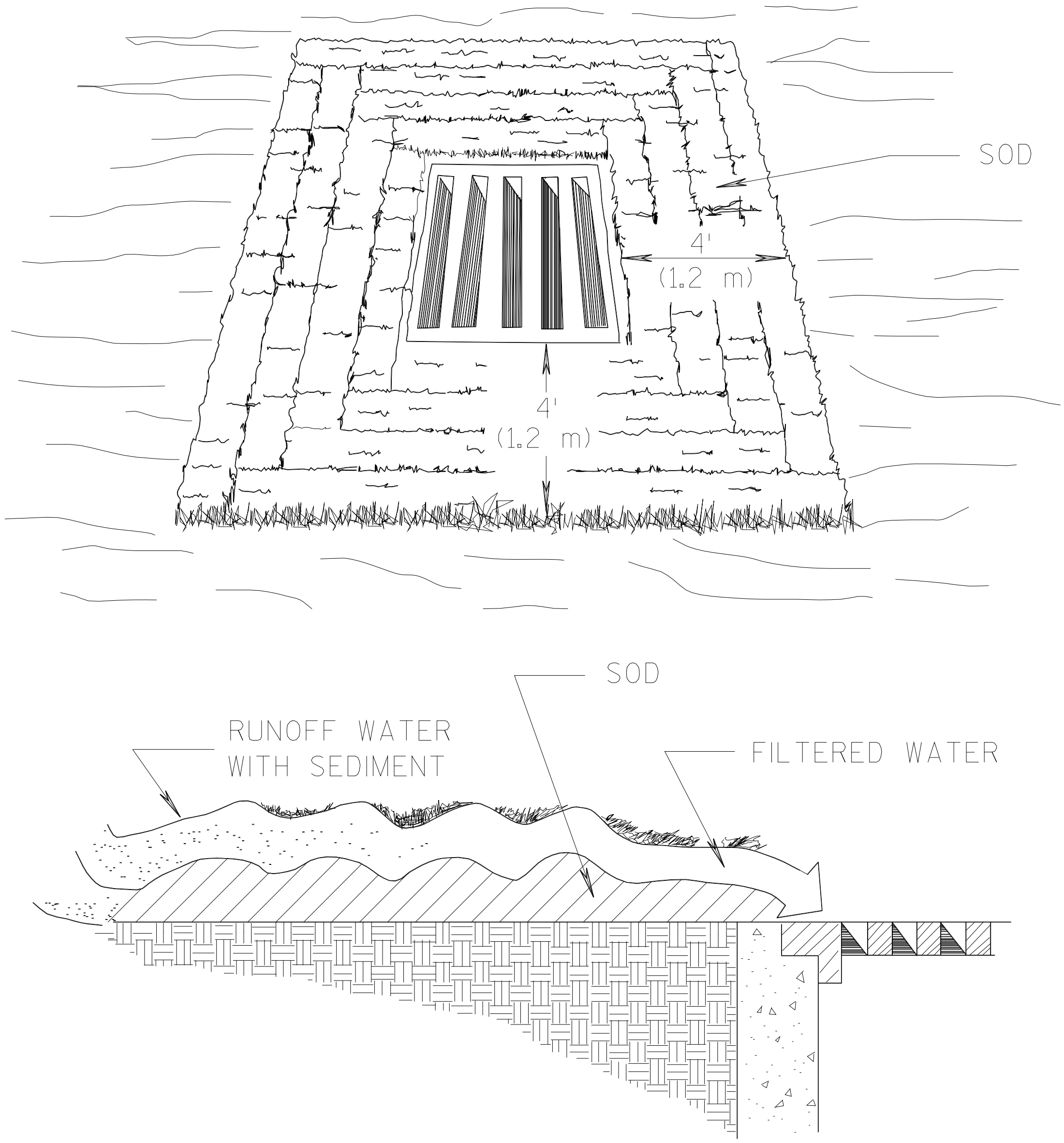
REFERENCE: SEE FDM PROCEDURE 10-10-9



SOD DETAIL FOR DITCHES

CELL NAME: SDDH

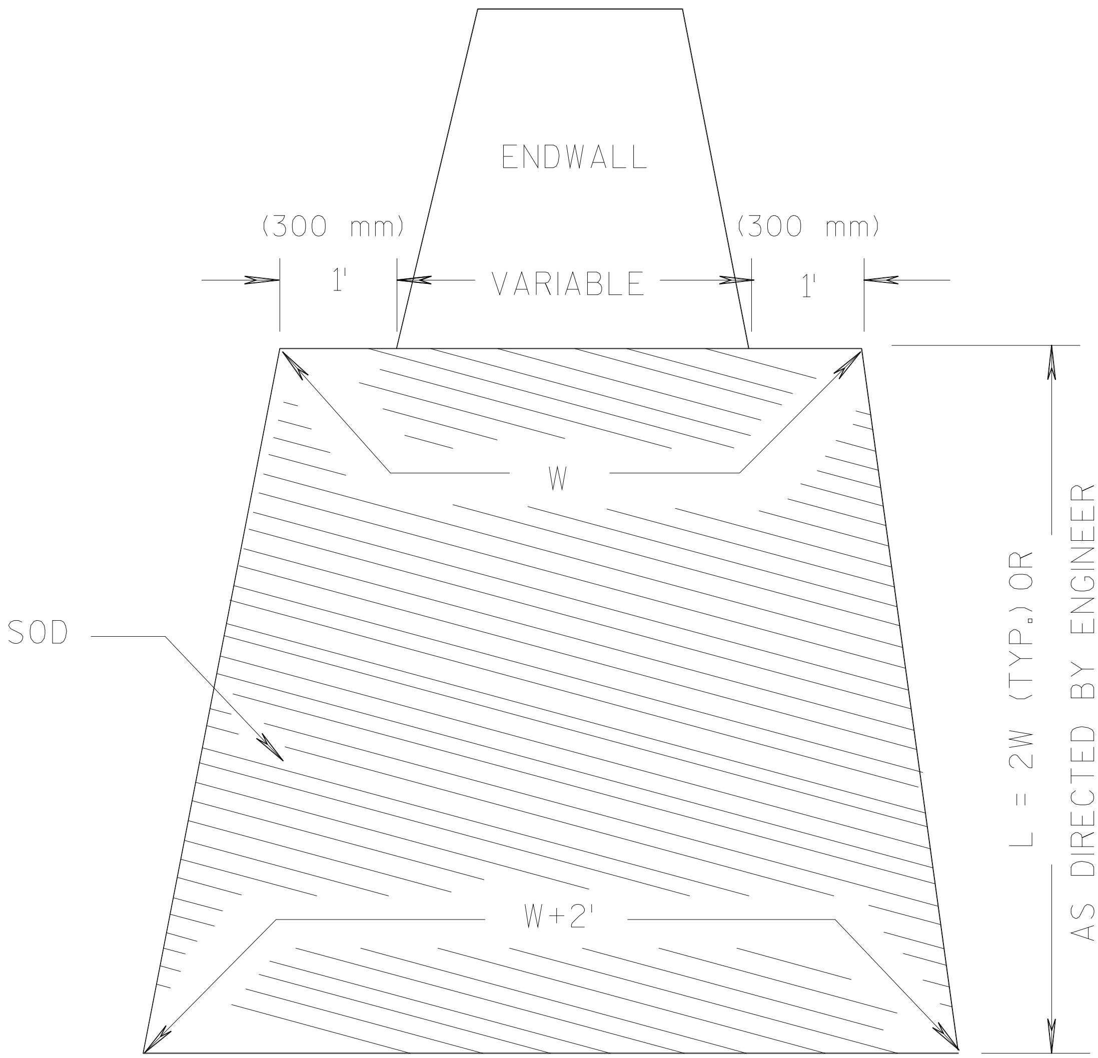
REFERENCE: SEE FDM PROCEDURE 10-10-9



SOD INLET SEDIMENT FILTER

CELL NAME: SEDFL1

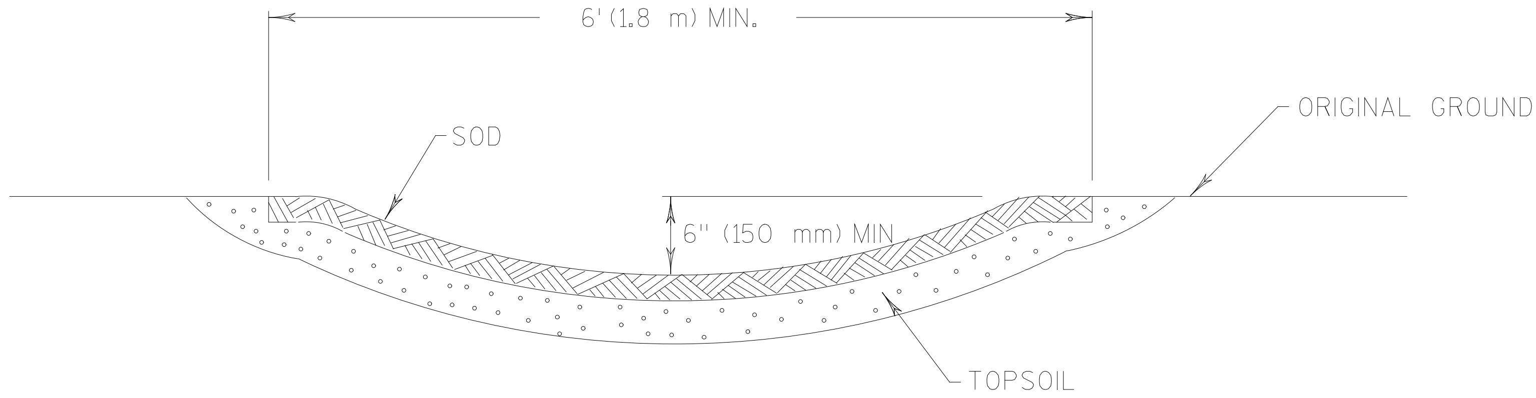
REFERENCE: SEE FDM PROCEDURES 10-10-9 and 10-10-27



SOD TREATMENT AT CULVERTS

CELL NAME: CULSD

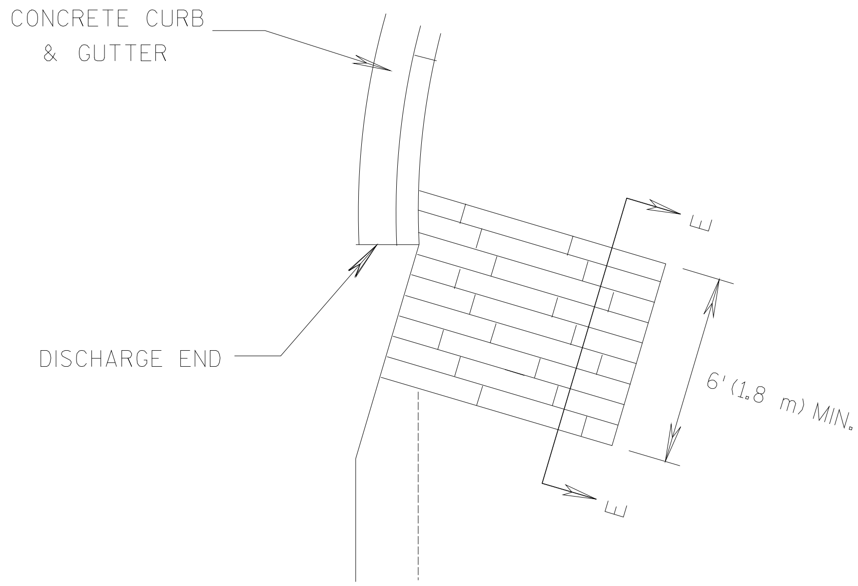
REFERENCE: SEE FDM PROCEDURES 10-10-9, 10-10-29 and 10-10-31

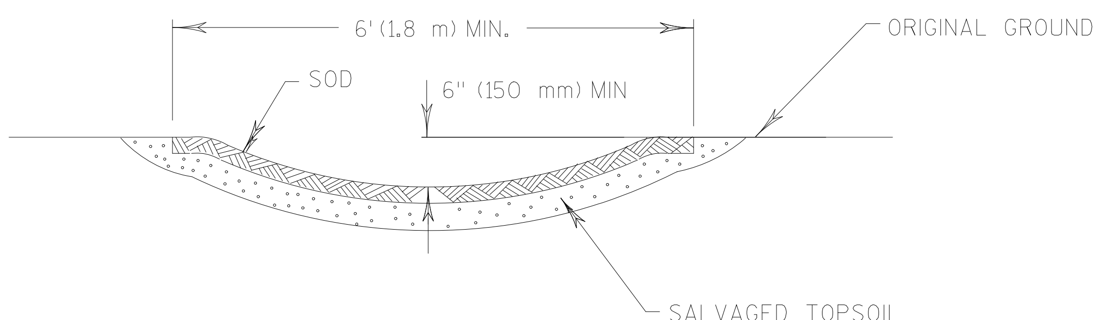


DETAIL OF SOD FLUME

CELL NAME: SDFLM1

REFERENCE: SEE FDM PROCEDURES 10-10-9, 10-10-57 and SDD 8E5-1



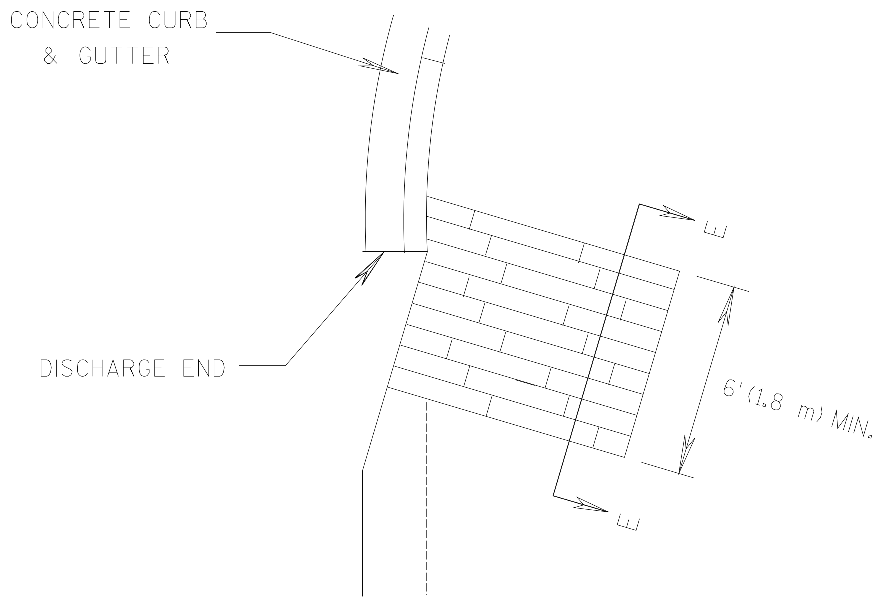


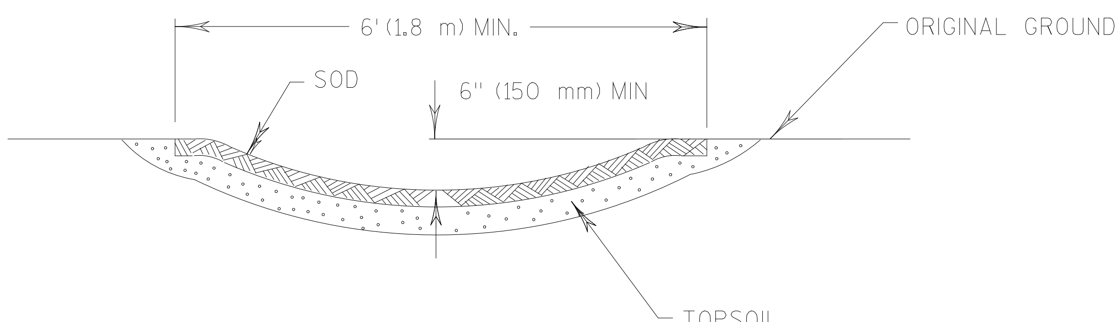
SECTION E - E

SOD FLUME DETAIL AT CURB ENDS

CELL NAME: SDFLM4

REFERENCE: SEE FDM PROCEDURES 10-10-9 and 10-10-57





SECTION E - E

SOD FLUME DETAIL AT CURB ENDS

CELL NAME: SDFLM3

REFERENCE: SEE FDM PROCEDURES 10-10-9 and 10-10-57

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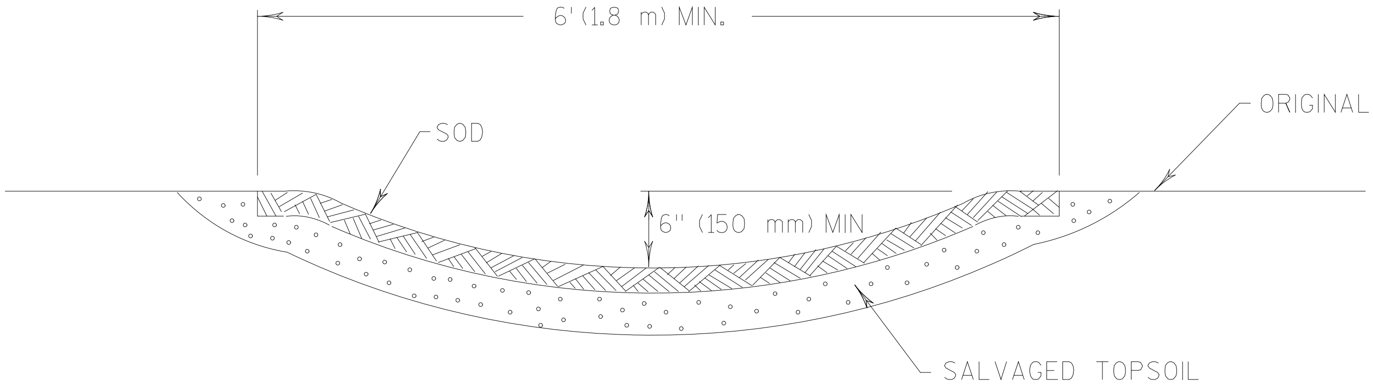
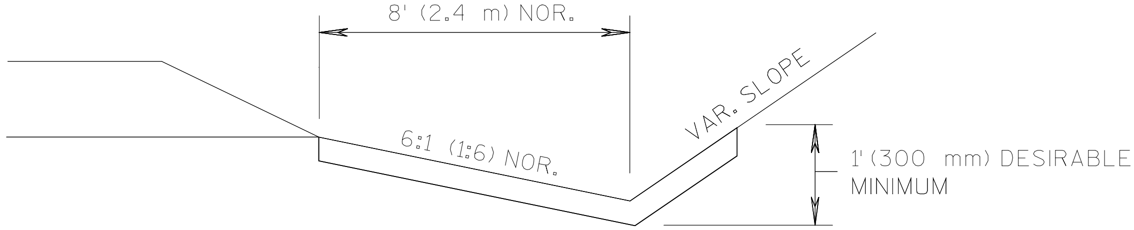


DETAIL OF SOD FLUME

CELL NAME: SDFLM2

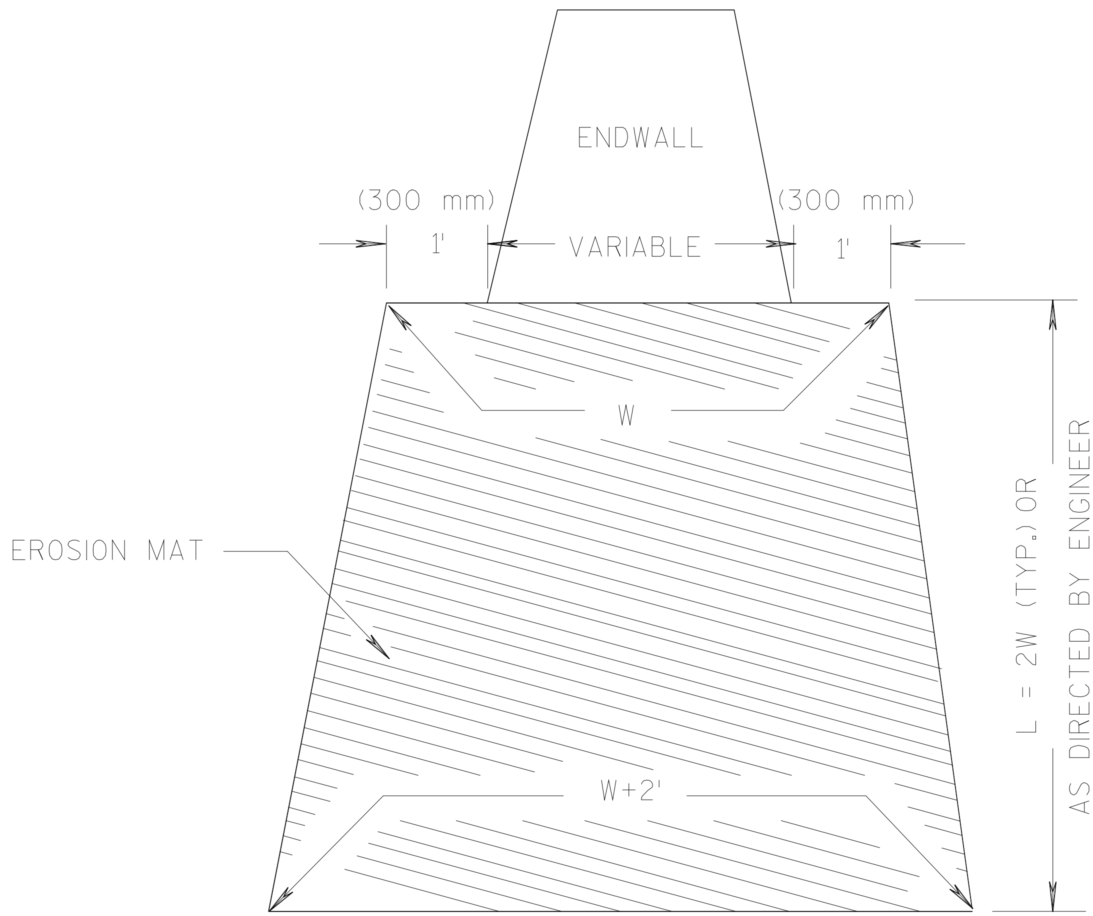
REFERENCE: SEE FDM PROCEDURES 10-10-9, 10-10-57 and SDD 8E5-1



EROSION MAT DETAIL FOR DITCHES

CELL NAME: EMDH

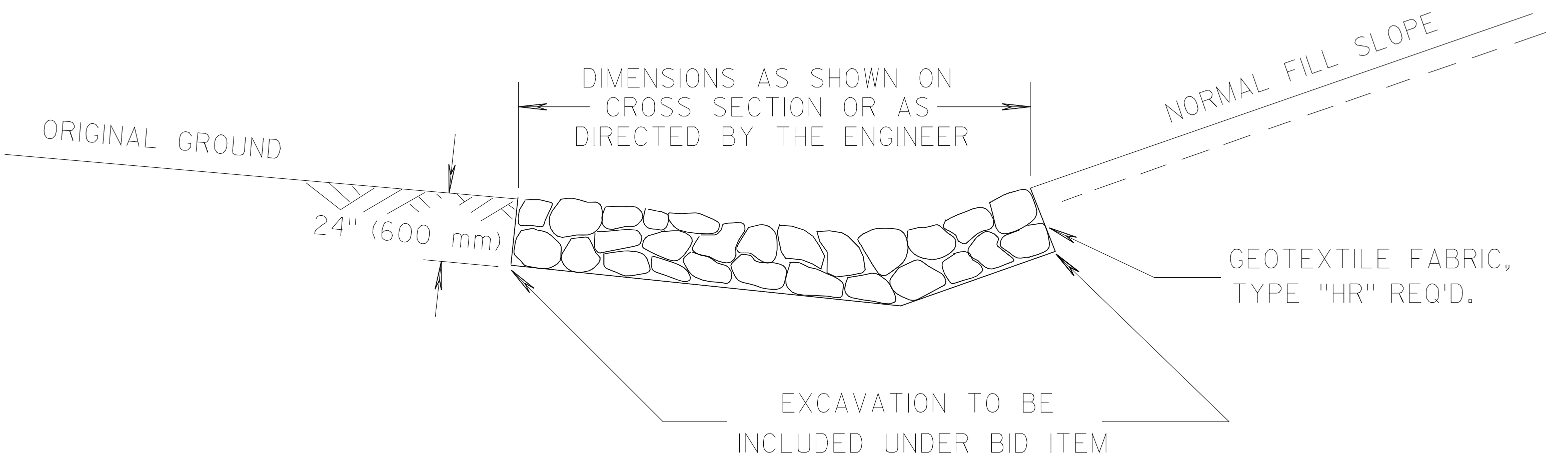
REFERENCE: SEE FDM PROCEDURE 10-10-15



EROSION MAT TREATMENT AT CULVERTS

CELL NAME: CULEM

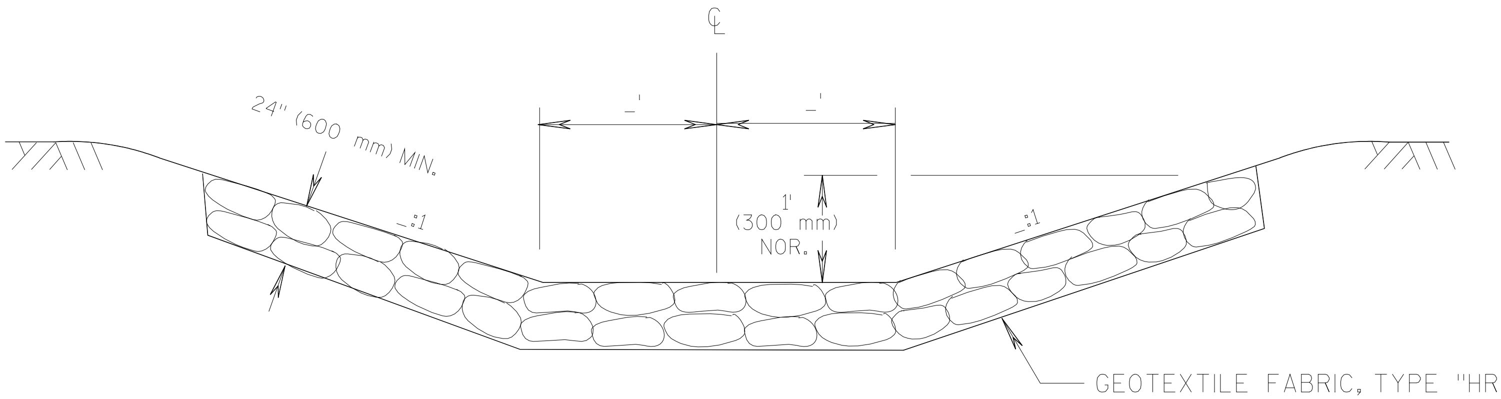
REFERENCE: SEE FDM PROCEDURES 10-10-15, 10-10-29 and 10-10-31



DETAIL FOR HEAVY RIPRAP IN DITCHES

CELL NAME: RIPRP3

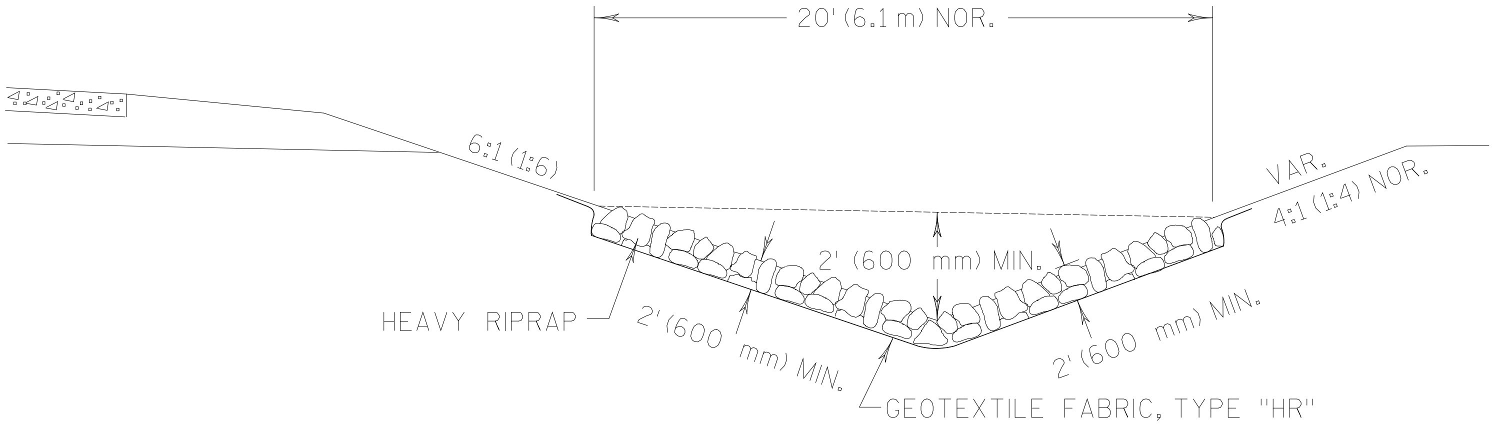
REFERENCE: SEE FDM PROCEDURE 10-10-19



DETAIL FOR SPECIAL DITCH WITH HEAVY RIPRAP AND GEOTEXTILE FABRIC

CELL NAME: SPDH3

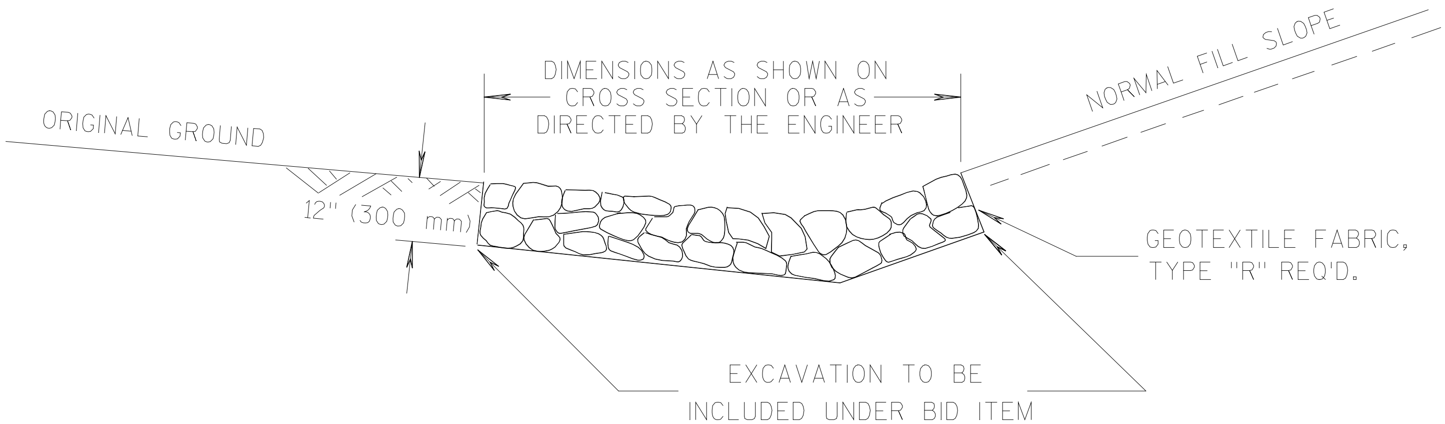
REFERENCE: SEE FDM PROCEDURE 10-10-19



DETAIL OF HEAVY RIPRAP DITCH

CELL NAME: RIPRP4

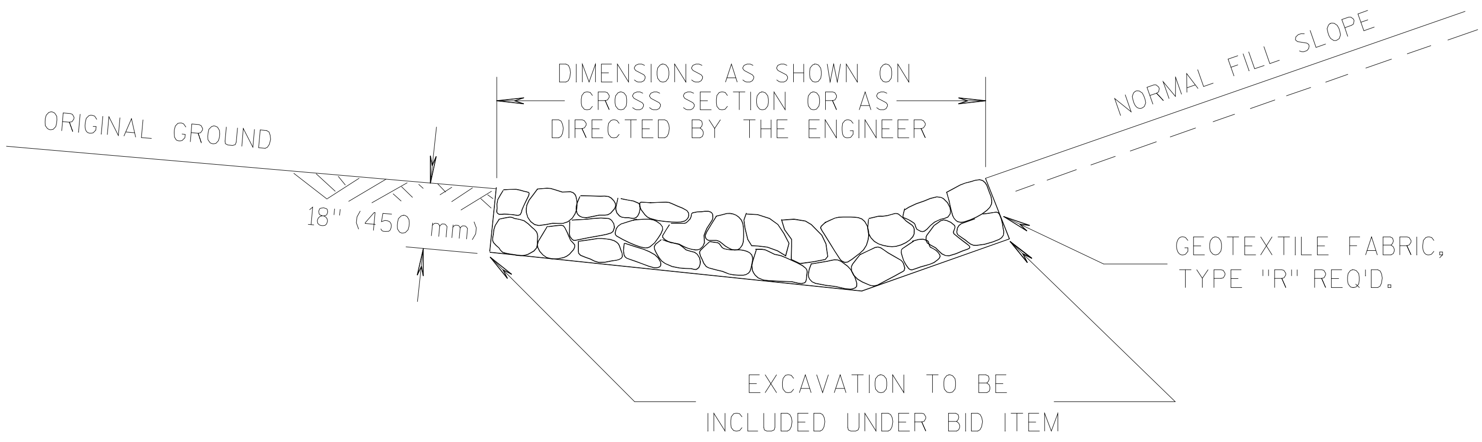
REFERENCE: SEE FDM PROCEDURE 10-10-19



DETAIL FOR RIPRAP IN DITCHES

CELL NAME: RIPRP1

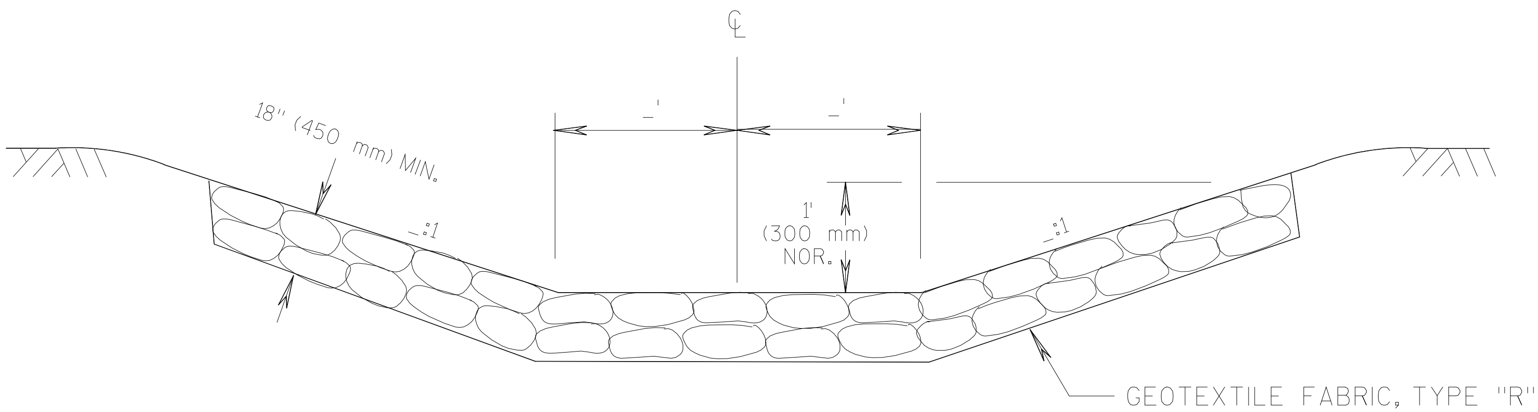
REFERENCE: SEE FDM PROCEDURE 10-10-19



DETAIL FOR MEDIUM RANDOM RIPRAP IN DITCHES

CELL NAME: RIPRP2

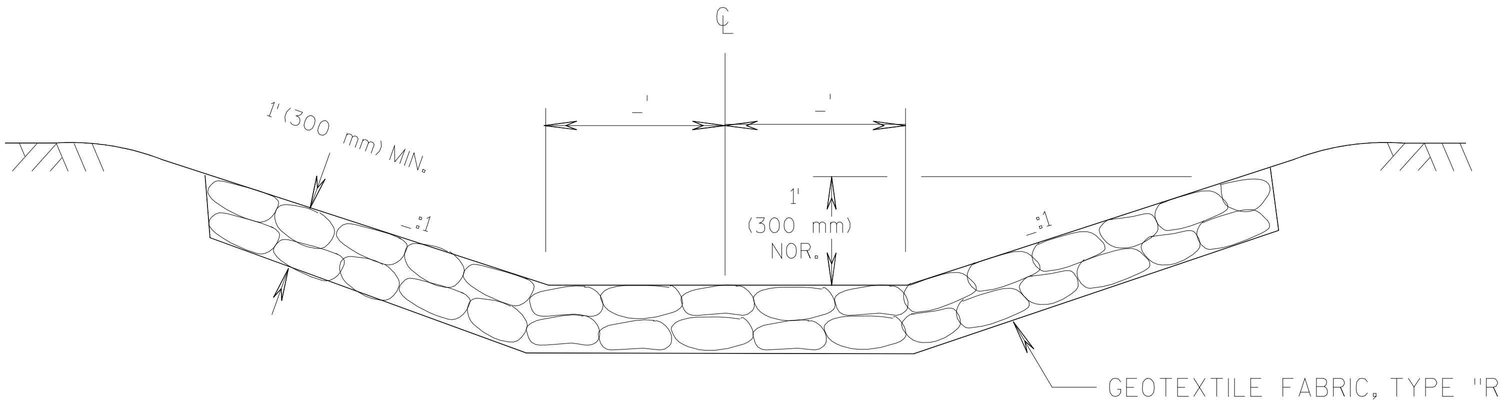
REFERENCE: SEE FDM PROCEDURE 10-10-19



DETAIL FOR SPECIAL DITCH WITH MEDIUM RANDOM RIPRAP AND GEOTEXTILE FABRIC

CELL NAME: SPDH2

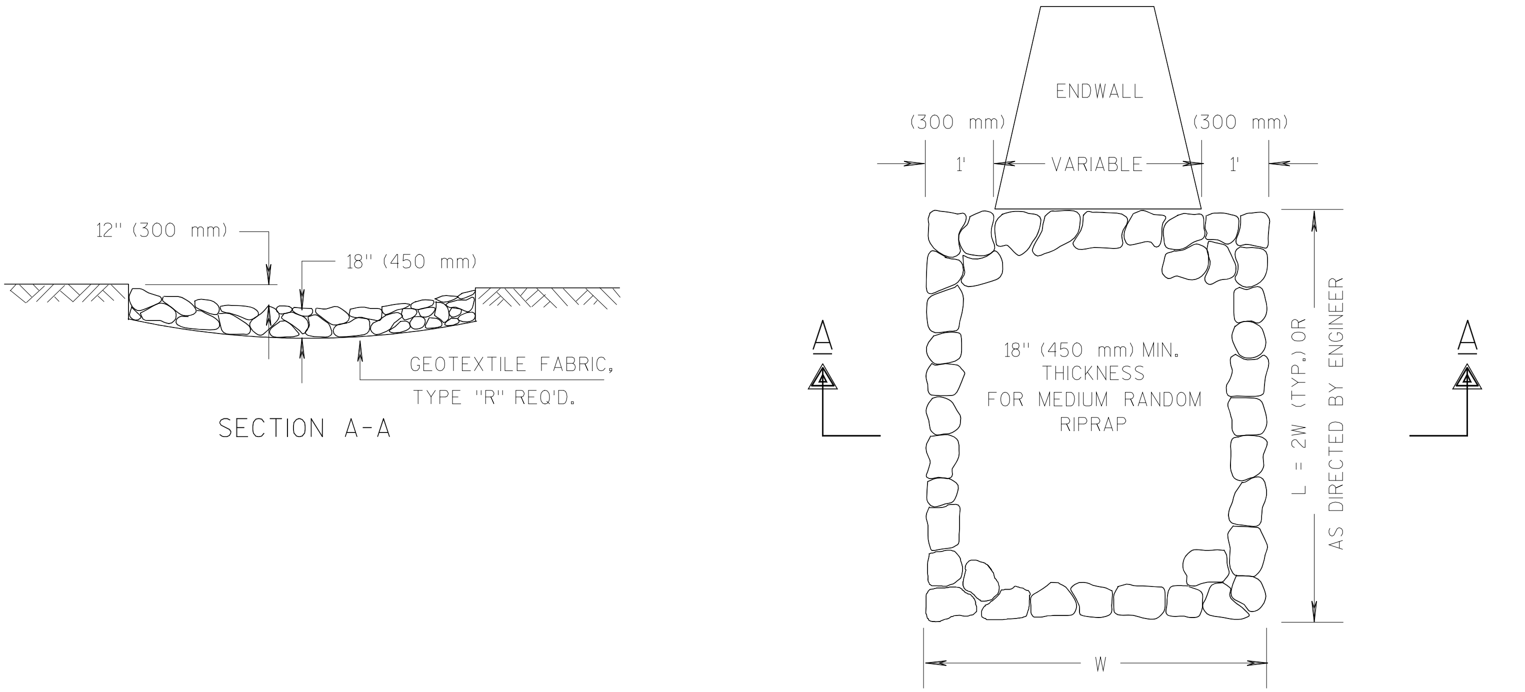
REFERENCE: SEE FDM PROCEDURE 10-10-19



DETAIL FOR SPECIAL DITCH WITH RIPRAP AND GEOTEXTILE FABRIC

CELL NAME: SPDH1

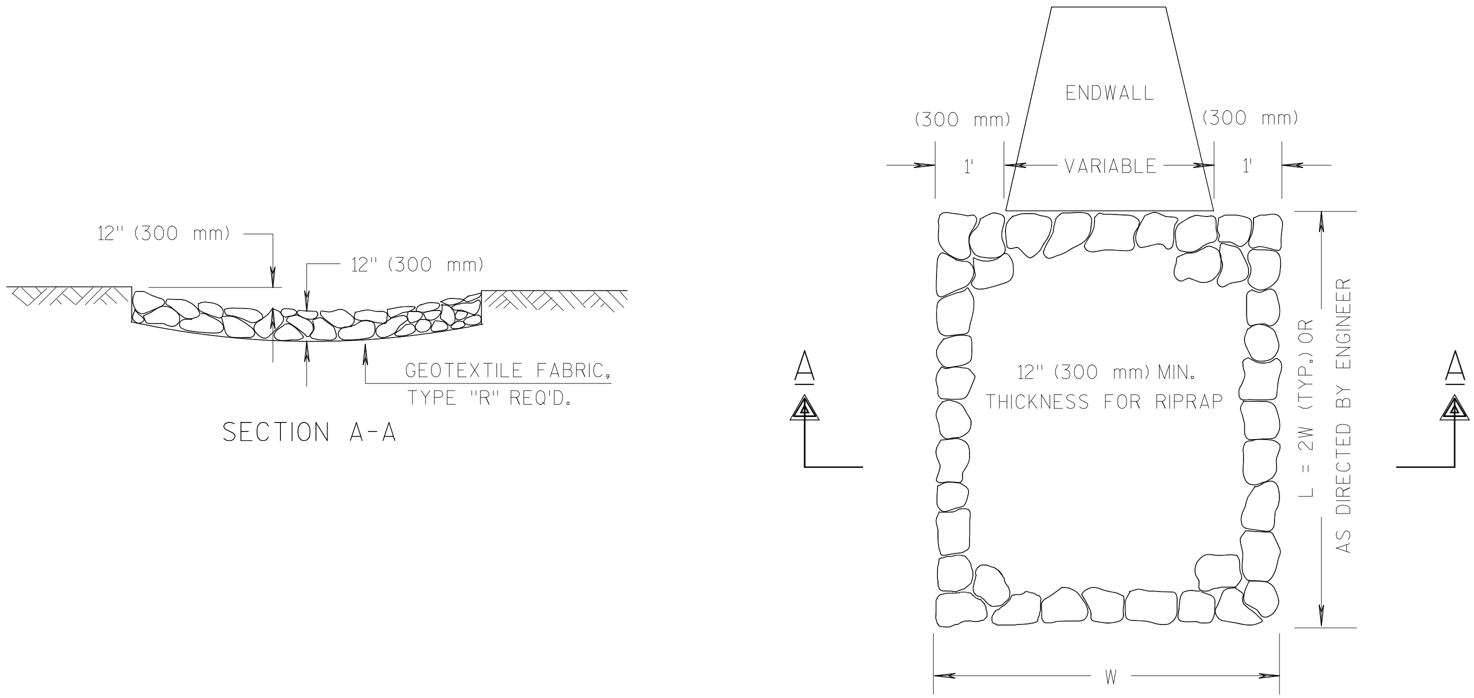
REFERENCE: SEE FDM PROCEDURE 10-10-19



MEDIUM RANDOM RIPRAP TREATMENT AT CULVERTS

CELL NAME: CULRP2

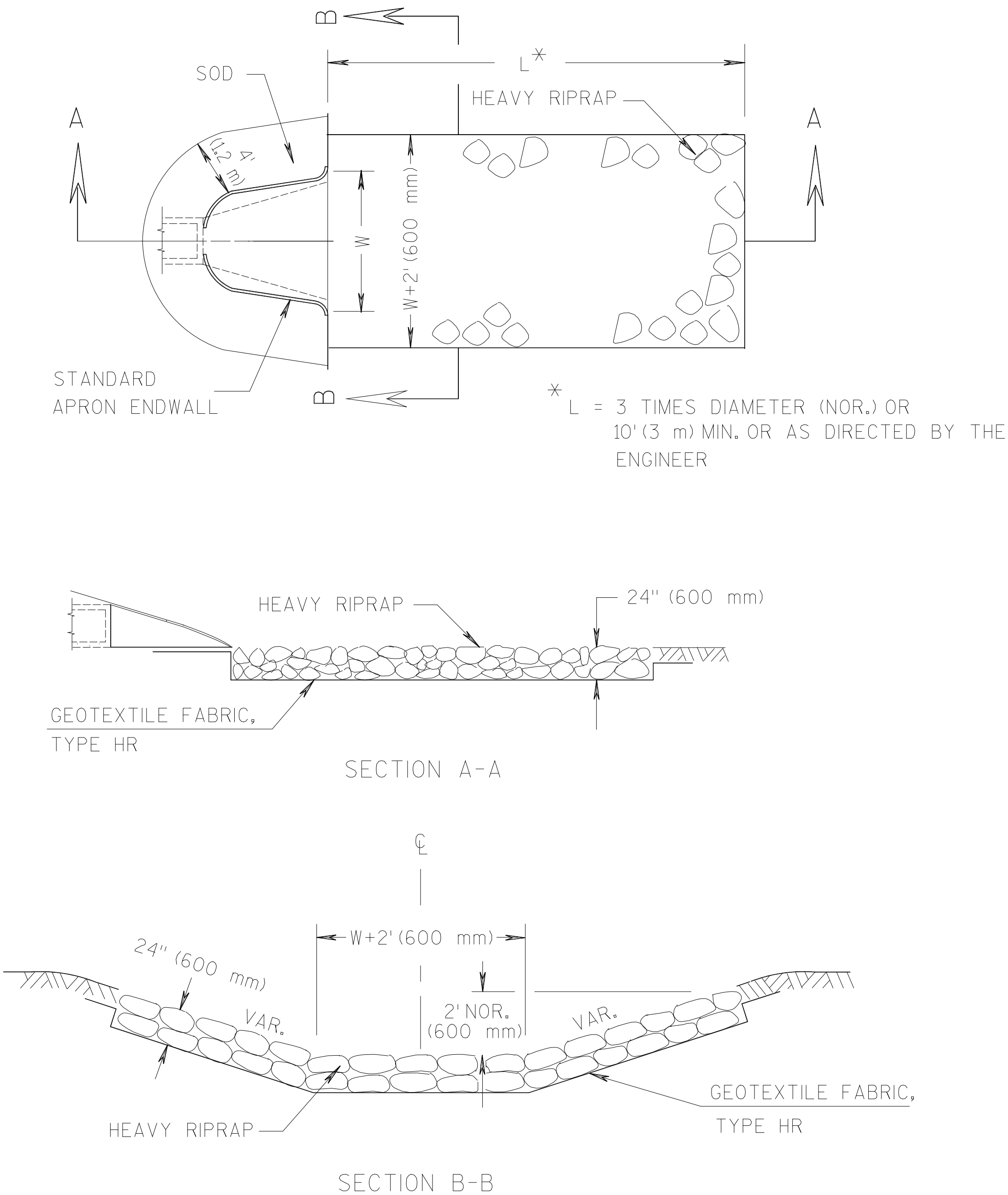
REFERENCE: SEE FDM PROCEDURES 10-10-19, 10-10-29 and 10-10-31



RIPRAP TREATMENT AT CULVERTS

CELL NAME: CULRP1

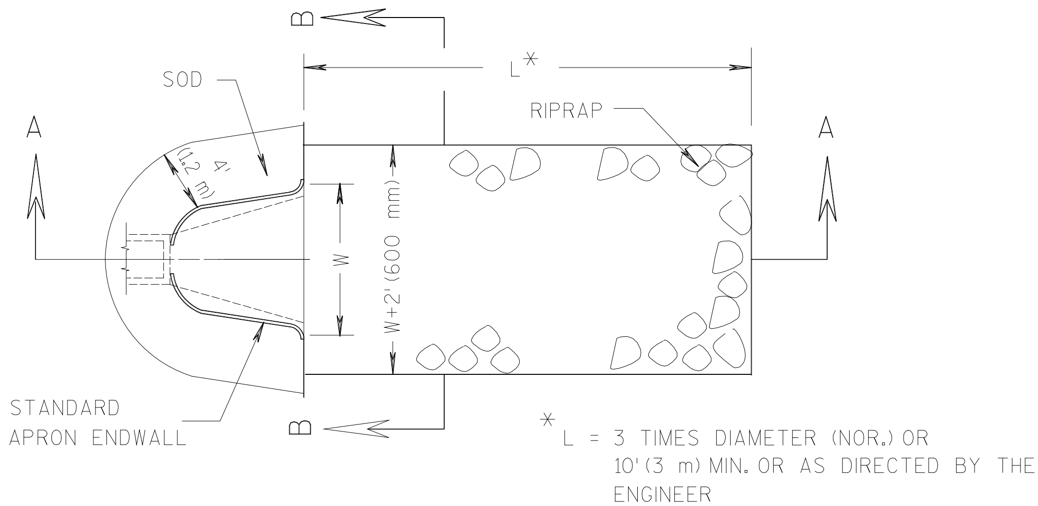
REFERENCE: SEE FDM PROCEDURES 10-10-19, 10-10-29 and 10-10-31

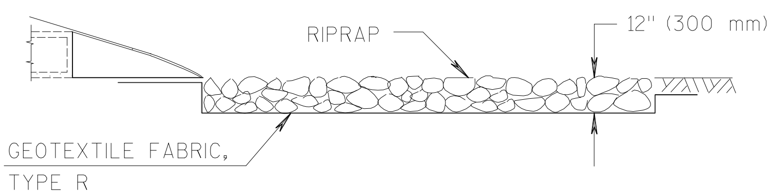


SOD, HEAVY RIPRAP AND GEOTEXTILE FABRIC
DETAIL AT APRON ENDWALLS

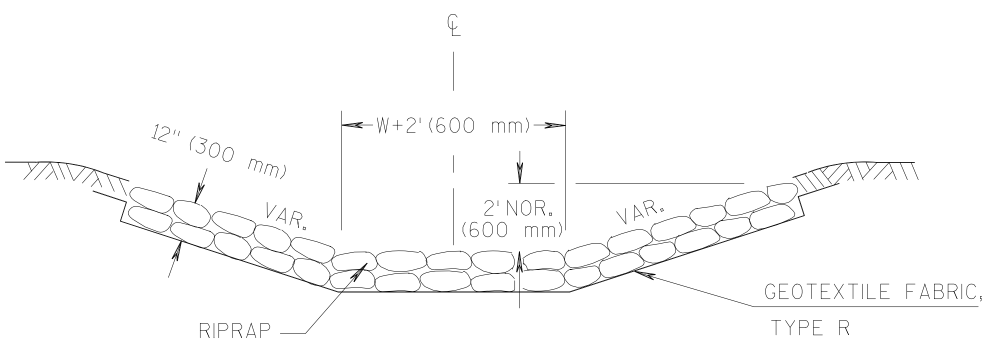
CELL NAME: APNEW3

REFERENCE: SEE FDM PROCEDURES 10-10-19, 10-10-29 and 10-10-31





SECTION A-A

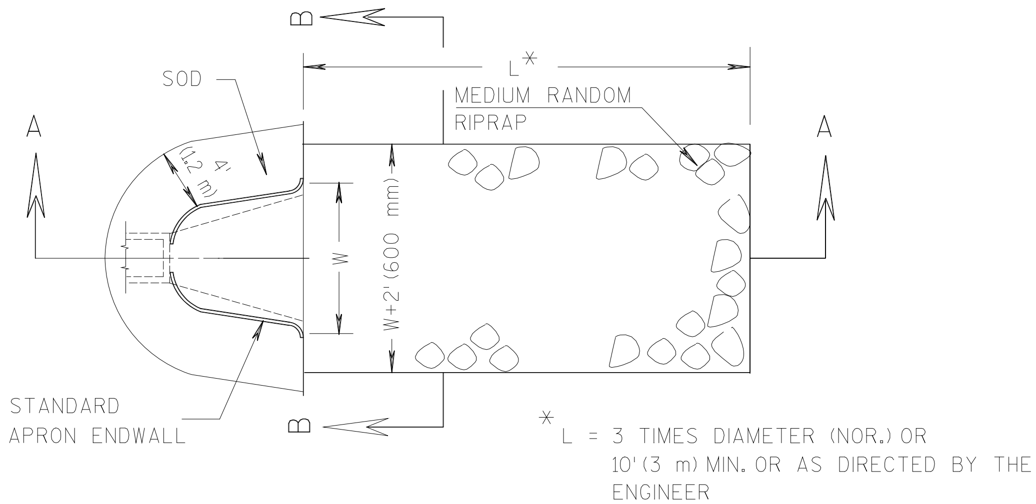


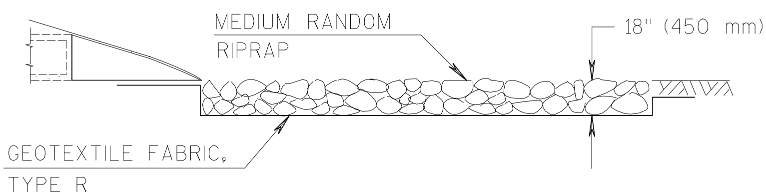
SECTION B-B

SOD, RIPRAP AND GEOTEXTILE FABRIC DETAIL
AT APRON ENDWALLS

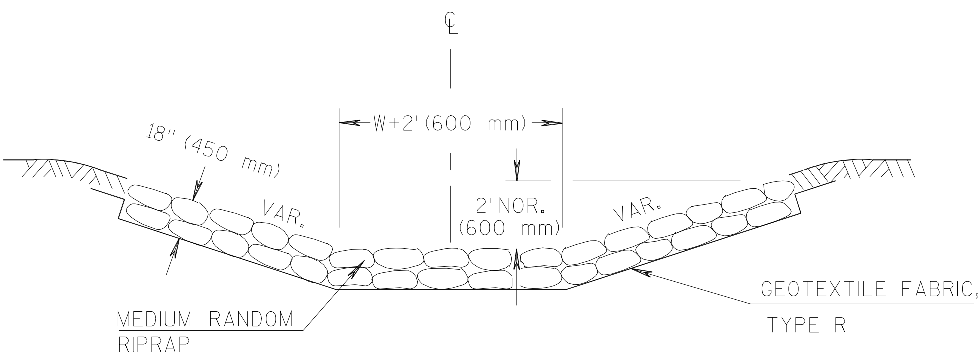
CELL NAME: APNEW1

REFERENCE: SEE FDM PROCEDURES 10-10-19, 10-10-29 and 10-10-31





SECTION A-A



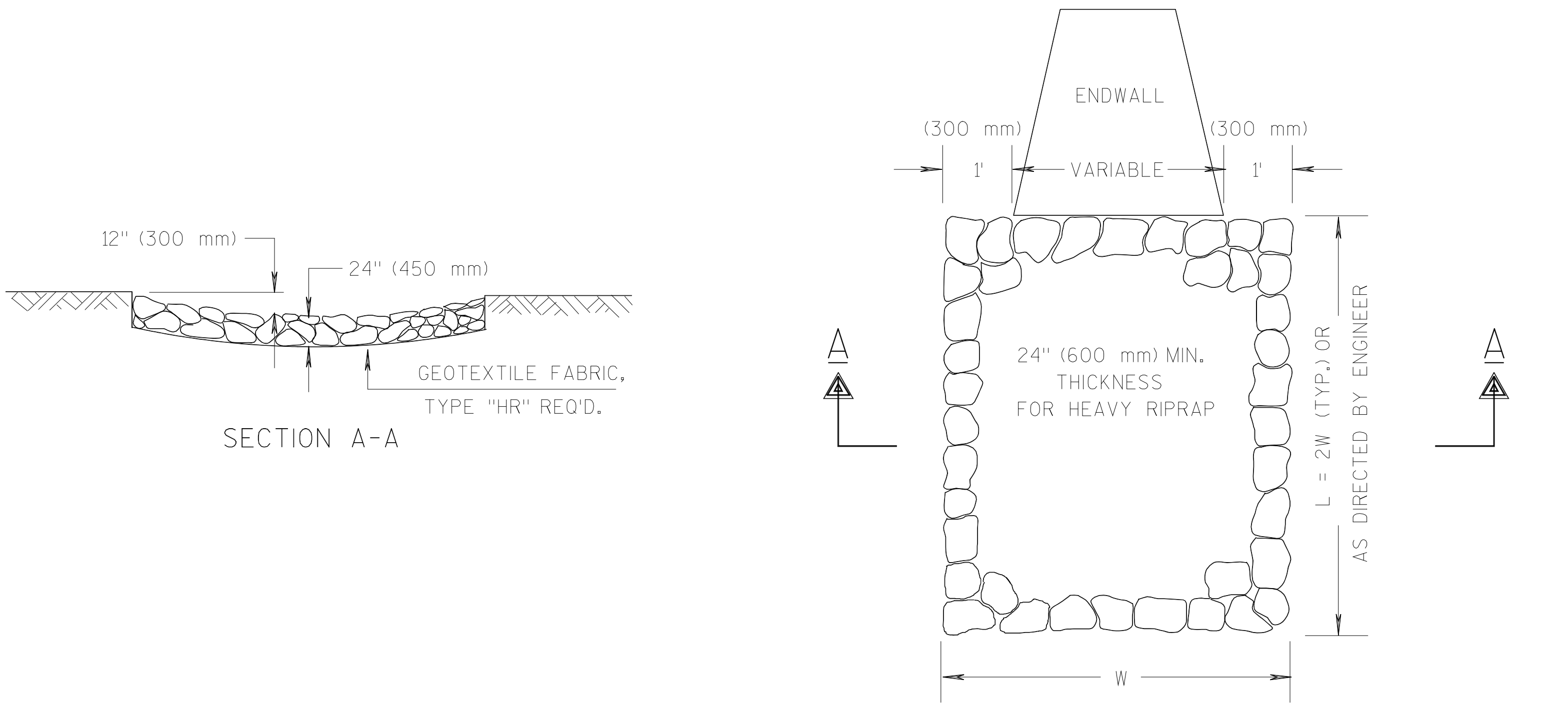
SECTION B-B

SOD, MEDIUM RANDOM RIPRAP AND GEOTEXTILE FABRIC

DETAIL AT APRON ENDWALLS

CELL NAME: APNEW2

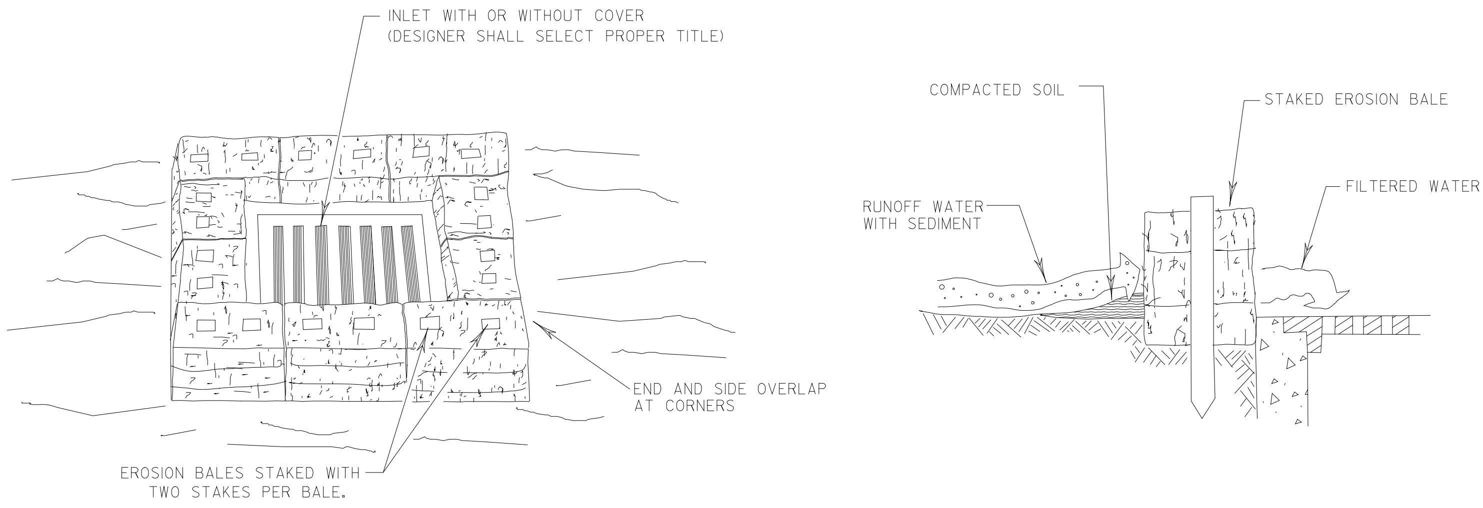
REFERENCE: SEE FDM PROCEDURES 10-10-19, 10-10-29 and 10-10-31



HEAVY RIPRAP TREATMENT AT CULVERTS

CELL NAME: CULRP3

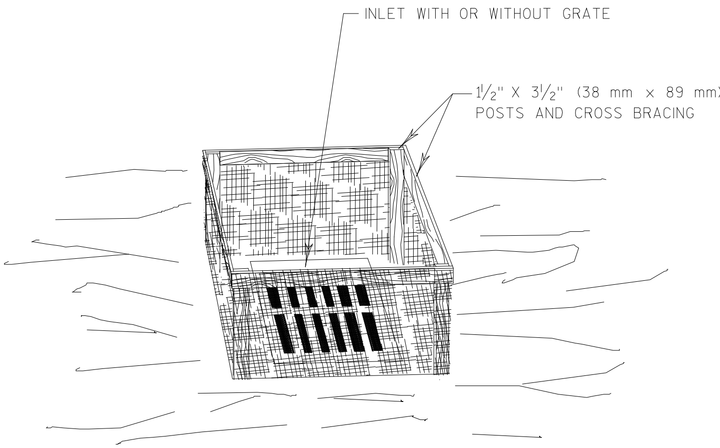
REFERENCE: SEE FDM PROCEDURES 10-10-19, 10-10-29 and 10-10-31



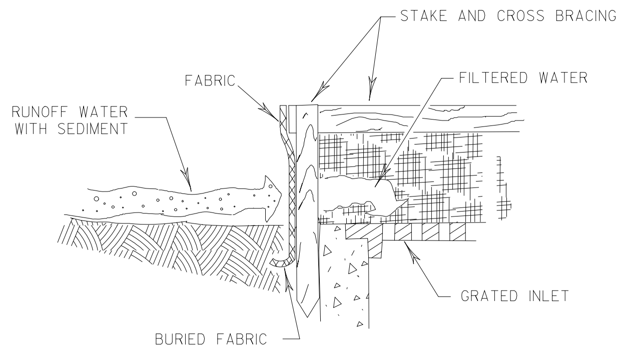
EROSION BALE INLET SEDIMENT BARRIER

CELL NAME: EBSEBR

REFERENCE: SEE FDM PROCEDURES 10-10-21 and 10-10-27



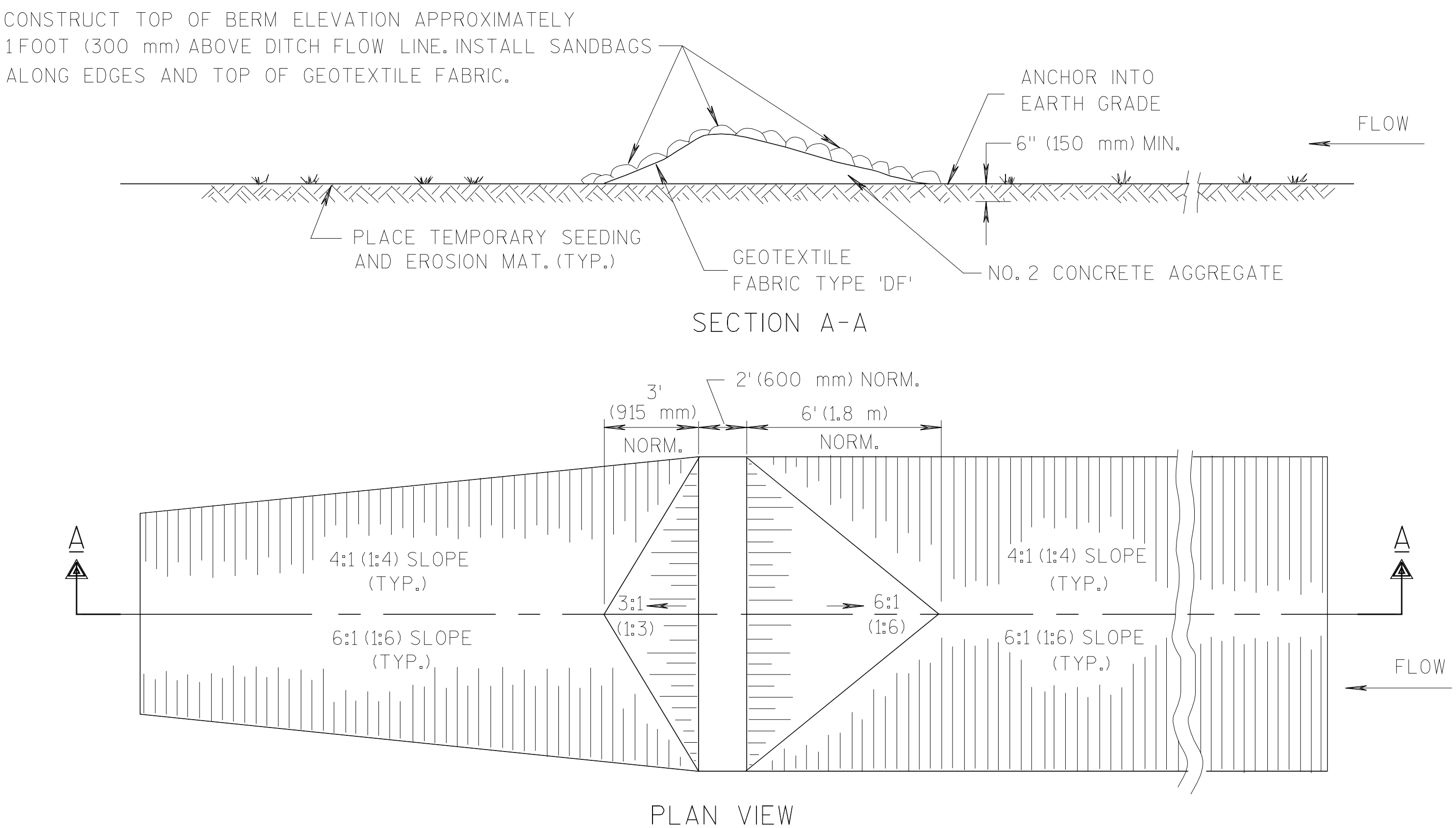
NOTE: ATTACH FABRIC TO THE TOP OF POSTS AND CROSS BRACINGS.



SILT FENCE INLET SEDIMENT BARRIER

CELL NAME: SEDBR3

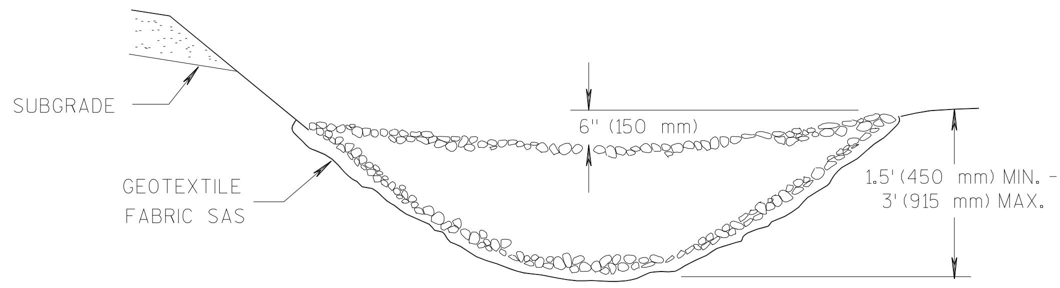
REFERENCE: SEE FDM PROCEDURES 10-10-23 and 10-10-27



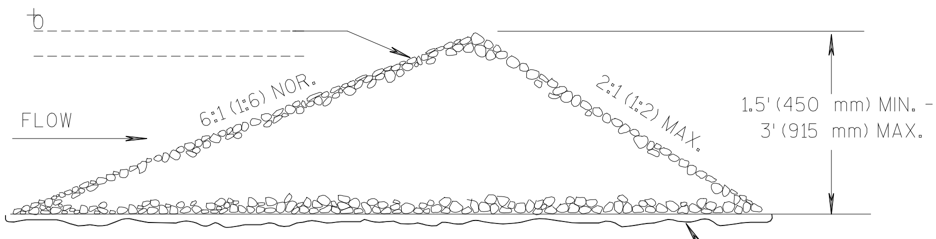
FILTER BERM

CELL NAME: FLBRM

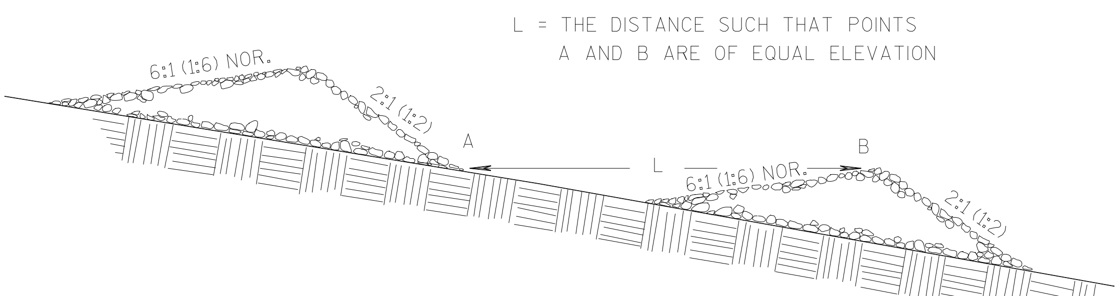
REFERENCE: SEE FDM PROCEDURE 10-10-25



CROSS SECTIONAL VIEW



SIDE VIEW

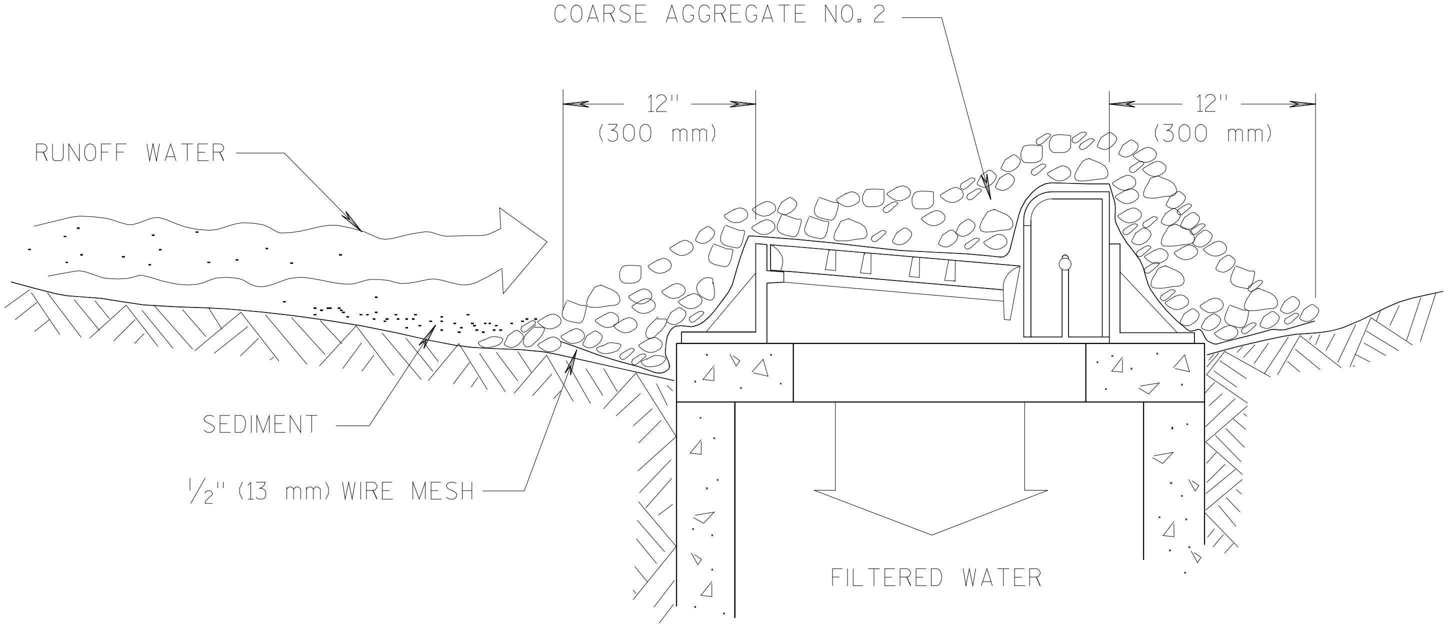


SIDE VIEW

PERMANENT STONE DITCH CHECK

CELL NAME: PSDHCK

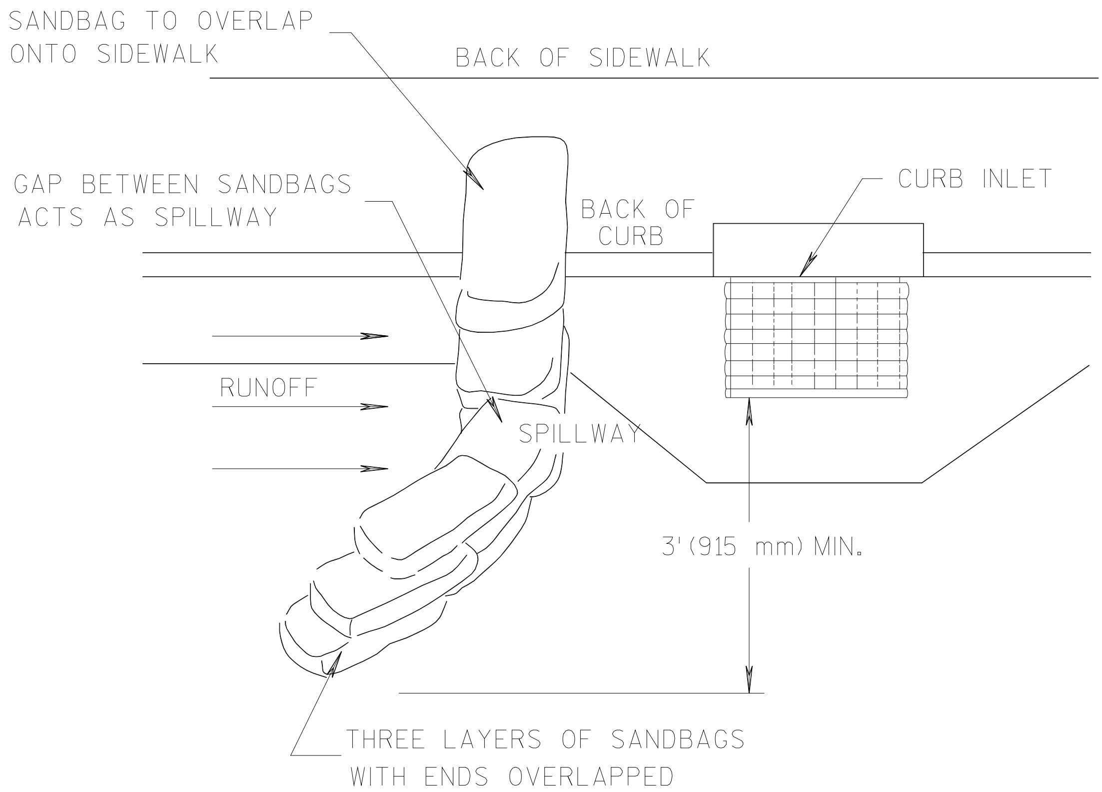
REFERENCE: SEE FDM PROCEDURE 10-10-25



COARSE AGGREGATE SEDIMENT FILTER FOR INLETS

CELL NAME: SEDFL3

REFERENCE: SEE FDM PROCEDURE 10-10-27

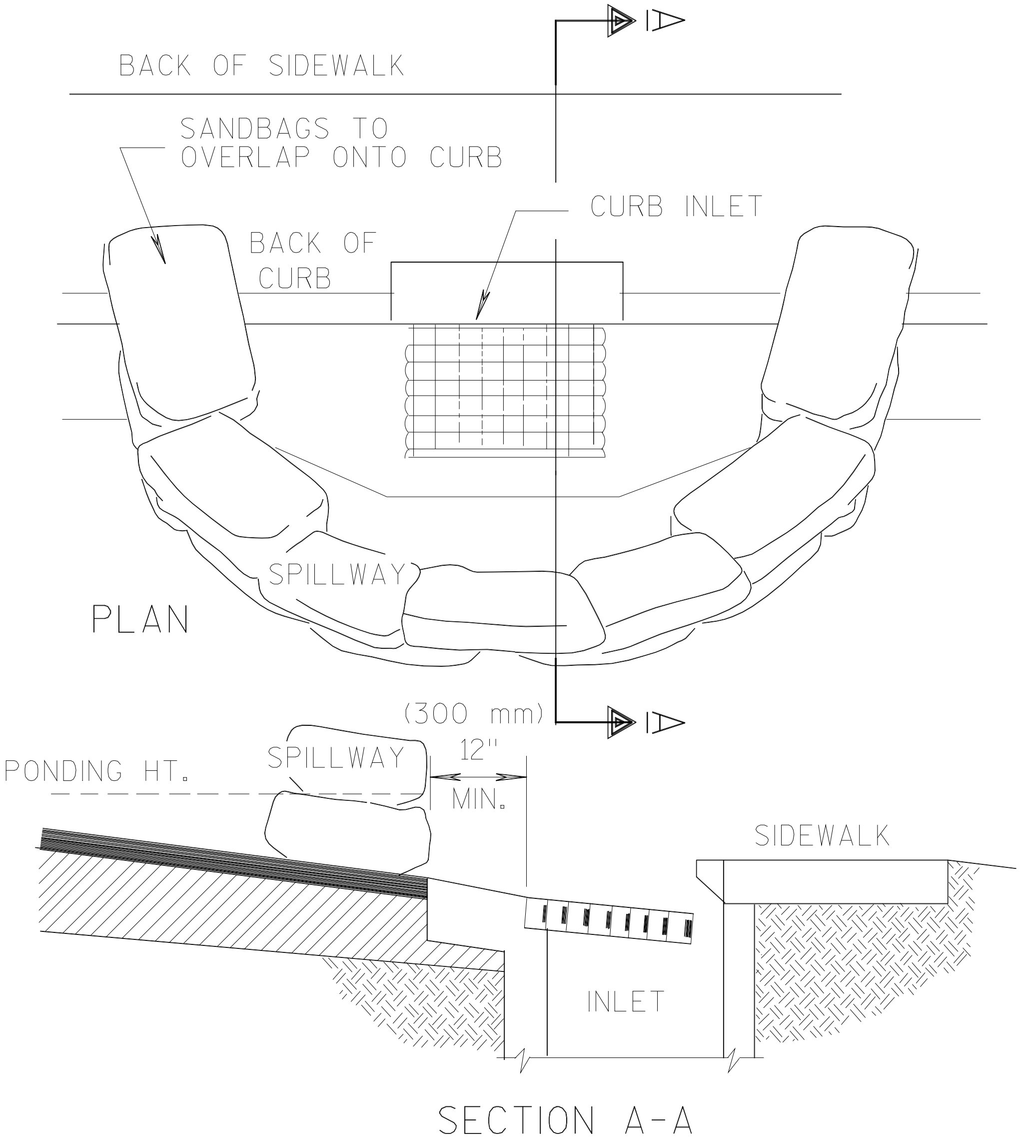


CURB INLET SEDIMENT BARRIER

(SANDBAG TYPE)

CELL NAME: SEDBR1

REFERENCE: SEE FDM PROCEDURE 10-10-27

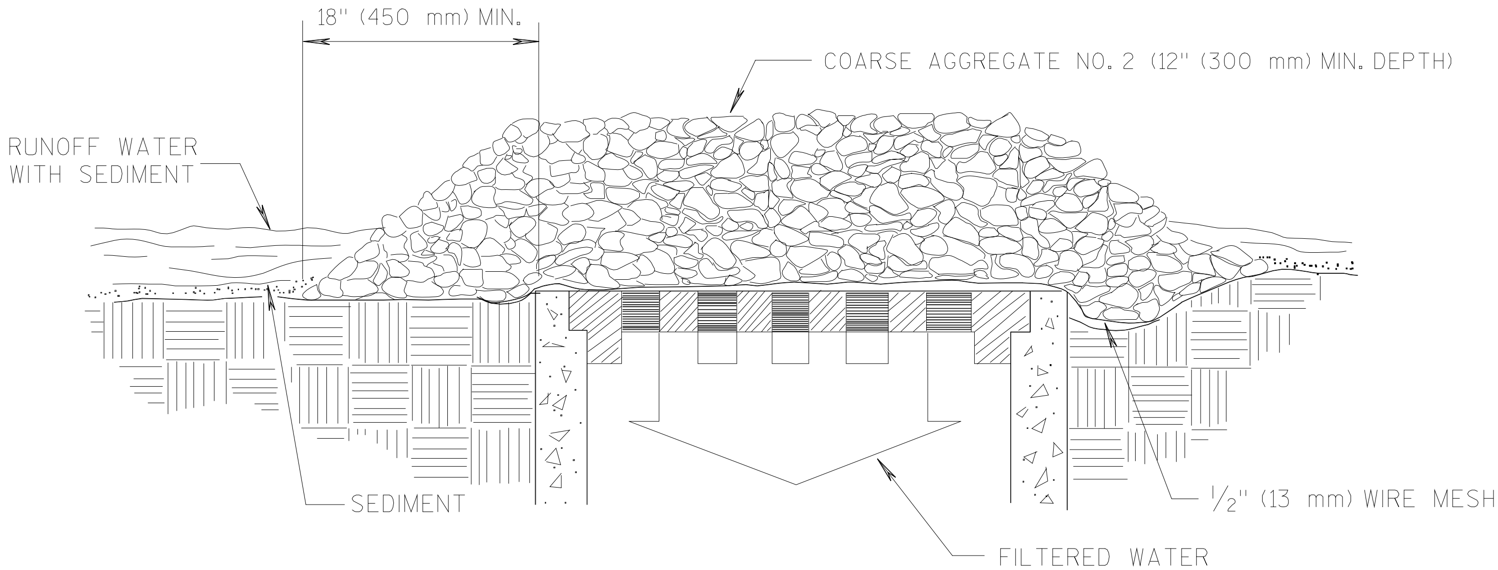


CURB INLET SEDIMENT BARRIER

(SANDBAG TYPE)

CELL NAME: SEDBR2

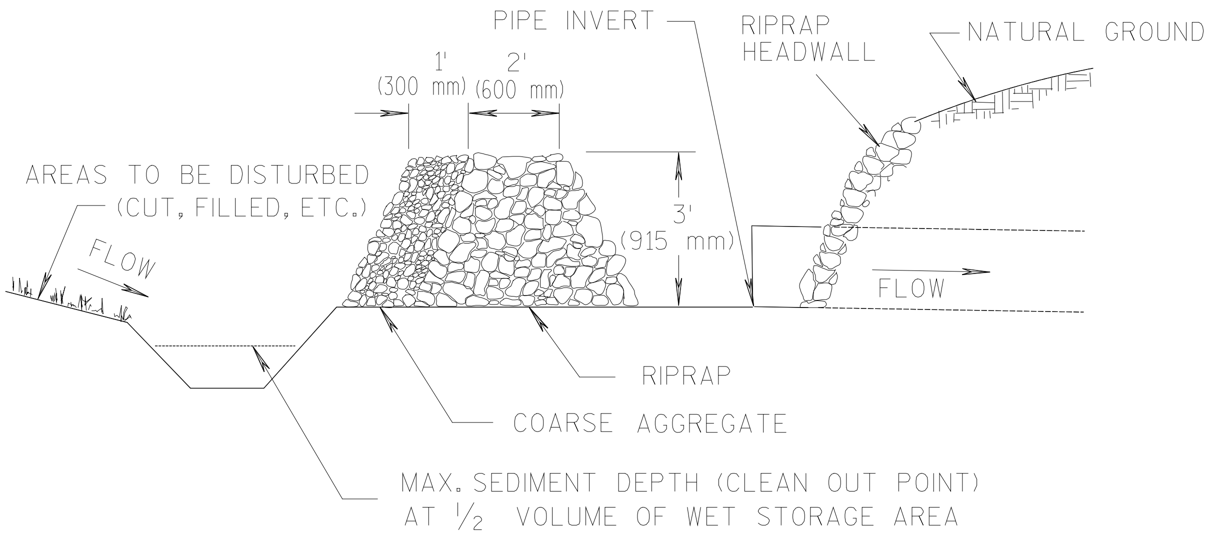
REFERENCE: SEE FDM PROCEDURE 10-10-27



COARSE AGGREGATE SEDIMENT FILTER FOR DROP INLETS

CELL NAME: SEDFL2

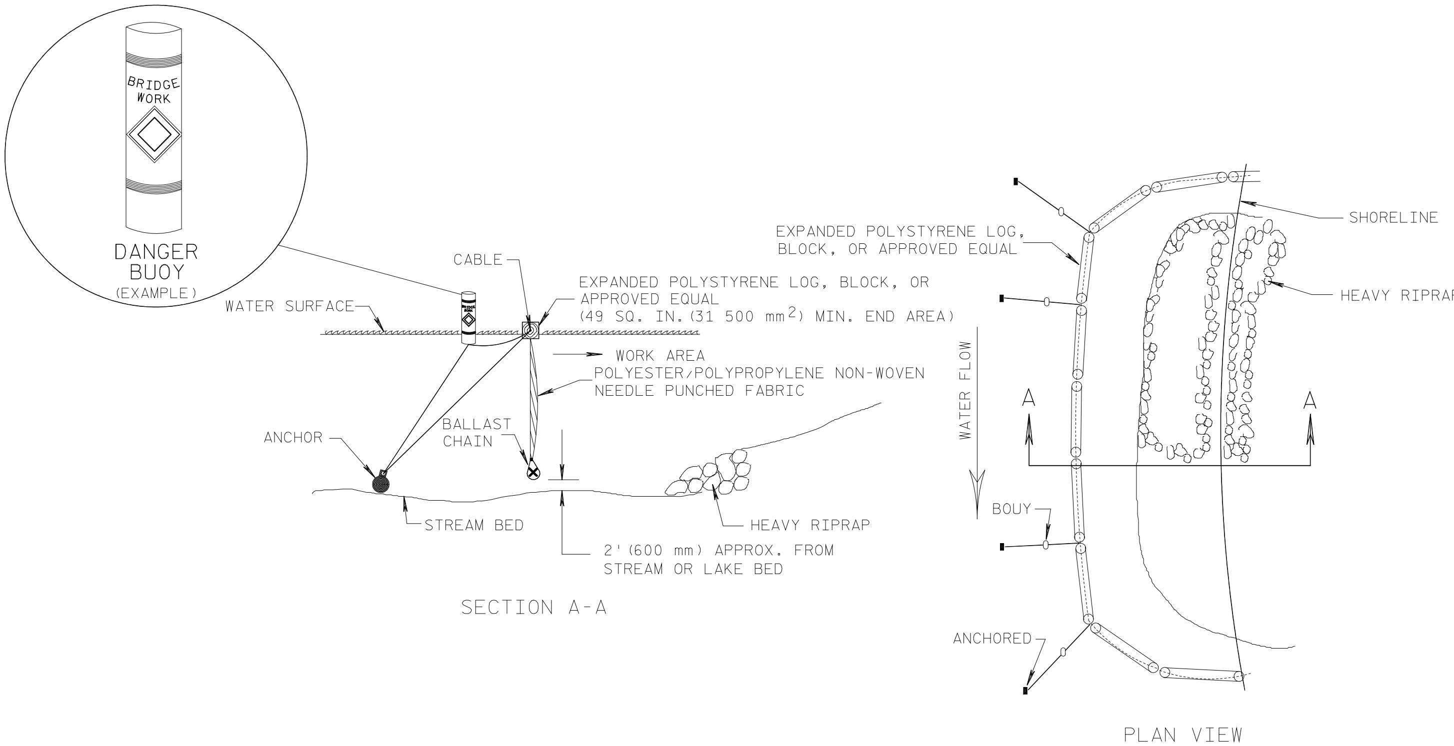
REFERENCE: SEE FDM PROCEDURE 10-10-27



CULVERT INLET SEDIMENT TRAP

CELL NAME: SEDTP2

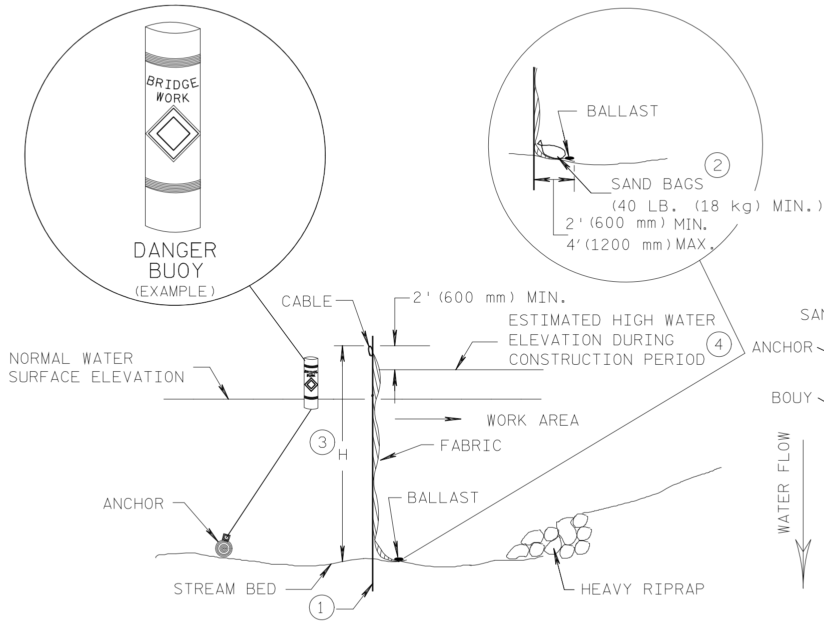
REFERENCE: SEE FDM PROCEDURES 10-10-29 and 10-10-51



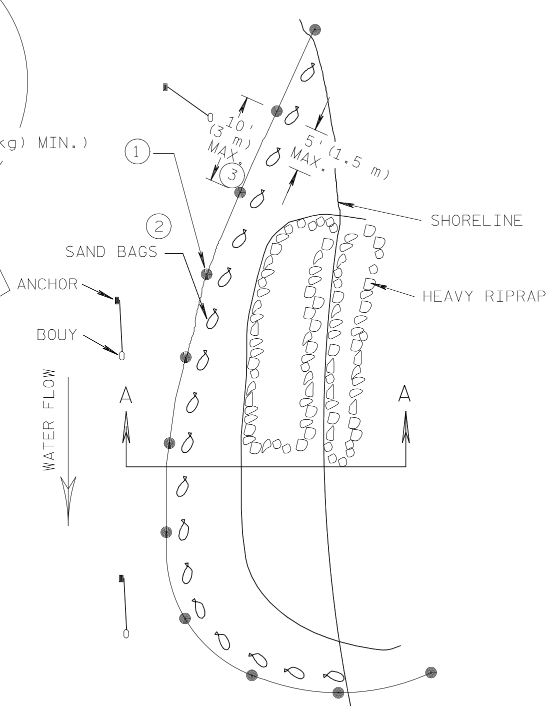
SILT SCREEN DETAIL

CELL NAME: SLTSCN

REFERENCE: SEE FDM PROCEDURE 10-10-43



SECTION A-A



PLAN VIEW

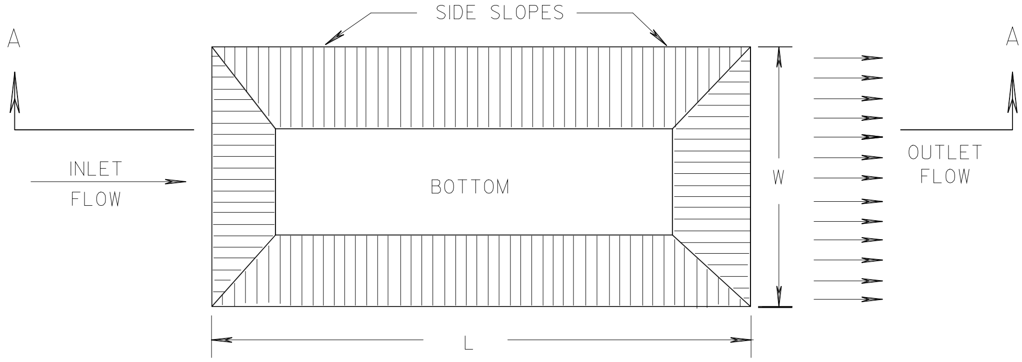
NOTES:

1. DRIVEN STEEL POSTS, PIPES, OR CHANNELS. LENGTH SHALL BE SUFFICIENT TO SECURELY SUPPORT BARRIER AT HIGH WATER ELEVATIONS.
2. SANDBAGS TO BE USED AS ADDITIONAL BALLAST WHEN ORDERED BY THE ENGINEER TO MEET ADVERSE FIELD CONDITIONS.
3. WHEN BARRIER HEIGHT, H, EXCEEDS 8 FT.(2.4 m), POST SPACING MAY NEED TO BE DECREASED.
4. ELEVATION VALUE TO BE ESTABLISHED BY THE CONTRACTOR BASED ON THE TIME OF YEAR AND DURATION OF THE ACTIVITY.

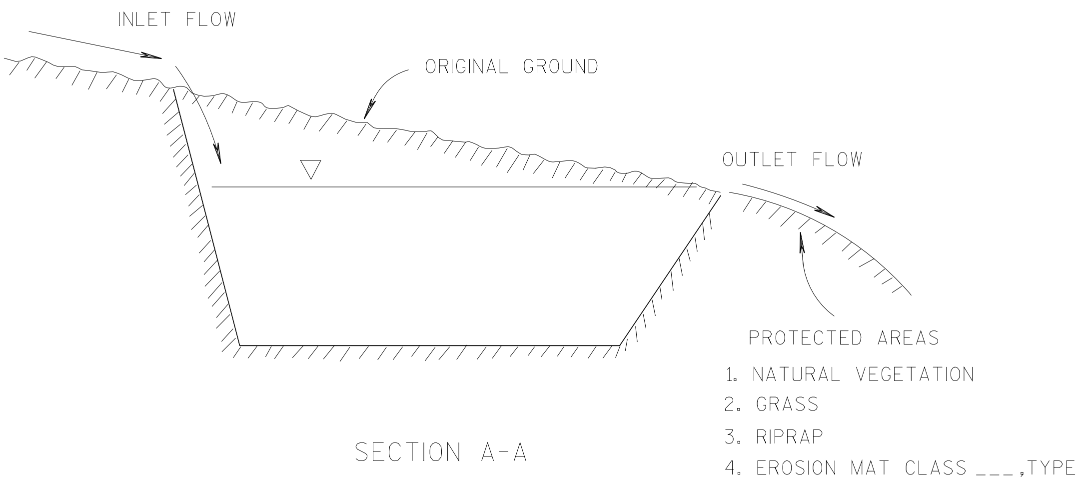
TURBIDITY BARRIER DETAIL

CELL NAME: TURBBR

REFERENCE: SEE FDM PROCEDURE 10-10-45



PLAN VIEW

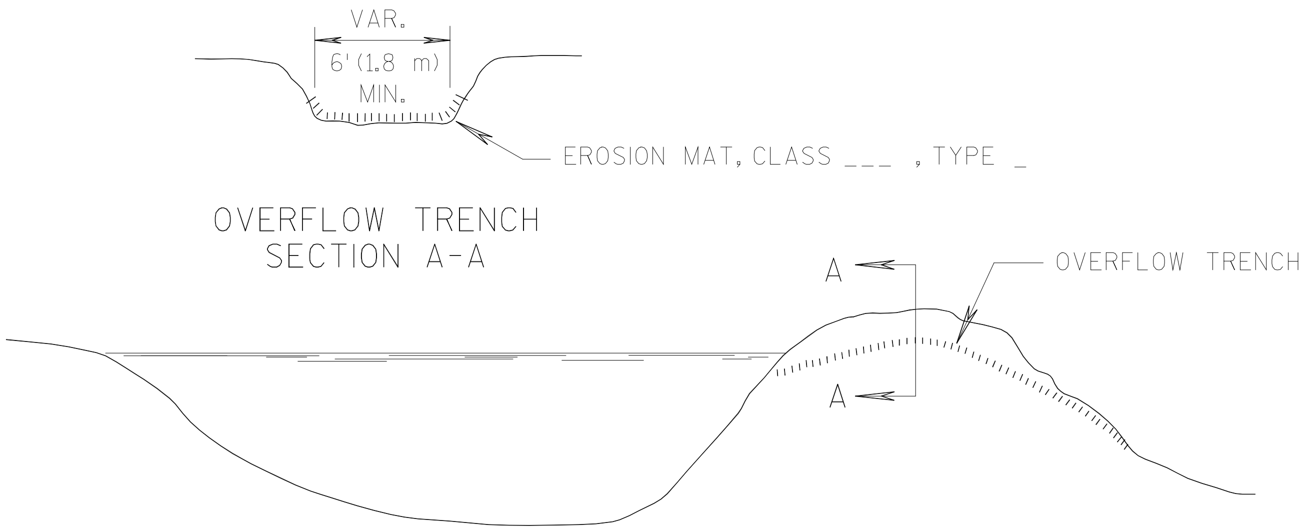


SECTION A-A

TYPICAL EXCAVATED SEDIMENT TRAP

CELL NAME: SEDTP1

REFERENCE: SEE FDM PROCEDURE 10-10-51



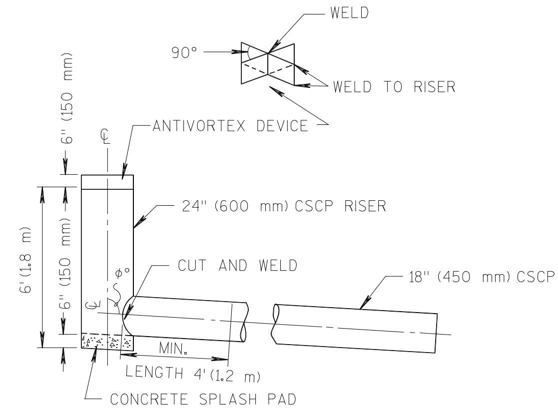
NOTE: EXCAVATION AND BACKFILL FOR SEDIMENT BASIN TO BE PAID FOR UNDER "UNCLASSIFIED EXCAVATION" ITEM. (EXACT DIMENSIONS TO BE AS DIRECTED BY THE ENGINEER.)

CLEANING OF SEDIMENT BASINS, WHEN DIRECTED BY THE ENGINEER, IS PAID FOR UNDER THE ITEM OF "CLEANING SEDIMENT BASINS" (C.Y.)

SEDIMENT BASIN AND OUTLET DETAIL

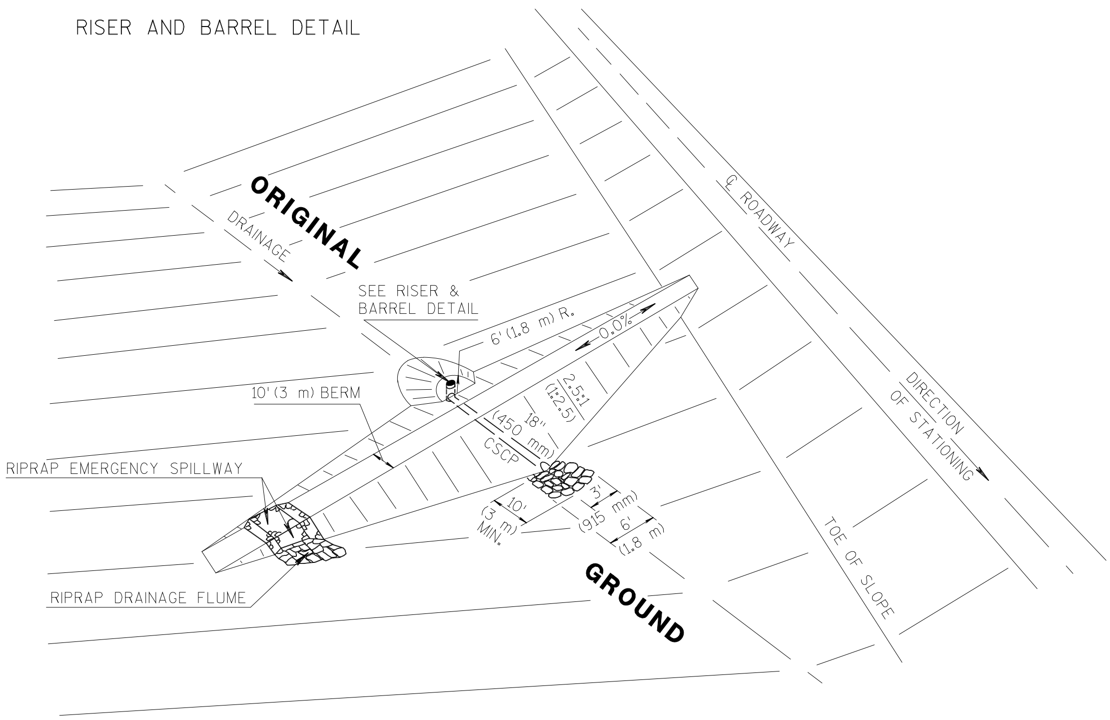
CELL NAME: SEBSN

REFERENCE: SEE FDM PROCEDURE 10-10-51



φ°=90° + PIPE SLOPE. PIPE SLOPE TO BE DETERMINED BY THE ENGINEER IN THE FIELD.

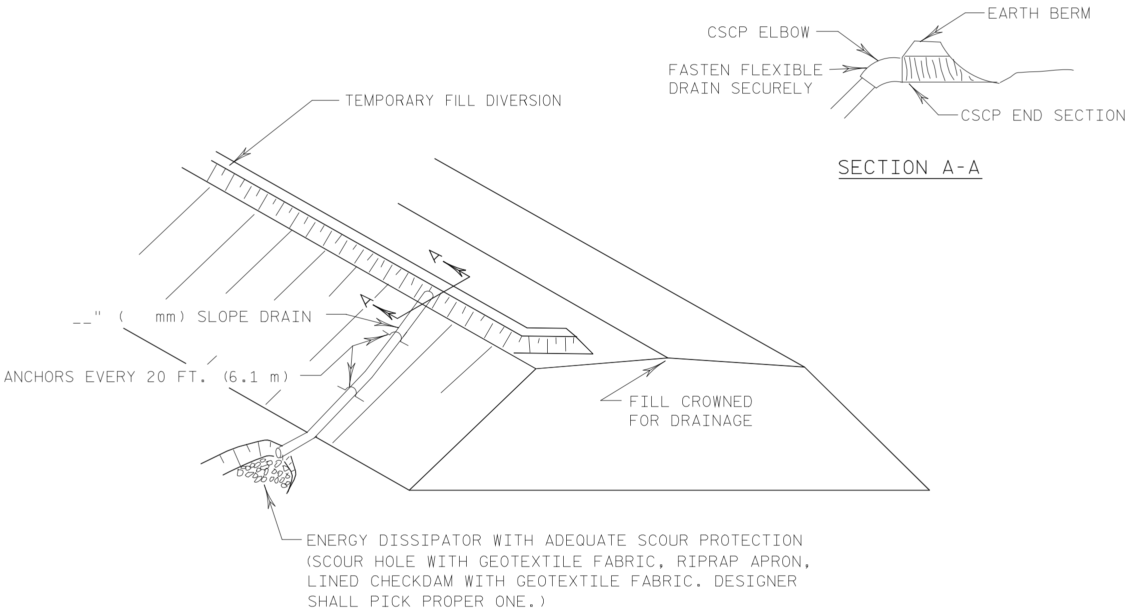
RISER AND BARREL DETAIL



SILTING POND DETAIL

CELL NAME: SLTPD

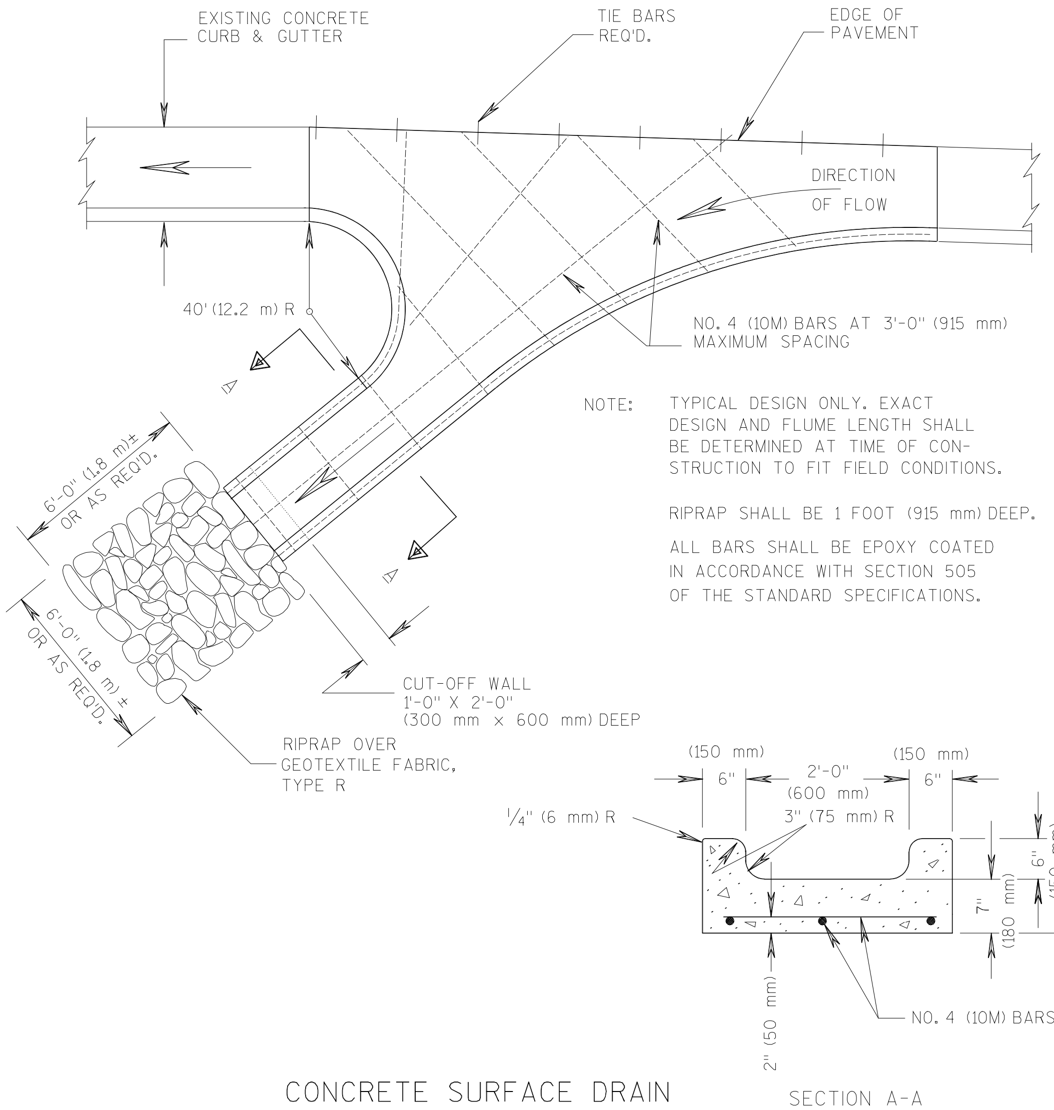
REFERENCE: SEE FDM PROCEDURE 10-10-51



TEMPORARY FLEXIBLE SLOPE DRAIN

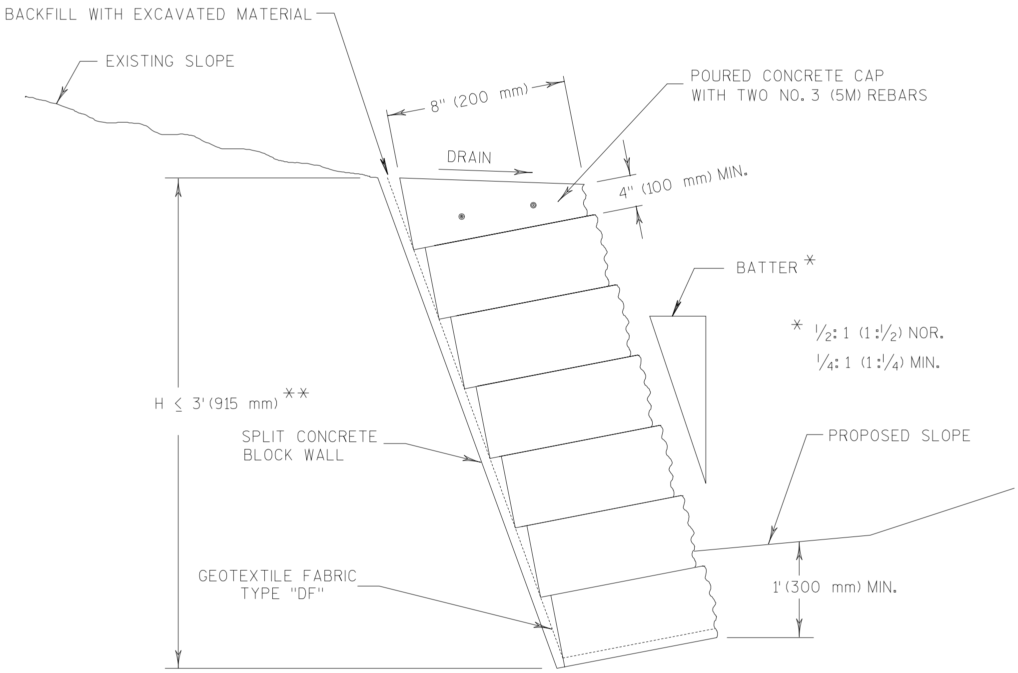
CELL NAME: SLPDR1

REFERENCE: SEE FDM PROCEDURE 10-10-57



CELL NAME: CSRFDR

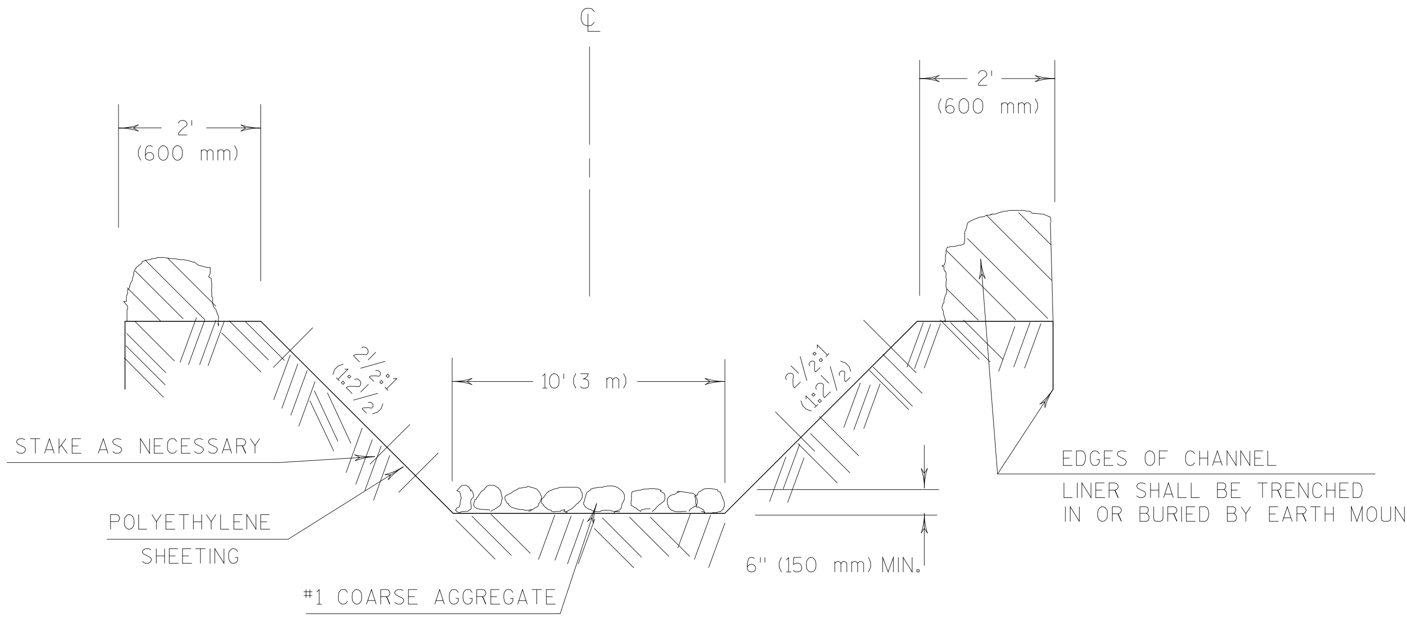
REFERENCE: SEE FDM PROCEDURE 10-10-57, SDD 8D2-4, SDD 8D3-4 and SDD 8D4-3



** SEE PLAN SHEETS AND/OR CROSS SECTIONS FOR ACTUAL DIMENSIONS. WALLS GREATER THAN 3' (915 mm) MUST BE DESIGNED BY A GEOTECHNICAL ENGINEER.

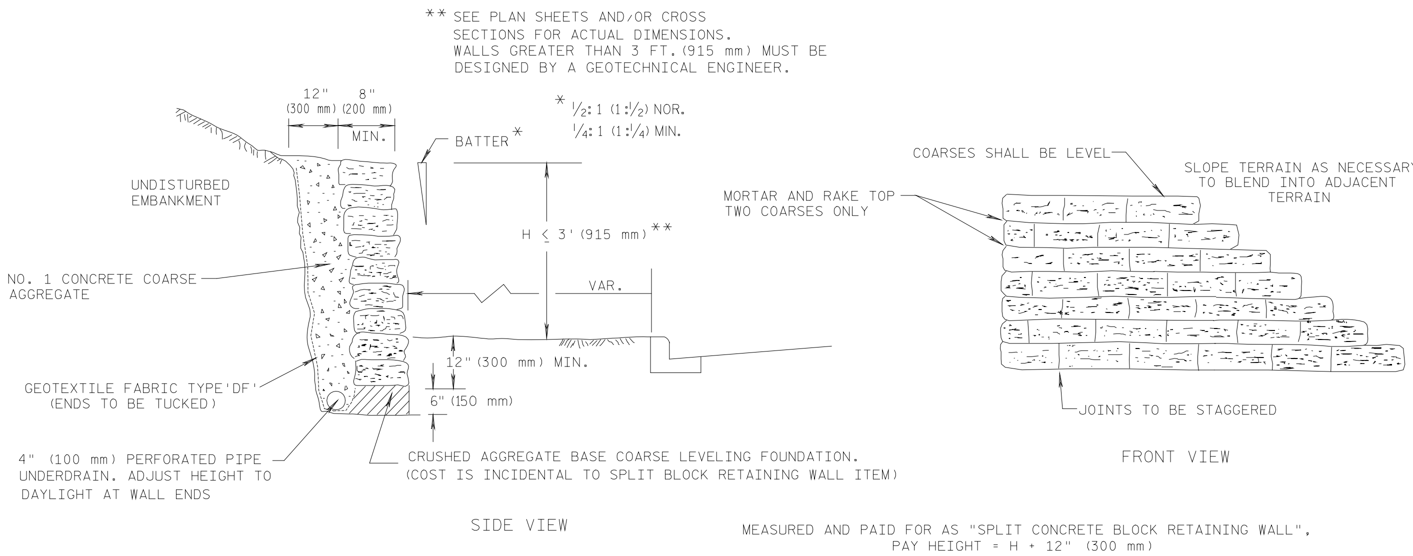
SPLIT CONCRETE BLOCK WALL

CELL NAME: CBLKWL



TYPICAL SECTION OF TEMPORARY CHANNEL CHANGE

CELL NAME: TCHL



DETAIL FOR SPLIT CONCRETE BLOCK RETAINING WALL

CELL NAME: BLKRWL

FDM 10-25-1 Stormwater Control Measure Selection October 22, 2012

1.1 Introduction

The purpose of this section is to give designers guidance in meeting Federal and State stormwater quality discharge laws and regulations (refer to FDM 10-1-2).

The objective of this section is to provide designers with the tools to reduce pollutants via the removal of sediment from stormwater, as most targeted pollutants attach themselves to sediment. In addition, though many pollutants are derived from sources beyond WisDOT's right-of-way and control, the primary focus of these practices should be to control pollutants generated by WisDOT facilities only.

Areas where WisDOT projects have the potential to impact outstanding resource waters (ORW), exceptional resource waters (ERW), exceptional wetlands, trout waters, 303d waters, or impact other unique public waters may be where the designer incorporates such measures. Any questions regarding stormwater quality should be directed to WisDOT's regional stormwater engineer or to WisDOT's Bureau of Technical Services Stormwater Engineer, Central Office.

1.2 Determining Project Water Quality Objective Goals

The department has developed a post-construction stormwater management program based upon Federal regulations, TRANS 401, the FDM, and the Maintenance Manual.

The designer should use the guidelines below to determine the water quality objectives for a project. Consult with the region stormwater engineer or the central office stormwater engineer if there are questions or concerns about the appropriate objectives.

To determine what the specific goal for a project is, see the flowchart in Attachment 1.1. Each transportation facility that meets these post-construction program applicability requirements must address the following post-construction stormwater management issues.

1.2.1 Total Suspended Solids

The total suspended solids (TSS) reduction goal for a project will be 0%, 40% or 80% depending upon the project characteristics.

1. New transportation facilities (roadways, airports, park and rides, etc). Annual total suspended solids loadings from a new facility must be reduced by 80% (or to the maximum extent practicable (MEP)), based upon an average annual rainfall year, when compared to no runoff management controls.
2. Reconstruction projects. Annual total suspended solids loadings from a reconstruction project must be reduced by 40% (or to MEP), based upon an average annual rainfall year, when compared to no runoff management controls.
3. Projects within TMDL drainage basins may have different TSS and other pollutant reduction requirements. Work with you r regional Stormwater Engineer to determine if your project has any TMDLs to meet.

Some projects may transition from, for example, a new alignment with a rural cross section to a curb and gutter cross section that was formerly a rural cross section, but on the same alignment. Each of these segment types will have a different TSS reduction goal. If this occurs, the project may be segmented with different water quality objectives for each type of condition. There are three possible segment types:

- Rural or urban cross sections on new alignments,
- Rural or urban cross sections on existing alignments, and
- Rural cross sections to urban cross sections.

Each of these segment types may have a different TSS reduction goal. The overall water quality TSS reduction goal for the project is the area-weighted sum of the TSS reduction objectives from the three different segment types.

1.2.2 Peak Discharge

Peak discharge rates for the 2-year design storm for a new project shall remain at pre-development levels, to

MEP.

1.2.3 Infiltration

WisDOT will not design stormwater control practices to infiltrate runoff from highway projects. Non-highway transportation projects that are near;

- karst features,
- where the seasonal high water table is within three feet of the infiltration device bottom,
- within 400 feet of a community water well,
- within 100 feet of a non-community or private well,
- or that meet other requirements described in TRANS 401.106(5)(d) will also not infiltrate.

If none of these criteria apply to a project, then the department shall infiltrate enough runoff volume so that the post construction infiltration volume is at least 60 percent of the annual pre-construction infiltration volume. However, no more than 2 percent of the project area is required as an effective infiltration area. If direct infiltration to groundwater occurs, pre-treat the runoff to reduce the TSS loading by 80% or to MEP.

1.2.4 Buffer Areas

Post construction stormwater control measures must be applied to any project that constructs a roadway within a buffer area as defined in TRANS 401.106(6). The Department will not construct projects within buffer areas adjacent to streams, lakes, or wetlands except when reasonably necessary and done in consultation with the Department of Natural Resources. If construction within a buffer occurs, adequate and appropriate vegetation must be established within the buffer areas. Transportation facilities that cross or access surface waters, such as boat landings, bridges and culvert, are exempt from this requirement (TRANS 401.106(6)(b)(4)(b)).

1.2.5 Timing

All stormwater control practices will be installed before the project has undergone final stabilization. The Department may use the water quality practices listed in the DOT Facilities Development Manual in its projects, but may use other control practices as appropriate to reduce stormwater runoff and pollutants from highway facilities. Biofiltration devices should be completed after project site permanent stabilization.

1.2.6 Swales

The Department may use grass swales to meet all rural post-construction stormwater requirements provided that the swales:

1. Are vegetated (unless riprap or check dams are employed to reduce erosion)
2. Are at least 200 feet in length and
3. Carry a flow velocity of no more than 1.5 ft/sec based upon a 2-year design storm (or the flow velocity is reduced to the maximum extent practical).

The Department will encourage the placement of swales in urban projects if they are appropriate for the project.

1.3 Stormwater Report Development

The stormwater report is a spreadsheet that, along with accompanying documentation if needed, provides a framework to calculate and document not only a project's hydrologic and hydraulic analysis but also any potential project runoff quality impacts. It should be used throughout the project to assist the engineer with the development of appropriate and cost effective stormwater treatment practices. Though the stormwater report must be submitted at the end of the project, it may also be submitted at the following times:

1. At the project planning level,
2. At the 30% submittal, to reflect stormwater and drainage coordination with all stakeholders,
3. At the 60% submittal, to include as much drainage and stormwater design information as is available,
4. At PS&E, the final, complete stormwater report should be submitted.

The transportation facility designer or planner should use the water quality matrix (Attachment 1.2) as described below to develop a conceptual stormwater plan, which normally should be completed prior to the Design Study Report (DSR). This conceptual plan should be submitted to the region stormwater engineer for review and DNR concurrence. As the design progresses, the designer or planner should use the stormwater report and other tools described in this section of the FDM to develop the final calculations and pollutant removal rates for the project. This process is described in more detail in FDM 10-35-3. Submit the final plan to the region stormwater engineer and the project manager for review.

The project manager can use the stormwater report to assist with negotiations for any cost sharing of stormwater control practices from offsite runoff with local communities because the stormwater report specifically distinguishes between on-site and offsite runoff and pollutant loading.

1.4 Stormwater Quality Matrix

The stormwater quality matrix, as shown in Attachment 1.2, was developed to simplify the planning and design process for WisDOT highway project stormwater quality control practice selection. The first column lists the standard stormwater quality control practices described in this section of the FDM. The second column is a list of the planning level percent TSS reduction values allowed for each of the control practices. This column is applied when the planning check box is checked when describing the design stage for the project (Line 13 on the Drainage – Summary worksheet). Use these values in the Stormwater Report water quality sections to determine, on a planning level, what control practices may be necessary for a project. The percent reduction values assume that all practices are designed and installed according to the appropriate design standard, and that they are properly maintained.

The third column is the design percent TSS reduction values allowed for each control practice. The values that are either in this column or determined by modeling or design are developed for the design phase (30% complete, 60% complete, 90% complete, or final design) of the project. Both grass swales and biofilters have an assigned 80% reduction rate, assuming that the practices are designed, constructed, and maintained according to the appropriate standard. Use the design method described in each section of the FDM to determine the final TSS reduction rate for the other control practices, and enter those values in the Stormwater Report to determine your overall project TSS reduction rate.

1.5 Stormwater Technical Standard and Procedure Links

Below is a list of Wisconsin post construction stormwater management technical design standards and references for water quality analysis. Refer to these standards in addition to the sections in FDM 10-35 for additional guidance, if needed;

- Bioretention for Infiltration Tech Note,
- Proprietary Storm Water Sedimentation Devices,
- Infiltration Basin Tech Note,
- Site Evaluation for Stormwater Infiltration,
- Swales (Updated 5/10/2007),
- Wet Detention Pond.

To view the standards, go to the WDNR Storm Water Management Technical Standards web site: http://dnr.wi.gov/topic/stormwater/standards/postconst_standards.html.

1.6 Stormwater Retrofit Projects

The SAFETEA-LU section 6006 allows states to participate in stand-alone retrofit projects to address water pollution or environmental degradation caused 'wholly or partially by a transportation facility.' Use of Surface Transportation Program (STP) and NHS funds may be used voluntarily for this purpose. To view guidance on whether this is the appropriate action for your project see FHWA guidance on 23 USC 328 (http://www.fhwa.dot.gov/hep/envrestore.htm).

LIST OF ATTACHMENTS

Attachment 1.1	Post Construction Stormwater Quality Management Goals
Attachment 1.2	Treatment Efficiencies for WisDOT Stormwater Control Practices as Required for Highway Facilities Covered Under TRANS 401

FDM 10-25-5 The Effects of Urbanization on Stormwater Quality *October 22, 2012*

5.1 Introduction

This procedure has been developed in order to help planners and designers understand the potential storm water quality impacts that urbanized areas may have on WisDOT facilities. This knowledge is beneficial when working with local planners or municipalities. However, it is not WisDOT's position to assume responsibility for pollutants discharged from sources other than WisDOT facilities.

5.2 Urbanization

There are two main reasons why urbanization increases pollutant loads in runoff:

1. The runoff is more contaminated due to the surfaces and activities occurring in the developed areas, and
2. The amount (and rate) of runoff is greater, resulting in greater amounts of pollutant discharges.

Although stormwater pollutants frequently impact the quality of surface water, groundwater quality can also be adversely affected. The greatest potential for groundwater contamination comes from pollutants that are soluble in water and not readily trapped or treated by the soil during percolation.

5.3 Hydrologic Changes

When an undeveloped area changes to support urban land uses, drastic changes in the local hydrology result. As land is covered with roads, buildings, and parking lots, the amount of rainfall that can infiltrate into the soil is reduced. The increases in the impervious covers and in compacting the soils results in substantially increased runoff volumes from the watershed. Typical impervious cover percentages for different land uses are shown below:

Typical Impervious Area Covers

Land Use	***Percent Impervious Cover***
Business District or Shopping Center	95-100
Residential, High Density	45-60
Residential, Medium Density	35-40
Resident, Low Density	20-40
Open Areas	0-10

Besides the increased volumes of runoff associated with the impervious covers, the flow rate of the increased runoff also increases, exasperating the hydrologic effects of urbanization. When an urban area is developed, natural drainage patterns are modified as runoff is channeled into road gutters, storm sewers, and paved channels. These modifications increase the velocity of runoff, which decreases the time required to convey it to the mouth of the watershed. This results in higher peak discharges and shorter times to reach peak discharges. Also, water that once seeped through the upper layers of soil as *interflow* now runs off the surface. The loss of this shallow groundwater is significant because it supplies much of the *baseflow* in streams between storms.

In many development projects, grading changes the slopes of the land surface to provide better drainage. Developers fill low spots and wetlands to provide more "buildable" land. These natural detention areas no longer collect stormwater for gradual release after a storm. Instead, storm sewers or ditches are built to improve drainage capacity by carrying runoff directly to lakes and streams.

Stormwater runoff problems continue after builders complete construction. Water runs off hard surfaces covered by buildings, streets, and parking lots, picking up speed and pollutants along the way. In some places, however, spreading top soil and planting trees and grass allows the land to regain some of its ability to soak up stormwater.

Higher flow rates can cause flooding and have adverse effects on natural streams. Under natural conditions and at bankfull capacity, studies have shown that streams can handle a flow approximately equal to about the 1- to 2-year frequency peak discharge. After urbanization, increased flows can cause bank-full flow to be exceeded several times each year, preventing regrowth of damaged vegetation during the high flows. In addition to frequent flood damage, this condition causes previously stable channels to erode and widen, damaging streamside infrastructure and the natural habitat. Sediment from stream bank erosion also increases in-stream turbidity levels and can eventually become deposits in streams, rivers, and lakes, smothering benthic organisms.

Base flow in streams is also affected by changes in the hydrology from urbanization because a large part of the natural base flow is supplied by shallow infiltration. As shallow infiltration is reduced by increased impervious cover, the volume of water available for base flow in streams is reduced. These changes in hydrology, combined with increased pollutant loadings, can have a dramatic effect on the aquatic ecosystem in urban streams. Studies of streams affected by urbanization have shown that fish populations either disappear or are dominated by rough fish that can tolerate a lower level of water quality.

An early understanding of, and response to, the effects of urbanization on water quality can result in a much greater chance of cost-effectively minimizing those effects. Stormwater control practices (sometimes referred to as “Best Management Practices (BMP's) or “Stormwater Control Measures (SCM’s) that slow runoff and increase infiltration are recommended as a first approach to effective stormwater management. Conventional interception of untreated runoff by storm sewers directed to the nearest waterway results in substantial receiving water problems associated with the increased runoff volumes and flow rates, and pollutant discharges.

5.4 Pollutants

Although urban areas cover only a small part of the land in Wisconsin, they are responsible for significant water quality problems, flooding, and habitat destruction.

The major urban pollutants include:

1. Sediment
2. Nutrients
3. Oxygen demanding materials such as grass clippings
4. Bacteria
5. Trace metals
6. Pesticides
7. Toxic chemicals, such as Hydrocarbons and PCBs
8. Chlorides
9. Temperature

Each of these pollutants is discussed below.

5.4.1 Sediment

Sediment is considered to be one of the most damaging pollutants, and is the major pollutant by quantity in state surface waters. Urban runoff produces a unique mix of sediment that includes flakes of metal from rusting vehicles, particles from vehicle exhaust, bits of tires and brake linings, chunks of pavement and soot from residential chimneys and industrial smokestacks, along with eroding soils.

Generally, the concentrations of sediment in urban runoff is lower than in rural runoff (except in areas undergoing active construction), but because more water runs off impervious surfaces in cities, the total load of sediment for urban areas can be comparable to rural areas. Land uses that produce the highest sediment loads in existing (post development) urban areas are industrial and commercial areas, and freeways. Parking lots are the predominant source of sediment in industrial areas. In residential and commercial areas, streets surfaces are the primary sources of sediment.

Although existing urban areas are important sources of sediment, by far the highest loads of sediment (and the highest concentrations) come from areas under construction.

5.4.2 Nutrients

Runoff from urban and rural areas contains nutrients such as phosphorus and nitrogen. Phosphorus is the greatest concern in stormwater runoff because it usually promotes weed and algae growth in Wisconsin freshwater lakes and streams.

Because particulate phosphorus compounds attach themselves to sediment particles, land uses that produce high sediment loads also tend to produce high phosphorus loads. The phosphorus in runoff from existing urban areas, in both particulate and filterable forms, come from areas where excessive fertilizers have been applied, leaves and grass have been left on paved areas, and from vehicle exhaust.

Nitrogen is usually so abundant in Wisconsin lakes and streams that nitrogen in runoff does not usually increase weed and algae growth, as phosphorus is the limiting nutrient.

Nitrate forms of nitrogen are found naturally at low levels in most water bodies. However, drinking waters contaminated with high levels of nitrates are a health hazard. Nitrates are very soluble and do not attach to soil particles. This allows nitrates to readily leach into groundwater when nitrogen fertilizer application rates exceed plant needs. Septic systems are another common source of nitrate contamination in groundwater.

5.4.3 Oxygen Demanding Materials

Urban runoff carries organic material such as pet waste, leaves, grass clippings, and litter. As these materials decay, they use oxygen needed by fish and other aquatic life. The sudden increase, or "pulse," in oxygen demand after a storm can totally deplete oxygen in an urban lake or stream. Shallow, slow-moving waterways are especially vulnerable to fish kills caused by the oxygen demands of urban runoff. However, more commonly, long-term sediment oxygen demand associated with organic-enriched sediments from stormwater can drive the oxygen levels in the benthos to consistently very low levels, causing dramatic shifts in the benthic organism populations to more tolerant species (such as to sludge worms compared to more desirable fish food sources).

5.4.4 Bacteria

The levels of bacteria found in urban runoff frequently exceed by large margins the public health standards for water contact recreation such as swimming and wading. Generally, fecal coliform bacteria counts in urban runoff are 20 to 40 times higher than the health standard for swimming. Sources of bacteria in urban runoff include sanitary sewer overflows, but more commonly pets (especially dogs) and urban wildlife such as pigeons, rodents, raccoons, geese and deer.

5.4.5 Trace Metals

The greatest challenge in urban watershed stormwater pollution control is toxic pollution, particularly trace metals. Metals are the most understood toxic pollutants in urban runoff because they were excessively monitored as part of the National Urban Runoff Program (NURP) in the early 1980's. Data collected recently in Wisconsin cities verify that trace metals such as lead, zinc and copper contaminate runoff from small and large cities.

Lead is an "indicator" for other toxic pollutants because it is relatively easy to monitor. Lead is a problem for both human and aquatic life. According to recent monitoring, about 40 percent of the runoff samples from a primarily residential area, and 70 percent of the samples from a commercial area have lead levels that exceed acute toxicity standards for aquatic life. However, lead levels in urban runoff are much lower today than they were before the move to unleaded gasoline.

Zinc is another trace metal in urban runoff that commonly violates water quality standards. While zinc does not create human health problems, it can be toxic to aquatic life. Zinc levels in urban runoff are more likely than lead to violate acute toxicity standards for aquatic life. Common sources of zinc in urban areas include galvanized metals and tire wear, with roof runoff commonly having very high zinc concentrations (if galvanized rain gutters and flashings are used, or especially for galvanized roofing).

Copper concentrations in urban runoff frequently violate water quality standards. Like lead, copper is toxic to both human and aquatic life. Copper can also be high from roofing (used as an algaecide on asphaltic roofs), but the highest concentrations are usually found in runoff from paved parking areas and from industrial areas.

Cadmium is another trace metal commonly detected in urban runoff. Unlike zinc and copper, cadmium concentrations usually do not exceed acute toxicity standards. However, cadmium has a low standard level for chronic toxicity that is frequently exceeded by urban runoff. This means cadmium concentrations are seldom high enough to kill aquatic life, but are likely to have long-term health problems for people such as cancer and kidney damage.

Chromium is frequently detected in urban runoff but usually does not violate acute toxicity standards. Organisms can excrete chromium very quickly and keep it from building up in body tissues. One form of chromium (chromium IV) is considered highly toxic in humans.

These metals originate from galvanizing, chrome plating, and other metal sources in urban areas. Lead and zinc in urban runoff have also been associated with application of road sand and salt.

Another significant source of trace metals is runoff from rooftops. Many roofs have galvanized gutters and downspouts that contaminate stormwater with zinc. In industrial areas galvanized roofs and gutters are the leading source of zinc (60%). In residential, roofs are a less significant source of zinc (7%). This dramatic difference happens because most residential downspouts discharge onto lawns that filter out zinc while most industrial downspouts discharge directly into storm sewers. Another source of trace metals on some roofs is copper flashing. Runoff from these roofs carries high concentration of copper and lead.

In some cities, a significant source of trace metals is uncovered outdoor storage piles of scrap metals, coal and salt. According to the USGS monitoring, scrap metal piles are the primary source of mercury in the area surrounding the Milwaukee harbor. Scrap metal piles are also a source of arsenic. Coal piles are another source of arsenic while salt piles are a source of chromium and lead.

The list of other sources of trace metals is long, ranging from combustion to deteriorating metal and paint. For example, paints and plated metals commonly contain cadmium or chromium. Fishing weights, lead shot and paint sold before 1977 may contain lead. Air-borne emissions from burning coal, oil, or municipal waste may carry cadmium, copper, lead, or mercury. Wood used in outdoor construction may contain arsenic, chromium, copper or zinc to prevent rotting.

5.4.6 Pesticides

While much is known about the sources of trace metals in urban runoff, the sources of pesticides are a subject of some debate. Turf experts conducted tests that suggest properly applied pesticides are bound up in plants and soil so little runs off. However, monitoring data for Wisconsin shows urban runoff contains many pesticides.

Common lawn and garden insecticides, like diazinon and malathion, may not persist in the environment, but they are toxic to bees, fish, aquatic insects and other wildlife. Diazinon is toxic to birds and is banned on golf courses and sod farms because of waterfowl deaths in diazinon treated feeding areas.

Finding agricultural herbicides like alachlor, atrazine and cyanazine in urban stormwater may seem surprising since these herbicides are not used in lawn and garden compounds. However, studies in Minnesota suggest that concentrations of atrazine observed in urban stormwater are consistent with concentrations observed in rainfall. These herbicides apparently are transported by wind and rain from surrounding farm fields in the region.

Pesticides in Urban Runoff		
Regulated Insecticides	***Lawn & Garden Insecticides***	***Agricultural Herbicides***
Aldrin	Diazinon	Alachlor
Chlordane	Malathion	Atrazine
DDT	Cyanazine	
Endrin		
Heptachlor		
Lindane		
Toxaphene		

5.4.7 Other Toxic Chemicals

Other toxic chemicals found in urban runoff include organic compounds. Some of these chemicals are health hazards even in very small doses and therefore have water quality standards set in parts per billion (ppb). Because sampling for these chemicals can be difficult and costly, data are very limited. Monitoring suggests that polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are the two groups of chemicals present in large enough concentrations in urban runoff to be of concern.

Polycyclic aromatic hydrocarbons (also called polynuclear aromatic hydrocarbons) are a large group of about 10,000 different compounds. They are common by- products of incomplete combustion from vehicles, wood and oil burning furnaces, and incinerators. PAHs are used in ingredients in gasoline, asphalt and wood preservatives. The best known PAH is benzene, which is used both as a solvent and as an antiknock additive in gasoline. While benzene levels in Wisconsin stormwater do not exceed surface or groundwater standards, several other PAHs do exceed the standards. PAHs affect human health in a variety of ways, but they are of particular concern because of several of the most toxic carcinogens are PAHs. According to monitoring from Wisconsin cities, a significant percent of urban runoff samples violate human cancer criteria due to PAHs.

Petroleum-derived hydrocarbons are commonly found in urban runoff. These materials initially float on water and create the familiar rainbow-colored film. Hydrocarbons have a strong affinity for sediment and are quickly adsorbed. The hydrocarbons are then transported with sediment and settle out. Common sources of hydrocarbons are spillage at oil storage and fueling facilities, leakage from crankcases, and improper disposal of drain oil.

Polychlorinated biphenyls (PCBs) are a group of over 200 compounds. They are very stable compounds that do not easily degrade, burn or dissolve in water (or conduct electricity, a major reason that PCB's have been used for insulation in transformers and electrical capacitors for fluorescent light fixtures and appliances). They have also been used as coolants or lubricants. PCB's are of special concern because they remain in the environment for a long time. They can build up in the food chain, accumulating in the fatty tissues of animals and humans, and may eventually cause health problems. PCB production stopped in 1977, but most of Wisconsin's urban runoff samples still violate the human cancer criterion for PCBs.

5.4.8 Chlorides

In Wisconsin, a tremendous amount of salt is used each year to melt ice from roads, parking lots, and sidewalks. Because it is extremely soluble, almost all salt applied ends up in surface or ground waters. If the concentration of chlorides becomes too high, it can be toxic to many freshwater organisms. Normal applications of salt to roads for de-icing typically do not have significant impacts on large lakes or streams because of dilution. However, temporary toxic conditions due to elevated chloride levels have been found in surface waters associated with small streams or wetlands. In addition, high (greater than 10,000 mg/L) chloride groundwater concentrations have been measured in aquifers adjacent to highways.

5.4.9 Temperatures

Besides changes in water chemistry, urbanization changes the quality of waterways by raising their temperatures. Reasons for increased temperatures in urban lakes and streams include:

- Pavement and roof surfaces store heat from the sun. Rainfall that falls on these surfaces, and runoff that flows over these surfaces, are warmed from the stored heat.
- Shallow ponds and impoundments heat up between storms and release a pulse of warm water during a storm.
- Fewer trees along streams that shade the water.

Temperature is a critical factor in determining what species can live in a lake or stream since increases in water temperature affects waterways in several ways. At higher temperatures, water holds less oxygen, and many chemical and biological processes that consume oxygen increase at higher temperatures, further driving down the dissolved oxygen. Therefore, as water temperature rise, the demand for oxygen increases while the supply decreases.

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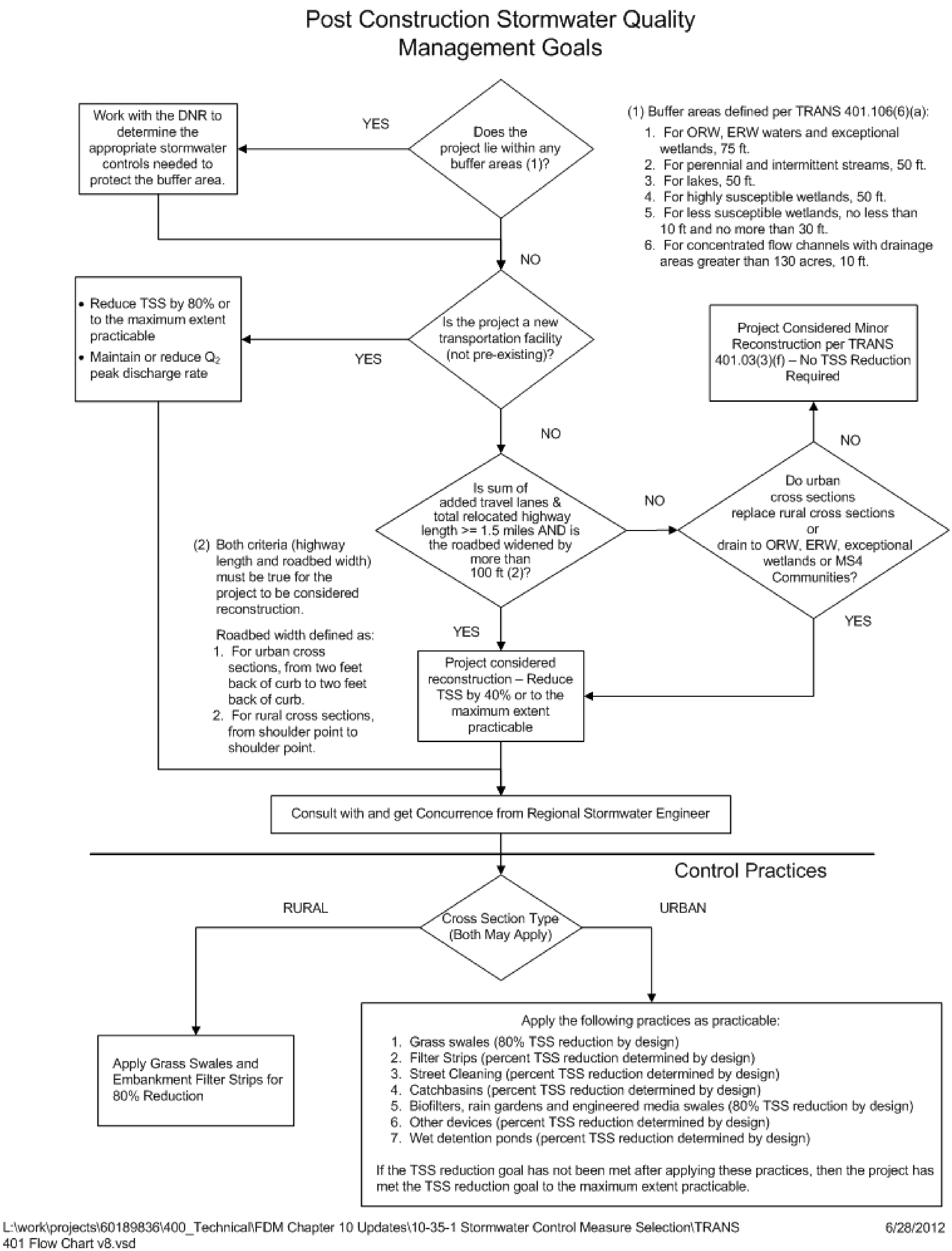

Post Construction Stormwater Quality Management Goals
Does the project lie within any buffer areas (1)?
YES
Work with the DNR to determine the appropriate stormwater controls needed to protect the buffer area.
NO
(1) Buffer areas defined per TRANS 401.106(6)(a):
1. For ORW, ERW waters and exceptional wetlands, 75 ft.
2. For perennial and intermittent streams, 50 ft.
3. For lakes, 50 ft.
4. For highly susceptible wetlands, 50 ft.
5. For less susceptible wetlands, no less than 10 ft and no more than 30 ft.
6. For concentrated flow channels with drainage areas greater than 130 acres, 10 ft.
Is the project a new transportation facility (not pre-existing)?
YES
• Reduce TSS by 80% or to the maximum extent practicable
• Maintain or reduce Q_2 peak discharge rate
NO
Is sum of added travel lanes & total relocated highway length >= 1.5 miles AND is the roadbed widened by more than 100 ft (2)?
(2) Both criteria (highway length and roadbed width) must be true for the project to be considered reconstruction.
Roadbed width defined as:
1. For urban cross sections, from two feet back of curb to two feet back of curb.
2. For rural cross sections, from shoulder point to shoulder point.
NO
Do urban cross sections replace rural cross sections or drain to ORW, ERW, exceptional wetlands or MS4 Communities?
NO
Project Considered Minor Reconstruction per TRANS 401.03(3)(f) – No TSS Reduction Required
YES
YES
Project considered reconstruction – Reduce TSS by 40% or to the maximum extent practicable
Consult with and get Concurrence from Regional Stormwater Engineer
Control Practices
Cross Section Type (Both May Apply)
RURAL
URBAN
Apply Grass Swales and Embankment Filter Strips for 80% Reduction
Apply the following practices as practicable:
1. Grass swales (80% TSS reduction by design)
2. Filter Strips (percent TSS reduction determined by design)
3. Street Cleaning (percent TSS reduction determined by design)
4. Catchbasins (percent TSS reduction determined by design)
5. Biofilters, rain gardens and engineered media swales (80% TSS reduction by design)
6. Other devices (percent TSS reduction determined by design)
7. Wet detention ponds (percent TSS reduction determined by design)
If the TSS reduction goal has not been met after applying these practices, then the project has met the TSS reduction goal to the maximum extent practicable.
L:\work\projects\60189836\400_Technical\FDM Chapter 10 Updates\10-35-1 Stormwater Control Measure Selection\TRANS 401 Flow Chart v8.vsd
6/28/2012

TREATMENT EFFICIENCIES FOR WISDOT STORMWATER CONTROL PRACTICES AS REQUIRED FOR HIGHWAY FACILITIES COVERED UNDER TRANS 401

Stormwater Control Practice	Planning Level Percent TSS Reduction	Final Design Percent TSS Reduction
Wet Detention Ponds	80% (1)	By Design (1)
Catchbasins (4)	15%	By Design (2)
Grass Swales	80%	Standard Met (8) (Apply 80% Reduction Rate)
Highway Embankment Filter Strips	Clay Soils - 60% Silt Soils - 70% Sandy Soils - 100%	By Design (3)
Biofiltration (5)	80%	80%
Street Cleaning (4)	10%	By Design (6)

Notes:

1. Assumes pond will be designed using FDM 10-35-15, Wet Detention Pond Stormwater Quality Design. This approach is developed from the WDNR Standard 1001, Wet Detention Pond.
2. Apply the appropriate design charts in FDM 10-35-20 for Catchbasin percent reductions for urban cross sections with sumps in the inlets.
3. Apply the appropriate design charts in FDM 10-35-10 (Not complete) for Filter Strip percent reductions for rural cross sections.
4. Percent reduction values assume that the control practice will be maintained.
5. Biofilter percent reductions assume that the biofilter is designed according to WDNR Standard 1004 and that the drain tile is located at the bottom of the device. Additional reductions can occur if the drain tile is raised above the bottom of the device.
6. Apply the appropriate design charts in FDM 10-35-25 (Not Complete) for Street Cleaning percent reductions for urban cross sections, assuming commercial land uses.
7. All stormwater control practices must comply with the relevant section of TRANS 401.106
8. May not apply to ERW, ORW (http://dnr.wi.gov/topic/SurfaceWater/orwerw.html), 303(d) listed waters (http://dnr.wi.gov/topic/impairedwaters/) with an approved TMDL.
9. DNR technical standards are available from: http://dnr.wi.gov/topic/stormwater/.

FDM 10-30-1 Project Stormwater Quality Analysis Process

October 22, 2012

1.1 Description and Purpose

Each WisDOT project that has a stormwater component must have a completed Stormwater Report (SR) spreadsheet. There are two components to the spreadsheet - a drainage section and a water quality section. This section describes how to fill out the water quality section of the sheet. Refer to FDM 13-1-10 for instructions on how to fill out the drainage section.

1.2 Water Quality Analysis Instructions

The WisDOT Stormwater Report spreadsheet incorporates the design guidelines and calculations needed to determine if a project meets the required TSS load reduction. The spreadsheet has a series of worksheets that a designer shall use to methodically prepare and summarize an analysis of the pollution control performance of the various stormwater quality practices used on a project.

The water quality section of the Stormwater Report spreadsheet has two parts. The first part, which is on a worksheet shared with the drainage section, is the Summary worksheet. This Summary worksheet includes basic project information, (project name, limits, county, etc.), a water quality analysis results summary and a list of questions that will help the designer determine the project's water quality requirements.

The second part includes the list of stormwater quality practices that are typically used to evaluate WisDOT facility sites. These practices include catchbasins, filter strips, grass swales, street cleaning and wet detention ponds. To identify these worksheets, the letters 'WQ', for Water Quality, have been inserted in front of the worksheet tab for each practice name.

To determine the overall project TSS percent reduction, the project engineer enters the required data for each control practice that is proposed for the project in the control practice worksheet. The percent reduction values for each practice are then automatically applied to the summary tab, which summarizes the values and calculates an overall percent TSS reduction for the project.

1.3 Stormwater Report Applicability

Each WisDOT project that has a stormwater component must have a completed Stormwater Report spreadsheet. The stormwater quality section of a Stormwater Report is not needed if the project is considered to be minor reconstruction, with no TSS reduction required. To determine this, refer to FDM 10-25-1. It is also not needed if there is no increase in paved area for a project or no change to the culvert or storm sewer system that drains the project. Stormwater Reports for water quality analyses are typically filed for the planning stage, the 60% design stage and the final design stage, although some projects might require submittals at different stages. If the project does not require any stormwater control features, then only fill in the Water Quality Results Summary Sheet to the extent necessary to explain why no features are required.

1.4 Water Quality Spreadsheet Description

There are ten worksheets in the SR. The Drainage-Summary and Drainage-Data worksheets are discussed in FDM 13-1-10. The water quality summary worksheet (WQ-Summary) is discussed in detail below and the water quality control practice worksheets are briefly discussed below. A line-by-line review of each water quality control practice worksheet is in the FDM section for that control practice. Access the SR at FDM 13-1-10, Attachment 10.1. Be sure to enable the spreadsheet Macros by clicking on the security warning "options" box on the top of the spreadsheet and then highlight the "enable this content" button.

1.4.1 Water Quality Summary

This worksheet includes basic project information, a Water Quality Results Summary section that includes a summary of the TSS reduction analysis for the project's control practices and a series of questions that address water quality issues. For Basic Project Information, only enter information in columns B and C of the Drainage-Summary worksheet; the information you enter there will be automatically entered in the WQ-Summary worksheet and the water quality control practice worksheets.

<u>Basic Project Information (entered in the Drainage-Summary worksheet)</u>

Line 2: Project ID Number: Enter the project ID number

Line 3: Title: Enter the project title

Line 4: Designer/Checker: Enter the name of designer and the checker

Line 5: DOT Region/Firm Name: Enter the WisDOT region the project is in and, if the form is filled out by a consultant, the name of the consultant firm.

Line 6: Date: Enter the date the spreadsheet was completed

Line 7: Highway: Enter the name of the highway

Line 8: Limits: Enter the limits of the project

Line 9: County: Enter the county of the project

Line 10: Description of Work: Describe the type of project

Line 11: Enter the name of the project manager(s)

Line 12: Enter the PS&E date

Line 13: Check the planning or design stage of the project**.**

1.4.2 Complete "Water Quality Results Discussion" Narrative

The ‘Water Quality Results Discussion’ narrative begins with line 14 on the WQ-Summary worksheet. The first section of the discussion narrative, from lines 15 to 17, calculates the percent TSS reduction for the project by transferring the TSS reduction percentages from each control practice worksheet to the WQ-Summary worksheet and calculates the overall percent TSS reduction for the project. The water quality objectives for the project are developed and explained in the Project Water Quality Objectives section. These goals are defined in lines 18-21 of this section and the description of how they were met is addressed in the balance of the questions on the worksheet.

Line 15: Drainage Area (ac): Enter the total project drainage basin area, which is the sum of the areas of all the drainage sub basins, for the entire project. This should include areas that are both within the WisDOT ROW and outside of the WisDOT ROW.

Line 16: ROW Drainage Area (ac): For the total project drainage area defined in cell above, enter the drainage area of the project that is within the WisDOT ROW.

Line 17: Percent TSS Reduction by Treatment Type: This row collects the percent reduction values from the WQ-Control Practice spreadsheets and, in the column “Total Project Drainage Basin” calculates the overall percent TSS reduction for the project. This is the value the designer should use to determine if the percent reduction requirement, as determined in Row 20 of this worksheet, is met. The designer should not enter any values in this row.

Line 18: THE PROJECT IS EXEMPT FROM TRANS 401 STORMWATER REQUIREMENTS AND REQUIRES NO FURTHER WATER QUALITY INFORMTION. DESCRIBE BELOW WHY IT IS EXEMPT. Check the box if the project is exempt from the stormwater quality requirements described in TRANS 401.

Line 19: Describe why the project is exempt.

Line 20: DESCRIBE THE STORMWATER QUALITY MANAGEMENT REQUIREMENTS PER TRANS 401 OR THE TMDL WASTELOAD ALLOCATION: Select the expected TSS reduction requirement per TRANS 401 or check ‘Other Reduction’ and enter the TMDL Wasteload Allocation value, if appropriate. Review FDM 10-25-1 or confer with the Region Stormwater Engineer if you are uncertain of the required TSS reduction percentage or TMDL wasteload allocation.

Line 21: Use Line 21 to describe the specific requirements in TRANS 401 or the TMLD Wasteload Allocation to document the selected TSS reduction value. Examples might be: “The project has more than 1.5 miles of new alignment, so per TRANS 401.106(3)(a), suspended sediments will be reduced by 80% or to the maximum extent practicable” or "The reconstruction project that replaces the existing pavement and storm sewer system is not widening the roadbed by more than 100 ft., and no rural cross sections are converted to urban cross sections, so no TSS reduction is required.” Refer to FDM 10-25-1 for additional information on TRANS 401 requirements.

Line 22: IF THE PROJECT REQUIRES STORMWATER MANAGEMENT EXPLAIN HOW THE TRANS 401 2-YEAR PEAK DISCHARGE REQUIREMENT WAS MET OR NOT REQUIRED. Note one of the following: a) the project is constructed on a new alignment, so this requirement applies, b) the project is a highway reconstruction site so this requirement does not apply (TRANS 401.106(4)(b)(2), c) the project does not increase the downstream receiving water surface by more than 0.01 feet as determined by a water surface model so this requirement does not apply, d) existing and proposed condition models of each basin show that the 2-year peak discharge has not increased so this requirement does not apply, or e) the project discharges directly into a lake over 5000 acres in area or to a stream or river segment draining more than 500 square miles (refer to http://dnr.wi.gov/topic/stormwater/documents/Modeling_Post-Construction_Guidance_2011.pdf), so this requirement does not apply. If the project cannot meet the 2-year peak reduction requirement, explain how the proposed design meets the requirement to the maximum extent practicable.

Line 24: HAS THE DEPARTMENT AGREED TO MEET ANY LOCAL STORMWATER QUALITY REQUESTS

FOR THIS PROJECT? IF SO, DESCRIBE. Enter either “Designed to meet WisDOT standards only.” or describe the municipal, county or regional ordinance, regulation or agreement(s) that the project is intended to meet and why it was necessary to meet the requirement.

Line 26: IF THE PROJECT REQUIRES STORMWATER MANAGEMENT EXPLAIN HOW THE TSS REDUCTION REQUIREMENT WAS MET. If the project meets the TSS reduction goal described in line 18, then state: “See practices as shown in lines 15-17.” Describe any practices or issues of special note. If any ‘Other Devices’ are used, describe them and where they are located. If the project does not meet the goal described in line 18, describe the proposed practices and provide a narrative that describes how the sediment reduction for the project has been controlled to the maximum extent practicable.

Line 28: LIST THE POST CONSTRUCTION STORMWATER QUALITY CONTROL TREATMENT MEASURES FOR THE PROJECT. List the control practices, distinguishing between the rural and urban sections of the project. An example might be: “Urban Section: one wet detention pond, catchbasins, median biofilters. Rural Section: Grass swales, filter strips.”

1.4.3 Water Quality Control Practice Worksheets

There are seven water quality control practice spreadsheets. They are listed below, with a brief description of how the designer can use them. Each worksheet can be expanded to increase the number of practices on each worksheet. To do this, follow these steps:

1. highlight the number of columns you want to add,
2. right-mouse click,
3. select insert,
4. select shift rows right, and
5. press the ‘OK’ button.

Do not enter data in the grey boxes on each worksheet - they contain formulas used to calculate values from other cells in the worksheet.

WQ-Wet Detention Ponds. The worksheet summarizes the analysis of TSS control from wet detention ponds. The data includes drainage area information and the information needed to evaluate wet detention pond performance using either the design process described in FDM 10-35-15 or using a computer model.

WQ-Catchbasins. The worksheet summarizes the analysis of suspended solids reduction using catchbasins. The data includes drainage area information and the information needed to evaluate catchbasin performance using the design charts in FDM 10-35-20.

LIST OF ATTACHMENTS

Sample Water Quality Results Summary Spreadsheets - Attached To The Stormwater-Drainage-WQ Report Spreadsheeet

(Use link to download a zipped working copy of the spreadsheets:

https://wisconsindot.gov/rdwy/fdm/files/WisDOT-Stormwater-Drainage-WQ-Channel-Spreadsheets.zip

1 **Project Summary**
2 **Project ID: XXXX-XX-XX**
3 **Title: Example Project**
4 **Designer/Checker:**
5 **DOT Region/Firm Name:**
6 **Date:**

7	**HIGHWAY:**	0
8	**LIMITS:**	0
9	**COUNTY:**	0
10	**DESCRIPTION OF WORK:**	0
11	**PROJECT MANAGER:**	0
12	**PS&E DATE:**	0
13	**DESIGN STAGE**	

Water Quality Results Discussion

14	***Water Quality Results Summary***	**Total Project Drainage Basin Area**	Grass Swales	Filter Strips	Wet Detention Ponds	Catch-basins	Street Cleaning	Biofilters	Other Devices	Untreated Areas
15	Drainage Area (ac)	**40.000**	0.631	0	27.000	3.750			7.700	0.919
16	ROW Drainage Area (ac)	**8.000**	0.438	0	3.400	0.750			1.400	2.012
17	Percent TSS Reduction by Treatement Type	**48.3%**	80.0%		80.6%	4.0%			53.0%	0.0%

Project Water Quality Objectives

18 **DESCRIBE THE STORMWATER QUALITY MANAGEMENT REQUIREMENTS PER TRANS 401.**

☑ **20 % Reduction** ☐ **40 % Reduction** ☐ **80 % Reduction** ☐ **Other Reduction** ______

19

20 **IF THE PROJECT REQUIRES STORMWATER MANAGEMENT EXPLAIN HOW THE TRANS 401 2-YR PEAK DISCHARGE REQUIREMENT WAS MET.**

21

22 **HAS THE DEPARTMENT AGREED TO MEET ANY LOCAL STORMWATER QUALITY ORDINANCES OR REQUIREMENTS FOR THIS PROJECT? IF SO, DESCRIBE.**

23

24 **IF THE PROJECT REQUIRES STORM WATER MANAGEMENT EXPLAIN HOW THE TOTAL SUSPENDED SOLIDS REDUCTION WAS MET. Refer to Water Quality Results Summary above.**

25

26 **LIST THE POST CONSTRUCTION STORMWATER QUALITY CONTROL TREATMENT MEASURES FOR THE PROJECT.**

27

REGIONAL STORMWATER ENGINEER CONCURRENCE (SIGN AND DATE)

26

Water Quality - Wet Detention Ponds Summary Sheet

1	**Wet Detention Pond Performance**
2	**Project ID: XXXX-XX-XX**
3	**Title: Example Project**
4	**Designer/Checker:**
5	**DOT Region/Firm Name:**
6	**Date:**

	Drainage Area Basin Number					**Total**
7	**Pond Number**	**1**	**2**			
8	**Pond Ending Station Number**	**30+00**	**48+00**			
9	**Pond Starting Station Number**	**20+00**	**35+00**			
10	**Left, Center, Right, or All**	**R**	**R**			
11	***Site Assessment***					
12	Highway Segment Length Treated (ft)	1000	1300			
13	Drainage Area (ac)	12.000	15.000			27.000
14	ROW Area (ac)	1.500	1.900			3.400
15	Percent Reduction	75%	85%			81%
16	***Results Summary***					
17	Percent Reduction per Treated Highway Segment	75.0%	85.0%			80.6%

Enter Line Number and Comment. Add more boxes if necessary

Water Quality - Catchbasins Summary Sheet

1	**Catchbasin Performance**
2	**Project ID: XXXX-XX-XX**
3	**Title: Example Project**
4	**Designer/Checker:**
5	
6	**Date:**

7	**Drainage Area Basin Number**				**Total**
8	**Catchbasin Number**				
9	**Catchbasin Station**	**10+00**	**12+00**		
10	**Left, Center, or Right**	**R**	**R**		
11	***Site Assessment***				
12	Distance to Next Catchbasin or Drainage Area (ft)	200	250		
13	Drainage Area (ac)	0.300	0.450		0.750
14	ROW Area (ac)	0.200	0.250		0.450
15	Cross Section Type (5 or 8)	5	8		
16	Catchbasin or Inlet Type/Size	Type 3 Inlet	Type 3 Inlet		
17	Predominant Cover Type	More Imperv	More Perv		
18	Predominant Soil Type		Silty/Clayey		
19	Design Chart Number	1	17		
20	Percent Reduction from Design Chart	17%	18%		
21	***Results Summary***				
22	Average Drainage Area Width (ft)	65.34	78.408		
23	Average ROW Width (ft)	43.56	43.56		
24	Percent Reduction per unit ROW Area	3.4%	4.5%		17.6%

Enter Line Number and Comment. Add more boxes if necessary

FDM 10-35-1 Stormwater Quality Practice Selection

October 22, 2012

1.1 Introduction

A Stormwater Control Measure (SCM) has been defined as "a combination of land use, conservation practices, and management techniques which, when applied to a unit of land, will result in the opportunity for a reasonable economic return with an acceptable level of water quality." When selecting SCMs, several considerations must be evaluated in order to meet this definition. These considerations are discussed below. There are generally two reasons to implement SCMs from a water quality standpoint:

1. To protect the water quality from future degradation.
2. To correct existing water quality problems. In this case, SCMs are implemented as remedial measures.

Almost without exception, changing an open or agricultural land use to an urban land use will affect water quality. Even if the actual concentration of pollutants does not increase, the total loading of pollutants can increase many times. This is because the volume of runoff must be considered in addition to the concentration of pollutants.

SCMs are typically site specific and depend upon many factors including proper design, installation, maintenance, and characteristics of the storm involved. In general, higher efficiencies can be expected for very small storms and lower efficiencies expected for very large storms.

It is usually necessary to use a combination of practices to meet water quality goals rather than relying upon just one practice.

1.2 Project Scoping for Stormwater Quality

The selection and placement of stormwater quality control practices begins at the project scoping stage. The scoping engineer, regional stormwater engineer and project development section must first determine the reduction goals for TSS, if any, and if the 2-year peak flow level must be maintained between the existing conditions and the proposed conditions. Once these requirements have been determined, the designer should select and evaluate control practices as described in the design process in FDM 10-35-1.8, but using the planning level percent TSS reductions listed for each control practice in the WisDOT stormwater control treatment efficiencies matrix (FDM 10-25 Attachment 1.2). At this point in the process it is also important to verify that the selected control practices will be properly maintained because practices that will not be maintained will receive no TSS reduction credit. By using this process, the designer can estimate the percent TSS reduction possible for the project at a planning level.

1.3 Physical Site Suitability

SCMs should only be used in areas where the physical site characteristics are suitable. Some of the physical characteristics that are important are soil type, watershed area, water table, depth to bedrock, site size and topography. If these conditions are not suitable, a practice can lose effectiveness, require excessive maintenance, or stop working altogether after a short period of time. Sometimes, unfavorable site conditions can be overcome with special design features. For example, the bottom of a detention pond can be sealed to prevent seepage into permeable soils at a site where a permanent pool is desired. In other cases, a practice will be excluded from consideration for a site because of conditions that are not practical to overcome. An example of this would be where a high water table or clay soils eliminate an infiltration basin from consideration.

1.4 Cost Effectiveness

Economics are an important consideration in the selection of SCMs. An economic analysis will identify the mix of SCMs that will achieve the water quality goal at the least cost. This should be considered when selecting SCMs and deciding how they will be implemented. To properly compare alternatives, all costs for the design life of a SCM should be included. These include expected maintenance costs as well as the initial costs for land, engineering and construction. For example, the use of grass swales in place of storm sewer pipes should be accounted for as a cost reduction. To create a true picture of the "cost" of a SCM, benefits other than water quality and flood prevention may also be considered. Some benefits such as increases in land values for property adjacent to an attractive detention pond are direct economic benefits. Other benefits such as incidental recreation benefits or wildlife benefits may be more difficult to quantify.

1.5 Maintenance Requirements

SCMs Maintenance is an important part in the operation of any SCM. The initial design of the SCM should take maintenance requirements into account. The cost of long-term maintenance should be evaluated during the selection process. In addition, responsibility for maintenance should be clearly assigned for the life of the system, because if a practice is not maintained, then it cannot receive a stormwater quality reduction credit. Typical maintenance requirements include:

- Inspection of basins and ponds after every major storm for the first few months after construction and annually thereafter;
- Mowing of grass filter strips and swales to prevent woody growth and promote dense vegetation;
- Removal of litter and debris from dry ponds, forebays, and water quality inlets;
- Regrading and revegetation of eroded areas;
- Periodic removal and replacement of filter media from infiltration trenches and filtration ponds;
- Deep cleaning of infiltration basins to maintain infiltration capability;
- Frequent (at least quarterly) vacuuming or jet hosting of porous pavements or concrete grid pavements;
- Quarterly clean-outs of water quality inlets;
- Periodic removal of floatables and debris from catch basins, water quality inlets, and other collection-type controls; and
- Periodic removal and proper disposal of accumulated sediment (applicable to all practices). Sediments in infiltration devices need to be removed frequently enough to prevent premature failure due to clogging.

1.6 Effect on Other Resources

When planning a SCM, consider the effect it will have on other resources. Without proper design, it is possible to shift a water quality problem to some other location. Ground water can be adversely affected by improperly designed SCMs.

1.7 Public Acceptance

In an urban environment, aesthetics are an important consideration for gaining public acceptance of SCMs. In many cases, practices such as wet detention ponds can be an asset visually to the surrounding area. However, if a detention pond is designed in a square shape with uniform slopes, it will not appear natural and can detract from the surround area. Odor, insects, weeds, turbidity and trash are also important to residents who live near structural SCMs. With regular maintenance, these problems can usually be overcome or are very temporary.

1.8 Suspended Solids Reduction Design Process

The general design approach is to apply the simplest, most cost-effective practices first and evaluate the suspended solids reduction from these practices. If the suspended solids reduction goal has not been met after doing this, add additional practices to increase the suspended solids reduction percentage for the project. If additional practices have been added to the project, but the goal has not been reached and it is not practicable to add additional treatment practices, then the project has been treated to the maximum extent practicable (MEP). The determination of MEP should be reviewed and confirmed by the Regional Stormwater Engineer.

Follow the process described below to determine the most cost effective suspended solids reduction system during the project design phase and when developing the project scoping analysis described above. When placing practices, considerations such as available right-of-way, soil type, water table, drainage area, slope, type of cross section, available head or other issues may affect the feasibility of the practice(s), and the location and placement of control practice(s). Coordinate to select the appropriate treatment practices for the project. Refer to the FDM section for each control practice for additional information on possible constraints or considerations.

1. Begin by determining the drainage areas for all grass swales along the project corridor. Properly designed and maintained swales have a vegetated embankment on the slope from the pavement to the swale, and will remove by design 80% of the suspended solids from the highway. Review proposed FDM 10-35-5 (*not complete yet*) to see the design criteria and detail for grass swales. Enter the required information in the WQ-Grass Swales worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27.
2. If the goal has not been met, review the project limits to determine if filter strips are appropriate control

practices in any project area. Note that filter strips may only be used for areas that have not been included as swale drainage areas. Review FDM 10-35-10 (*not complete yet*) to see the design criteria and detail for filter strips. Enter the required information in the WQ-Filter Strips worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27.

3. If the goal has not been met and there are urban areas in the project with curb and gutter, consider using street cleaning as a control practice. This practice will require a maintenance agreement with the appropriate local unit of government. Use the design guidelines in FDM 10-35-25 (*not complete yet*) to evaluate the suspended solids removal rates for street cleaning. Enter the required information on the WQ-Street Cleaning worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27. *TSS control from street cleaning shall not be applied in areas where TSS control is achieved through catchbasins with sumps, nor should catchbasins with sumps be applied in areas where TSS control is achieved through street cleaning.*
4. If the goal has not been met and there are urban areas in the project with curb and gutter, and inlets or catchbasins, add sumps to the catchbasins and inlets. Review FDM 10-35-20 to see the design criteria and process for catchbasins. Enter the required information in the WQ-Catchbasins worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27.
5. If the goal has not been met, look for areas of the project that can accommodate biofilters, rain gardens or swale drainage with engineered soils. Use the design guidelines in FDM 10-35-30 (*not complete yet*) to evaluate the suspended solids removal rates for these systems. Enter the required information on the WQ-Biofilter worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27.
6. If the goal has not been met, look for areas of the project that can accommodate wet detention ponds. Use the design guidelines in FDM 10-35-15 to evaluate the suspended solids removal rates for these systems. Enter the required information on the WQ-Wet Detention Ponds worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27.
7. If the goal has not been met and there are control practices on the project that do not fit any of the other categories, compete the worksheet WQ-Other. Use the guidelines in FDM 10-35-35 (*not complete yet)* to evaluate the suspended solids removal rates for these systems. Enter the required information on the WQ-Other worksheet and then review the Summary worksheet. If the percent TSS reduction by treatment type value for the total project drainage basin is equal to or greater than the suspended solids reduction goal, then the design process is complete. Enter the appropriate narrative information in lines 23, 25 and 27.

If it becomes impractical to add stormwater control practices to reach the suspended solids reduction goal, which means the project has been treated to the maximum extent practicable (MEP), document this on the WQ-Summary worksheet.

1.9 Effectiveness in Reducing Peak Discharges

Peak discharge control is a concern from a water quality standpoint because of the channel erosion problems that uncontrolled runoff from urban areas can cause. Requirements for peak discharge control are normally regulated by a local watershed district or water management organization. SCMs such as detention ponds can be very effective for reducing peak discharges. The effectiveness of a SCM for peak flow reduction varies depending upon the design and location of the structure.

1.9.1 2-Year Design Flow Peak Discharge Analysis

Peak TRANS 401.106(4) requires designers to maintain the existing 2-yr design storm discharge peak rate for new highway facilities. To meet this requirement, the water surface elevation in the receiving water may increases by no more than 0.01 ft compared to the existing condition. To evaluate the water surface elevation, typically a water surface profile model like HEC-RAS is used. This requirement does not apply to project sections that discharge directly into a lake over 5,000 acres or to a stream or river segment draining more than

500 square miles, refer to:

http://dnr.wi.gov/topic/stormwater/documents/Modeling_Post-Construction_Guidance_2011.pdf

The highway reconstruction exemption means that only those projects that are on a new alignment, or have new alignment sections totaling more than 1.5 miles, need to meet the 2-year peak flow discharge requirement.

If the 2-year peak discharge requirement applies to a project, then the analysis is typically part of the standard drainage design process, except that in addition to evaluating the 10-year, 25-year, and possibly the 50-year rainfall events, the designer will also evaluate the 2-year rainfall event. If the peak discharge for the post construction 2-year rainfall event is greater than the peak for the existing discharge, then the designer can either lengthen the time of concentration, modify the soil to reduce the discharge rate, or provide detention storage. Each of these options is discussed below.

1. Lengthen the Time of Concentration. Options include:
   - Increasing the flow path length
   - Flattening the ditch line
   - Widening the ditch
   - Adding ditch checks if the ditch is out of the clear zone.
2. Modify the Soil to Reduce the Discharge Rate. Options include:
   - Adding sand, peat, compost, or mulch to the soil to increase the soil porosity and lower the discharge rate.
   - Increase the soil porosity by subsoiling (soil ripping) and planting deep rooted native plants.
   - Adding a drain tile in a ditch with engineered soil to reduce the peak discharge from the ditch.
3. Provide Detention Storage. Options include:
   - Providing small depressions in a widened conveyance swale.
   - Wet or dry detention ponds.

FDM 10-35-5 Grass Swales — *March 28, 2014*

5.1 Description and Purpose

Vegetated or grass swales are shallow channels with a dense stand of vegetation established in them. They are designed to promote infiltration and trap pollutants. The combination of low velocities and vegetative cover provides an opportunity for pollutants to settle out or be treated by infiltration. In addition to pollutant removal, this practice can result in reduced runoff volumes and peak discharges.

5.2 Target Pollutants

Grass swales can be used to trap solids such as sediment, associated particulate pollutants, and organic matter from runoff. Grass swales can also be effective for runoff volume reductions, peak flow-rate reductions, metals, and soluble pollutant removal, but only to the extent that runoff infiltrates into the soil and pollutants are filtered or become attached to soil particles.

5.3 Planning Issues

5.3.1 WisDOT Design Requirements

Per TRANS 401.106(3):

- For transportation facilities first constructed after 2002, where there was previously no transportation facility, total suspended solids (TSS) discharges shall be reduced, when compared with no stormwater quality discharge controls, by the maximum extent practicable, up to 80%, based on an average annual rainfall.
- Highway reconstruction and non-highway redevelopment projects must reduce TSS discharges by the maximum extent practicable, or up to 40%.
- Projects classified as minor reconstruction do not require TSS removal.

See the Region Stormwater Engineer or FDM 10-35-1 for guidance on setting the correct TSS reduction level for a project. Off-site pollutant loads, however, are typically excluded from the analysis because the source of the pollutants (from off the DOT right-of-way) is not controlled by the DOT. If the highway has an ADT of more than 2,500 vehicles per day and runoff from the transportation facility directly enters an outstanding resource water, exceptional resource water, 303(d) listed water or waters with targeted performance standards (such as TMDLs), then the designer should work with the Region Stormwater Engineer and the WDNR Liaison to determine how to meet water quality standards.

Grass swales must have a design velocity of less than 1.5 ft/sec, using the 2-year design storm, for the swale to achieve the 80% reduction described in TRANS 401.106(10). These values can be determined by applying the design flow to each swale segment using the WisDOT Grass Channel design spreadsheet described in FDM 13-30-15.

5.3.2 Site Assessment

Conduct and document a site assessment to determine where grass swales are appropriate. The primary issues affecting their use are:

- Swale length
- Bottom width
- Design flow depth
- Slope and vegetation type

because this information will affect how the swale performs. Generally, if the swale slopes are greater than 4%, the swale will not effectively remove pollutants from the adjacent roadway runoff unless other measures such as permanent ditch checks are included in the design. To evaluate grass swales, identify the proposed drainage area for each swale section. The drainage area is defined by distance between the roadway crown and the top of the back slope draining to the swale and by the length of the highway that drains to the swale. Grass swale drainage areas can extend past the highway right-of-way depending upon the slope of the land, and can include significant areas outside of the right-of-way, depending upon local topography. Grass swale drainage areas should also be divided when soil types or swale treatments or geometries change. For example, if a section of the grass swale has permanent ditch checks or a different bottom width than other sections, then this section should be considered as a separate grass swale section.

5.3.3 Grass Swale Design Considerations

Planning considerations are intended to suggest to the designer issues that may be of concern for a project. If you believe that a consideration may affect your project, contact your regional stormwater engineer for additional guidance. If the channel is unstable, you have the following options:

- Flatten the longitudinal slope by modifying the slope grade, alternating longer flatter sections with short, steep riprap lined sections, or putting in permanent ditch checks that are not in the clear zone. If you use properly spaced permanent ditch checks, assume a longitudinal slope of 1%. Ditch checks should be spaced such that the base of the upstream check is at the same elevation as the top of the downstream check.
- Flatten the side slopes and/or widen the ditch bottom to decrease the flow depth.

5.4 Design Recommendations

The design guidelines described below provide a set of methods to calculate the percent TSS reduction from a grass swale. These guidelines assume that the swale will reduce TSS by 80% if the swale velocity is less than or equal to 1.5 feet per second and that the swale length is at least 200 feet.

1. Flow: Compute runoff flows from sources within the right-of-way separately from those contributing from outside the right-of-way. The Q2 water quality design storm, Q10 for erosion, and ditch capacity design flow rate as required in FDM 13-10 Attachment 1.1 need to be computed from both sources within and outside of the right-of-way. Each grass swale transition location should be evaluated for these flows; however, transition locations need not be evaluated closer than 200 feet apart.

2. Side slopes: The side slopes should be flat as possible to aid in providing pretreatment for lateral incoming flows and to maximize the channel-filtering surface. Steeper side slopes are likely to have erosion gullying from incoming lateral flows. A maximum slope of 3:1 is recommended; a 4:1 slope or flatter is preferred where space permits.

3. Channel longitudinal slope: The slope of the channel should be steep enough to ensure uniform flow and which can be constructed using conventional construction equipment without ponding, but not steeper than 4.0%. A desirable minimum slope of between 1.0% to 0.5% is recommended, and the absolute minimum slope is 0.3% where necessary.

5.4.1 Grass Swale Water Quality Analysis using the WisDOT Stormwater Report Spreadsheet

WisDOT has prepared two spreadsheets that incorporate the design guidelines and calculations needed to determine if a project meets the required TSS load reduction. The first spreadsheet, the Stormwater Report, has a series of worksheets that a designer can use to methodically prepare and summarize an analysis of the water quality benefits of the various stormwater quality practices used on a project.

The WQ-Grass Swales Worksheet in the Stormwater Report provides a place for the designer to describe and summarize the performance of any grass swales used in a project. The use of the complete spreadsheet to summarize water quality performance for a project is described in FDM 10-30-1. The second spreadsheet is the grass lined channel design spreadsheet developed for FDM 13-30-15. This spreadsheet is used to determine the velocity of the flow in the channel for the 2-yr design storm. The spreadsheet is part of the documents that can be downloaded at:

https://wisconsindot.gov/rdwy/fdm/files/WisDOT-Stormwater-Drainage-WQ-Channel-Spreadsheets.zip

The grass swale analysis procedure described below uses the grass swale analysis summary worksheet "WQ-Grass Swales" shown in Attachment 5.1. The worksheet is only used to summarize the grass swale data in an organized fashion - it does not calculate grass swale performance, but instead selects the TSS reduction value based upon the design variable, the velocity of the 2-yr design storm.

To use WQ-Grass Swale Worksheet, enter data into the appropriate worksheet cells. The worksheet is designed so that you can insert additional columns before the final Total column, as needed. Do NOT enter information in the grey cells because they contain formulas that should not be modified. However, you will have to modify the formula in the row 22 Totals column to correctly calculate the total percent reduction per unit ROW area.

On a plan view of the drainage system, delineate the drainage area for each grass swale section that will be providing water quality benefits designed in accordance with this standard. Number the sections, determine their station and if they are left, right or in the center median. Enter this information on lines 7 through 10 of the worksheet, and then determine the following information and enter it on the appropriate line of the worksheet.

Line 12 - The length of the grass swale adjacent to the highway, which will typically be the difference between the starting and ending station numbers entered in lines 8 and 9.

Line 13 - The average drainage area width outside of the right-of-way. The area this width is calculated from includes all areas outside of the right of way that drain to the grass swale.

Line 14 - The average right-of-way width. The average distance from edge of right-of-way to edge of right-of-way for the highway segment the grass swale drains. If there are grass swales or other treatment devices in either the median or the other side of the highway, then extend this distance from the edge of the right-of-way to the limit of the treatment area (eg, the crown of the highway). If there are no other treatments for this drainage area segment, use the total right-of-way width. If there is more than one swale in a highway segment (for example, a median swale and a left side swale) use two separate drainage basins.

Line 15 - The average swale slope.

Line 16 - The swale segment 2-year design flow rate. This value can be determined using an appropriate method described in FDM 13-10-5.

Line 17 - The swale segment 2-year design flow velocity. This value can be determined from line 55 of the Grass Channel Design Spreadsheet described in FDM 13-30-15.

The worksheet will determine the percent reduction for each basin in Line 18.

If you need to record comments about the design for any of the drainage areas, enter them in the comment boxes below the worksheet. Add more comment boxes if necessary.

5.4.2 Other Design Criteria

1. This design approach isn't intended for riprap channels. Appropriate soil-stabilization methods, such as mulch, mats or blankets, should be used before establishment of vegetation
2. Avoid convergence of flows that may result in erosion or gullies. Convergence points shall be treated with additional practices like permanent ditch checks or sediment traps.
3. If permanent ditch checks are used to reduce the channel slope, then the permanent ditch checks must meet the following criteria:
    1. They must be spaced by installing one permanent ditch check for every two feet of drop.
    2. Assume a 0.5% slope for properly spaced ditch checks when calculating flow velocity.
    3. They must not be in the clear zone.

5.5 Maintenance

5.5.1 Maintenance Requirements

Properly designed grass swales should require little maintenance. Typical loading rates to swales from the highway surface on a per foot basis are lower than the rate necessary to clog the swale. If clogging does occur, it is usually due to off right-of-way erosion, or from an embankment or swale failure within the right-of-way, which should be addressed before repairing the grass swale. Other causes of swale damage include tire rutting due to a car driving over the embankment into a swale, or by a spill along the highway. Minor repairs are managed by the WisDOT region maintenance staff. If swale damage does occur, it should be repaired in a timely manner.

5.5.2 Maintenance Plan

A maintenance plan is typically unnecessary for grass swales because regular highway maintenance and inspection practices detect and repair shoulder, embankment and swale problems. Standard WisDOT maintenance practices include:

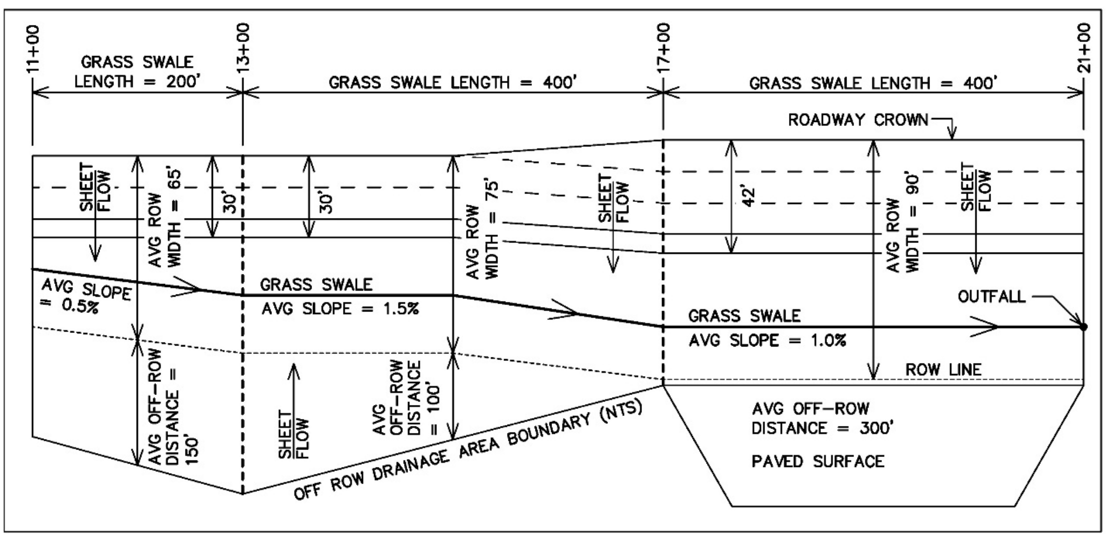
1. Grading the shoulder one to two times per year, typically in the spring and the fall. Grading consists of blading the shoulder away from the edge of the pavement, returning it, settling and then compacting it with rubber tired rollers.
2. Inspecting embankments while mowing and during routine maintenance surveillance. Rilling or other embankment problems are then repaired on a spot basis.

5.6 Grass Swale Water Quality Design Example

Vegetated swales should be maintained to keep the grass dense. The grass should be mowed occasionally, but

Given the drainage areas and site conditions described below, determine the water quality reduction percentage using grass swales for the highway section.

Problem - One thousand feet of a highway corridor is drained by a standard V-ditch grass swale, as shown in the drawing below. Determine the percent reduction of TSS due to the swale. To do this, determine the velocity of the flow for each segment of the grass swale system and then enter the data from the table below into the Grass Swale tab of the Stormwater Report spreadsheet. Assume that the ROW width extends only from the roadway crown to the ROW line.



STA – STA	11+00 - 13+00	13+00 - 17+00	17+00 - 21+00
Paved Area (ac)	200’ x 30’ = 0.14 ac	400’ x 32 = 0.29 ac’	400’ x (42’+300’) = 3.14 ac
Unpaved Area (ac)	200’ x (65’-30'+150’) = 0.85 ac	400’ x (75’-32’+100’) = 1.31 ac	400’ x (90’-42’) = 0.44 ac
Composite Runoff Coefficient	0.37	0.39	0.87
Rainfall Intensity	2-yr, 24-hr. 4.0 in/hr		
Flow	1.5 cfs	2.5 cfs	12.5 cfs
Cumulative Flow	1.5 cfs	4.0 cfs	16.5 cfs
Swale Geometry	V-Ditch, 6:1, 4:1 Side Slopes		
Safety Factor	1.0		
Retardance Class	C		
Vegetation Condition	Good		
Growth Form	Turf		
Soil Type	Cohesive		
ASTM Soil Class	SC		
Plasticity Index	16		

Solution - First complete the Grass Channel Design spreadsheet using the data listed above. The purpose of the analysis is to determine the velocity of the flow for the 2-yr design storm in each swale segment. Note that for this example, the spreadsheet (shown below) has been slightly modified to include the average velocity (line 55) for each segment. For assistance using the Grass Channel Design spreadsheet, review FDM 13-30-15. For an illustration of a typical grass swale cross section, see Figure 10.1 of FDM 13-30-10. The results of the analysis show that the first two segments, at STA 11+00 and 13+00, have average velocities that are less than 1.5 ft/sec, while the last segment, at STA 17+00, does not. This means that, for the initial design, only the first two segments will receive the 80% reduction.

The example Grass Channel Design spreadsheet below also includes a second column for the swale at STA 17+00 to demonstrate how to use the spreadsheet to evaluate different swale options. If it were possible to increase the width of the swale bottom to 12 feet, then the swale section at STH 17+00 would also meet the average velocity requirement.

7	STA	11+00	13+00	17+00	17+00
8	Left, Center or Right	R	R	R	R
9	***Channel/Ditch Geometry***				
10	Channel Slope, S_o (ft/ft)	0.005	0.015	0.01	0.01
11	Channel Bottom Width, B (ft)	0	0	0	12
12	Channel Side Slope, z_1	6	6	6	4
13	Channel Side Slope, z_2	4	4	4	4
14	Flow Depth, d (ft) Solve iteratively	0.79	0.79	1.42	0.75
15	Safety Factor, SF	1.0	1.0	1.0	1.0
16	***Vegetation/Soil Parameters***				
17	Vegetation Retardance Class	C	C	C	C
18	Vegetation Condition	good	good	good	good
19	Vegetation Growth Form	turf	turf	turf	turf
20	Soil Type	cohesive	cohesive	cohesive	cohesive
21	D_{75} (in) (Set at 0.00 for cohesive soils)				
22	ASTM Soil Class	SC	SC	SC	SC
23	Plasticity Index, PI	16	16	16	16
24	***Results Summary***				
25	Design Q (ft^3/s)	1.5	4.0	16.5	16.5
26	Calculated Q (ft^3/s)	1.5	4.0	16.6	16.4
27	Difference Between Design & Calc. Flow (%)	-1.4%	-0.5%	0.7%	-0.3%
28	**Stable (Yes or No)**	YES	YES	YES	YES
29	***Channel Parameters***				
55	Average Velocity, V (ft/s)	0.48	1.28	1.64	1.47

Figure 5.1 Example Grass Channel Design Sheet

Once the velocity of each swale segment has been determined, complete the Grass Swale Analysis Summary spreadsheet. The project information (lines 2 - 5) will be filled in when you enter project information on the summary tab of the stormwater report. Define the grass swale sections in lines 7-10 of the Grass Swale Analysis Summary Spreadsheet, (Attachment 5.1). Next, enter the site and calculated data into lines 12 - 17 of the spreadsheet.

Once the data have been entered, the worksheet will determine the overall TSS reduction due to grass swales. This value is transferred to the Water Quality Summary worksheet to include the grass swale TSS reduction with the reductions from any other stormwater quality control practices used on the project.

7	Drainage Area Basin Number	1	1	1		Total
8	Grass Swale Ending Station Number	13+00	17+00	21+00		
9	Grass Swale Starting Station Number	11+00	13+00	17+00		
10	Left, Center, or Right	R	R	R		
11	***Site Assessment***					
12	Grass Swale Length (ft)	200	400	400		
13	Average Drainage Area Width Outside of ROW (ft)	150	100	300		
14	Average ROW Width (ft)	65	75	90		
15	Average Swale Slope	0.50%	1.50%	1.00%		
16	Swale Segment Q2 Flow Rate (cfs)	1.5	4.0	16.5		
17	Average Swale Velocity (ft/s)	0.48	1.28	1.64		
18	Percent Reduction	80.0%	80.0%	0.0%	80.0%	
19	***Results Summary***					
20	Drainage Area (ac)	0.99	1.61	3.58	0.00	6.18
21	ROW Area (ac)	0.30	0.69	0.83	0.00	1.81
22	Percent Reduction per unit ROW Area	80.0%	80.0%	0.0%	80.0%	43.5%

Figure 5.2 Stormwater Report WQ Grass Swales Worksheet

5.7 References

Claytor R and Schueler T, Design of Stormwater Filtering Systems. Center for Watershed Protection, Silver Spring, MD, prepared for the Chesapeake Research Consortium, Inc. with supplemental funding of U.S. EPA Region 5. 1996.

Caraco D and Claytor R. Stormwater BMP Design Supplement for Cold Climates. U.S. EPA Office of Wetlands, Oceans and Watersheds. 1996.

Schueler T. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, D.C. 1987.

Vegetated Infiltration Swales (1005) Interm Technical Standard, Storm Water Post-construction Technical Standards, Wisconsin Department of Natural Resources, updated May 10, 2007.

Wisconsin State Legislature, Revisor of Statutes Bureau, Wisconsin Administrative Code; for information on the codes of state agencies, including WDNR, see http://www.legis.state.wi.us/rsb/code.htm.

LIST OF ATTACHMENTS

Attachment 5.1 Grass Swale Analysis Summary Spreadsheet

FDM 10-35-10 Filter Strips

December 20, 2013

10.1 Description and Purpose

Filter strips are grass strips or other close growing vegetation designed to receive overland or sheet flow and reduce the stormwater runoff volume and stormwater pollutant concentrations and mass discharges. The vegetation slows and infiltrates the runoff (and associated pollutants) and further traps particulate pollutants in the exiting overland flow. Highway embankments can act as filter strips if they are graded to not concentrate runoff after it flows off a roadway surface and if the flow path across the embankment is sufficiently long and of low or moderate slope. Refer to typical filter strip illustration in Figure 10.1.

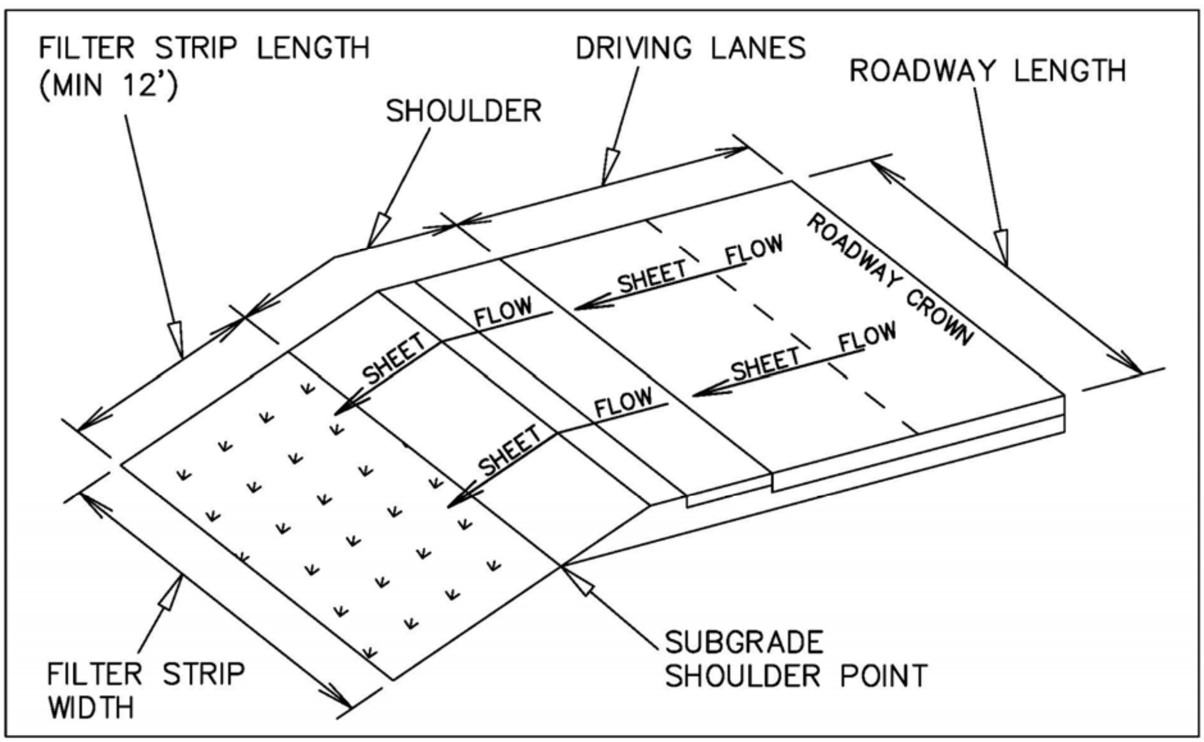


Figure 10.1 Typical Filter Strip

10.2 Targeted Pollutants

Filter strips can be used to trap solids such as; sediment, associated particulate pollutants, trash, and organic matter from runoff. Filter strips can also be effective for runoff volume and peak flow rates reductions, and soluble pollutant removal, but only to the extent that runoff infiltrates into the soil.

10.3 Effectiveness

The effectiveness of filter strips for pollutant removal is a function of the length and, to a lesser extent, the slope of the filter strip, the soil permeability, the size of the drainage area, and the height, type and density of vegetative cover. Also critical to the performance of filter strips is the distribution of overflowing water. If water is allowed to concentrate because of poor grading or uneven runoff distribution, the filter will be short-circuited and have only minimal benefit. When properly designed and maintained, highway embankment filter strips can trap 30 to 90 percent of the sediment in roadway runoff, depending upon the embankment soil type. Runoff volume reductions are determined by infiltration losses, and particulate losses are determined through particle trapping.

The runoff volume reduction is calculated using the wetted area and the dynamic infiltration rate of the filter strips for each time step of the filter strip inflow hydrograph. The calculated flow and the filter strip geometry are used to iteratively determine the Manning's n and the depth of flow in the filter strip for each time step. Using traditional VR-n (Velocity-Hydraulic Radius - Manning's n) curves based upon retardance measurements (USDA, 1954) that were extended (Kirby, et al, 2005) to cover the smaller flows found in roadside filter strips for VR values smaller than about 0.1 ft^2/sec (see Figure 10.2). For shallow sheetflows, as expected in filter strips, hydraulic radius can be approximated by the flow depth.

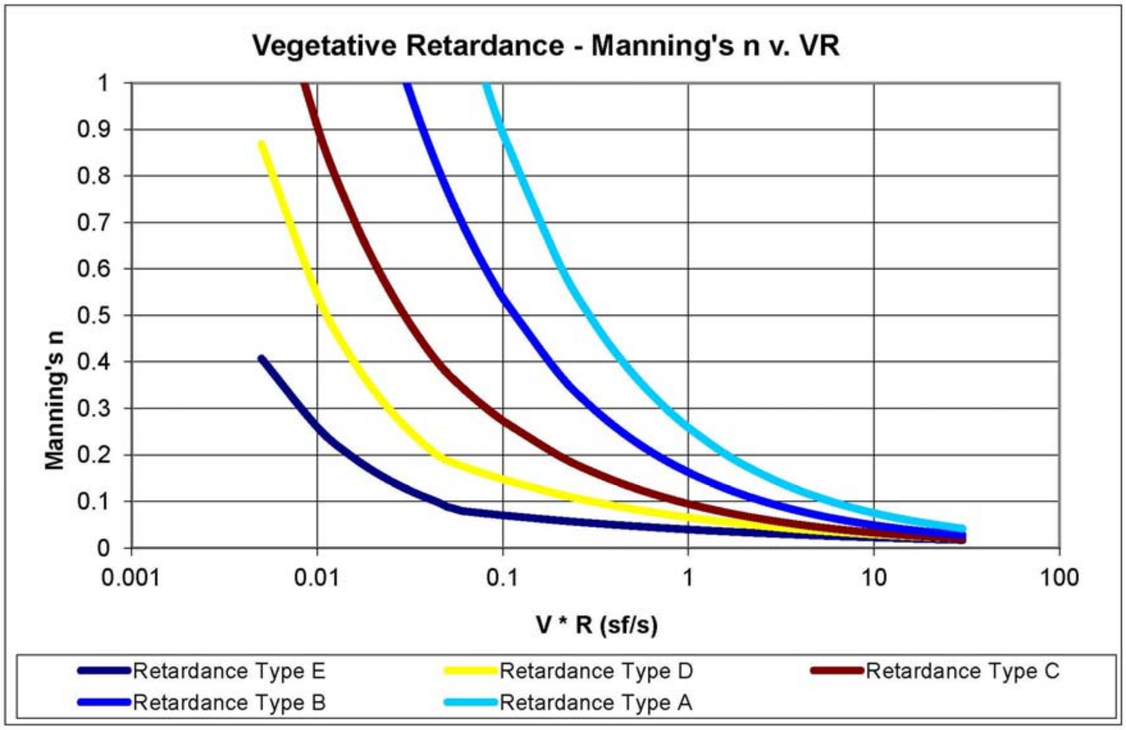


***Figure 10.2* Vegetative Retardance - Manning's n vs. VR**

The wetted perimeter (the width of the filter strip) is multiplied by the total effective flow length (filter strip length less 10 ft.) to determine the area used to treat the runoff. The design charts have a minimum filter strip length of 12 feet, as shown on the above illustration, which is a minimum effective length of 2 ft. As shown in the filter strip schematic, assume that the filter strip width is the same as the length of the roadway draining towards it. Stretches of a roadway directed to a mildly sloped filter strip ten feet or less in length cannot be evaluated by the procedure presented here, but would require a more detailed analysis.

The design charts in this section assume that particulate filtering is calculated for each time step of the highway surface runoff hydrograph using the average flow length to the end of the filter strip and the calculated depth of flow for each time step of the hydrograph. The depth of grass also affects the particulate trapping in the filter strip. The depth of flow is used to calculate the flow velocity, which in turn is used to determine the travel time, and particulate settling frequency for the average filter strip length in the project area for each particle size increment. Particulate trapping is based on the settling frequency: what is the probability that a particle of a given size would be able to completely settle during the length of the filter strip. Particles with a higher probability of settling in the filter strip (the large particles) are much more likely to remain trapped in the filter strip, while particles that settle less frequently have a greater probability of moving through the filter strip. Taller grass is also more effective in trapping the particles than shorter grass, though current data limitations preclude the analysis of grasses greater than four inches in height.

10.4 Planning Issues

10.4.1 WisDOT Design Requirements

Per TRANS 401.106(3):

- for transportation facilities first constructed after 2002, where there was previously no transportation facility, total suspended solids (TSS) discharges should be reduced, when compared with no stormwater quality discharge controls, by the maximum extent practicable, up to 80%, based on an average annual rainfall.
- for highway reconstruction and non-highway redevelopment projects TSS discharges must be reduced by the maximum extent practicable, or up to 40%.

See FDM 10-35-1 for guidance on setting the correct TSS reduction level for a project. Off-site pollutant loads, however, are typically excluded from the analysis because the source of the pollutants (from off the WisDOT right-of-way) are not controlled by WisDOT. If the highway has an ADT of more than 2,500 vehicles per day and runoff from the transportation facility directly enters an:

- Outstanding resource water
- Exceptional resource water
- 303(d) listed water or
- Waters with targeted performance standards (such as total maximum daily load (TMDLs))

then the designer should work with the DNR Liaison to determine how to meet water quality standards.

It is critical that filter strips are designed and constructed so that runoff flows uniformly across the filter. In order to accomplish this, the top edge of the filter should be even. Any depressions will concentrate runoff and short circuit the filter. In some cases, a shallow stone trench can be used to uniformly distribute runoff at the top of the filter. If a filter has been used to trap sediment during construction, it may be advisable to regrade and reseed the top of the filter. Otherwise, sediment accumulations may cause runoff to concentrate in certain locations.

10.4.2 Site Assessment

Conduct and document a site assessment to determine where embankment filter strips are appropriate. The primary issue affecting their use is the length of the filter strip. Generally, if the filter strips flow path is less than 12 feet, the filter strip will not effectively remove pollutants from adjacent roadway runoff. Do not use enhancements to the filter strip such as sub-soiling, incorporating sand into the embankment to improve drainage, or adding a drain tile interceptor into the embankment if the filter strip is steeper than 4:1 because of slope stability issues. To evaluate filter strips, collect the following information to characterize the drainage area for each filter strip for the water quality analysis.

1. Identify the proposed drainage area for each filter strip section. The drainage area is defined by the highway and shoulder surface drainage to the filter strip along with the filter strip area. Filter strip drainage areas should be split when soil types or soil treatments change. For example, if a section of the embankment soil has subsoiling and compost or sand enhancement, then this section should be considered as a separate filter strip section.
2. The filter strip soil type affects the filter strip performance because it determines the infiltration rate of the embankment. The five soil types for filter strips and the corresponding dynamic infiltration rates are listed in the table below. The infiltration rates are default values determined for state of Wisconsin highway projects. When selecting the appropriate design chart to determine filter strip pollutant removal effectiveness, also select the soil type from the table that is most similar to the project soils. Since it is sometimes difficult to determine the embankment soil type during design, especially when different soil types on a long corridor project may be mixed, engineers should use their best judgment to determine the appropriate infiltration rate.

Soil Type	Dynamic Infiltration Rate
Sand	1.8 in/hr
Loamy Sand	0.82 in/hr
Sandy Loam	0.25 in/hr
Loam	0.12 in/hr
Silty Clay Loam	0.04 in/hr

10.4.3 Filter Strip Design Considerations

Design considerations are intended to suggest to the designer issues that may be of concern for a project. If you believe that a consideration may affect your project, contact your region stormwater engineer for additional guidance.

1. Enhancing Soil - If the embankment soil type limits the effectiveness of the filter strip, consider enhancing the soil by subsoiling and adding sand or compost to the embankment, if the embankment slope is equal to or flatter than 4:1. If 30% sand, by volume, is added to the sandy loam, loam or silty clay loam typical soil types described in this section, then assume the soil infiltration rate is the equivalent of loamy sand. See Attachment 10.3 for a discussion of the infiltration curves used to develop this value. The sand must be mixed with the site soils to a depth of at least 20 inches using the Subsoiling Filter Strips special provision (SPV). The subsoil limits on the embankment should begin two feet from the swale flow line, can extend no more than five vertical feet towards the highway, and end no closer than 10 feet from the subgrade shoulder point. The actual filter strip length begins at the subgrade shoulder point and continues to the downgradient edge of the subsoiled filter strip.

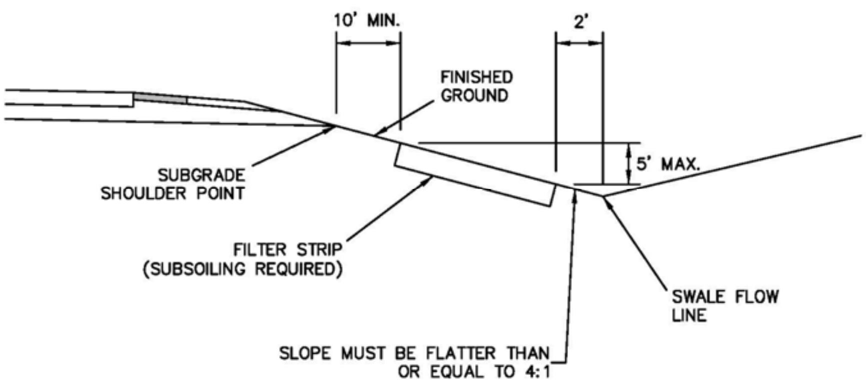


Figure 10.4 Typical Enhancing Soil Diagram

10.5 Design Recommendations

The design guidelines described below provide a method to calculate the percent TSS reduction from a filter strip. These guidelines use a series of curves that describe the percent TSS reduction based upon the number of lanes draining to the filter strip, the filter strip soil type and the filter strip length. They were developed using the NURP (National Urban Runoff Program) particle size distribution in WinSLAMM v 10.0. Each of the curves was developed assuming a seven-foot wide shoulder in addition to the twelve foot wide driving lanes. If the project is using filter strips with significantly different pavement contributing areas or soil types with known, different infiltration rates that cannot be characterized using the design curves, then the pollution control effectiveness of the device should be modeled using a pollutant loading model such as WinSLAMM, P8, or an equivalent acceptable methodology.

10.5.1 Filter Strip Design Charts

There are four design charts in Attachment 10.1. Each chart describes the percent TSS reduction for one to four highway lanes, as a function of filter strip length and soil type.

10.5.2 Filter Strip Water Quality Analysis Using the WisDOT Stormwater Report Spreadsheets

WisDOT has prepared a spreadsheet that incorporates the design guidelines and calculations needed to determine if a project meets the required TSS load reduction. The spreadsheet has a series of worksheets for a designer to methodically prepare and summarize an analysis of the water quality benefits of the various stormwater quality practices, including filter strips, used on a project. The WQ-Filter Strips worksheet provides a place for the designer to describe and summarize the performance of any filter strips used in a project. The use of the complete spreadsheet to summarize water quality performance for a project is described in FDM 10-30-1. The spreadsheet is part of the working documents that can be downloaded (refer to FDM 10-35-5.4.1).

The filter strip analysis procedure described below uses the filter strip analysis summary worksheet WQ-Filter Strips shown in Attachment 10.2. The worksheet is only used to summarize the filter strip data in an organized fashion - it does not calculate filter strip performance, which is determined from the design charts.

To use this spreadsheet, enter data into the appropriate worksheet cells. The worksheet is designed so that you can insert columns between the last column and the first column and then select the cells in a data column from rows 7 to 25 and drag them across to create columns for additional filter strip sections. Do NOT enter information in the grey cells because they contain formulas that should not be modified.

On a plan view of the drainage system, delineate the drainage area for each filter strip section that will be providing water quality benefits designed in accordance with this standard. Number the sections, determine their station and if they are left, right or in the center median. Enter this information on lines 7 through 10 of the spreadsheet, and then determine the following information and enter it on the appropriate line of the spreadsheet. For convenience, some of the items can be selected using a drop down menu list on the spreadsheet.

Line 12 - The width of the filter strip parallel to the highway, which will typically be the difference between the starting and ending station numbers entered in lines 8 and 9.

Line 13 - The average drainage area width (feet). This distance extends from the crown of the road to the toe of the filter strip. This area includes all areas both within the right of way and outside of the right of way that includes the filter strip.

Line 14 - The average right of way width that the filter strip is in (feet). The average distance from edge of right-of-way to edge of right-of-way for the highway segment the filter strip is in. If there are filter strips or other treatment devices in either the median or the other side of the highway, then extend this distance from the edge of the right-of-way to the limit of the treatment area (eg, the crown of the highway). If there are no other treatments for this drainage area segment, use the total right-of-way width.

Line 15 - Use the drop down menu to enter the number of lanes of pavement (not including the shoulder) that drain to the filter strip.

Line 16 - Enter the length of the filter strip (feet) from the edge of the shoulder to the toe of the filter strip. This distance should include the 10 foot length (minimum) from the shoulder to the subsoiled filter strip edge if the filter strip is subsoiled.

Line 17 - Use the drop down menu to select the filter strip soil type.

Line 18 - Use the drop down menu to select the Filter Strip design chart number you used to determine the percent TSS reduction.

The design charts are organized by typical cross section as follows:

Chart 1 - One paved freeway or highway lane draining to the filter strip

Chart 2 - Two paved freeway or highway lanes draining to the filter strip

Chart 3 - Three paved freeway or highway lanes draining to the filter strip

Chart 4 - Four paved freeway or highway lanes draining to the filter strip

Each of these charts was developed using WinSLAMM v 10.0 for the conditions described in the chart. To get a specific percent reduction, interpolate the appropriate value from a chart.Line 19 - Enter the percent reduction from the design chart (Attachment 10.1) based on the information entered and lines 15, 16, and 17.

If you need to record comments about the design for any of the drainage areas, enter them in the comment boxes below the worksheet. Add more comment boxes if necessary.

10.5.3 Other Design Criteria

There must be no impediment in the roadway or shoulder to prevent the roadway surface runoff from sheet flowing off the roadway, onto the shoulder, and then onto the embankment. For example, a curb and gutter system would typically preclude the use of filter strips because they channel and concentrate runoff from the roadway.

10.6 Maintenance

10.6.1 Maintenance Requirements

Properly designed filter strips require little maintenance. The loading rates to filter strip from the highway surface on a per foot basis are usually lower than the rate necessary to clog the filter strip.

The only exception to this is if concentrated flow occurs, causing rills. This could be caused by tire rutting due to a car driving over the embankment or by a spill along the highway. Typically, minor grading along the shoulder should eliminate this problem. If rilling or other embankment erosion does occur, it should be repaired in a timely manner.

10.6.2 Maintenance Plan

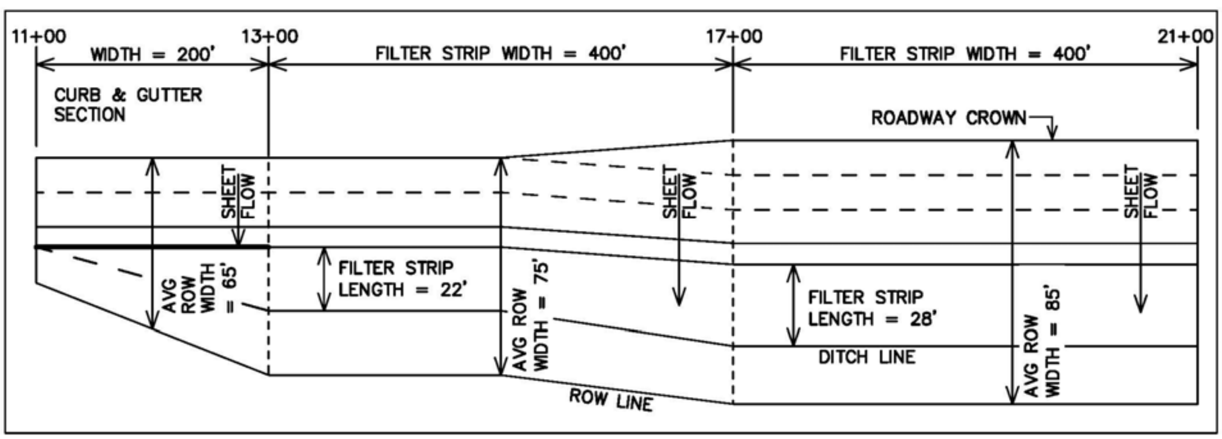
A maintenance plan is typically unnecessary for embankment filter strips because regular highway maintenance and inspection practices detect and repair shoulder and embankment problems. Standard WisDOT maintenance practices include:

1. Grading the shoulder is typically a component of routine maintenance, and performed as needed. Grading consists of blading the shoulder away from the edge of the pavement, returning it, settling, and then compacting it.
2. Inspecting embankments while mowing and during routine maintenance surveillance. Rilling or other embankment problems are then repaired on a spot basis.

10.7 Filter Strip Water Quality Design Example

Given the drainage areas and site conditions described below, determine the water quality reduction percentage using filter strips for the site.

- <u>Problem</u> - One thousand feet of a highway corridor has an embankment that may act as a filter strip. Two hundred feet of this section is a curb and gutter section, as illustrated in the drawing below. Determine the percent reduction of TSS due to the embankment acting as a filter strip. Enter the data from the table below into the Filter Strip Performance tab of the Stormwater Report spreadsheet. Assume that the ROW width extends only from the roadway crown to the ROW line.



7	Drainage Area Basin Number	1	2	3
8	**Filter Strip Ending Station Number**	**13+00**	**17+00**	**21+00**
9	**Filter Strip Starting Station Number**	**11+00**	**13+00**	**17+00**
10	**Left, Center, or Right**	**R**	**R**	**R**
	Site Assessment	Curb & Gutter		
12	Filter Strip Width parallel to Highway (ft)	200	400	400
13	Average Drainage Area Width (ft)	50	56	66
14	Average ROW Width (ft)	65	75	85
15	Number of Treated Freeway Lanes	2	2	3

16	Filter Strip Length perpendicular to Highway (ft)	0	22	28
17	Filter Strip Soil Type	Sandy Loam	Sandy Loam	Sandy Loam
18	Design Chart Number	2	2	3
19	Percent Reduction of Treated Area	0%	85%	86%

- Solution - The project information (lines 2 - 5) is entered as project information on the summary tab of the stormwater report. Define the filter strip sections in lines 7-10 of the Filter Strip Analysis Summary Spreadsheet, (Attachment 10.2). Next, enter the site data into lines 12 - 19 of the spreadsheet. On lines 12 - 16, enter the numeric values for widths, number of lanes and filter strip lengths. Use the drop down menus to enter the soil type in line 17 and the Design Chart Number in line 18.

  Enter a 0% reduction for drainage basin 1 because it is in a curb and gutter area, and so no treatment is allowed.

  Use Chart 2 for the filter strip in drainage basin 2. Based upon the filter strip length and the soil type, enter an 85 percent reduction in line 19.

  Use Chart 3 for the filter strip in drainage basin 3. Based upon the filter strip length and the soil type, enter an 86 percent reduction in line 19.

As illustrated in Attachment 10.2, the TSS reduction result from this example shows that, when all the areas are combined, the total reduction is 60.8%. This result includes the curb and gutter section that, by definition, does not get any TSS reduction.

10.8 References

Kirby, Jason T., "Determination of Vegetal Retardance in Grass Swales Used for the Remediation of Urban Runoff", Masters Thesis, Graduate School of the University of Alabama, Tuscaloosa, Alabama, 2003.

Kirby, Jason T., S. Rocky Durrans, Robert Pitt, Pauline Johnson, "Hydraulic Resistance in Grass Swales Designed for Small Flow Conveyance", ASCE Journal of Hydraulic Engineering, January, 2005.

Nara, Yukio, and Robert Pitt, Alabama Highway Drainage Conservation Design Practices – Particulate Transport in Grass Swales and Grass Filters, University Transportation Center for Alabama, The University of Alabama, Tuscaloosa, Alabama, Project Number 04117, November 6, 2005.

USDA, 1954, Handbook of Channel Design for Soil and Water Conservation, Washington, D.C., USDA Technical Paper TP-61.

Pitt, R. and J. Voorhees, "WinSLAMM, the Source Loading and Management Model for Windows version 10.0," PV and Associates, LLC, 2012.

Wisconsin State Legislature, Revisor of Statutes Bureau, Wisconsin Administrative Code; for information on the codes of state agencies, including WDNR, see http://www.legis.state.wi.us/rsb/code.htm

LIST OF ATTACHMENTS

Attachment 10.1	Filter Strip Water Quality Design Charts
Attachment 10.2	Filter Strip Analysis Summary Spreadsheet
Attachment 10.3	Filter Strip Sand Amendment Analysis

FDM 10-35-15 Wet Detention Pond Stormwater Quality Design — October 22, 2012

15.1 Description and Purpose

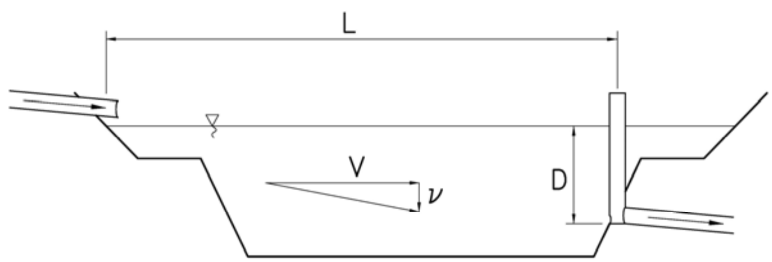
A wet detention pond is a permanent pool of water with designed dimensions, inlets, outlets, and storage capacity that is constructed to collect, detain, treat and release stormwater runoff. The primary purposes of this practice are to improve water quality and reduce peak flow rates. This stormwater quality control practice usually applies to urban areas where stormwater runoff pollution due to particulate solids loading and attached pollutants is a concern. It also applies where increased runoff from highway improvements is a concern. Site conditions must allow for runoff to be directed into the pond so that a permanent pool of water is maintained.

15.2 Target Pollutants

Wet detention ponds are most effective at removing suspended solids and associated particulate forms of pollutants. A well designed pond can remove as much as 85% - 90% of the TSS (total suspended solids) entering the pond. Pollutants associated with TSS, such as the particulate forms of metals like cadmium, copper, lead and zinc may also be removed at relatively high rates, as are hydrocarbons. Wet ponds are less effective at removing dissolved contaminants, such as some forms of phosphorus and nitrogen nutrients, and bacteria such as coliform and e.coli.

15.3 Effectiveness

Wet detention pond performance is calculated by assuming flow through a quiescent settling area. The particulate removal in this settling area is assumed to occur due to ideal settling as described by Stokes Law (for laminar flow which is most common for stormwater ponds), or Newton's law (for turbulent flow that may occur for very large particulates). The path of the settling particles is the vector sum of the particle velocity through the pond and the settling velocity of the particle. It is assumed (and verified by field monitoring) that particles settling to the pond bottom before the outlet zone is reached are captured in the pond. Therefore, if the water velocity is slow, slowly falling particles can be retained. If the water velocity is fast, then only the heaviest (fastest falling) particles are likely to be retained. The critical ratio of water velocity to particle settling velocity must therefore be equal to the ratio of the sedimentation pond length (L) to depth to the bottom of the outlet (D), as shown in equation (1) and the illustration below.



$$\frac{V}{\nu} = \frac{L}{D} \qquad (1)$$

The water velocity is equal to the water volume discharge rate (Q, such as measured by cubic feet per second) divided by the pond cross-sectional area (a, or depth times width: DW, in equation (2):

$$V = \frac{Q}{a} \quad \text{, or,} \quad V = \frac{Q_{out}}{DW} \qquad (2)$$

Where:

L = pond length

D = Outlet Depth

V = Water velocity through Pond

v = settling velocity

Q_{out} = Outlet from Pond

a = Pond Cross Sectional Area

The pond outflow rate equals the pond inflow rate under steady state conditions. The critical time period for steady state conditions is the time of travel from the inlet to the outlet. During critical portions of a storm, the inflow rate (Q_{in}) will be greater than the outflow rate (Q_{out}) due to freeboard storage. Therefore, the outflow rate controls the water velocity through the pond. Substituting this definition of water velocity into the critical ratio to results in equation (3):

$$\frac{Q_{out}}{DW\nu} = \frac{L}{D} \quad (3)$$

and cancel D to get:

$$\frac{Q_{out}}{W\nu} = L \quad \text{or} \quad \frac{Q_{out}}{\nu} = LW \quad (4)$$

Where:

L = pond length

D = Outlet Depth

V = Water velocity through Pond

v = settling velocity

Q_{out} = Outlet from Pond

a = Pond Cross Sectional Area

However, pond length (L) times pond width (W) equals pond surface area (A). Substituting leaves:

$$\frac{Q_{out}}{\nu} = A \quad (5)$$

Solving for the settling velocity results in the conventional surface overflow rate equation:

$$\nu = \frac{Q_{out}}{A} \quad (6)$$

Therefore, for an ideal sedimentation pond, particles having settling velocities less than this settling velocity will be removed. Only increasing the surface area or decreasing the pond outflow rate will increase pond settling efficiency. Increasing the pond depth does lessen the possibility of bottom scour, decreases the amount of attached aquatic plants, and decreases the chance of a winter fish kill. Deeper ponds may also be needed to provide sacrificial storage volumes for sediment between pond cleaning operations.

Since the settling velocity increases as particle size increases (using Stokes or Newton's law and appropriate shape factors, specific gravity and viscosity values), the pond water quality performance (or percent removal) is determined from the particle size distribution of the solids in the runoff entering the pond. This is done by determining the settling velocity and then calculating the particle size associated with that settling velocity, which is referred to as the critical particle size. The percent of the particles that will settle is then determined from the particle size distribution of the total suspended solids (TSS) concentration of the sediment in the stormwater runoff. The particle size distribution, which is called the NURP (National Urban Runoff Program) particle size distribution, used for stormwater runoff in Wisconsin is illustrated below.

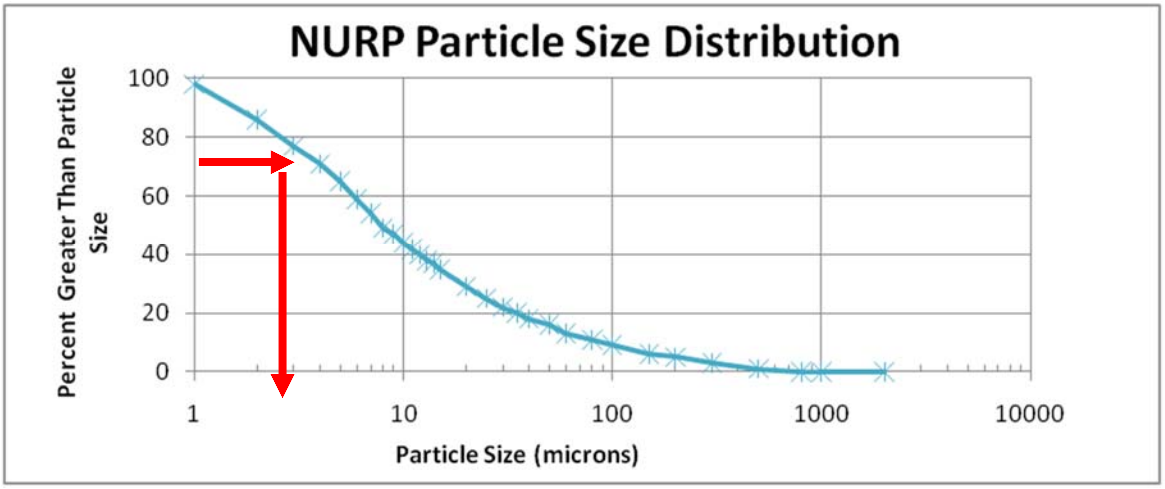


Figure 15.1 ***NURP Particle Size Distribution Curve***

By inspection of this NURP particle size distribution, all particles greater than three microns would need to be trapped to achieve 80% particulate solids control of the stormwater runoff entering a pond.

15.4 Planning Issues

15.4.1 Initial Coordination

Assess potential environmental impacts as part of the NEPA/WEPA project assessment process. Contact the WisDOT regional environmental coordinator and see FDM Chapter 21. The assessment should use historical information about the site to determine if the potential for environmental hazard exists, e.g., contaminated soils, contaminated groundwater, abandoned dumps or landfills. For questions regarding other planning considerations, contact the regional stormwater engineer.

15.4.2 DOT Design Requirements

Per TRANS 401.106(3), for transportation facilities first constructed (previously no transportation facility) after 2002, reduce total suspended solids (TSS) discharges, when compared with no stormwater quality discharge controls, by 80% or to the maximum extent practicable, based on an average annual rainfall. Highway reconstruction and non-highway redevelopment projects must reduce TSS discharges by 40% or to the maximum extent practicable. Runoff entering a pond from outside of the DOT right of way (off-site run-on) will affect the performance of the pond and must be accounted for during the pond design.

15.4.3 Federal State and Local Laws

The location and use of wet detention ponds may be limited by regulations relating to stormwater management, navigable waters (Ch. 30, Wis. Stats.), floodplains, depth to groundwater, wetlands, buildings, wells and other structures, or by land uses such as waste disposal sites and airports. The pond embankment may be regulated as a dam under Ch. 31, Wis. Stats., and further restricted under NR 333, Wis. Adm. Code, which includes regulations for embankment heights and storage capacities. Review the project with DNR liason and regional stormwater engineer. Specific regulatory concerns include wellhead protection areas, ponds near airports and pond sediment disposal as described below.

1. Wellhead protection area pond liner requirements - Some municipalities have wellhead protection areas and all municipalities have source water protection areas delineated by WDNR. If a pond is proposed near a well, first consider using other stormwater control practices. If no other options are feasible, consult with the local community about when a liner will be needed if a pond is located within one of these areas. According to NR 811, Wis. Adm. Code, wet detention ponds shall be constructed 400 feet from community wells and 25 feet from non-community and private wells. The 25 foot setback from non-community and private wells is a final construction distance. This may not be sufficient to prevent running over the well with heavy equipment during construction of the pond. Refer to FDM 10-35-15.5 for pond liner requirements.
2. Any ponds proposed for areas near airports should be evaluated for wildlife attractive hazards.
3. Sediment should be disposed of according to NR 528, Wis. Admin. Code (Management of Accumulated Sediment from Stormwater Management Structures).

15.4.4 Site Assessment

Conduct and document a site assessment to determine the site characteristics that will affect the placement, design, construction, and maintenance of the pond. Document the pond design. Items to assess include:

1. On a site map with the pond location identified:
    a. Identify buildings and other structures, parking lots, property lines, wells, wetlands, 100-year floodplains, surface drains, navigable streams, known drain tile, roads, and utilities (both overhead and buried) showing elevation contours and other features specified by the applicable regulatory authority.
    b. Show location of soil borings and test pits on site map, characterize the soils, seasonally high groundwater level, and bedrock conditions to a minimum depth of 5 feet below the proposed bottom of the pond or to bedrock, whichever is less. Conduct one test pit or boring per every 2 acres of permanent pool footprint, with a minimum of two per pond. Include information on the soil texture, color, structure, moisture and groundwater indicators, and bedrock type and condition, and identify all by elevation. Characterize soils using both the USDA and USCS classification systems. (Note: USCS characterization is used for soil stability assessment while USDA soil characterization identifies the soil's potential permeability rate.)
    c. Investigate the potential for karst features nearby by contacting nearby sources or by checking the Wisconsin Geological and Natural History Survey at http://wisconsingeologicalsurvey.org/karst.htm ,or by contacting the Bureau of Technical Services Hydrogeologist.
2. In the watershed, on a watershed map:
    a. Identify predominant soils, the drainage ways, navigable streams and floodways, wetlands, available contour maps, land cover types and known karst features. Identify the receiving surface waters, or whether the drainage basin drains directly to groundwater.
    b. Show channels and overland flow (before and after development), contours, and property lines.
    c. Show the Tc (time of concentration) flow paths and subwatershed boundaries used in runoff calculations.
3. Ponds should not be located on navigable waters. Consult with DNR liaison to determine if the water body is navigable.

15.4.5 Planning Considerations

1. Additional conservation practices should be considered if the receiving water body is sensitive to temperature fluctuations, oxygen depletion, excess toxicants, or nutrients.
2. Determine if the control of the accumulation of floating trash or the use of vortex controls or hydrodynamic settlers are appropriate.
3. Watershed size and land cover should be considered to ensure adequate runoff volumes to maintain a permanent pool. If adequate volume is a concern, evaluate the pond using an annual water balance approach.
4. Aesthetics of the pond should be considered in designing the shape and specifying landscape practices. Generally, square or rectangular ponds are aesthetically unappealing.
5. If downstream flood management or bank erosion is a concern, consider conducting a watershed study to determine the most appropriate location and design for bank stability measures, including consideration of potential downstream impacts on farming practices and other land uses.
6. Consider vegetative buffer strips along drainage ways leading to the detention pond and around the pond perimeter to help filter pollutants.
7. After the site assessment is complete, review and discuss it with the WisDOT regional stormwater engineer to determine and agree on the appropriate pond design for the site.
8. Conduct a groundwater boring to 15 feet below the pond and consider the historic capillary fringe "mottling marks" in assessing groundwater levels.
9. Where the soils are fine, consider groundwater monitoring if the groundwater table is less than 10 feet below the bottom of the wet pond because the water table may fluctuate seasonally. Other impacts on the groundwater table elevation may be from seasonal pumping of irrigation wells or the influence of

other nearby wells. Monitoring or modeling may be necessary in these situations to identify the groundwater elevation.

10. Consider conducting additional test pits if needed to determine the variability of the soil boundary or to identify perched water tables due to clay lenses. For the soils analysis, provide information on soil thickness, groundwater indicators - such as soil mottle or redoximorphic features - and occurrence of saturated soil, groundwater, or disturbed soil.
11. Consider direct and indirect impacts to area wetland hydrology and wetland hydroperiod due to area hydrologic modifications that result from routing wetland source waters through a wet detention pond or releasing the discharge from a wet detention pond directly into a wetland.
12. If public access is provided to the pond, determine how the access will be controlled.

15.5 Design Recommendations

These design guidelines described below provide a method to demonstrate that a wet detention pond achieves 80% total suspended solids (TSS) reduction and peak flow control. Pollutant loading models such as WinSLAMM, P8, DETPOND or an equivalent methodology may also be used to evaluate the efficiency of the design in reducing TSS. When performing a wet detention pond water quality analysis, either use a model to evaluate a proposed pond or use these guidelines. However, it is recommended that engineers use the most current version of a modeling program because the manual evaluation process described in this section uses an iterative and potentially conservative design approach. Attachment 15.4 Figure 1 is a plan view schematic drawing of a typical pond design and Figure 2 is a schematic of a typical pond cross section.

15.5.1 Water Quality Design Guidelines

Pollutant reduction (TSS and particulate forms of phosphorus) is a function of the permanent pool area and depth, the outlet structure and the active storage volume. The following criteria apply:

1. Permanent Pool - The elevation below which runoff volume is not discharged and particles are stored.
    a. Develop an initial estimate of the necessary area needed for a water quality pond using Attachment 15.1 for the initial estimate of the permanent pool area based on drainage area. If there is enough land area available for the pond, proceed to step b.
    b. Design ponds to include a permanent pool of water. The surface area of the permanent pool is measured at the invert of the lowest outlet. The minimum surface area of the permanent pool must address the total drainage area to the pond. Use Attachment 15.1 for the initial estimate of the permanent pool area based on drainage area. Prorate values for mixed land uses as described in the Attachment. Use Equation 1 to solve for qo and iterate as needed.
    c. The permanent pool surface area is sized based on the desired particle size to be retained and the peak outflow during the 1-yr., 24-hour design storm using Equation 1:

$$S_a = 1.2 * (q_o / v_s) \qquad 1(a)$$

$$q_o = (v_s * S_a) / 1.2 \qquad 1(b)$$

Where:

S_a = Permanent pool surface area measured at the invert of the lowest outlet of the wet detention pond (square feet)

q_o = Post-construction peak outflow (cubic feet/second) during the 1-yr., 24-hour design storm for the principal outlet

v_s = Particle settling velocity (feet/second)

1.2 = EPA recommended safety factor

    d. Particle settling velocities (vs) shall be based on representative particle sizes for the desired percent TSS reduction.

80% (3 micron): v_s = 1.91 x 10-5 ft/sec

60% (6 micron): v_s = 7.37 x 10-5 ft/sec

40% (12 micron): v_s = 2.95 x 10-4 ft/sec

Note: Particle settling velocities were calculated assuming a specific gravity of 2.5, a water temperature of 50 degrees Fahrenheit (10 degrees C) and a kinematic viscosity of 0.01308 cm2/sec, and the appropriate unit conversions (Pitt, 2002). The calculations also assume discrete and quiescent settling conditions during laminar flow per Stoke's Law.

2. Active Storage Volume - Volume above the permanent pool that is released slowly to settle particles. Calculate the volume with the following method:

   Use a hydrograph-producing method, such as the one outlined in Natural Resources Conservation Service (NRCS), Technical Release 55 (TR-55), to determine the storage volume for detention ponds. This can be accomplished by using Attachment 15.2 where:

   q_o = Peak outflow during the 1-yr., 24-hour design storm for the principal outlet calculated using Equation 1. The one-year, 24-hour design storm rainfall depths are listed in Attachment 15.3, Tables 2 or 3.

   q_i = Calculated the post-construction peak inflow or runoff rate during the 1-yr., 24-hour design storm using TR-55.

   V_R = Volume of runoff from the 1-year, 24-hour design storm for the entire contributory watershed area draining to the pond, as calculated using TR-55.

   V_S = The required active storage volume determined using Attachment 15.2.

   Note: This method may require iterative calculations because the calculated storage volume may not be consistent with the initial pond surface area assumption.

3. Depth - The average water depth of the permanent pool shall be a minimum of 3 ft., excluding the safety shelf area and sediment storage depth. The maximum depth should be 10 feet to limit fish populations.

4. Length to Width - Maintain a length to width ratio of between 3:1 and 5:1 to prevent short-circuiting, poor circulation and dead zones (areas of stagnant water). The flow path is considered the general direction of water flow within the pond, including the permanent pool and forebay. Avoid open water areas that are non-circulating.

5. Sediment Forebay - A sediment forebay should be located at each inlet (unless inlet is < 10% of total inflow or an equivalent upstream pretreatment device exists) to trap large particles such as road sand. The storage volume of the sediment forebay should be consistent with the maintenance plan, with a goal of 5%-15% of the permanent pool surface area. The sediment forebay should be a minimum depth of 3 ft. plus the depth for sediment storage. Refer to Attachment 15.4, Figures 1 and 2 for a conceptual forebay illustration.

6. Sediment Storage - After all construction has ceased and the contributory watershed has been stabilized, one of the following applies:

   a. A minimum of 2 ft. shall be available for sediment storage (for a total of 5 ft. average depth, excluding the safety shelf area). For ponds greater than 20,000 sq. ft., 50% of the total surface area of the permanent pool shall be a minimum of 5 ft. deep. For ponds less than 20,000 sq. ft., maximize the area of 5 ft. depth.

   b. Less than 2 ft. of sediment storage is allowed if modeling shows that for 20 years of sediment accumulation, less than 2 ft. sediment storage is needed (not to be less than 0.5 feet).

   c. A minimum of 4 ft. shall be available for sediment storage if the contributory area includes cropland not stabilized by any other practice, such as strip cropping, terraces and conservation tillage.

7. Side Slopes Below Safety Shelf - All side slopes below the safety shelf shall be 2:1 (horizontal:vertical) or flatter as required to maintain soil stability, or as required by the applicable regulatory authority.

8. Outlets - Wet detention ponds shall have both principal water quality outlet(s) and an emergency spillway.

   a. Prevent Damage - Incorporate into outlet design trash accumulation preventive features, and measures for preventing ice damage and scour at the outfall and beyond to prevent secondary impacts downstream of the pond. Direct outlets to channels, pipes, or similar conveyances designed to handle prolonged flows.

b. Principal Water Quality Outlet - Design the outlet to control the proposed 2-yr., 24-hour discharge from the pond within the primary principal outlet without use of the emergency spillway or other outlet structures. If a pipe discharge is used as the primary principal outlet, then the minimum diameter shall be 4 inches. Where an orifice is used, features to prevent clogging must be added.

c. Backward Flow - Any storm up to the 10-yr., 24-hour design storm shall not flow backward through the principal water quality outlet or principal outlet. Flap gates or other devices may be necessary to prevent backward flow.

d. Emergency Spillway - All ponds shall have an emergency spillway. Design the spillway to safely pass peak flows produced by a 100-yr., 24-hour design storm routed through the pond without damage to the structure. The flow routing calculations start at the permanent pool elevation. If at all possible, locate the spillway on native material, not fill.

e. Peak Flow Control - Design the peak flow control to maintain stable downstream conveyance systems and comply with local ordinances or conform with regional stormwater plans where they are more restrictive than this standard. At a minimum:

- The post-development outflow shall not exceed pre-development peak flows for the 2-yr., 24-hour design storm.
- Use a hydrograph-producing method such as TR-55 for all runoff and flow calculations.
- When pre-development land cover is cropland, use the runoff curve numbers in Table 1 below, unless local ordinances are more restrictive.
- For all other pre-development land covers, use runoff curve numbers from TR-55 assuming “good hydrologic conditions.”
- For post-development calculations, use runoff curve numbers based on proposed plans.

Note: If the project requires control of larger storm events than the 2-yr., 24-hour storm, additional or compound outlets may be required.

Table 15.1 Maximum Pre-Development Runoff Curve Numbers for Cropland Areas (from TRANS 401.106(4), Table 2)

Hydraulic Soil Groups	A	B	C	D
Runoff Curve Number	56	70	79	83

15.5.2 Other Pond Criteria

1. Inflow Points - Design all inlets to prevent scour during peak flows produced by the 10-yr., 24-hr. design storm, such as using half-submerged inlets, stilling basins and rip-rap. Where infiltration may initially occur in the pond, the scour prevention device shall extend to the basin bottom.

2. Side Slopes - All interior side slopes above the safety shelf shall be 3:1 (horizontal:vertical), or flatter if required by the applicable regulatory authority.

3. Ponds in Series - To determine the overall TSS removal efficiency of ponds in series, the design shall use an approved model such as DETPOND or P8 that can track particle size distribution from one pond to the next. If the ponds follow one after another without any additional inflow, then the largest pond will remove the most sediment.

4. Earthen Embankments - Earthen embankments (refer to Attachment 15.4, Figure 3) shall be designed to address potential risk and structural integrity issues such as seepage and saturation. All constructed earthen embankments shall meet the following criteria.

   a. Vegetation - Remove the parent material (including all vegetation, stumps, and topsoil, etc.) beneath the proposed base of the embankment.

   b. Core Trench or Key-way - For embankments where the permanent pool is ponded 3 ft. or more against the embankment, include a core trench or key-way along the centerline of the embankment up to the permanent pool elevation to prevent seepage at the joint between the existing soil and the fill material. The core trench or key-way shall be a minimum of 2 ft. below the existing grade and 8 ft. wide with a side slope of 1:1 (horizontal:vertical) or flatter. Follow the construction and compaction requirements detailed in 15.5.2.4c below for compaction and fill material. Also refer to Attachment 15.4, Figure 3.

c. Materials - Construct all embankments with non-organic soils and compact to 90% standard proctor according to the procedures outlined in AASHTO T-99 or by using compaction requirements of DOT Standard Specification 207.3.6.3, Special Compaction. Do not bury tree stumps or other organic material in the embankment. Increase the constructed embankment height by a minimum of 5% to account for settling.

d. Freeboard - Ensure that the top of embankment, after settling, is a minimum of 1 vertical foot above the flow depth for the 100-yr., 24-hr. storm.

e. Pipe Installation, Bedding, and Backfill - If pipes are installed after construction of the embankment, the pipe trench shall have side slopes of 1:1 or flatter. Bed and backfill any pipes extending through the embankment with embankment or equivalent soils. Compact the bedding and backfill in lifts and to the same standard as the original embankment.

f. Seepage - Take measures to minimize seepage along any conduit buried in the embankment. Measures such as anti-seep collars, sand diaphragms, or use of bentonite are acceptable.

g. Exterior side slopes shall be 2:1 (horizontal:vertical) or flatter, with a minimum top width of the embankment of 4 ft., or 10 ft. if access for maintenance is needed. The embankment must be designed for slope stability.

5. Topsoil and Seeding - Spread topsoil on all disturbed areas above the safety shelf, as areas are completed, according to the standard specifications. Stabilize according to the permanent seeding criteria in Standard Spec 630, Seeding. To maximize safety and pollutant removal, spread topsoil along the safety shelf to promote plant growth.

6. Liners - Highway land uses are classified as ‘dirty source areas’ when determining the type of pond liner for highway runoff. If groundwater wells are located near a project as described in 15.4.3(1) of this procedure, use a liner with permeability of 10^{-7} cm/sec. Otherwise, the liner needs to have a permeability of 10^{-6} cm/sec. If synthetic liners are used, see the liner requirements in the Wisconsin DNR Wet Detention Pond Design Standard 1001. If a liner is used, provide a narrative that sets forth the liner design and construction methods. Modify SPV.0035 (Pond Clay Liner) with the appropriate permeability value to bid the liner. If the pond will be constructed in native soil that meets the permeability requirement, then no liner is needed.

7. Bedrock - If blasting in bedrock is performed to construct a wet detention pond in bedrock, then a liner with a permeability of 10^{-7} cm/sec is required if located near a well or 10^{-6} cm/sec elsewhere.

8. Access - Include maintenance access features in the pond design including:

    a. A maintenance right of way or easement must be provided to a pond from a public or private road.

    b. Maintenance access should be at least 12 feet wide, having a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.

    c. The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, be designed to allow vehicles to turn around.

    d. Provide access to the riser by lockable manhole covers, and manhole steps within easy reach any of valves and other controls

9. Wetlands - For wet detention ponds that discharge to wetlands, use level spreaders, gabions, rip-rap or other methods to prevent channelization and erosion and to reduce sedimentation in the wetlands.

10. Mosquito (Vector) Control - Maximize the amount of deeper open water to promote mosquito control while maintaining the maximum depth of 10 ft.

11. Consult a geotechnical engineer if stability of the embankment is a concern or to justify slopes steeper than 2.5:1.

15.5.3 Safety Requirements

1. Side Slopes – All interior side slopes above the safety shelf shall be 3:1 (horizontal:vertical), or flatter if required by the applicable regulatory authority.

2. All outlet structures should have trash racks.

3. Include a safety shelf (or aquatic shelf) that extends a minimum of 8 ft. from the edge of the permanent pool waterward with a slope of 10:1 (horizontal:vertical) or flatter. The maximum depth of the permanent pool of water over the shelf shall be 1.5 ft.
4. Provide a safety barrier of vegetation that would discourage access to the pond upgradient of the safety shelf. Do not mow the pond perimeter or allow grass down to the pond edge to discourage geese.

15.5.4 Design Considerations

1. For ease of maintenance, consider incorporating a pond draw down system including a pipe and gate valve.
2. Consider a hard surface for the bottom of the forebay to ease sediment removal.
3. If sand is used in the winter on highways in the pond drainage area, consider increasing the sediment storage depth or area.
4. Consider providing a method to facilitate dewatering for accumulated sediment removal.
5. Baffles may be used to artificially lengthen the flow path in the pond. In some designs, a circular flow path is set up in a pond even when the inlet and outlet are next to each other and no baffles are used. Then the flow path can be calculated using the circular path.
6. Consider providing additional width to the safety shelf, above or below the wet pool elevation, to enhance safety.
7. To prevent damage or failure due to ice, all risers extending above the pond surface should be incorporated into the pond embankment.
8. The use of underwater outlets should be considered to minimize ice damage, accumulation of floating trash or vortex control.
9. For wet detention ponds with surface area more than 2 acres or where the fetch is greater than 500 feet, consider reinforcing banks, extending the safety shelf, vegetating the safety shelf or other measures to prevent erosion of embankment due to wave action.
10. To prevent failure, consider reinforcing earthen emergency spillways constructed over fill material to protect against erosion.
11. All flow channels draining to the pond should be stable to minimize sediment delivery to the pond.
12. Consider using backflow preventers to minimize fish entrapment.
13. Consider providing a terrestrial buffer of 10-15 feet around the pond if it has low or no embankments.
14. Consider additional safety features beyond the safety shelf where conditions warrant them.
15. Design so that the 10-yr., 24-hour design storm does not flow through the emergency spillway. The 10-yr. design criteria protects the embankment from premature failure due to frequent or long-duration flows through the emergency spillway.
16. For partially or fully submerged inlet pipes, consider using pipe ties or some other method to keep pipes from dislodging during frost movement.
17. Submerged and emergent aquatic vegetation can play an important role in pollutant removal in a stormwater pond. It can also enhance the appearance of the pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a pond design, along the safety bench and side slopes, and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation.

15.6 Maintenance

15.6.1 Maintenance Requirements

Maintenance Agreement - A wet detention pond requires both regular and long-term maintenance. These requirements are defined in a maintenance plan that typically includes the maintenance issues listed below. If the DOT transfers maintenance responsibility for a pond and its buffer to a responsible authority such as a municipality by means of a legally binding and enforceable maintenance agreement, then the agreement should include a discussion of both regular maintenance and pond dredging requirements. It should also reference the maintenance plan to provide a clear guideline for what work is needed to maintain the water quality and quantity control purposes of this practice. Coordinate the plan development with the WisDOT project manager so that it is included in the maintenance agreement. Contact the planning section in your region for additional information on maintenance agreement requirements.

Regular Maintenance - Regular maintenance items can include the following, as appropriate for the site:

1. Berm Settlement. If any part of the berm has settled 4 inches lower than the design elevation it should be built back to the design elevation.
2. Piping. If water flow is discernible through pond berm or ongoing erosion is observed, have a geotechnical engineer inspect and evaluate the condition and recommend appropriate repairs.
3. Tree Growth. Tree growth on emergency spillways reduces spillway conveyance capacity and may cause erosion elsewhere on the pond perimeter due to uncontrolled overtopping. Tree growth on berms over 4 feet high may lead to piping through the berm, which could lead to failure of the berm and related erosion or flood damage. Such trees should be removed. If the root system is small (base less than 4 inches), the root system may be left in place; otherwise, the roots should be removed and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
4. Emergency Spillway Lining. If only one layer of rock exists above native soil in area 5 square feet or larger or native soil is exposed at the top of outflow path of spillway, then the rocks and pad depth should be restored to the design condition.
5. Trash and Debris. Clear trash and debris from the site when accumulations exceed 5 cubic feet (about equal to the amount of trash needed to fill one standard-size garbage can) per 1,000 square feet. In general, there should be no visual evidence of dumping. If debris accumulation is less than this threshold level, then the trash and debris should be removed as part of the next scheduled maintenance.
6. Poisonous Vegetation and Noxious Weeds. Poisonous, noxious or nuisance vegetation may constitute a hazard to maintenance personnel or the public. Remove this vegetation and apply the requirements of adopted integrated pest management policies for the use of herbicides.
7. Rodent Holes. For facilities acting as a dam or berm, if rodent holes are evident or there is evidence of water piping through dam or berm via rodent holes, destroy the rodents and repair the dam or berm.
8. Side Slope Erosion. If eroded damage is over 2 inches deep and the cause of damage is still present, or there is potential for continued erosion, stabilize slopes using appropriate erosion control measures (such as rock reinforcement, planting of grass, and compaction). If erosion is observed on a compacted berm embankment, review the proposed erosion control measures with an erosion control specialist.
9. Pond Dredging. Sediment removal in the forebay should occur every five to six years or after 50% of total forebay capacity has been lost. In the main sediment accumulation areas of the pond, sediment removal should occur once the average depth of the permanent pool is 3.5 ft. Sediment should be disposed of according to NR 528, Wis. Admin. Code (Management of Accumulated Sediment from Stormwater Management Structures).

15.6.2 Maintenance Plan

Develop an operation and maintenance plan that is consistent with improving stormwater quality, the wet detention pond's intended life, safety requirements, and the criteria for its design. The operation and maintenance plan will:

1. Identify the responsible party for operation, maintenance, and documentation of the plan.
2. Require sediment removal once the average depth of the permanent pool is 3.5 ft. At a minimum, include details in the plan on inspecting sediment depths, frequency of accumulated sediment removal, and disposal locations for accumulated sediment (NR 528, Wis. Adm. Code).
3 Include inlet and outlet maintenance, keeping embankments clear of woody vegetation, and providing access to perform the operation and maintenance activities.
4. Identify how to reach any forebay, safety shelf, inlet, and outlet structures.
5. Address weed or algae growth and removal, insect and wildlife control and any landscaping practices.
6. If a liner is used, show how the liner will be protected from damage during sediment removal or when the liner is undergoing repair.

7. Prohibit excavation below the original design depth unless geotechnical analysis is completed in accordance with FDM 10-35-15.4.4,1b. and c.
8. Use of algaecides, herbicides or polymers to control nuisance growths or to enhance sedimentation may require a permit under NR 107, Wis. Adm. Code. Contact the appropriate WisDOT regional stormwater engineer.

15.6.3 Maintenance Considerations

Consider using low fertilizer inputs on the embankments and collecting the clippings.

15.7 Wet Detention Pond Water Quality Analysis Using the WisDOT Stormwater Report Spreadsheet

1. WisDOT has prepared a spreadsheet that incorporates the design guidelines and calculations needed to determine if a project meets the required TSS load reduction. The spreadsheet has a series of worksheets for a designer to use to methodically prepare and summarize an analysis of the water quality benefits of the various stormwater quality practices, including wet detention ponds, used on a project. The WQ-Wet Detention Ponds worksheet provides a place for the designer to describe and summarize the performance of any ponds in a project. The use of the complete spreadsheet to summarize water quality performance for a project is described in FDM 10-30-1. The spreadsheet is located at FDM 13-30 Attachment 15.2.
2. The wet detention analysis procedure described below uses the wet detention analysis summary worksheet WQ-Wet Detention Ponds shown in Attachment 15.5. The worksheet is only used to summarize the wet detention data in an organized fashion - it does not calculate pond performance, which is determined from the design analysis procedure or from model output.
3. To use this spreadsheet, enter data into all the white cells. The spreadsheet is designed so that you can easily add additional columns for additional ponds. To do this, follow these steps:
    1. Highlight the number of columns you want to add,
    2. Right-mouse click,
    3. Select insert,
    4. Select shift rows right, and
    5. Press the ‘OK’ button. Only enter data in the white boxes on each worksheet.
4. On a plan view of the drainage system, delineate the drainage area for each pond that will be providing water quality benefits. Number the ponds, determine the starting and ending station of their drainage areas and if they are left, right or in the center median. Enter this information on lines 7 through 11 of the spreadsheet, and then determine the following information and enter it on the appropriate line of the spreadsheet.
5. Line 13 - The length of the highway segment treated, which is typically the difference between the starting and ending stations that define the limits of the drainage area.
6. Line 14 - The drainage area of the pond. This area includes all areas both within the right of way and outside of the right of way that drain to the pond.
7. Line 15 - The drainage area of the pond within the right of way.
8. Line 16 - Enter the percent reduction from the analysis or computer model output.

The percent reduction entered for each pond is then transferred to the summary worksheet, where it is used to help determine the total loading reduction for the project.

If you need to record design comments about the design for any of the drainage areas, enter them in the comment boxes below the worksheet. Add more comment boxes if necessary.

15.8 References

R. Pitt and J. Voorhees, The Design and Use of Detention Facilities for Stormwater Management Using DETPOND, 2000.

United States Department of Agriculture, Natural Resources Conservation Service, Conservation Practice Standard 378, Pond, July 2001.

United States Department of Agriculture, Natural Resources Conservation Service, Engineering Field Handbook.

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United States Department of Agriculture, Natural Resources Conservation Service, Technical Release 55, Urban Hydrology for Small Watersheds, 1986.

United States Department of Agriculture, Natural Resources Conservation Service, Wisconsin Field Office Technical Guide, Section IV.

United States Department of Commerce, Weather Bureau, Rainfall Frequency Atlas of the United States, Technical Paper 40.

University of Wisconsin - Extension, The Wisconsin Storm Water Manual, Part Four: Wet Detention Basins, Publication No. G3691-P.

Wisconsin State Legislature, Revisor of Statutes Bureau, Wisconsin Administrative Code; for information on the codes of state agencies, including WDNR, (http://www.legis.state.wi.us/rsb/code.htm).

LIST OF ATTACHMENTS

Attachment 15.1	Calculation of Preliminary Permanent Pool Surface Area for TSS Reduction
Attachment 15.2	Pond Volume/Discharge Design Curve
Attachment 15.3	Rainfall and Runoff Tables
Attachment 15.4	Conceptual Pond Design Illustrations
Attachment 15.5	Wet Detention Pond Analysis Summary Spreadsheet

FDM 10-35-20 Catchbasin Design and Maintenance *October 22, 2012*

20.1 Description and Purpose

Catchbasins are chambers or sumps installed in a storm sewer, usually at the curb, which allow surface runoff to enter the sewer. Catchbasins have a sump area below the outlet intended to retain captured sediment. By trapping coarse sediment, the catchbasin prevents trapped solids from clogging the downstream sewer or being washed into receiving waters. The sumps must be cleaned out periodically to maintain their sediment trapping ability. If the sumps are not cleaned, then the catchbasin does not provide any water quality benefit and does not provide any total suspended solids pollutant reduction.

20.2 Target Pollutants

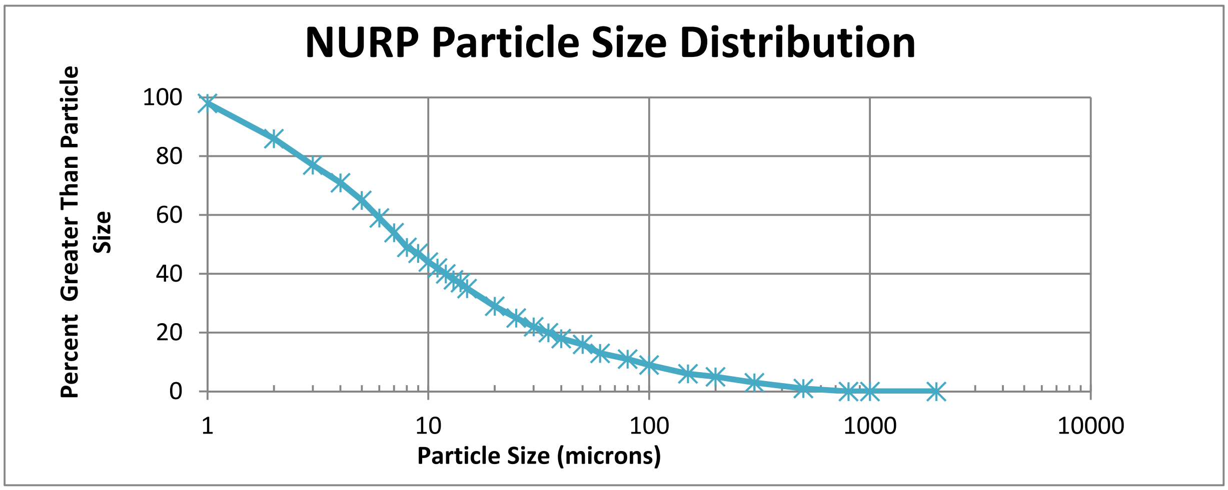
Catchbasins with sumps are effective for trapping coarse sediment and large debris and trash. If outfitted with hoods over the outlets, the capture of floatables and other litter can also be improved. In addition to reducing sediment loads, catchbasin cleaning may also reduce particulate nutrients, metals, and other pollutants in a particulate form and the load of oxygen demanding substances that reach surface water. However, in the absence of suitable cleaning, catchbasins may make water quality worse due to the degradation of captured material and subsequent flushing of material into the downstream system. Therefore, it is important for designers to coordinate with WisDOT maintenance regarding the cleaning schedule or develop a maintenance agreement with the community in which the catchbasins are located (refer to Planning Considerations).

20.3 Effectiveness

Catchbasin performance is calculated by assuming flow through a settling area defined by the surface area of the catchbasin. The particulate removal in this settling area is assumed to occur due to ideal settling as described by Stokes Law (for laminar flow), or Newton's law (for turbulent flow). Catchbasin performance has been monitored during many field trials through EPA-sponsored research, and by other international researchers. For example, Lager, et al. (1977) developed an idealized catchbasin geometry based on laboratory and field experiments.

Properly designed catchbasins can withstand extreme flows with little scouring losses and no significant differences between the water quality of the water retained in catchbasins between events and runoff quality (Pitt, 1985). They will trap the bed-load from the stormwater (especially important in areas using sand for traction control) and will trap a low to moderate amount of suspended solids (about 30 to 45% of the annual loadings). The largest size fractions of the sediment in the flowing stormwater will be trapped (typically larger than 50 µm), in preference to the finer material that has greater amounts of associated pollutants. Their hydraulic capacities are designed using conventional procedures (grating and outlet dimensions), while the sump is designed based on the desired cleaning frequency. Pitt and Khambhammettu (2006) reviewed the performance of catchbasins from many studies, and recommended a basic catchbasin configuration having an appropriately sized sump with a hooded outlet, though the hood is not a typical component of WisDOT catchbasin design.

If the water velocity through the catchbasin is slower, smaller (slowly falling) particles can be more easily retained. If the water velocity is faster, then only the heaviest (fastest falling) particles are likely to be captured and retained. The critical particle settling velocity is a function of the ratio of the discharge water rate to the surface area of the catchbasin. Particles having settling velocities greater than this ratio will be removed. Only increasing the surface area or decreasing the outflow rate will increase settling efficiency. Increasing the catchbasin sump depth does lessen the possibility of bottom scour and increases the estimated time between sump cleanings, though this may not be possible due to utility conflicts, high groundwater levels, or other site conditions. Since the settling velocity increases as particle size increases (using Stokes or Newton's law and appropriate shape factors, specific gravity and viscosity values), the catchbasin water quality performance (or percent removal) is determined from the particle size distribution of the solids in the runoff entering the catchbasin. This is done by determining the settling velocity and then calculating the particle size associated with that settling velocity, which is referred to as the critical particle size. The percent of the particles that will settle is then determined from the particle size distribution of the total suspended solids (TSS) concentration of the sediment in the stormwater runoff. The particle size distribution, which is called the NURP (National Urban Runoff Program) particle size distribution used for stormwater runoff in Wisconsin, as illustrated below.



Field test results indicate that the performance of catchbasins is strongly related to the inflowing water rate relative to the surface area of the catch basin. The standard surface-overflow-rate (SOR) approach used in water and wastewater treatment facilities, and in sedimentation controls in WinSLAMM, normalizes the inflowing water rate with the surface area of the catchbasin. Detailed scour tests (computational fluid dynamics modeling and full-scale tests) were conducted to verify this approach and to measure critical scour conditions (Avila, H., R. Pitt, and S.E. Clark, 2011).

Note that while the NURP particle size distribution is both required in Wisconsin and is suitable for an outfall particle size distribution, source area and inlet monitored samples usually contain larger particles not included as part of total suspended solids (TSS). These particles, which would be captured in catchbasin sumps, would mostly be deposited in conventional drainage systems if there were no catchbasins. With short highway drainages near streams, these larger particles would likely be delivered to the outfall and therefore to the stream, if not captured in a catchbasin. This means that catchbasins with sumps can be especially useful reducing the coarse sediment load to water bodies.

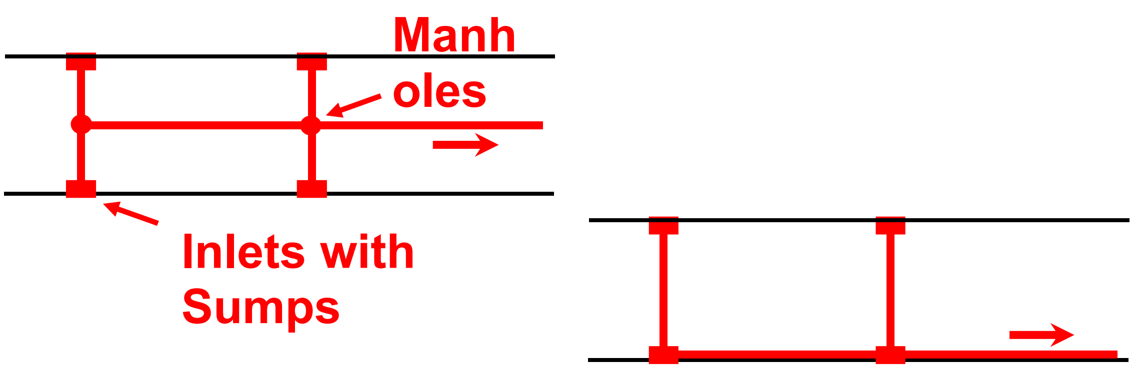
Based on the NURP particle size distribution, all particles greater than 80 µm would need to be trapped to achieve 15% particulate solids control of the stormwater runoff entering a catchbasin, which is the planning level control allowed for catchbasins for WisDOT projects, as described in FDM 10-25-1. However, the high level of turbulence in a catchbasin sump usually restricts the capture of sediment to particles larger than 50 µm. Also, scour of previously captured material likely occurs when the overlying water depth over the captured sediment is less than about one foot (Avila, et al, 2011). The methods for calculating the performance of catchbasins have been verified during several field monitoring projects where inlet and effluent samples were collected and analyzed under widely varying conditions (see Pitt and Field 2004 for a summary of these monitoring activities and results).

20.4 Planning Issues

20.4.1 DOT Design Requirements

Per TRANS 401.106(3), for transportation facilities first constructed after 2002, where there was previously no transportation facility, reduce total suspended solids (TSS) discharges, when compared with no stormwater quality discharge controls, by the maximum extent practicable, up to 80%, based on an average annual rainfall. Highway reconstruction and non-highway redevelopment projects must reduce TSS discharges by the maximum extent practicable, or up to 40%. Refer to FDM 10-25-1 for guidance on setting the correct TSS reduction level for a project. Runoff entering a catchbasin from outside of the DOT right of way (off-site run on) will affect the performance of the catchbasin and must be accounted for during the catchbasin design. Off-site pollutant loads, however, are typically excluded from the analysis because the source of the pollutants (from off the DOT right-of-way) is not controlled by the DOT.

Catchbasin layouts in storm sewer systems are classified as either in series or in parallel, although typical layouts are usually a combination of both types. The diagrams below illustrate the difference between these two systems. Catchbasins placed in series mean that the water leaving one catchbasin enters the next downstream catchbasin through the storm sewer system. For the series collection system example, the lower (downstream) two inlets convey water not only from the direct surface runoff, but also convey water through pipes from upstream inlets. This can dramatically reduce their sediment capture performance because the influent flows are larger, which reduces sedimentation while increasing the scour potential. When catchbasins are placed in parallel, only surface runoff enters each catchbasin, and the water is discharged through laterals to the main drainage system. For the parallel collection system, each inlet only collects direct surface water; none of them convey water through pipes from other inlets. The catchbasin performance charts in this section assume that the collection system is set up in parallel.



Parallel Collection System **Series Collection System**

20.4.2 Site Assessment

Conduct and document a site assessment to determine how to place, design, and maintain catchbasins. The starting point for the water quality analysis is typically the design developed to accommodate the appropriate design flow from the highway. For catchbasins, this design will be developed from the inlet spacing guidelines described in FDM 13-35-30, the Hydraulic Design of Inlets. Collect the following information to characterize the drainage area for each catchbasin for the water quality analysis.

1. Identify the proposed drainage area for each catchbasin. The drainage area can extend outside of the right of way. Determine the distance between each catchbasin. This should already have been done when developing the initial inlet spacing for drainage (based on FDM 13-35-30).
2. Classify the highway cross section as either a Type 5 or a Type 8 cross section by matching as closely as possible the proposed cross section with the two available types. These two typical cross section types are illustrated in Attachments 20.1 and 20.3. The Type 5 cross section, which includes two lanes of traffic, a parking lane and a paved median, can also be used for three lanes of traffic with no parking. The Type 8 cross section, which includes two lanes of traffic, can also be used for one lane of traffic and a parking lane.

3. Classify the type of land use in the drainage area outside of the right of way as either largely impervious, as in strip mall or paved parking, or as largely pervious, as in a residential area with grass swale drainage.

20.4.3 Catchbasin Design Considerations

Planning considerations are intended to suggest to the designer issues that may be of concern for a project. If you believe that a consideration may affect your project, contact your regional stormwater engineer for additional guidance.

1. Determine whether the drainage system should be designed with a parallel or series collection system. The series collection system may be less expensive because it requires fewer structures or might be more constructible given traffic control considerations, but the water quality requirements of the project might require a parallel drainage system to maximize system performance.
2. Determine if the control of the accumulation of floating trash using hooded outlets or the use of vortex controls or hydrodynamic settlers are appropriate.

20.5 Design Recommendations

The design guidelines described below provide a method to calculate the percent TSS reduction from a catchbasin or inlet with a sump in a WisDOT urban cross section. These guidelines use a series of curves that describe the percent TSS reduction based upon the characteristics and size of the contributing drainage area. They were developed using WinSLAMM v 9.4, using the NURP particle size distribution. The curves were developed for four standard size WisDOT structures - the Type 3 Inlet (2' x 3'), the Type 1 Catchbasin (4' diameter), a 5' diameter catchbasin and a Type 5 Catchbasin (6' diameter). If the project is using devices with different footprints or the drainage area cannot be characterized using the design curves, then the pollution control effectiveness of the device should be modeled using a pollutant loading model such as WinSLAMM, P8, DETPOND or an equivalent methodology.

20.5.1 Catchbasin Design Charts

There are ten design charts in Attachments 20.2 and 20.4. Each set describes the percent TSS reduction for a cross section type and catchbasin of a different surface area as a function of the length of highway draining to the catchbasin. The design charts are setup to account for the following criteria and assumptions:

1. The surface area of the catchbasin (a Type 3 Inlet (2' x 3'), a Type 1 Catchbasin (4' diameter), a five foot diameter Catchbasin or a Type 5 Catchbasin (6' diameter)).
2. The drainage area of the catchbasin as described by the width of the highway from the crown of the road to edge of the drainage basin and the distance between inlets.
3. The cross section type (either one lane of pavement or two lanes of pavement).
4. The inlets are placed in a parallel drainage system so that flow does not accumulate from one inlet to the next.

20.5.2 Catchbasin Water Quality Analysis Using the WisDOT Stormwater Report Spreadsheet

WisDOT has prepared a spreadsheet that incorporates the design guidelines and calculations needed to determine if a project meets the required TSS load reduction. The spreadsheet has a series of worksheets for a designer to methodically prepare and summarize an analysis of the water quality benefits of the various stormwater quality practices, including catchbasins, used on a project. The WQ-Catchbasins worksheet provides a place for the designer to describe and summarize the performance of any catchbasins used in a project. The use of the complete spreadsheet to summarize water quality performance for a project is described in FDM 10-30-1. The link to the spreadsheet is located at FDM 13-1-10 Attachment 10.1.

The catchbasin analysis procedure described below uses the catchbasin analysis summary worksheet WQ-Catchbasin shown in Attachment 20.5. The worksheet is only used to summarize the catchbasin data in an organized fashion - it does not calculate catchbasin performance, which is determined from the design charts.

To use this spreadsheet, enter data into the appropriate worksheet cells. The worksheet is designed so that you can insert columns between the last column and the first column and then select the cells in a data column from rows 7 to 24 and drag them across to create columns for additional catchbasins or inlets. Do NOT enter information in the grey cells because they contain formulas that should not be modified.

On a plan view of the drainage system, delineate the drainage area for each catchbasin that will be providing water quality benefits designed in accordance with this standard. Number the catchbasins, determine their station and if they are left, right or in the center median. Enter this information on lines 7 through 10 of the spreadsheet, and then determine the following information and enter it on the appropriate line of the spreadsheet. For convenience, many of the items can be selected using a drop down menu list on the spreadsheet.

Line 12 - The distance downstream to the next catchbasin (or the total length of roadway draining to the catchbasin if it is located in a sag section of the vertical profile).

Line 13 - The drainage area of the catchbasin. This area includes all areas both within the right of way and outside of the right of way that drain to the catchbasin.

Line 14 - The drainage area of the catchbasin within the right of way.

Line 15 - The cross section type, either Type 5 or Type 8. Select the type that is most similar to the project cross section using the drop down menu. Refer to Attachment 20.1 for an illustration of cross section Type 5 and Attachment 20.3 for an illustration of cross section Type 8. Other cross section types are rural cross sections that do not typically use catchbasins as treatment practices.

Line 16 - Select the catchbasin or inlet size/type using the drop down menu, labeled as 'DD Menu' in the cell.

Line 17 - Select the predominant cover type - either 'Mostly Impervious' or 'Mostly Pervious' using the drop down menu. Select "Mostly Impervious" if the predominant cover type is more than 50% impervious surface.

Line 18 - Enter the design chart number used to evaluate the catchbasin or inlet.Select the chart based upon the cross section type, inlet or catchbasin type, and predominant cover type.

Line 19 - Enter the percent reduction from the design chart (Attachment 10.2) based on the information entered and lines 12, 15, 16, 17 and the average drainage area width (Line 21).

If you need to record design comments about the design for any of the drainage areas, enter them in the comment boxes below the worksheet. Add more comment boxes if necessary.

The design charts are organized by typical cross section as follows:

Cross Section Type 5:

- Chart 1 – Type 3 Inlet: 2' x 3' (6 sf)
- Chart 2 – Type 1 Catchbasin: 4' diameter (13 sf)
- Chart 3 – Catchbasin: 5' diameter (20 sf)
- Chart 4 – Catchbasin: 6' diameter (28 sf)
- Chart 5 – All Types, Mostly Pervious Beyond Curb Line

Cross Section Type 8:

- Chart 6 – Type 3 Inlet: 2' x 3' (6 sf)
- Chart 7 – Type 1 Catchbasin: 4' diameter (13 sf)
- Chart 8 – Catchbasin: 5' diameter (20 sf)
- Chart 9 – Catchbasin: 6' diameter (28 sf)
- Chart 10 – All Types, Mostly Pervious Beyond Curb Line

Each of these charts was developed using WinSLAMM v 9.4 for the conditions described in the chart. To get a specific percent reduction, interpolate the appropriate value from a chart.

20.5.3 Other Design Criteria

Sump depth (the distance between the outlet invert and the bottom of the catchbasin) must be at least three feet. If the sump is less than one foot deep, then it has no water quality benefit due to scour. If the sump is less than three feet deep, but greater than one foot, then the designer should determine the cleaning frequency of the system using a stormwater quality model.

20.5.4 Design Considerations

1. If sand is used in the winter on highways in the drainage area or there are other consistent sources of coarse material, consider increasing the sump depth.
2. Performance can be enhanced by modifications to the catchbasins, including:
    a) Using a hood over the outlet that submerges the outlet restricting the loss of floatables from the catchbasin,
    b) Restricting the outlet diameter to be more in-line with optimized catchbasin geometry, if the flow capacity reduction can be accommodated, or
    c) Inserting an effective inlet filter into the catchbasin.

20.6 Maintenance

20.6.1 Maintenance Requirements

The DOT typically transfers maintenance responsibility for catchbasin cleaning to a responsible authority such as a municipality by means of a legally binding and enforceable project or maintenance agreement. These agreements should include a clear statement of regular maintenance requirements and, if necessary, should reference a maintenance plan. If a maintenance plan is developed it should provide a clear guideline for what work is need to maintain the water quality and quantity control purposes of this practice. Check with your regional office planning section for additional information on maintenance agreement requirements.

Regular maintenance includes clearing sediment, trash and debris from the sump. Cleaning should occur when accumulations are within 1.5 feet of the distance from the pipe outlet invert elevation to the top of the sediment. This requirement typically means that catchbasins need to be cleaned once every one to three years. Typically sediment is disposed of at a licensed landfill. Cleaning sump trash and debris may need to be more frequent (such as every 6 months) if significant organic debris or trash accumulates in the sump to prevent degradation of the material and worsening sump water quality.

20.6.2 Maintenance Plan

Develop a project or operation and maintenance plan that is consistent with improving stormwater quality, fall and spring bypass requirements for salt contamination minimization (FDM 10-35-35 - Winter Bypass Options to Reduce Chloride Contamination (*not complete yet*), safety requirements and the criteria for its design. The operation and maintenance plan will at a minimum:

1. Identify the responsible party for operation, maintenance, and documentation of the plan.
2. Require that the depth of sediment in the catchbasins be inspected and recorded annually.
3. Include a cleaning frequency requirement that addresses the sediment depth requirements described above. The cleaning frequency must be adjusted to reflect the actual sediment accumulation rate for the catchbasins, as determined by the inspections.

20.6.3 Maintenance Considerations for Mosquito Prevention

A preventative measure includes the use of mosquito donuts that can be placed in mesh bags and secured to small anchors and placed in the sumps. These normally last for several months and may only be needed late in the summer months.

20.7 Catchbasin Water Quality Design Example

Given the drainage areas and site conditions described below, determine the percent water quality reduction using catchbasins for the site. Assume there is a maintenance agreement with the local municipality to clean the sumps at least annually.

- Problem - Two catchbasins located at Station 10+00 and 12+00 (R), with primarily impervious drainage areas of 0.3 acres (200 ft to the next drainage area) and 0.45 acres respectively (250 ft to the next drainage area). There are small silty/clayey pervious areas within the STA 10+00 catchbasin drainage area and significant silty/clayey areas within the STA 12+00 drainage area. The area within the right-of-way for both catchbasins is 0.2 acres. The cross section at STA 10+00 most closely resembles a Type 5 cross section, and the cross section at STA 12+00 most closely resembles a Type 8 cross section. Both catchbasins will be Type 3 Inlets with a three foot sump.
- Solution - The project information (lines 2 – 5) will be filled in when you enter project information on the summary tab of the stormwater report. Define the catchbasins in lines 7-9 of the Catchbasin Analysis Summary Spreadsheet, (Attachment 10.3). Next, enter the site data into lines 12 – 18 of the spreadsheet. On lines 12 – 14, enter the numeric values for distance and area. Use the drop down menus to enter values in lines 15 – 18. Use the drop down menu to enter the design chart number in line 18 based upon the cross section type, catchbasin or inlet type/size and predominant cover type entered in lines 15 – 18.

  Use Chart 1 for the inlet at STA 10+00 because this chart is for a Type 3 Inlet in Cross Section Type 5 with little pervious area. The worksheet will calculate, in line 21, the average drainage area width. Use that width (in this example, 65 ft), to interpolate a percent reduction of 22%.

  Use Chart 10 for the inlet at STA 12+00 because this chart is for a Type 3 Inlet in Cross Section Type 8 with significant pervious area. The worksheet will calculate, in line 21, the average drainage area width. Use that width (in this example, 78 ft), to interpolate a percent reduction of 23%. Enter both values into line 19. The worksheet will calculate the overall percent reduction of TSS for the right-of-way area, which in this case is 19.0%

20.8 References

Avila, H., R. Pitt, and S.E. Clark. “Development of effluent concentration models for sediment scoured from catchbasin sumps.” Journal of Irrigation and Drainage Engineering. (http://dx.doi.org/10.1061/(ASCE)IR.1943-4774.0000183). Vol. 137, No. 3. pp 114-120. March 2011.

Lager, J., W. Smith, R. Finn, and E. Finnemore. 1977. Urban Stormwater Management and Technology: Update and Users' Guide. US EPA. EPA-600/8-77-014. 313 pp.

Pitt, R. Characterizing and Controlling Urban Runoff through Street and Sewerage Cleaning. U.S. Environmental Protection Agency, Storm and Combined Sewer Program, Risk Reduction Engineering Laboratory. EPA/600/S2-85/038. PB 85-186500. Cincinnati, Ohio. 467 pgs. June 1985.

Pitt, R. and Field, R., Catchbasins and Inserts for the Control of Gross Solids and Conventional Stormwater Pollutants, ASCE World Water and Environmental Resources Congress, Salt Lake City, Utah, June, 2004

Pitt and Khambhammettu, Field Verification Tests of the UpFlow™ Filter, Small Business Innovative Research, Phase 2 (SBIR2) Report. U.S. Environmental Protection Agency, Edison, NJ. 275 pages. March 2006

Pitt, R. and G. Shawley. *A Demonstration of Non-Point Source Pollution Management on Castro Valley Creek*. Alameda County Flood Control and Water Conservation District and the U.S. Environmental Protection Agency Water Planning Division (Nationwide Urban Runoff Program). Washington, D.C. June 1982.

Clark, S., R. Pitt, and R. Field. “Stormwater Treatment Using Inlet Devices, Filter Media, and Filter Fabrics.” In: *Proceedings of the Engineering Foundation Conference: Stormwater NPDES Related Monitoring Needs*. Edited by H.C. Torno. Engineering Foundation and ASCE. New York, NY. 1994. pp. 641 – 650.

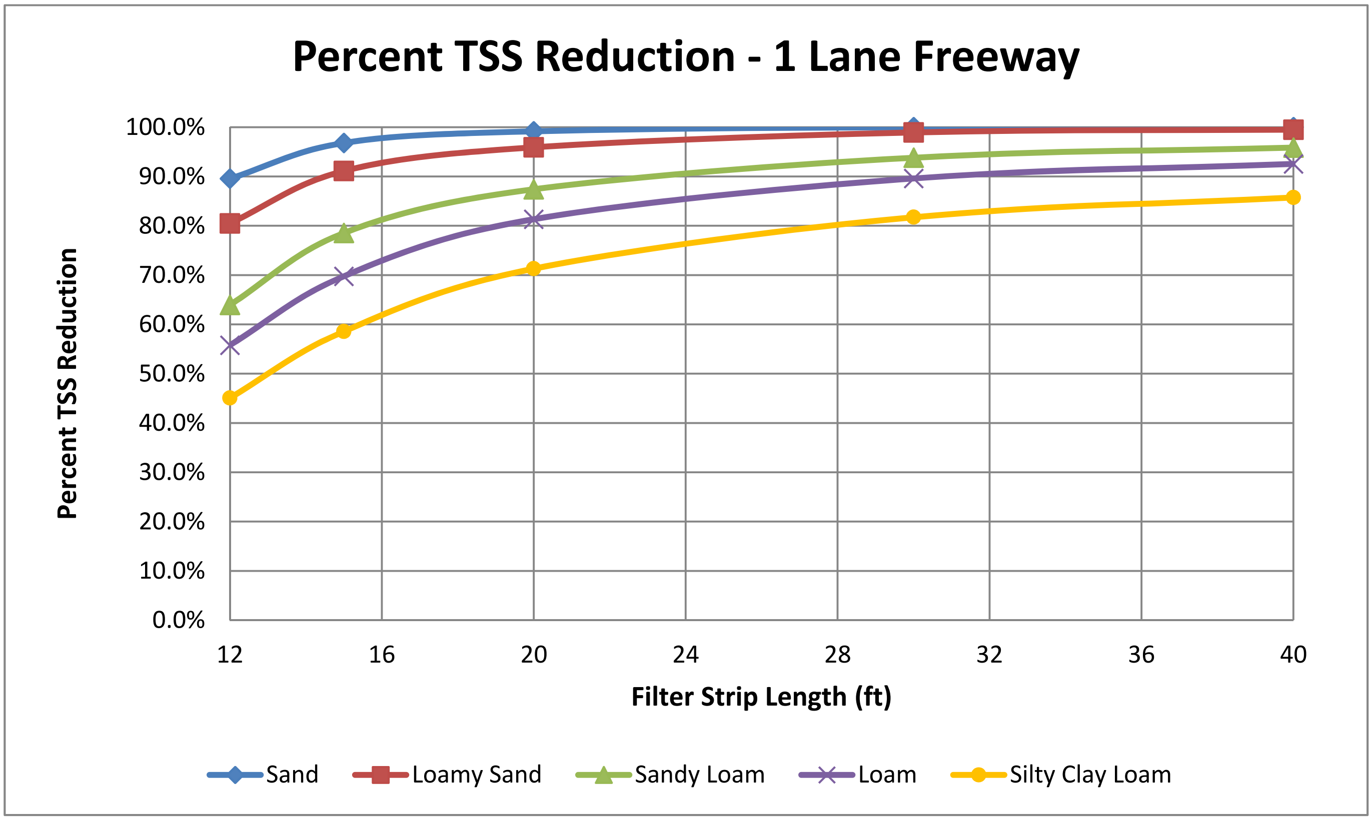
Pitt, R. and J. Voorhees, “WinSLAMM, the Source Loading and Management Model for Windows version 9.4,” PV and Associates, LLC, 2010.

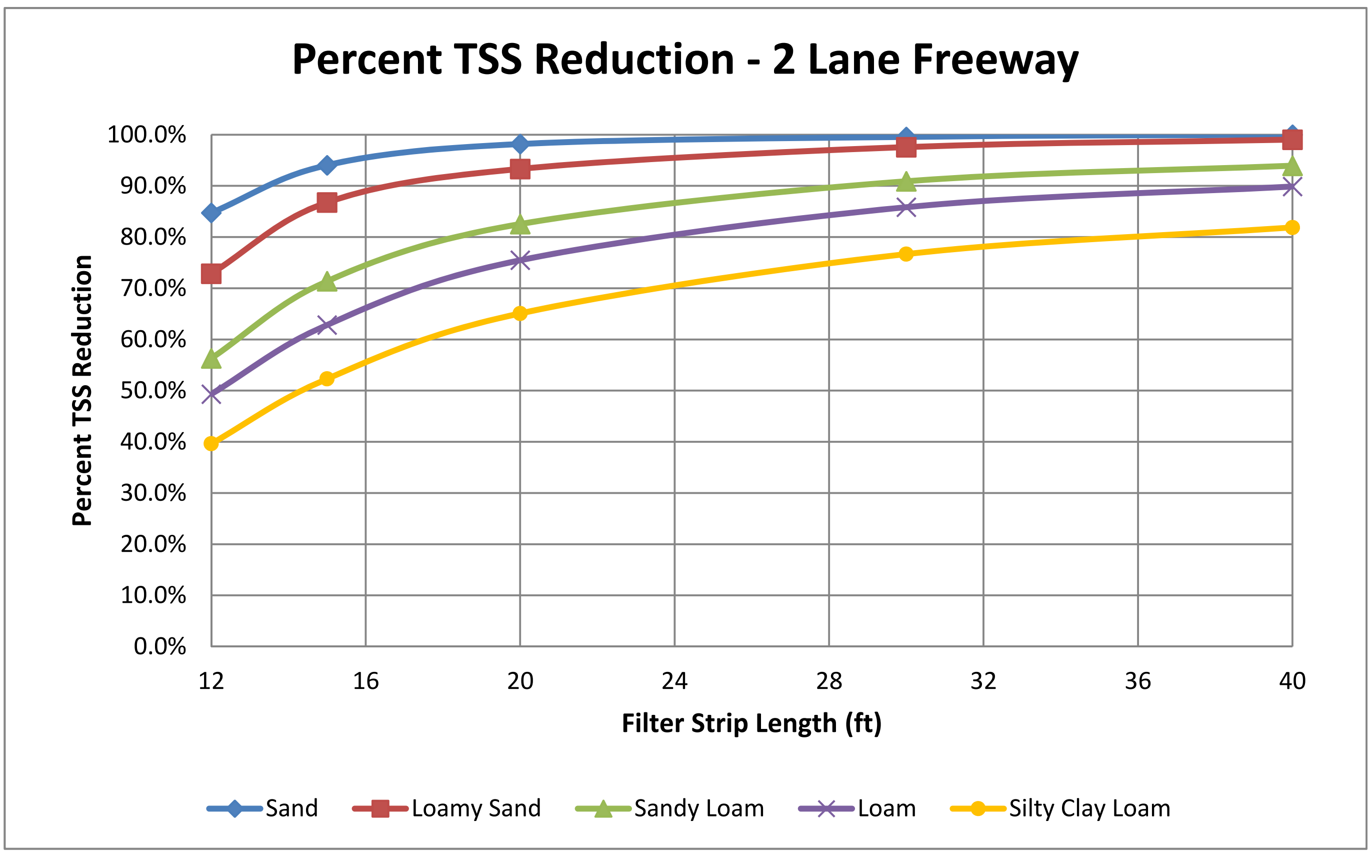
Wisconsin State Legislature, Revisor of Statutes Bureau, Wisconsin Administrative Code; for information on the codes of state agencies, including WDNR, refer to http://www.legis.state.wi.us/rsb/code.htm.

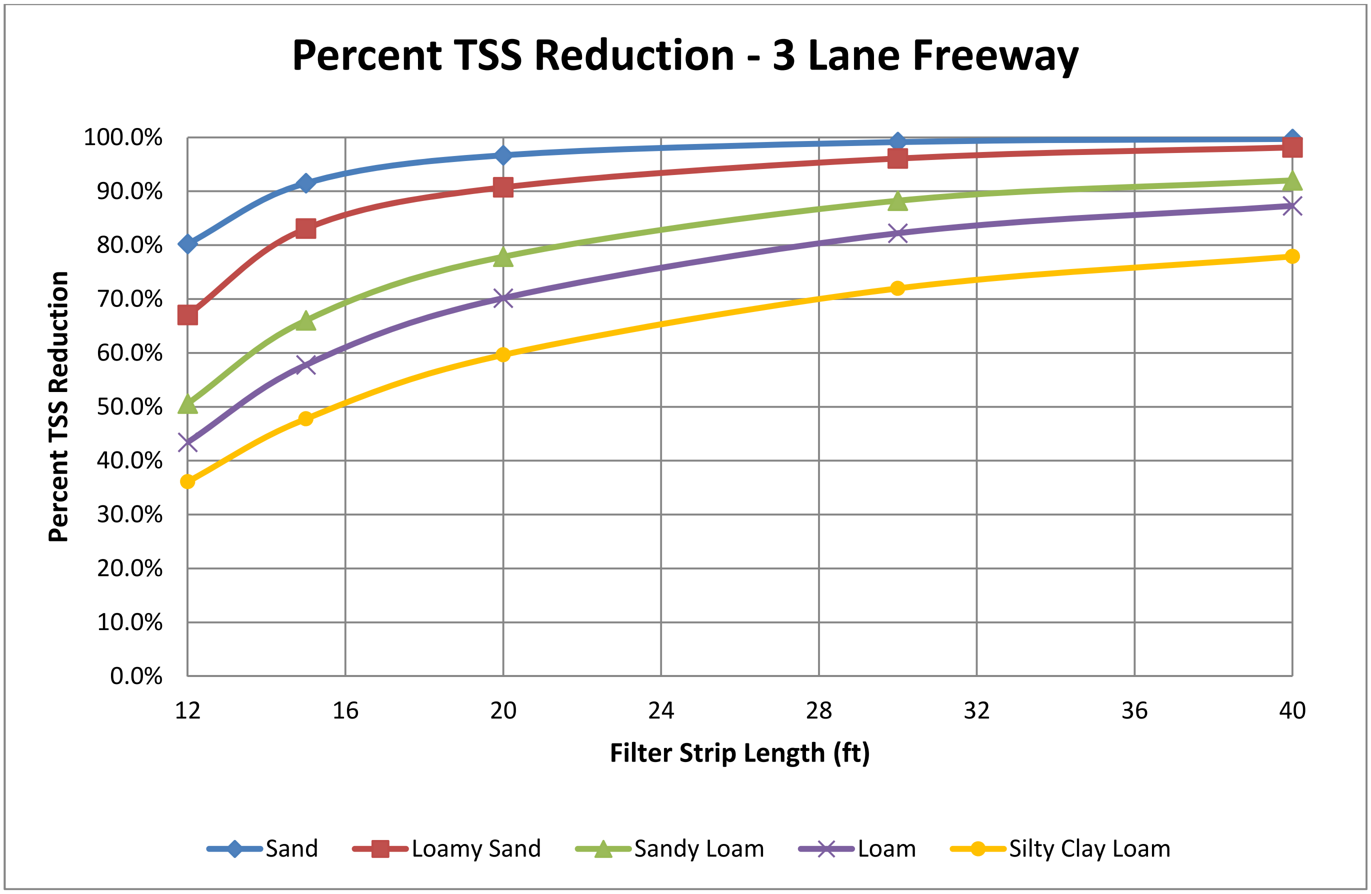
LIST OF ATTACHMENTS

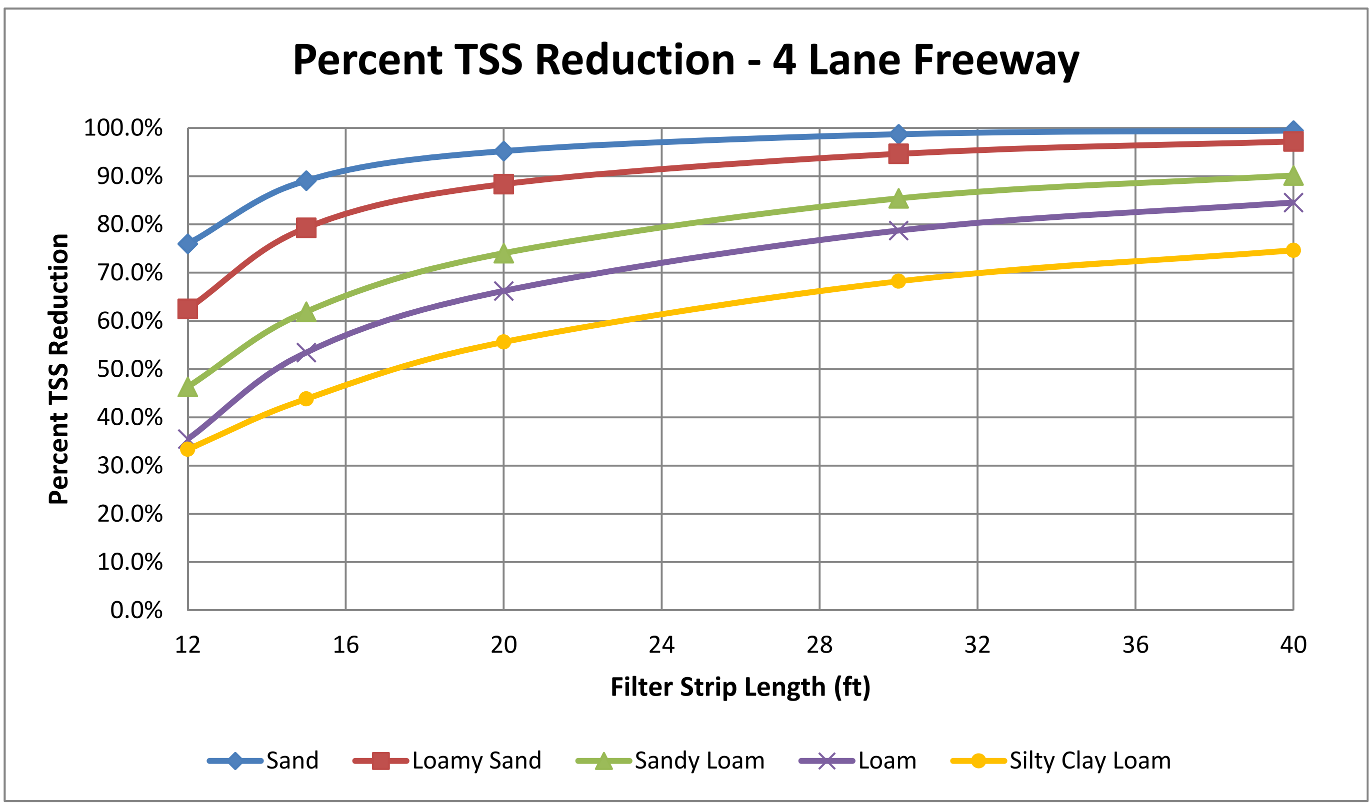
1	**Grass Swale Performance**					
2	**Project ID: XXXX-XX-XX**					
3	**Title: Example Project**					
4	**Designer/Checker:**					
5	**DOT Region/Firm Name:**					
6	**Date:**					
7	**Drainage Area Basin Number**	**1**	**1**	**1**		**Total**
8	**Grass Swale Ending Station Number**	**13+00**	**17+00**	**21+00**		
9	**Grass Swale Starting Station Number**	**11+00**	**13+00**	**17+00**		
10	**Left, Center, or Right**	**R**	**R**	**R**		
11	***Site Assessment***					
12	Grass Swale Length (ft)	200	400	400		
13	Average Drainage Area Width Outside of ROW (ft)	150	100	300		
14	Average ROW Width (ft)	65	75	90		
15	Average Swale Slope	0.50%	1.5	1		
16	Swale Segment Q2 Flow Rate (cfs)	1.5	4.0	16.5		
17	Average Swale Velocity (ft/s)	0.48	1.28	1.64		
18	Percent Reduction	80%	80%	0%	80%	80%
19	***Results Summary***					
20	Drainage Area (ac)	0.987	1.607	3.581	0.000	6.175
21	ROW Area (ac)	0.298	0.689	0.826	0.000	1.814
22	Percent Reduction per unit ROW Area	80.0%	80.0%	0.0%	80.0%	43.5%

Enter Line Number and Comment. Add more boxes if necessary


Percent TSS Reduction - 1 Lane Freeway
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Percent TSS Reduction
12
16
20
24
28
32
36
40
Filter Strip Length (ft)
Sand
Loamy Sand
Sandy Loam
Loam
Silty Clay Loam


Percent TSS Reduction - 2 Lane Freeway
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Percent TSS Reduction
12
16
20
24
28
32
36
40
Filter Strip Length (ft)
Sand
Loamy Sand
Sandy Loam
Loam
Silty Clay Loam


Percent TSS Reduction - 3 Lane Freeway
Percent TSS Reduction
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
12
16
20
24
28
32
36
40
Filter Strip Length (ft)
Sand
Loamy Sand
Sandy Loam
Loam
Silty Clay Loam


Percent TSS Reduction - 4 Lane Freeway
Percent TSS Reduction
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
12
16
20
24
28
32
36
40
Filter Strip Length (ft)
Sand
Loamy Sand
Sandy Loam
Loam
Silty Clay Loam

1	**Filter Strip Performance**
2	**Project ID: XXXX-XX-XX**
3	**Title: Example Project**
4	**Designer/Checker:**
5	**DOT Region/Firm Name:**
6	**Date:**

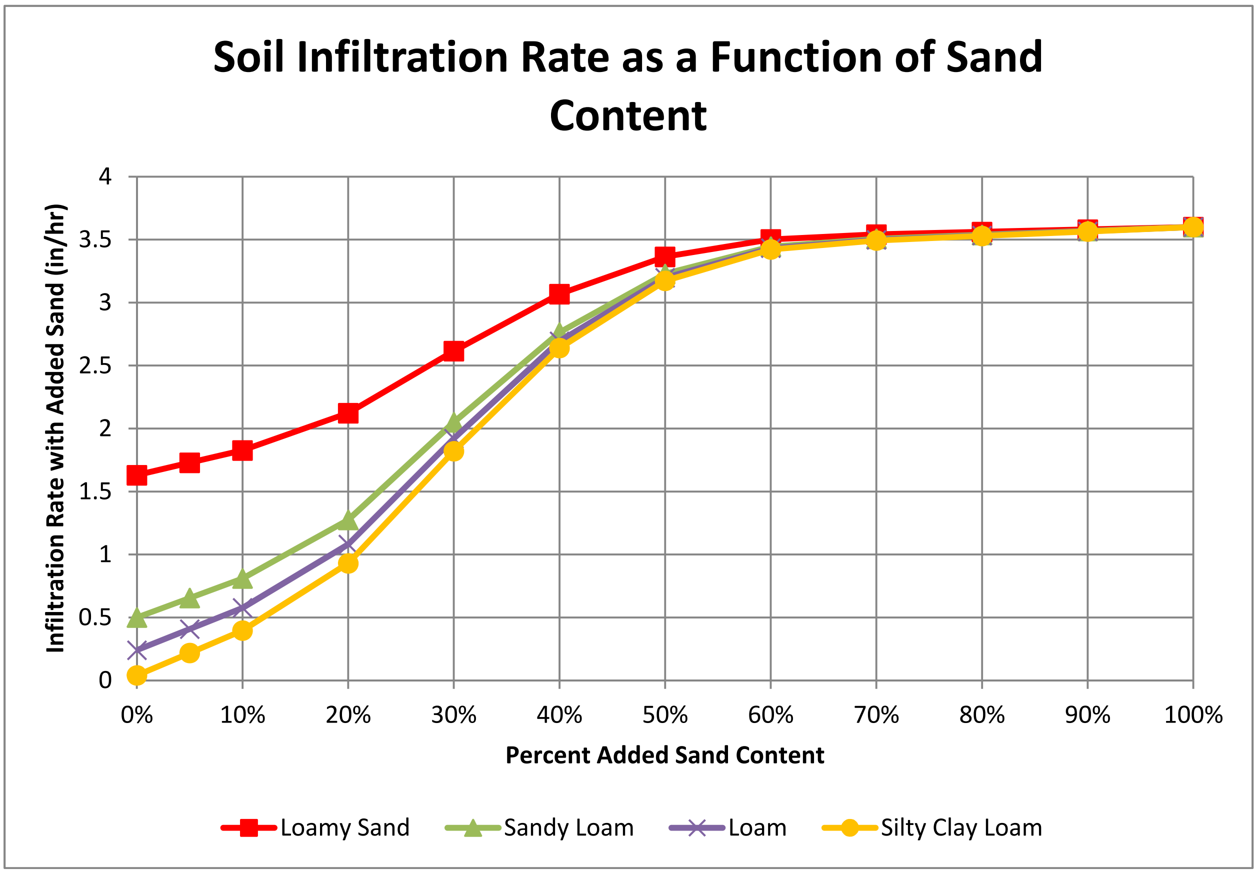
7	**Drainage Area Basin Number**	**1**	**2**	**3**	**Total**
8	**Filter Strip Ending Station Number**	**13+00**	**17+00**	**21+00**	
9	**Filter Strip Starting Station Number**	**11+00**	**13+00**	**17+00**	
10	**Left, Center, or Right**	**R**	**R**	**R**	
11	***Site Assessment***	Cut/Fill Trans.			
12	Filter Strip Width parallel to Highway (ft)	200	400	400	1000.000
13	Average Drainage Area Width (ft)	50	56	66	172.000
14	Average ROW Width (ft)	65	75	85	225.000
15	Number of Treated Freeway Lanes	2	2	3	
16	Filter Strip Length perpendicular to Highway (ft)	0	22	28	
17	Filter Strip Soil Type	Sandy Loam	Sandy Loam	Sandy Loam	
18	Design Chart Number	2	2	3	
19	Percent Reduction of Treated Area	0%	85%	86%	60.8%
21	***Results Summary***				
22	Treated Highway Area (ac)	0.142	0.487	0.652	1.281
23	Drainage Area (ac)	0.230	0.514	0.606	1.350
24	ROW Area (ac)	0.298	0.689	0.781	1.768
25	Percent Reduction per unit ROW Area	0.0%	85.0%	86.0%	60.8%

Enter Line Number and Comment. Add more boxes if necessary

Filter Strip Sand Amendment Analysis

If the designer elects to enhance the embankment soils on slopes 4:1 or flatter to increase the performance of the filter strip, FDM 10-35-10.4.3 suggests that 30% sand, by volume, should be added to the sandy loam, loam or silty clay loam typical soil types to achieve the soil infiltration rate equivalent to loamy sand. This value was developed from the chart illustrated below. The chart describes the soil infiltration rate as sand is added to the soil types described in the filter strip performance charts. These infiltration rates, which are static rates that are assumed to occur when the depth of the water flowing down the filter strip is less than 0.015 feet, which is a reasonable assumption for sheet flow down a highway embankment. For example, a mixture of 30% sand and 70% silty clay will achieve an infiltration rate of about 1.8 inches per hour. This value is close to the 1 63 in/hr static infiltration rate for silty clay with no added sand. This 30% sand amendment volume, as described in Section 10.4.3, was selected from the curve to approximate the infiltration rate for loamy sand, without additional sand, as applied in the design charts.

The chart was developed from a modified soil media table in the WinSLAMM v10.0 program that calculates the infiltration rate of soil mixture combinations. The table was developed from laboratory and field measurements of many soil type combinations.



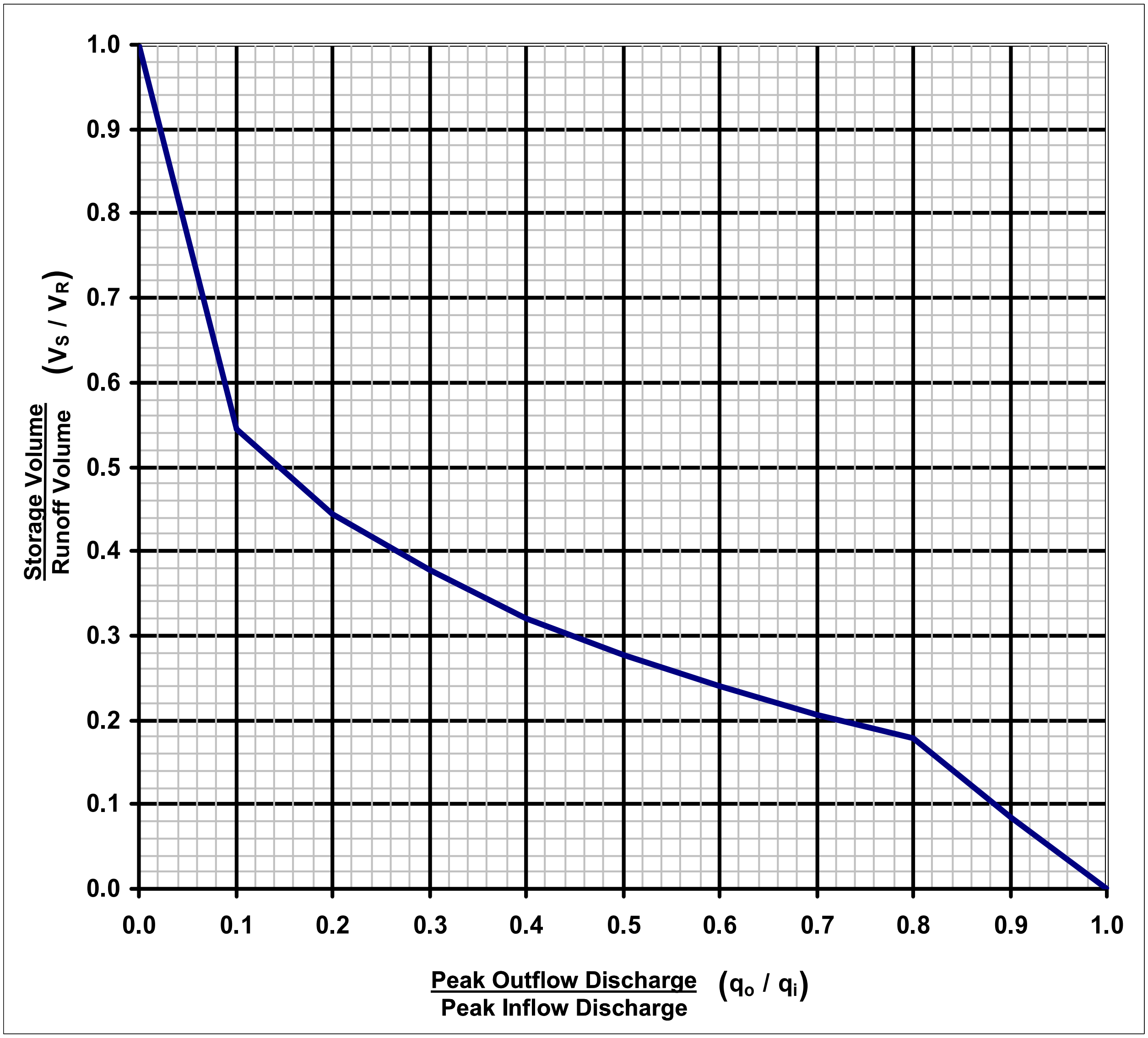
Calculation of Preliminary Permanent Pool Surface Area for TSS Reduction

Appendix A—Calculation of Preliminary Permanent Pool Surface Area for TSS Reduction [1]

		80%	60%
Land Use/Description/Management[2]	Total Impervious (%)[3]	Minimum Surface Area of the Permanent Pool (% of Watershed Area)	Minimum Surface Area of the Permanent Pool (% of Watershed Area)
Commercial/Office Park/Institutional/Warehouse/Industrial/Manufacturing/Storage[4] (Non-retail related business, multi-storied buildings, large heavily used outdoor parking areas, material storage, or manufacturing operations	<60 60-80 80-90 >90	1.8 2.1 2.4 2.8	0.6
Parks/Open Space/Woodland/Cemeteries	0-12	0.6	0.2
Highways/Freeways (Includes right-of-way area) Typically grass banks/conveyance Mixture of grass and curb/gutter Typically curb/gutter conveyance	 <60 60-90 >90	 1.4 2.1 2.8	 1.0

[1] Multiply the value listed by the watershed area within the category to determine the minimum pond surface area. Prorate for drainage areas with multiple categories due to different land use, management, percent impervious, soil texture, or erosion rates. For example, to achieve an 80% TSS reduction, a 50 acre (residential, 50% imperviousness) x 0.01 (1% of watershed from table) = 0.5 acre + 50 acres (office park, 85% imperviousness) x 0.024 (2.4% of watershed) = 1.2 acre. Therefore 0.5 acre + 1.2 acre = 1.7 acres for the minimum surface area of the permanent pool.
[2] For offsite areas draining to the proposed land use, refer to local municipalities for planned land use and possible institutional arrangements as a regional stormwater plan.
[3] Impervious surfaces include rooftops, parking lots, roads, and similar hard surfaces, including gravel driveways/parking areas.
[4] Category includes insurance offices, government buildings, company headquarters, schools, hospitals, churches, shopping centers, strip malls, power plants, steel mills, cement plants, lumber yards, auto salvage yards, grain elevators, oil tank farms, coal and salt storage areas, slaughter houses, and other outdoor storage or parking areas.
Source: This table was modified from information in “The Design and Use of Detention Facilities for Stormwater Management Using DETPOND” by R. Pitt and J. Voorhees (2000).

Pond Volume/Discharge Design Curve



Source: Technical Release 55, United States Department of Agriculture, Natural Resources Conservation Service, Washington, D.C. 1986. NRCS Bulletin No. WI-210-8-16 (Sept. 12, 1988) amended the TR-55 routing graph for Type II storms to include flows outside the original range.

Rainfall and Runoff Tables

Table 2 – Rainfall for Wisconsin Counties for a 1-year, 24-hour Rainfall[1]	
Inches of Rainfall	County
2.1	Door, Florence, Forest, Kewaunee, Marinette, Oconto, Vilas
2.2	Ashland, Bayfield, Brown, Calumet, Douglas, Iron, Langlade, Lincoln, Manitowoc, Menominee, Oneida, Outagamie, Price, Shawano, Sheboygan
2.3	Barron, Burnett, Dodge, Fond du Lac, Green Lake, Marathon, Milwaukee, Ozaukee, Portage, Racine, Rusk, Sawyer, Taylor, Washburn, Washington, Waukesha, Waupaca, Waushara, Winnebago, Wood
2.4	Adams, Chippewa, Clark, Columbia, Dane, Dunn, Eau Claire, Jackson, Jefferson, Juneau, Kenosha, Marquette, Pepin, Pierce, Polk, Rock, St. Croix, Walworth
2.5	Buffalo, Green, Iowa, La Crosse, Monroe, Richland, Sauk, Trempealeau, Vernon
2.6	Crawford, Grant, Lafayette
[1]TP – 40: Rainfall Frequency Atlas of the United States, U.S. Department of Commerce Weather Bureau.	

Table 3 - Rainfall for Wisconsin Counties for a 1-year, 24-hour Rainfall[2]		
Zone	Inches of Rainfall	County
1	2.22	Douglas, Bayfield, Burnett, Washburn, Sawyer, Polk, Barron, Rusk, Chippewa, Eau Claire
2	2.21	Ashland, Iron, Vilas, Price, Oneida, Taylor, Lincoln, Clark, Marathon
3	1.90	Florence, Forest, Marinette, Langlade, Menominee, Oconto, Door, Shawano
4	2.23	St. Croix, Dunn, Pierce, Pepin, Buffalo, Trempealeau, Jackson, La Crosse, Monroe
5	2.15	Wood, Portage, Waupaca, Juneau, Adams, Waushara, Marquette, Green Lake
6	1.96	Outagamie, Brown, Kewaunee, Winnebago, Calumet, Manitowoc, Fond du Lac, Sheboygan
7	2.25	Vernon, Crawford, Richland, Sauk, Grant, Iowa, Lafayette
8	2.25	Columbia, Dodge, Dane, Jefferson, Green, Rock
9	2.18	Ozaukee, Washington, Waukesha, Milwaukee, Walworth, Racine, Kenosha
[2]Bulletin 71: Rainfall Frequency Atlas of the Midwest, Midwest Climate Center and Illinois State Water Survey, 1992.		

Table 4 – Runoff for Selected Curve Numbers and Rainfall Amounts[1]											
	Runoff Depth in Inches for Curve Number of:										
Rainfall (inches)	50	55	60	65	70	75	80	85	90	95	98
1.9	0.00	0.01	0.04	0.11	0.20	0.33	0.50	0.72	1.01	1.39	1.68
1.96	0.00	0.01	0.05	0.12	0.23	0.36	0.54	0.77	1.06	1.44	1.73
2.1	0.00	0.02	0.08	0.16	0.28	0.43	0.62	0.87	1.18	1.58	1.87
2.15	0.00	0.03	0.09	0.18	0.30	0.46	0.66	0.91	1.22	1.63	1.92
2.18	0.00	0.03	0.10	0.19	0.31	0.47	0.68	0.93	1.25	1.65	1.95
2.2	0.00	0.04	0.10	0.19	0.32	0.48	0.69	0.94	1.27	1.67	1.97
2.21	0.00	0.04	0.10	0.20	0.32	0.49	0.69	0.95	1.28	1.68	1.98
2.22	0.00	0.04	0.10	0.20	0.33	0.49	0.70	0.96	1.28	1.69	1.99
2.23	0.01	0.04	0.11	0.20	0.33	0.50	0.71	0.97	1.29	1.70	2.00
2.25	0.01	0.04	0.11	0.21	0.34	0.51	0.72	0.98	1.31	1.72	2.02
2.3	0.01	0.05	0.12	0.23	0.36	0.54	0.75	1.02	1.35	1.77	2.07
2.4	0.02	0.07	0.15	0.26	0.41	0.59	0.82	1.10	1.44	1.87	2.17
2.5	0.02	0.08	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
2.6	0.03	0.10	0.20	0.34	0.50	0.71	0.96	1.26	1.62	2.06	2.37
[1]NRCS TR-55, Equations 2-1 to 2-4 used to determine runoff depths.											

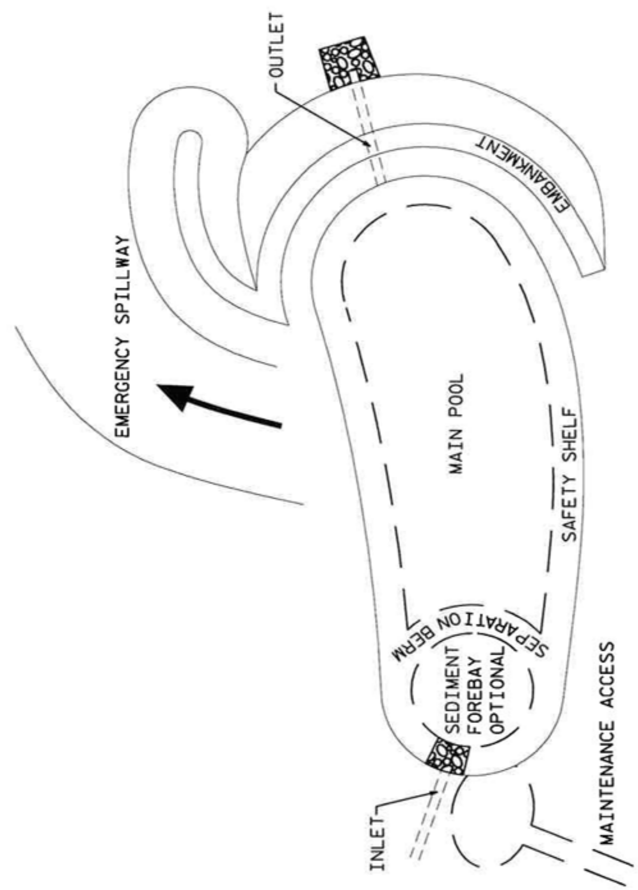
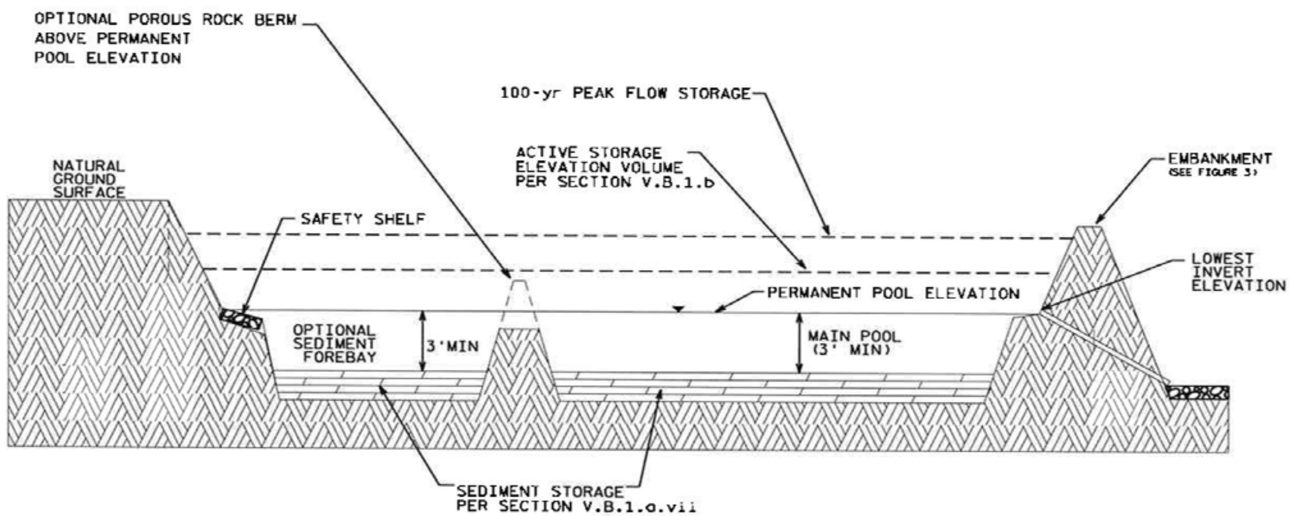


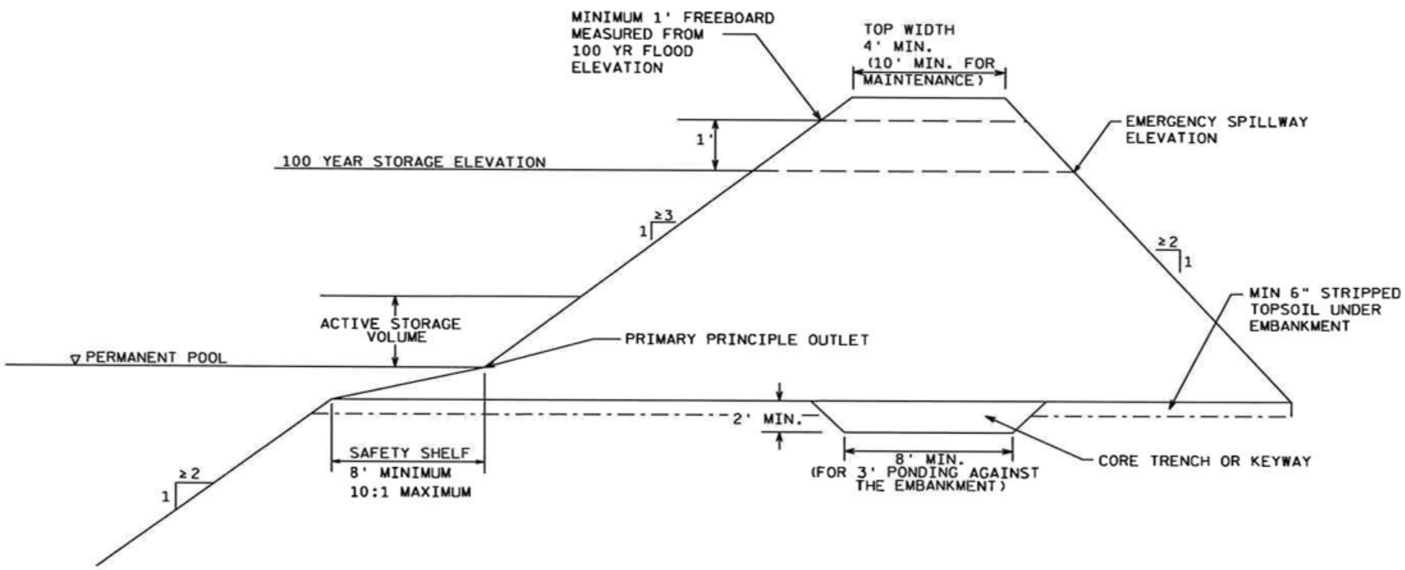
FIGURE 1
CONCEPTUAL WET DETENTION POND
PLAN VIEW
NOT TO SCALE

FIGURE 2
CONCEPTUAL WET DETENTION POND
CROSS SECTION
NOT TO SCALE



CROSS SECTION

FIGURE 3
TYPICAL EMBANKMENT CROSS SECTION FOR WET DETENTION POND
NOT TO SCALE



1. THESE ARE CONCEPTUAL OUTLET LOCATIONS TO INDICATE THE NEED TO HAVE DIFFERENT OUTLETS FOR THE DIFFERENT PURPOSES. NUMEROUS OUTLET DESIGNS WILL MEET THE CRITERIA OF THE STANDARD

SAMPLE WET DETENTION PERFORMANCE SPREADSHEET: DRAINAGE-SUMMARY WORKSHEET

A working copy of this form is available at:

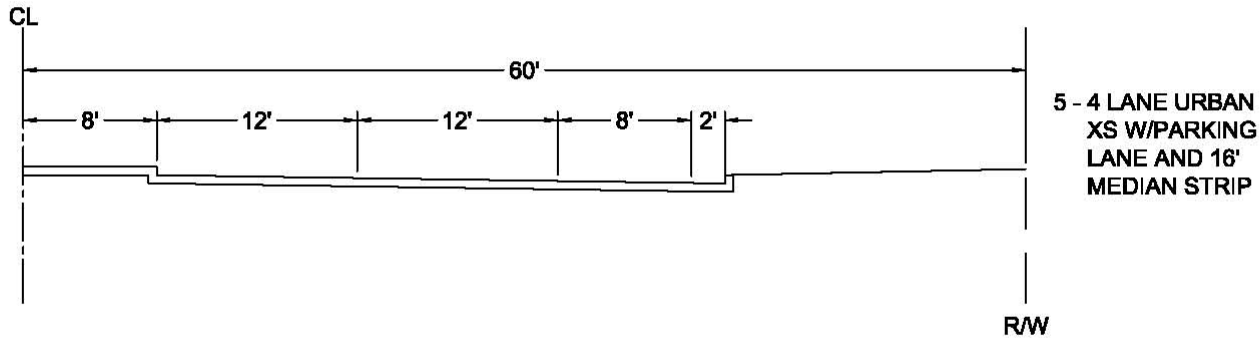
http://wisconsindot.gov/rdwy/fdm/files/WisDOT-Stormwater-Drainage-WQ-Channel-Spreadsheets.zip

1	**Wet Detention Pond Performance**
2	**Project ID: XXXX-XX-XX**
3	**Title: Example Project**
4	**Designer/Checker:**
5	**DOT Region/Firm Name:**
6	**Date:**

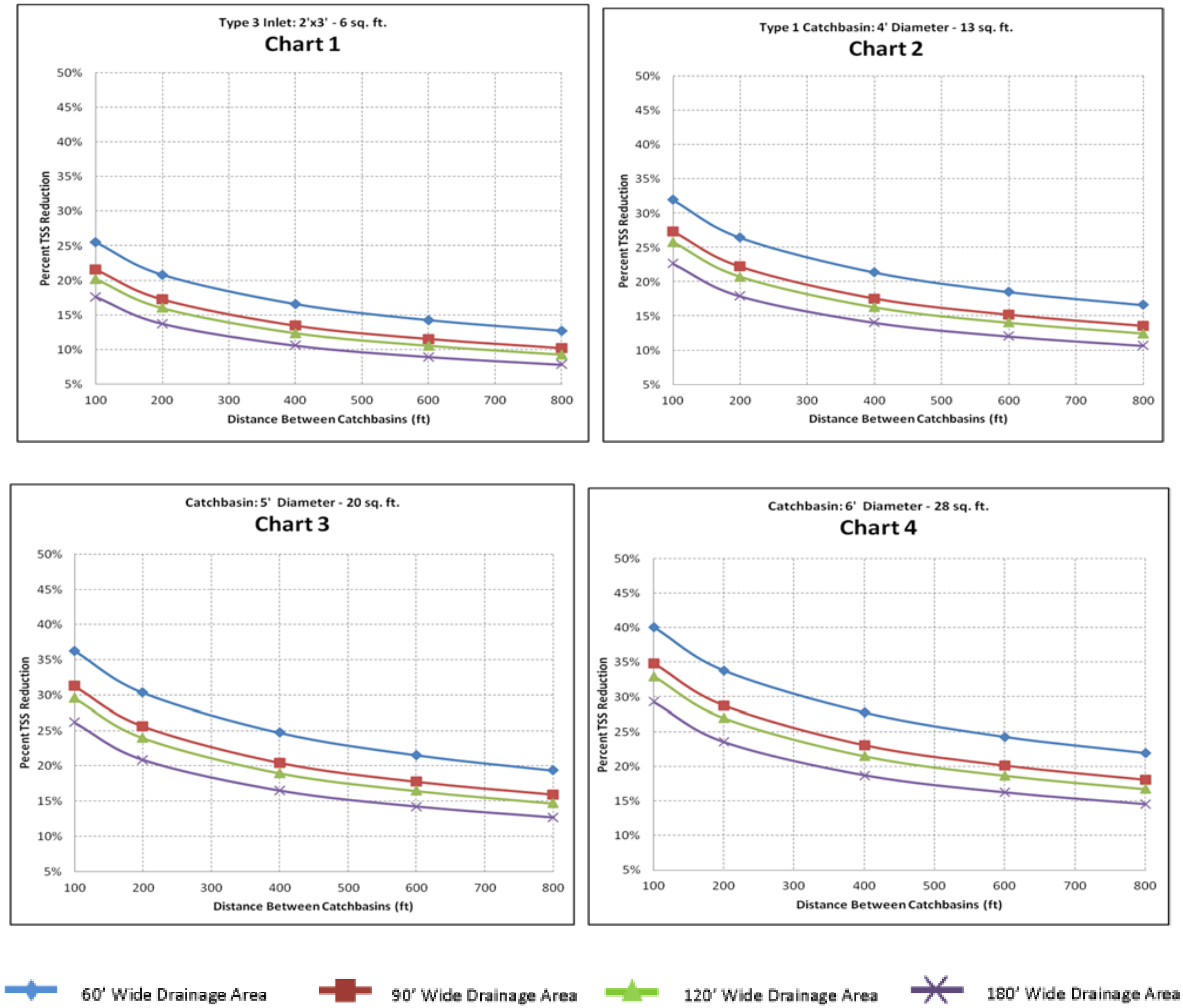
7	**Drainage Area Basin Number**					**Total**
8	**Pond Number**	**1**	**2**			
9	**Pond Ending Station Number**	**30+00**	**48+00**			
10	**Pond Starting Station Number**	**20+00**	**35+00**			
11	**Left, Center, Right, or All**	**R**	**R**			
12	***Site Assessment***					
13	Highway Segment Length Treated (ft)	1000	1300			
14	Drainage Area (ac)	12.000	15.000			27.000
15	ROW Area (ac)	1.500	1.900			3.400
16	Percent Reduction	75%	85%			81%
17	***Results Summary***					
18	Percent Reduction per Treated Highway Segment	75.0%	85.0%			80.6%

Enter Line Number and Comment. Add more boxes if necessary

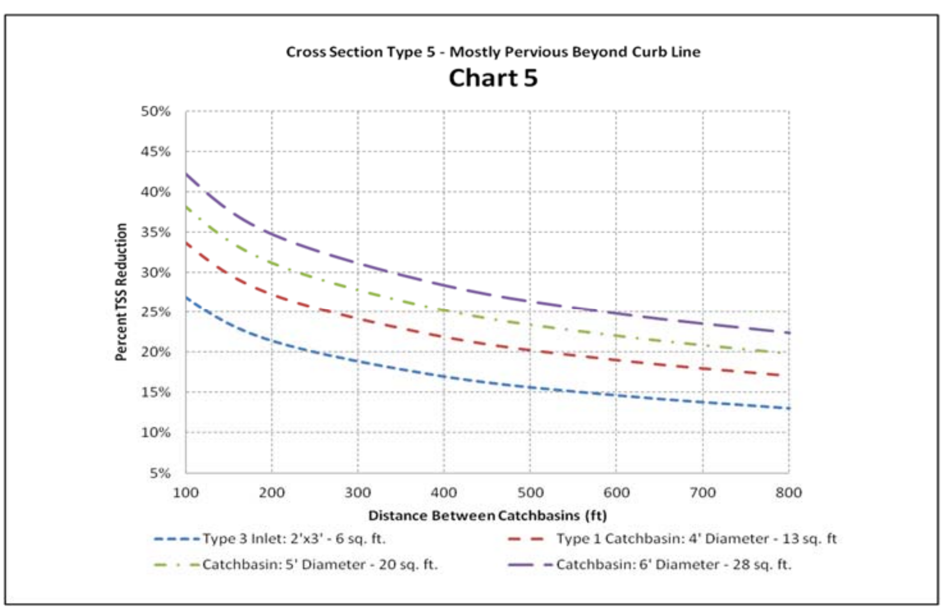
TYPICAL Cross Section TYPE 5



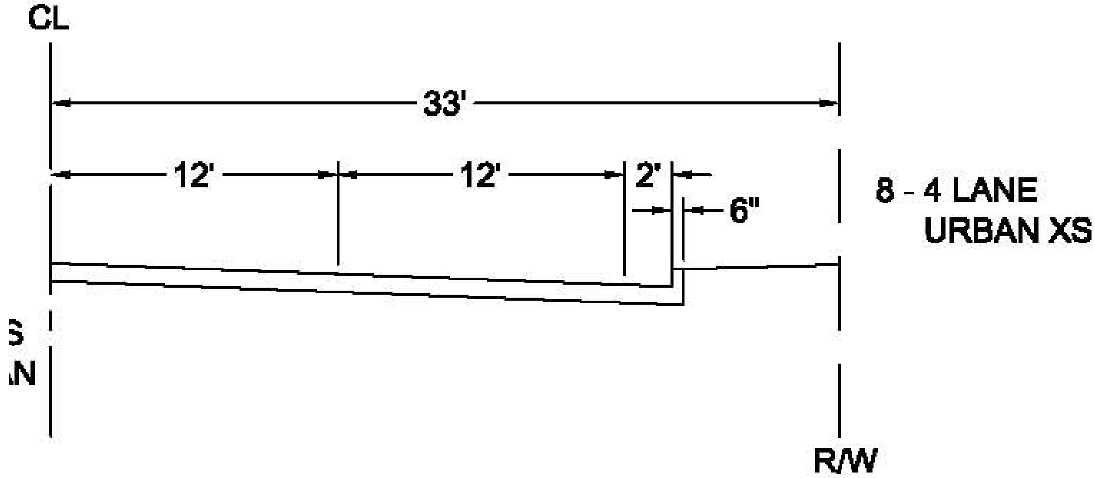
Cross Section Type 5 – Mostly Impervious Surface Beyond Curb Line



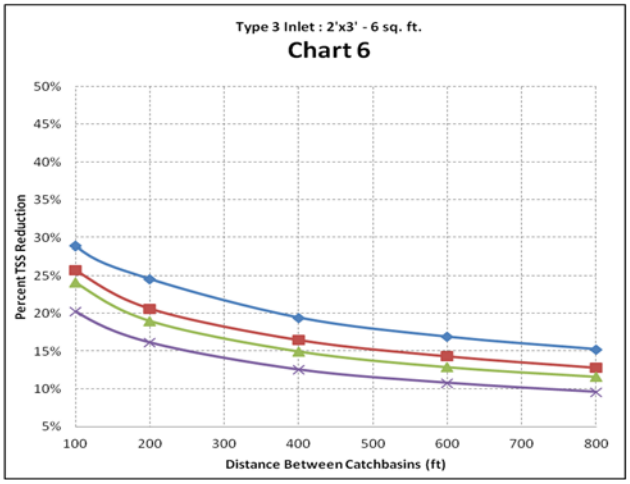
Cross Section Type 5 – Mostly Pervious Surface Beyond Curb Line

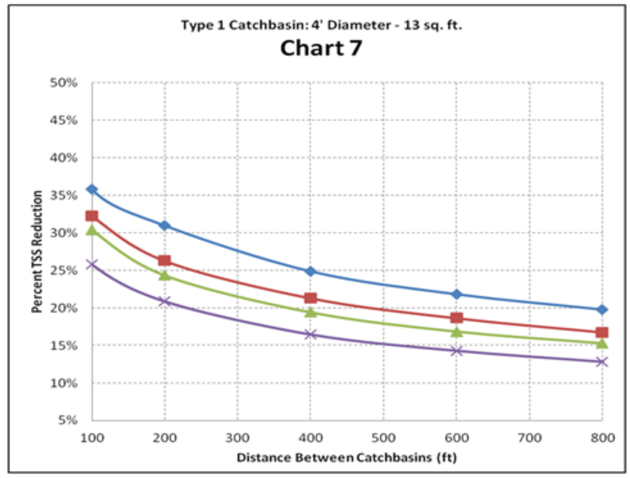


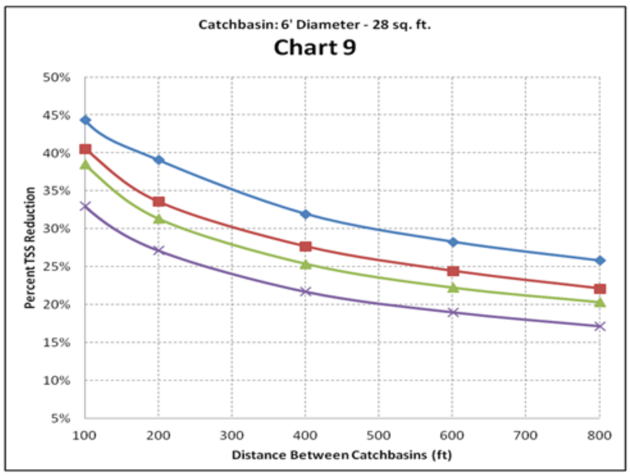
TYPICAL Cross Section Type 8

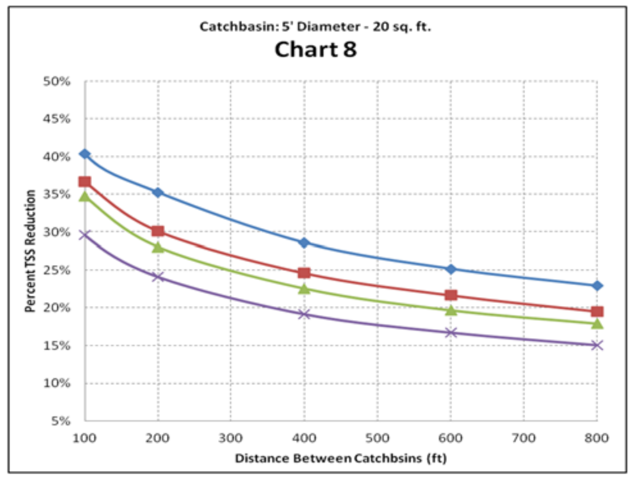


Cross Section Type 8 – Mostly Impervious Surface Beyond Curb Line



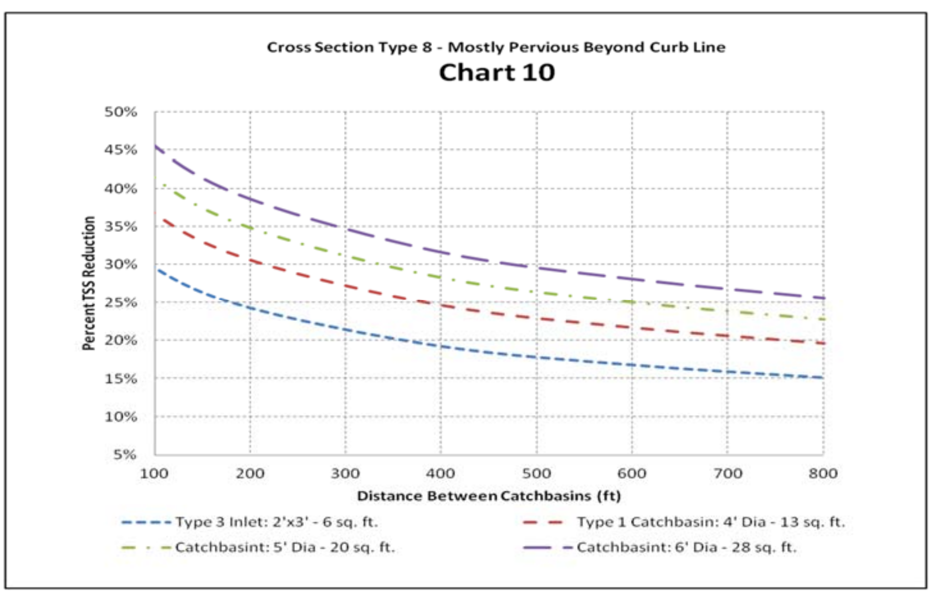






60' Wide Drainage Area   90' Wide Drainage Area   120' Wide Drainage Area   180' Wide Drainage Area

Cross Section Type 8 – Mostly Pervious Surface Beyond Curb Line



SAMPLE CATCHBASIN ANALYSIS SUMMARY SPREADSHEET: DRAINAGE-SUMMARY WORKSHEET

Refer to Attachment 15.5 for a working copy of this form.

1	Catchbasin Performance							
2	**Project ID: XXXX-XX-XX**							
3	**Title: Example Project**							
4	**Designer/Checker:**							
5								
6	**Date:**							
7	**Drainage Area Basin Number**							**Total**
8	**Catchbasin Number**							
9	**Catchbasin Station**	**10+00**	**12+00**	**12+01**	**12+02**	**12+03**		
10	**Left, Center, or Right**	**R**	**R**	**R**	**R**	**R**		
11	***Site Assessment***							
12	Distance to Next Catchbasin or Drainage Area (ft)	200	250	333				
13	Drainage Area (ac)	0.300	0.450	3.000				3.750
14	ROW Area (ac)	0.200	0.250	0.300				0.750
15	Cross Section Type (5 or 8)	5	8					
16	Catchbasin or Inlet Type/Size	Type 3 Inlet	Type 3 Inlet	Type 1 CB	Type 3 Inlet		DD Menu	
17	Predominant Cover Type	More Imperv	More Perv				DD Menu	
18	Design Chart Number	1	10				DD Menu	
19	Percent Reduction from Design Chart	14%	23%	22%				
20	***Results Summary***							
21	Average Drainage Area Width (ft)	65.34	78.408	392.432432	#DIV/0!	#DIV/0!		
22	Average ROW Width (ft)	43.56	43.56	39.2432432	#DIV/0!	#DIV/0!		
23	Percent Reduction per unit ROW Area	2.8%	5.8%	6.6%	0.0%	0.0%		4.0%

FDM 10-40-1 Introduction

January 24, 1997

The following BMPs are effective water quality management measures but must be coordinated with WisDOT Maintenance staff, and/or local units of government. They are ineffective if they are not maintained or performed on a regular basis, therefore a schedule for this work must be considered by the designer. Consideration must also be made, by WisDOT Maintenance, to budget sufficient funds for this work when it cannot be incorporated into the project agreement with the local unit of government.

FDM 10-40-5 Street Sweeping

October 22, 2012

5.1 Description and Purpose

Street sweeping involves the removal of grit, debris, and trash from urban impervious areas such as streets, parking lots, and sidewalks. If these materials are removed from the streets where they are deposited, they are no longer available for loss in urban runoff.

5.2 Target Pollutants

Street sweeping is most effective form removal of coarse particles, leaves, trash, and other similar materials. In some cases, there could be a relatively high delivery ratio for these materials if they were not removed from street surfaces. The specific pollutants generally reduced by street sweeping include sediment, nutrients, and oxygen demanding substances.

5.3 Planning Considerations

A semi-annual street sweeping program is recommended to remove debris after spring snowmelt and after leaves fall in the autumn.

Two common types of street sweepers are used. They are vacuum sweepers and mechanical broom sweepers. Vacuum sweepers are more effective for removing fine particles than broom sweepers. Removing fine particles is important because many pollutants are adsorbed to them. Vacuum sweepers have the disadvantage of being ineffective at cleaning wet street surfaces.

Broom sweepers are effective at picking up large particulate matter and are effective on wet street surfaces. Broom sweepers also cost less to operate than vacuum sweepers. Broom sweepers generally create airborne dust during their operation which increases atmospheric loadings to a certain extent.