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Erosion Control Handbook

for Local Roads

Minnesota Local
Road Research
Board

U.S. Department of Transportation
Federal Highway
Administration

Minnesota Department of Transportation

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1.1 INTRODUCTION

Roadside erosion and runoff is a problem during and after construction. Erosion and the sediment it causes can result in an unhealthy growing environment for vegetation, and can impact waterways in the area. Erosion can also result in additional maintenance and costly repairs.

Heavy rains result in erosion during construction.

Gully erosion results when small erosion problems are not corrected in time.

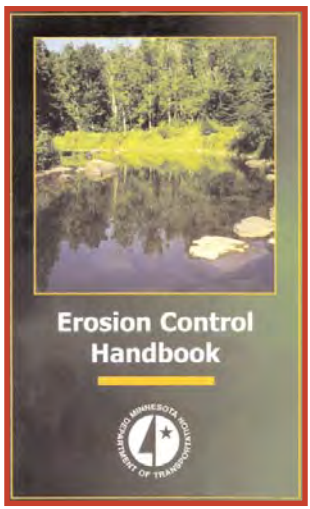
Effective erosion control requires an integrated approach, which considers government statutes and regulations, a broad knowledge of temporary and permanent erosion control methods; design, construction, and maintenance considerations; and new technology. All of those elements are included in this manual.

Who Should Use this Manual?

This manual will assist counties, townships and local units of government by providing guidelines and methods for effective erosion control practices on low volume roads.

Local agencies are required to develop erosion control plans and abide by the National Pollutant Discharge Elimination System (NPDES) permit requirements. Detailed information is provided to guide the user through both Phase I and II of the NPDES permit process, and help is given for dealing with local watershed districts and other agencies. This manual will provide guidance for maintenance activities, and case studies outlining best management practices.

Many agencies outline requirements for erosion control activities during construction. They include the Federal Highway Administration, the Pollution Control Agency, the Department of Natural Resources, and the Corps of Engineers. Local soil and water conservation agencies and Watershed Districts may also have requirements for an area. Permitting information for these agencies is given in Chapter 2.



Note: Mn/DOT has published an Erosion Control Handbook (2002) that may be used in conjunction with this manual. It offers very useful information for planning erosion and sediment control measures on a construction project, and working with Mn/DOT and governing agencies. The Handbook is available from the Mn/DOT Office of Environmental Services.

1.2 Physical and Environmental Factors Affecting Erosion

Erosion can be caused by wind, gravity, or water. However, water-generated erosion is the most damaging factor, especially in developing areas. The five types of water erosion and techniques for minimizing them are outlined in Table 1-1.

Table 1-1. Types of Erosion

Type of Erosion	Description	Technique Minimization
Raindrop splash	Raindrop impact of the raindrop dislodges soil, causing it be splashed into the air. The splash effect also increases compaction and destroys open soils structure.	Stabilize the soil to prevent erosion. Mulch.
Sheet erosion	Transportation mechanism of soil loosened by raindrop splash, removal of soil from sloping land in thin layers. Dependent on soil type, depth and flow velocity.	Minimize by diverting flow away from the slope. Surface Roughening.
Rill erosion	Occurs where sheetflow becomes concentrated in small, defined channels a few cm deep. Form of erosion in which most rainfall erosion occurs.	Prevent by slope stabilization and diverting flow. Repair immediately with disking or tilling.
Gully erosion	Concentrated flow in unrepaired rills.	Requires extensive repair. Prevent by dispersing and diverting sheetflow.
Channel erosion	Occurs at bends and in constrictive areas.	Smooth bends, add riprap. Use of bendway weirs or soil bioengineering methods.

A soil's type and physical characteristics are important factors in the amount of erosion it may experience. According to the Natural Resource Conservation Services, four major soil groups exist, based on their infiltration rate:

- Type A: Sands and gravels, which have low runoff potential, high infiltration rates.
- Type B: Average to medium coarse-textured soils, with average runoff potential and moderate infiltration rates.
- Type C: Moderate to fine-grained soils, with high runoff potential and slow infiltration rates.
- Type D: Clay soils, with very high runoff potential and very low infiltration rates.

Generally, the permeability and water holding capacity of a soil increases with its organic content, soil structure, and fertility.

Topography also affects the roadside conditions and erodibility. Runoff and erosion potential are increased in areas with high topographic relief. Flat, low spots will hold water, allowing for sediment to settle and remain on site. Vegetation and erosion control needs should be selected with topography in mind. Chapter 8 of the Mn/DOT Road Design Manual (RDM) provides guidance on selecting vegetation and erosion control features.

In general, reduce erosion by:

- *slowing water velocity*
- *dividing runoff into smaller quantities*
- *allowing for water infiltration*
- *providing mechanical or structural retention methods.*

A combination of adequate drainage, installation of protective devices and elements, and establishment of desirable vegetation offer the best means for soil conservation.

Shaping and the re-establishment of vegetation are the basic erosion prevention methods. If done properly, the resulting erosion potential will approach that of the natural geologic erosion prior to the disturbance by the project. At times, conditions may be encountered where vegetation will not handle the anticipated flow conditions. In these areas, bioengineered and/or hard armored structures or channel liners may be needed.

Mn/DOT Specifications

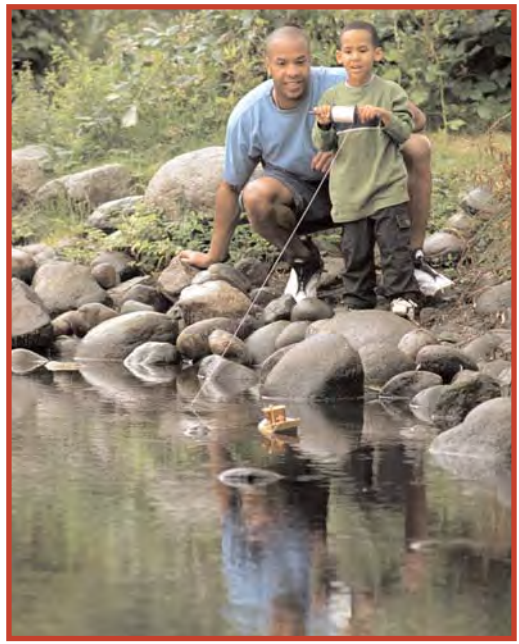
Specifications from the Minnesota Department of Transportation Standard Specifications for Construction, 2000 Edition (Standard Specifications) that pertain to erosion control are listed below:

- Section 1717, Air, Land and Water Pollution
- Section 1803.5, Erosion Control
- Section 2105.5, Excavation and Embankment
- Section 2573, Temporary Erosion Control
- Section 2575, Turf Establishment
- Section 2577, Soil Bioengineered Systems
- Section 3876, Seed
- Section 3878, Sod
- Section 3882, Mulch Material
- Section 3884, Hydraulic Soil Stabilizers
- Section 3885, Erosion Control Blankets
- Section 3886, Silt Fence
- Section 3887, Flotation Silt Curtain
- Section 3888, Erosion Stabilization Mats
- Section 3889, Temporary Ditch Checks
- Section 3891, Inlet Protection
- Section 3892, Temporary Down Drains
- Section 3893, Sandbags
- Section 3894, Sediment Mat
- Section 3895, Fiber Log
- Section 3896, Soil and Root Additives
- Special Provision 2573, Rapid Stabilization

For implementation, the Minnesota Department of Transportation (Mn/DOT) Standard Plan Sheets 5-297.404, .405, .406, and .407 have been developed. These sheets are available through the Mn/DOT Office of Technical Support, or on the Mn/DOT Web Site.

Basic principles for erosion and sediment control

1. Minimize both the area and time that soil is exposed.
2. Manage stormwater moving across a site by reducing the velocity and volume.
3. Install erosion and sediment control measures early in construction. Keep them well maintained.
4. Keep sediment on site.
5. Staged seeding as areas of a project are complete can reduce erosion by 90%
6. Maximize vegetation establishment by selecting the appropriate seed, knowing and preparing the soil, preparing the seedbed, and planting at the right time.



Reducing erosion preserves our water quality.

2.0 Regulation And Permitting

There are a variety of local, state, and federal policies that regulate erosion and sediment control. The primary agencies that regulate or have an interest in controlling erosion and sedimentation within Minnesota include:

- The Natural Resource Conservation Service (NRCS)
- Minnesota Pollution Control Agency (MPCA)
- County Soil and Water Conservation Districts
- Watershed Districts and Management Organizations
- Local cities, townships, and counties

This section provides information on the regulations and permitting requirements for erosion and sedimentation control within Minnesota.

2.1 Minnesota Pollution Control Agency - NPDES Phase I

The National Pollutant Discharge Elimination System (NPDES) Phase I program was implemented in November 1990 by the US Environmental Protection Agency. The Minnesota Pollution Control Agency (MPCA) administers this program locally. The purpose of the permit is to preserve, protect, and improve water quality. Phase I requires a general permit for:

- Storm water runoff from cities with a population greater than 100,000 people
- Industrial activities
- Construction sites that disturb 5 or more acres

This handbook focuses only on the construction permit.

Requirements of the Phase I NPDES Construction Permit

Projects that disturb 5 acres or more of land require an NPDES Phase I construction activity permit. Construction site disturbance includes grading, clearing, and excavation, excluding agricultural activities. The disturbed area does not have to be contiguous and the entire project corridor must be evaluated to determine the amount of disturbance anticipated. It should be noted that the NPDES Phase I permit will expire in September 2003 and be replaced with the Phase II permit (see section 2.2).

As part of NPDES Phase I, **Temporary and Permanent Erosion and Sedimentation Control Plans** must be developed. Elements of the plan must be incorporated into the final plans and specifications for the project. The Temporary Erosion and Sedimentation Control Plan:

- Outlines the Best Management Practices that are to be used to minimize sediment during construction, such as using silt fence, bale checks, rock checks, or temporary ponding,
- Identifies the party responsible for implementing and managing each element during construction,
- Must be incorporated into the project's final plans and specifications, and
- outlines the BMP's that are to be used for temporary erosion control during construction, such as temporary seeding, mulching, and erosion control blanket.

Following proper BMP's will reduce erosion and sedimentation at storm sewer inlets and wetlands

The **Permanent Erosion and Sedimentation Control Plan** also must be incorporated into the final plans and specifications for the project. It describes measures to be taken to prevent erosion and sedimentation after construction is complete. The NPDES Phase I permit also requires that if a new roadway results in a cumulative increase in impervious area of one acre or more and the runoff "has not been accounted for in a local unit of government's existing storm water management plan", the storm water runoff must be treated in a sedimentation basin prior to discharge to a wetland or lake.

An exception covering sedimentation basins for reconstruction work on existing roadways states that, while pretreatment in a sedimentation basin is recommended, it is not required for existing roadway work where the following applies:

- The drainage area is served by an existing storm sewer system which is daylighted off the road's right-of-way, or
- Proximity to bedrock or vertical relief precludes pretreatment, or
- Existing right-of-way precludes pretreatment

For projects where it is not possible to create a sedimentation basin and the above exemption applies, other Best Management Practices such as the use of grass swales or ditch blocks are required.

Application Process

An "Erosion Control Plan Sheet Checklists" is included in Chapter 3, and contains all of the forms listed below. The forms may also be obtained online at *www.pca.state.mn.us/water/stormwater*

To obtain an NPDES Storm Water Permit from the MPCA:

1. Complete the permit application and prepare a Temporary and Permanent Erosion and Sedimentation Control Plan.
2. Incorporate the Erosion and Sedimentation Control Plan into the project's final plans and specifications.
3. Send the application form and the appropriate fee to the MPCA. The Erosion and Sedimentation Control Plan is required to be available at the construction site (see Records and Inspections, below).

The MPCA will send the NPDES storm water permit and a Notice of Termination to the applicant. Construction can start within 48 hours of submitting a completed NPDES permit application to the MPCA. Once the site has undergone final stabilization, the applicant completes the Notice of Termination and sends it to the MPCA.

Communication with agencies and local governments is important during the application process.

Records and Inspections

The final plans and specifications for the project, incorporating both the Temporary and Permanent Erosion and Sedimentation Control Plan, must be available at the construction site and made available to any federal, state, or local officials that request to see these documents. The actual Temporary and Permanent Erosion and Sedimentation Control Plan must be made available within 24 hours of a request from federal, state, or local officials.

A record of all inspections must also be made available within 24 hours of a request from federal, state, or local officials.

The record of inspections shall include:

- Date and time of inspections
- Findings of inspections
- Corrective actions taken
- Documentation of the changes to the Temporary Erosion and Sedimentation Control Plan made during construction
- Date of rainfall events

Tracking rainfall events is a important part of inspection.

2.2 Minnesota Pollution Control Agency - NPDES Phase II

In 1999, the Environmental Protection Agency (EPA) announced the expansion of the NPDES Phase II program to be implemented by the MPCA. In general, Phase II requires that cities with populations between 10,000 and 100,000 people and construction activities that disturb one acre or more of land obtain an NPDES Phase II storm water permit after March 2003. This section will focus on the portion of the NPDES Phase II storm water permit that addresses construction activities.

Requirements of Phase II NPDES Permit

After March 10, 2003, any project that disturbs more than one acre of land will require an NPDES Phase II Construction Permit. Disturbance includes grading, clearing, and excavation, excluding agricultural activities. Disturbed areas do not have to be contiguous and the entire project corridor must be evaluated to determine the amount of disturbance anticipated.

The Minnesota Pollution Control Agency's web site contains NPDES information, application forms, and fee information.
www.pca.state.mn.us

SWPPP - Stormwater Pollution Prevention Plan

As part of NPDES Phase II, a Storm Water Pollution Prevention Plan (SWPPP) must be developed for the project. Elements of the SWPPP must be incorporated into the final plans and specifications for the project. The SWPPP must contain a number of items including:

- Location and type of temporary and permanent erosion control Best Management Practices (BMP's)
- Standard plates and/or specifications for the BMP's
- Site map showing impervious surfaces, soil types, direction of stormwater flow, and other items.

For a complete description of what must be included in the SWPPP, refer to the Phase II permit available from the MPCA.

Application Process

To obtain an NPDES Phase II permit, an application form and application fee must be submitted to the MPCA. The SWPPP must be complete prior to submitting the application to MPCA, but does not need to be sent with the application unless the project is greater than 50 acres. All forms and fee information are available from the MPCA.

Records and Inspections

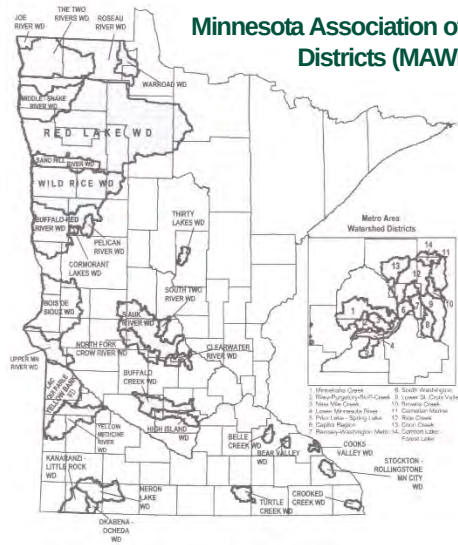
Similarly to Phase I, a record of inspections must be kept that documents rainfall events, maintenance of erosion control measures, and erosion control corrections made in the field. Specific information about records and inspections requirements can be found in the NPDES Phase II permit from the MPCA.

MS4 - Municipal Separate Storm Sewer System

2.3 Watershed Districts

In a number of areas within the State of Minnesota, Watershed Districts or Watershed Management Organizations (WD/WMO's) exist that generally have rules or requirements associated with erosion and sedimentation control. WD/WMO's mainly exist within the Twin Cities Metropolitan Area, but there are also others located in out-state Minnesota. To find out if there is a WD/WMO in the area, contact the Minnesota Board of Water and Soil Resources at (651) 296-3767 or on the internet at *www.bwsr.state.mn.us.*

Minnesota Association of Watershed Districts (MAWD)



http://www.bwsr.state.mn.us/relatedlinks/mawd101.pdf

Requirements of the WD/WMO

Each WD/WMO has different requirements, and the WD/WMO should be contacted early in the planning process to ensure that their requirements are incorporated into the project.

2.4 Other Local Government Units

Many cities, townships, and counties have their own policies on erosion and sedimentation control. Every local government is different, so it is important to contact them early in the planning process to determine what the requirements are, if any.

Requirements of Local Government Units

Local governments' policies and requirements may range from providing general guidelines for erosion control to requiring permits for projects. Some local governments also require storm water to be treated to a different standard than the NPDES permit, such as National Urban Runoff Program (NURP) guidelines (see Section 6).

Application Process

Every local government unit is different and must be contacted early in the process to ensure the project is in compliance with local policies. Most local governments will review the plans for the project to determine whether or not they meet their policies.

Local government units have different requirements, from ponds to silt fence.

Useful Web-sites

Minnesota Pollution Control Agency
www.pca.state.mn.us

Board of Water and Soil Resources
www.bwsr.state.mn.us

Department of Natural Resources
www.dnr.state.mn.us

US Army Corps of Engineers
www.mvp.usace.army.mil

Minnesota Association of Watershed Districts
www.watershed.org

Metropolitan Council's BMP Information
www.metrocouncil.org/environment/watershed/

Minnesota Erosion Control Association
www.mnerosion.org

3.0 Designing An Erosion Control Plan

A Stormwater Pollution Prevention Program (SWPPP), 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 plan length and complexity should be in line with the size of the project, the severity of the site conditions, and the potential for off-site drainage.

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

Considerations

Considerations during the plan development are outlined below:

Step 1. Determine what agencies, if any, will be involved in issuing permits for the project and identify the rules and regulations the project will need to conform to (see Chapter 2 for more information about permits).

Step 2. Identify all site constraints, potential erosion problem areas, or natural features within the site such as highly erodible soils, steep slopes, and wetlands/lakes/streams. This information can be obtained from the County's soil survey, soil borings, topography maps, the National Wetland Inventory, and an on-site wetland delineation. Determine what erosion control measures these areas will need such as extra silt fence around wetlands, avoidance or stabilization of steep slopes, stabilization along water flowage areas, etc. as discussed within this handbook. Provide for rapid stabilization in these areas. See Chapter 5 for more information on stabilization of small critical areas. Consider design life for each alternative. Incorporate design life into the project timeline and maintenance considerations.

Step 3. Determine any other erosion control methods that will be needed on site to meet local and State regulations and to prevent erosion within the project site as outlined in this handbook.

Step 4. Include all erosion control measures for the project within the construction plans. Details and specifications of each erosion control method should be provided as well as where these measures will be implemented within the project area.

Step 5. Include erosion control measures in the special provisions and specifications for the project. Typical items related to erosion prevention and sediment control found in the special provisions include:

- **Withholding from partial payment based on surface area exposed to probable erosion** (See Standard Specification 2105.5, also known as "per acre value"). Based on local conditions, the design personnel oftentimes modify the withheld amount.
- **Limiting the amount of erodible surface area exposed at any one time.** This is especially important on projects in sensitive areas, as well as those with rolling or steep topography. This can be provided under Mn/DOT Standard Specification 1803.5 A2. Limiting the amount of exposed surface should be clearly indicated in the special provisions and should be based on balance points.
- **Defining enforcement and consequences of non-compliance with the Erosion Control Plan.** Define penalties and incentives.
- **Defining responsibility for management of the erosion control provisions.**
- **Staging and sequencing information.**
- **Describing the over-winter and maintenance measures of the erosion control provisions.**

Erosion Control Plan Sheet Checklist

An Erosion Control Plan Sheet Checklist is included in this section.

Sample Erosion Control Plans

Erosion control for a project can be incorporated into the project plan in several ways. The Appendix contains four sample Erosion Control Plans, as described below:

Plan 1: This plan illustrates how one Minnesota county includes the erosion control requirements into their own plan views for the project. Plan sheets are developed specifically for erosion control.

Plan 2: This plan illustrates erosion control shown in plan views for the project outlined in Case Study 2.

Plan 3: This plan illustrates how another county incorporates erosion control requirements in tabular form. Tables summarizing placement of various erosion control techniques and products, along with standard details are provided that correlate to project plan view drawings.

Plan 4: This plan illustrates erosion control for the project outlined in Case Study 1. This erosion control plan was also implemented through the use of details and tables.

Erosion Control Plan Sheet Checklist

Not all the following items are necessary for each plan, but relevance should be considered. Sensitive areas should have added protection measures.

It is suggested that the Temporary erosion and sediment control devices be placed on the Drainage Sheets, where the flow arrows, ditches and culverts already exist. Permanent erosion and sediment control can remain on their own plan sheets such as the Turf Establishment sheets.

Temporary Erosion Control

- ❑ Construction phasing. Has a narrative been developed to indicate:
- ❑ When ponds should be built
- ❑ When critical storm sewer lines are to be placed
- ❑ Areas to be staged to limit duration of exposed soil areas
- ❑ Phasing/timing of installation of devices and maintenance (2573.3)
  - Incorporate Rapid Stabilization (S.P. 2573) in critical areas.

- ❑ Temporary Mulch Quantity (Type 1 or Type 4, general estimate is 20% of seeded area)
  - Consider extras areas such as temporary bypasses, stockpiles
- ❑ Temporary Blanket Quantity (Last 100 feet of majority of ditch bottoms entering a water of the state)
- ❑ Hydraulic Soil Stabilizer (For steep slopes or difficult areas)
- ❑ Outlet Protection, especially if outlets to an environmentally sensitive area
- ❑ Temporary Seed (general estimate is 20% of seeded area)
  - Consider temporary bypasses, stockpiles, slopes sitting idle for consolidation
- ❑ Staged buffer zones next to waters for as long as possible
- ❑ Temporary down drains (steep or long slopes with concentrated water)
- ❑ Diversion berm (sandbags, earth berm)
- ❑ Locations or areas not to disturb and show detail for method of protection

Temporary Sediment Control

- ❑ Downgradient perimeter sediment control
  - Silt fence, biologs/haybales stomped into wetland edges
- ❑ Construction phasing. Narrative sheet to include:
  - Timing of installation of devices
  - Maintenance of devices (Spec. 2573.3)
    - Silt Fence Maintenance: Use pay item for backhoe hours, assume 1 hour per 300 LF and one cleanout.
- ❑ Sandbags
- ❑ Temporary ponds
- ❑ Ditch checks
- ❑ Stabilized vehicle entrance (usually not practical for linear projects)
- ❑ Inlet protection
- ❑ Flotation silt curtain
- ❑ Sediment mat
- ❑ An acceptable location of where to wash concrete trucks or store oils/gasses

Permanent Erosion Control

- ❑ Topsoil
- ❑ Seed or sod
- ❑ Fertilizer
- ❑ Mulch
- ❑ Blanket
- ❑ Compost
- ❑ Erosion stabilization mat
- ❑ Adequate stabilization at pipe outlets

Permanent Sediment Control

- ❑ Wet sedimentation basin
- ❑ Stormcepter, vortex system, or other alternative when wet pond will not fit or if next to a critical area

Storm Water Treatment

- ❑ Grass swales
- ❑ Wetlands constructed for treating storm water
- ❑ Planting of emergent vegetation around the perimeter of the wet pond

Additional NPDES Requirements

- ❑ Designated location for stockpiles
- ❑ Designated location and method for dewatering effluent, e.g. filter bag, pond
- ❑ Location and type of all temporary or permanent BMPs
- ❑ Existing and final grades
- ❑ Dividing lines and direction of flow for all storm water runoff drainage areas coming into or leaving the project
- ❑ Location and name/type of all waters of the state in and within ½ mile of the project that receives direct storm water runoff during and after construction
- ❑ Total land features in acres for pre and post construction
  - ❑ Project Area
  - ❑ Impervious surface area
  - ❑ Pervious surface area
  - ❑ Estimated impervious surface area of ultimate development
  - ❑ Estimated pervious surface area of ultimate development
- ❑ Note that a Phase II permit requires the implementation of extraordinary BMP's and identification of Outstanding Value Resources.

Miscellaneous

- ❑ Legend on every sheet
- ❑ Appropriate Standard Plan sheets
- ❑ Right-of-way, easements, and construction limits
- ❑ Topographic features (e.g. Ravines, steep slopes, tree lines, drainage ways)

Note: The Standard Specifications for Construction book, Special Provisions and any other document tied to the plan are considered part of the final plans and specifications for the project.

4.0 Treatment Selection

Temporary Erosion Control

Temporary erosion control methods are needed during construction while soil is bare, drainage channels and ditches are dug and left open, fills are placed and cuts are made. Inevitably, rain and winds occur during the time when vulnerable areas are unprotected, causing accelerated erosion.

Erosion control during construction depends on the timely installation of the erosion protection provisions shown in the plans over the duration of the project. Placing sod, mulch, and seed promptly as the project progresses reduces both the area of unprotected soil and the length of time it is exposed.

Temporary measures must also be provided for use during construction. Projects where temporary erosion protection must be provided due to the high potential for erosion impacts during construction, include those:

1. in steep rolling topography;
2. where most of the drainage from the highway construction limits enters directly into wetlands, streams, lakes, ponds, water courses and adjacent land; and
3. with erosive subsoils such as loamy sands, silt loams, an silty clay loams.

Temporary erosion control devices are described later in the handbook. Factors affecting the selection of these treatments include:

- purpose
- grade or slope
- amount of flow
- need to control erosion or sediment?
- length of time treatment must be effective
- maintenance requirements
- ease of construction
- cost

Types of Erosion and Sediment Control Treatments

Erosion and sediment control during construction describes those methods used during construction to prevent erosion from occurring, and for containing any sediment that does result. Of all the phases of highway development and maintenance, construction produces the most erosion and sediment problems. In addition to the erosion damage that occurs on the project, off-site damage frequently occurs in the form of siltation in streams, lakes, reservoirs, and adjacent lands.

All of the temporary erosion and sediment control measures and permanent erosion control measures included in this handbook are listed in Table 4-1

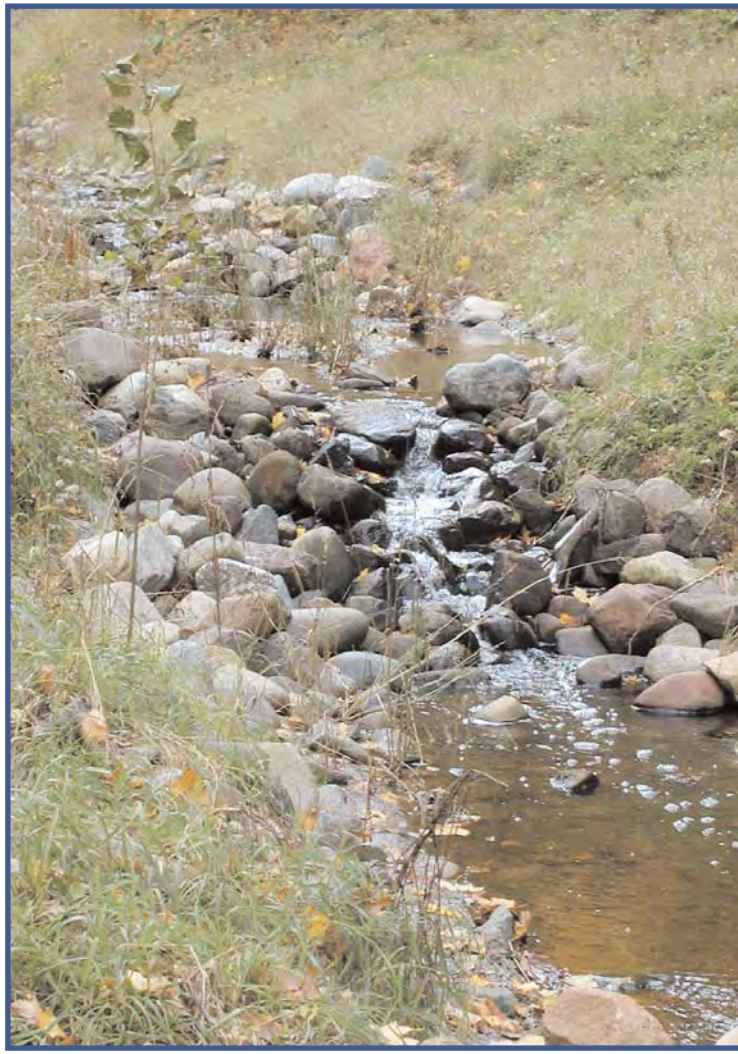
The table lists each technique along with criteria for selecting each one. Average treatment life and costs vary depending on the project location and conditions. Each agency could prepare a similar table to assist in selecting a specific treatment. The table can be prepared using expertise within an agency and supplemented with information from suppliers, contractors, consultants, and association representatives. Once prepared, a treatment method can be identified given specific area conditions.

Design, installation, and maintenance of each of the treatment measures are outlined in chapters 5, 6, and 7 of this handbook.

Controlling erosion and sedimentation during construction will prevent muddy roads, like the one shown here.

Table 4-1. Erosion Control Technique Selection

Technique	Ditches			Slopes		Drop-Inlet Protection
	Grade ≤6%	Grade > 6%	High flows expected	Erosion control	Sediment Protection	
Erosion Control During Construction						
Earth diversions and swales	X			X		
Erosion control blanket	X	X	X	X		
Erosion control stabilization mats	X	X	X	X		
Mulching and turf establishment	X	X	X	X		
Rock ditch checks		X	X	X		
Temporary ditch checks	X	X		X		
Temporary slope stabilization	X			X		
Triangular silt dikes	X			X		
Sediment Control During Construction						
Biorolls	X				X	X
Erosion control soil berms	X	X				
Inlet protection			X			X
Perimeter control			X			
Sediment basins			X			
Sediment traps			X			
Silt curtain					X	
Silt fence	X					X
Standpipes						
Treatment basins			X			
Permanent Erosion Control						
Design elements	X	X	X	X		
Detention pond			X			
Ditches	X	X	X	X		
Riprap			X			
Runoff spreaders	X	X				
Soil bioengineering and streambank or shoreline protection	X	X	X			
Turf establishment	X	X	X	X	X	X



Proper treatment selection and thoughtful design yields attractive and environmentally friendly results.

5.0 Erosion Control During Construction

Construction produces the most erosion and sediment problems. Best practices for reducing or controlling erosion during construction include:

1. **Minimize the area exposed at one time, and the exposure duration.** Develop a staging plan that specifies temporary seeding as areas of construction are completed.
2. **Minimize the disturbed area.** Clear only within the construction limits or as required for safety or clear zones.
3. **Use erosion control practices throughout construction,** such as keeping the soil covered, roughening the slope on the contour, or tracking the area with a cleated dozer.
4. **Place gravel base immediately after the subcut is completed.**
5. **Strip existing topsoil, and store for use later. Seed stockpiles.**
6. **Temporary mulching and seeding** are very effective at controlling erosion. Repeat several times as needed throughout the project.
7. **Erosion control is generally more cost-effective than sediment control and requires less maintenance and repair.**
8. **Stabilize small critical areas adjacent to wetlands and culvert outlets.**

Table 5-1. Temporary Erosion Control Measures

Practice	Material	Equipment Needed	Effective Duration
Temporary slope mulching	Mulch Type 1, 3	Mulch blower	1+ rain event of up to one month
Temporary slope mulching	Spray-on newspaper/ wood mulch[1]	Hydro seeder	1+ rain event of up to one month
Temporary slope seeding[2], fertilizing & mulching	Seed	Any mechanical seeder, mulch blower	One field season
Grading slopes (shaping and rounding)	Topsoil	Shaping dozer	Should be done prior to temporary seeding
Ditch stabilization within 200 feet of stream	Erosion control blanket	Rake, shovel, staples	Project duration
Pipe inlet protection	Erosion control blanket	Rake, shovel, staples	Project duration
Runoff velocity control	Very high flow geotextile	Soil sliced silt fence machine	Project duration

Notes:

1. Use of recycled products, such as newspaper or compost mulch may be effective.Material placed should be non-toxic to animal and plant life.

2. Note optimal seeding dates in the Mn/DOT Standard Specifications, Section 2575.

Table 5-2. Erosion Control Devices

Device	Application Areas
Earth diversions and swales	Use at construction perimeter, toe of slopes, around stockpiles, near wetlands to protect adjacent areas.
Erosion control blanket	Slopes steeper than 1:3 and in v-shaped erosion ditch bottoms.
Stabilization mats	Use on longer term projects.
Mulching and turf establishment	To hold bare soil in idle areas. Areas withexposed soil 200 linear feet from a water source.
Ditch checks	For use at the crest of back or fill slopes or to divert runoff from a work area.
Sandbag barrier	To protect excavations, for culvert replacements, to dike channel changes and to serve as sumps during de-watering.
Shaping and grading	Slopes and ditches as construction progresses
Silt fence	As a temporary barrier to filter sediment from sheet flow. Not intended for use in ditches and swales where flows are greater than 1 cfs.
Soil berms	Where land adjacent to a planned cut section drains toward a highway, and the area will yield sufficient runoff to cause erosion.
Temporary slope stabilization and pipe downdrain	To convey drainage down cut or fill slopes.
Triangular silt dikes	Place in ditches with slopes of 6% and less. Use only during construction.

Earth Diversions and Swales

Description

Earth diversions may be used to divert runoff away from a work area and/or to protect slopes. They can be used on drainage areas up to 5 acres and where the grade of the diversion will be less than five percent.

Earth diversions may in themselves erode and become erosion problems, and should only be used when necessary. In areas with grades greater than five percent, slope rounding and other temporary measures are preferred. Erosion on the slope may occur until vegetation is established.

Broad shallow channels containing a dense stand of vegetation can be designed to promote infiltration and trap pollutants. The combination of low velocities and vegetative cover allows pollutants to settle out or be treated by infiltration. They can also reduce the runoff and peak discharges for a rain event.

Design

- Place as shown in Mn/DOT Standard Plan Sheet 5-297.405.
- Cross sections may be parabolic, v-shaped or trapezoidal. Design the side slope to be less than the stable slope of the soil being used. In areas that will be mowed, specify slopes less than 3:1.
- Swales should be designed to flow at a maximum velocity of 2 ft/sec.
- The grade of the channel should be as flat as possible, and less than 2 percent.
- Typical diversion cross sections are shown in Figure 5-1.

Installation

- Locate at the top of a slope.
- Use across a slope to break up its length or to redirect water flow.
- Locate diversion ditches and berms where they will empty into stable disposal areas to collect sediments.
- Use a combination of a ditch and a berm or mound of earth or stone in areas where runoff is hard to control or when constructed on a slope.
- Design and line diversion ditches the same as other ditches.

Maintenance

- Regularly inspect vegetation, especially during establishment, and repair as needed.
- Remove excessive amounts of deposited sediment which reduces capacity or damages vegetation.
- Mow grass occasionally, but not too short, which reduces the filtering effect of the swale.

A swale with field stone was used to direct water and reduce erosion from this site.

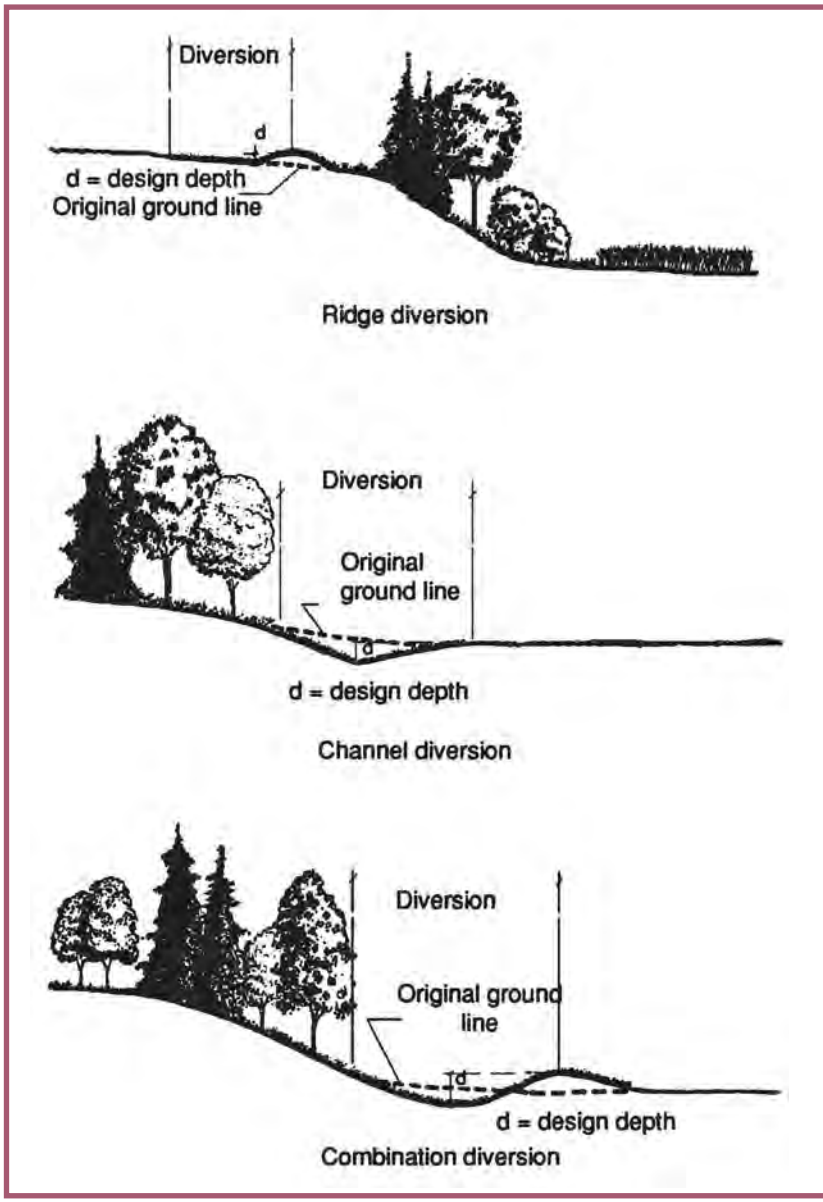


Figure 5-1. Typical Earth Diversion Cross Sections
Source: Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota, MPCA, 2000

Erosion Control Blanket and Stabilization Mats

Description

Blankets and stabilization mats may be used to stabilize and protect the soil from rainfall impact, to increase infiltration, decrease soil compaction and crusting, and conserve soil moisture. They are effective at critical areas and/or on steep slopes. Blanket is especially effective in controlling sheet erosion and in aiding seed germination. An appropriate seed mixture is important for use in conjunction with the blanket.

Design

- See Mn/DOT Standard Specification section 3885 for material specifications.
- Use erosion control blankets on steep slopes and streambanks, where vegetation is slow to establish, and in channels where flow velocities are likely to wash out new vegetation.
- Blankets may be used:
  - on slopes steeper than 1:3 that are longer than 25 feet (as measured along the slope),
  - where runoff from adjacent areas flows over or across the slope, or
  - on slopes 1:3 or flatter depending on the critical nature of the area, the soil conditions and the quantity of runoff flowing over the slope.
- To ensure that runoff flows over the erosion control blanket and not under it, the upper end of the blanket should be buried in a 6 inch deep trench and all strip ends overlapped a minimum of 10 inch. In addition, overlap the edges of adjacent strips minimum of 3 inches.
- Further protection at the upper end of the blanket may be required. In those cases, use a sodded runoff spreader at the upper end and overlap the top of the erosion control blanket.
- Place erosion stabilization mats within 24 hours after seeding is completed.

Blanket use is outlined in Table 5-3. Erosion stabilization mat use is outlined in Table 5-4.

Table 5-3. Erosion Control Blanket Use

Category	Service Application	Use	Notes
1	Very Temporary	Flat areas, edge drains, shoulder drain outlets, roadway shoulders, lawns, and mowed areas.	Netting one side Blanket is rapidly degradable
2	One Season	Slopes 1:3 to 1:2, and less than 50 feet long Ditch slopes less than 2% Flow velocities less than 5.0 ft/sec.	Netting one side of blanket
3	One Season	Typically used for temporary stabilization Slopes 1:3 to 1:2 and less than 50 feet long Ditches slopes less than 3% Flow velocities less than 6.5 ft/sec.	Netting on both sides of blanket
4	Semi-permanent	Slopes 1:2 and steeper Ditch slopes less than 4% Flow velocities less than 7.0 ft/sec.	Composite blanket w/netting on both sides
5	Semi-permanent	Ditch slopes less than 8% Flow velocities less than 9 ft/sec. Depth less than 8 inches Use on ditch banks within the normal flow elevation.	Netting on both sides of blanket

Table 5-4. Erosion Stabilization Mat Use

Mat Class	Application	Minimum Sustained Permissible Shear Stress on base soil channel (lbs/sf) (A)	General Description	Maximum peak runoff velocity (ft/sec) (C)
1	Not soil filled	2.0	Composite of grids and wood fiber	<10
2	Filled or not filled	3.5	Composite of grids and coconut	<14
3	Filled or not filled	5.0	Synthetic	<18
4	Soil filled	6.0	Synthetic	<20

(A) Sustained shear for minimum ½ hour.
(B) Soil containment cells are required for Class 2, 3, and 4.
(C) For ten minutes.

Installation

For erosion control blanket

- Seed area first, and place blankets within 24 hours of seeding.
- Anchor blanket at the top of the slope in a 6 inch vertical slot, backfill and compact.
- Unroll in the direction of the water flow; overlap ends 7 inches, edges 4 inches; staple every 3 feet.
- Use longer anchors for loose soils.
- When blankets are placed shingle style, overlap 7 inches and staple every 3 feet.
- Lay blankets loosely and maintain direct contact with the soil. Do not stretch the blanket.

For erosion stabilization mat:

- After broadcasting half of the seed and fertilizer, spread fine topsoil to fill the mat using lightweight equipment and avoiding sharp turns. Then, broadcast the remaining seed and fertilizer over the topsoil.
- Cover the seeded topsoil with a category 2 or 3 blanket.
- Don't drive tracked or heavy equipment over the mat.
- Avoid any traffic over the mat if the soil is wet or loose.

Erosion control blanket was successfully used on the upper slopes to reduce erosion into the pond.

Mulching and Turf Establishment for General Areas

Description

Six major items are significant in the establishment of good vegetative cover. They include applying a good topsoil base, controlling water flow, preparation of slope and topsoil, seeding and fertilizing, using mulch and erosion control products, and mowing.

Mulching provides a cover over the seed and bare soil. It keeps soil cool and moist, allowing for better germination and plant establishment, and provides for temporary erosion control while the vegetation is establishing. Hydraulic soil stabilizers can be used with the mulch, and are generally used in areas with limited access and steep slopes. They may be sprayed over the top of other mulches, and are not used on ditches.

Design

- Turf establishment is outlined in Mn/DOT Standard Specification 2575.
- Refer to the Mn/DOT Seeding Manual for guidance on seed mixtures.
- Hydraulic soil stabilizers are included in Mn/DOT Standard Specification section 3884, and application rates are outlined in Standard Specification section 2575.3I.

Table 5-5 describes the types of hydraulic soil stabilizers and their uses.

Mulch along road shoulders to stabilize the soil.

Installation

- Mulch within 24 hours after seeding, and on all seeded areas, with the exception of level swamp disposal areas. Materials include hay and straw, and should be free of noxious weeds.
- After mulch is applied, drive over the area with a disc to anchor the mulch to the ground, or cover with liquid tack next to shoulders. Use wood chips as mulch around trees.
- Table 5-6 defines the mulch types and application areas. Also see Mn/DOT Standard Specification section 3882 for additional guidance.

Table 5-5. Hydraulic Soil Stabilizers

Type	Material	Application
1	Guar	Over straw and on seed, areas with slopes < 1:3 Install as per manufacturer's recommendations
5	Wood fiber	Temporary applications in non-flow areas Permanent application in flat areas Install at 2500 lbs/acre by itself Use at a rate of 750 lbs/acre with Type 4 mulch
6	Paper/Wood blend	Temporary applications in non-flow areas Permanent application in flat areas Install at 2500 lbs/acre
8	Bonded fiber matrix	Use to control erosion in inaccessible areas except those showing gully erosion. Application rate dependent on slope and runoff velocity. Install at 3400 lbs/acre

Maintenance

- Mulch until the vegetation is established.
- Check mulched areas for adequate cover after high winds or rainfall; apply new mulch if necessary.
- Inspect newly seeded areas frequently to identify areas that need to be reseeded, or spot seed if needed.
- If plastic netting has been used to anchor mulch, use caution during initial mowings to keep mower height high. Until the netting degrades, it can wrap up on the mower blade shafts.

Erosion can cause costly repairs, to the roadside and pavement structure.

Table 5-6. Mulch Types and Applications

Type	Description	Application
1	Grain straw, hay, cuttings of agricultural grasses and legumes. When used with native grasses (mixes 5B-38B), it shall consist of grain straw only.	Most commonly used type for erosion control. Use on slopes 1:3 and flatter. Disc anchoring is used most often. Place with blower equipment at a rate of 2 tons per acre.
3	Clean grain straw that is certified by the Minnesota Crop Improvement Association (MCIA) to be weed free.	Use to minimize weeds in areas with limited access, or in areas adjacent to sensitive areas (such as wetlands or farmlands.) Use with native seed mixtures. Place with blower equipment at a rate of 2 tons per acre.
4	A combination of Type 1 mulch and Type 5 hydraulic soil stabilizer.	Use on slopes steeper than 1:3 where erosion control blanket would be too costly. Do not use in drainageways. Apply in a dual operation with the Type 1 mulch blown on the soil surface at a rate of 1-1/2 tons per acre, and immediately over-sprayed with Type 5 hydraulic soil stabilizer at a rate of 750 lbs/acre. Disk anchoring is not required.
6	Raw wood material from either hard or soft timber, and is a product of a mechanical chipper, hammermill, or tub grinder.	Used around landscape plantings or on steep slopes. Could be used as slash mulch in large areas of clearing and grubbing.
7 Prairie mulch	Prairie mulch that has thrashed to remove seeds so that it consists of clippings, chaff, or residue from harvesting or cleaning operations.	Use in areas to enhance an existing prairie, in wetland or prairie mitigation areas, or in areas with high value. Place with blower equipment at a rate of 2 tons/acre.
8 Prairie hay	Prairie mulch that has not been thrashed to remove seeds so that it consists of material that has been bailed directly. May be harvested from native stands or from native grass production fields.	Use in areas to enhance an existing prairie, or to create a new one. Not to be relied on solely for seed. Place with blower equipment at a rate of 2 tons/acre.
9	Aggregate mulch 3/8 to 2 inch in size.	Use for landscaping and for goore areas encircled by plate beam guardrails.

Stabilizing Small Critical Areas

Description

The purpose of stabilizing small critical areas is to prevent off-site sedimentation and/or comply with permit requirements. The work may be performed at any time during the contract and can be conducted on small areas that may not be accessible with normal equipment.

Mn/DOT Technical Memorandum No. 02-14-ENV-03 outlines the guidelines and implementation for these areas, called "Rapid Stabilization". The methods described in the Tech Memo are to be adopted on all active Mn/DOT construction projects.

Design

Design methods are included in Mn/DOT Special Provision 2573 for Rapid Stabilization.

Five methods are described in the section: temporary mulching with disc anchoring, tempoary mulching with tack, temporary hydromulching, temporary erosion control blanket, and the use of rock. Any of the five methods may be used. The intent is to be highly mobile and flexible and to stabilize the small critical areas on a project site.

The methods should be used for areas within 100 feet of Waters of the State and to stabilize the critical areas within the timeframe designated in the NPDES permit.

Other critical areas include:

- Embankment slopes abutting wetlands and lakes.
- Bridge slopes draining towards rivers and streams.
- Disturbed areas around culvert inlets and outlets.
- Roadside ditches draining from construction sites.
- Disturbed slopes near storm drain inlets.
- Disturbed median ditches draining into storm drain inlets.
- Disturbed banks of rivers, lakes, and streams.

Materials to be used are as outlined in Table 5-7.

Table 5-7. Material Requirements for Rapid Stabilization

Method	Description	Materials	Method
1	Mulch and disc anchoring	Type 1 mulch at 2 ton/acre	Slopes
2	Mulch and tack with hydraulic soil stabilizer	Type 1 mulch at 1.5 ton/acre Type 5 hydraulic soil stabilizer at 750 lbs/ac	Slopes
3	Hydrospread seed, fertilizer, and hydraulic soil stabilizer	Type 6 hydraulic soil stabilizer at 350 lbs/1000 gal of slurry mix Seed mix 190 at 10 lbs/1000 gal slurry mix Fertilizer 10-10-10 at 50 lbs/1000 gal of slurry mix Water at 875 gal/1000 gal of slurry mix	Slopes
4	Hand install seed, fertilizer and erosion control blanket	Erosion control blanket category III Seed mixture 190 at 2 lbs/100 yd^2 Fertilizer 10-10-20 at 8 lbs/100 yd^2	Ditches
5	Place geotextile and riprap in various configurations	Riprap class II Geotextile type III	Ditch checks w/rock

Installation

Installation is as follows:

Method 1 - Loosen soil so that mulch can be anchored. Place the mulch using blower equipment, and place by hand in areas inaccessible to equipment. Anchor mulch immediately after placement with a disc anchoring tool.

Method 2 - Loosen soil so that mulch can be anchored. Place mulch to obtain approximately 75% ground coverage. Place the mulch using blower equipment, or place by hand in areas inaccessible to equipment. Immediately after placement, over-spray the mulch with Type 5 hydraulic soil stabilizer.

Method 3 - Hydrospread seed. The rate of slurry application is dependent on the surface roughness, but estimated at 6000 gallons per acre. Apply as much as needed to obtain 100% soil coverage.

Method 4 - Place fertilizer, seed and erosion control blanket according to Mn/DOT standard specification 2573.5. Bury the upgrade end of each blanket strip at least six inches in a vertical check slot. Place staples at seams and throughout the blanket at a maximum spacing of 2 feet in all directions.

Method 5 - Place rock and geotextile in the areas and to the configurations as needed.

Rock Ditch Checks

Description

Rock ditch checks intercept and pond sediment-laden runoff, which dissipates the energy of the incoming flow and allows a large portion of the suspended sediment to settle out. Water exits the ditch check by flowing over its crest.

Design

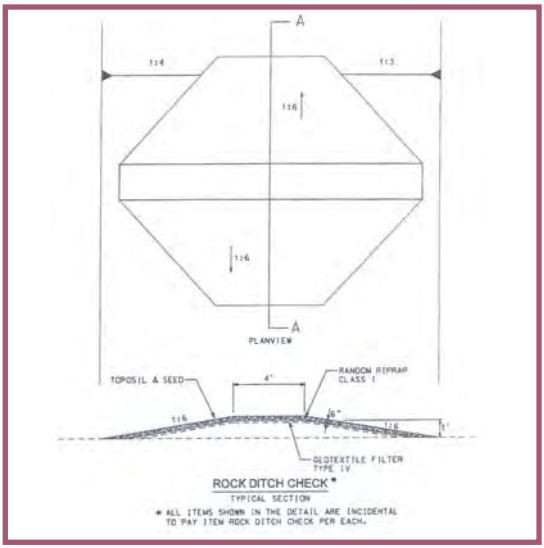
- Rock used is Class I to IV riprap placed over secured geotextile fabric liner, then placed across the ditch in a berm approximately 2 feet high.
- Place rock ditch checks perpendicular to the flow of the ditch.
- Design rock ditches so that water can flow over them, not around them. They should extend far enough so that the ground level at the ends of the check is higher than the low point on the crest of the check.
- Locate rock ditch checks in ditches that will eventually be lined with riprap, so that the rock won't have to be removed at the completion of construction.
- Rock ditch checks can be permanent, or the rock can be removed and reused within the project
- Use them in high flow areas, in ditch grades 3.5% and steeper, and in steep cuts
- Place rock ditch checks in pairs located about 25' apart. Exceeding this spacing may allow erosion to occur between the ditch checks.
- Installation is outlined in Mn/DOT Standard Plan 5-297.405.

The easiest way to remove sediment from behind a rock ditch check is with a bulldozer or backhoe.

Maintenance

Inspect rock ditch checks every seven days and within 24 hours of a rainfall of a half-inch or more. Check the following during each inspection:

1. **Does water flow around the ditch check?** This is usually caused by insufficient ditch check length.
2. **Have high-velocity flows displaced any stones away from the check?** If a large portion of the ditch check has washed away, fill in the void with new stone.
3. **Does the sediment need to be removed from behind the ditch check?** Sediment must be removed when it reaches one-half of the original exposed height of the rock ditch check. Allowing too much sediment to accumulate behind a ditch check drastically reduces its effectiveness. One high-intensity rainfall can dislodge enough sediment from surrounding slopes to completely fill the space behind the ditch check. This is why it is important to inspect ditch checks within 24 hours of a large rainfall.



Typical rock ditch check section.

Temporary Ditch Checks

Description

Temporary ditch checks may be used to trap silt and/or reduce runoff velocities in ditches and drainageways.

Design

- The five types of ditch checks that are outlined in Mn/DOT Standard Specification 3889 are listed in Table 5-8. Design of these products is based on the expected and desired runoff flow.
- Placement and installation is outlined in Table 5-8.
- Installation is outlined in Mn/DOT Standard Plan 5-297.405.

Silt fence as temporary ditch check.

Table 5-8. Temporary Ditch Check Selection

Type	Name	Description	Use
1	Sliced in silt fence	Geotextile fabric with higher number of openings secured to posts, and sliced into the ground. Fabric opening size dependent on flow requirements.	Max ditch grade of 5%. Max drainage area 1 acre. Lasts up to two years, but must be removed before seeding. Use also for perimeter control and in wetland areas.
2	Bioroll	Straw or wood excelsior enclosed in polyester or plastic netting; 6" in diameter.	During rough grading operations.
3	Bioroll blanket	Consists of straw or wood excelsior enclosed in polyester or plastic netting; 6" in diameter. The bioroll is placed on top of a category 3, spec. 3885 erosion control blanket.	1 roll/1% grade/50 feet, evenly spaced. Can be permanent. Use in ditch over bare soil. Can remove & replace as work requires; use one season. Use as energy dissipater on inlets.
6	Geotextile triangular dike	Triangular urethane foam, enclosed in a woven geotextile fabric.	One dike/1% grade/100 feet, evenly spaced over bare soil. Use one season. Use only during construction. Can remove & replace as work requires; must remove before seeding.
7	Rock check	Class I to IV riprap placed over secured geotextile fabric liner, placed across the ditch in a berm approximately 2 feet high. Aggregate size dependent on expected flow quantity and duration.	Can be permanent. Use in high flow areas, ditch grades 3.5% and steeper, and in steep cuts. Use in pairs located about 25' apart. Can remove rock later and reuse within the project.

Soil Berms

Description

Water flowing over disturbed earth will erode the soil and deposit the eroded soil as sediment in lower areas or pollute waters with its sediment-laden runoff. Avoid this if at all possible. One practical method is using slope protection dikes constructed at the top of the slope (see Figure 5-2.)

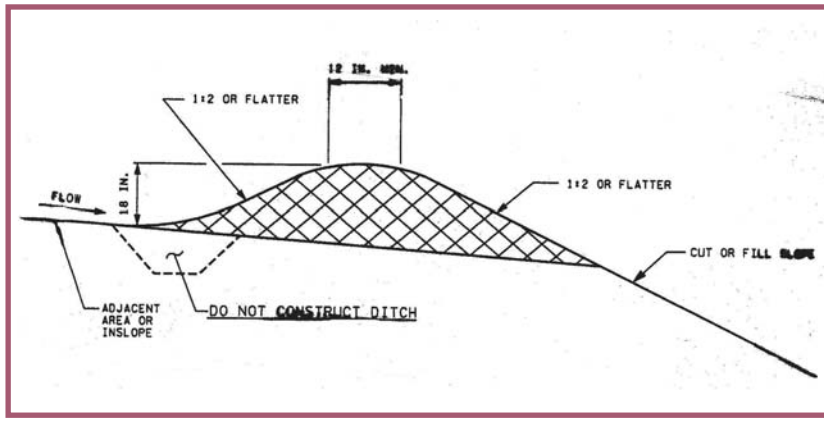


Figure 5-2. Slope Protection Berm Dikes.
See Mn/DOT Road Design Manual Chapter 8.

Design

Provide soil berm dikes wherever land adjacent to a planned cut section drains toward the highway, and the area involved will yield sufficient runoff to cause rill or gully erosion before permanent turf can be established. Except in urban areas or in front of residences or similar structures, it may be advisable to leave the dike as a permanent feature rather than to incur the expense of removing it and the risk of disturbing the earth. Leaving the dike as a permanent installation will lengthen the time available for the establishment or permanent turf or seeded areas of the project.

- Provide payment for construction, and removal if required, of the berms and outlets in construction plans and proposals. Measure and pay for dikes by the lineal foot. Measure and pay for outlets by like items in accordance with the specifications.
- Construct berms by placement of erosion resistant embankment material, not by cut and fill or by plowing of a furrow.
- If slight rises in the natural ground occur over relatively short distances, shallow cuts may be made, but must be sodded to prevent erosion.
- Where swales occur such that flooding beyond the right of way is expected, provide flumes to carry the water down the slope.

Installation

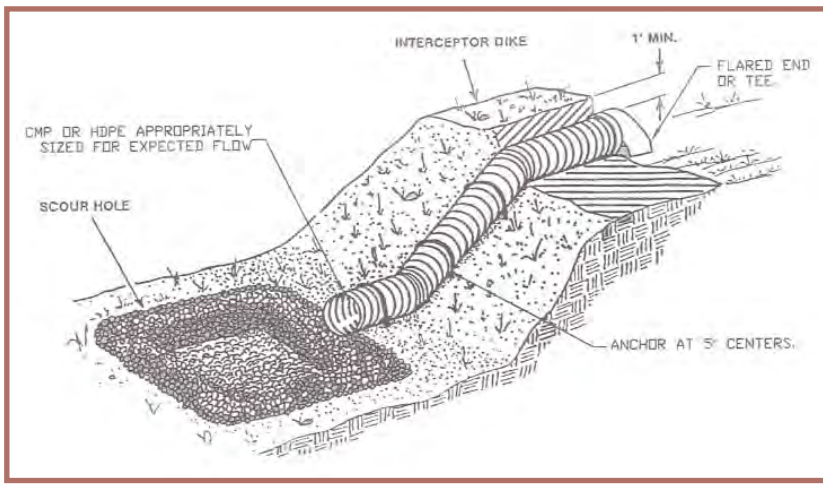
- Berms should be approximately 1.5 feet high, 2 feet wide on top, with 1:2 or flatter side slopes.
- Compact by the ordinary compaction method.
- Terminate berms where the soil is protected from erosion by natural cover such as grasses waterways or dense woods.
- Where protected outlets do no exist or where auxiliary outlets are needed to prevent large concentrations of water, construct protected outlets utilizing sod, level spreaders, metal pipe flumes or plastic pipes.
- To reduce water velocity at pipe outlets, place the last section of the pipe as flat as possible. If relatively flat pipes are impractical, use riprap (See Mn/DOT Standard Plate 3134) or surge basins.
- Install surge basins at the bottom of the slope.

Temporary Slope Stabilization and Pipe Downdrains

Description

Temporary down drains consisting of enclosed metal pipe, plastic pipe, hose or flexible rubber pipe may be used to carry concentrated runoff and thus reduce erosion. Use temporary drains on fill slopes, in cut-to-fill transition swales, on cut slopes, in drainageways and at other locations where a temporary structure may be required to carry water prior to the installation of permanent facilities, or while vegetation is establishing.

The NPDES permit and Mn/DOT specification 1803.5B2 requires that exposed slopes left idle be protected. Use a temporary cover of Type 1 mulch on a slope prior to final shaping to reduce the erosion potential. If the slope is to grade or will be left over six months, apply a Type 1 mulch and a temporary seed mixture. Erosion control blankets can also be used for temporary slope stabilization, installed immediately after seeding operations.



A Temporary pipe downdrain can be used to carry concentrated runoff to reduce erosion.

Design and Installation

- See the Mn/DOT Drainage Manual for guidelines on pipe sizing.
- Refer to Mn/DOT Standard Plate No. 3134 for direction on rip rap placement at CMP pipe outlet.
- Use blanket on slopes steeper than 1:3, and in highly erodible areas, such as on bridge slopes.
- Mulching with straw or hydraulic soil stabilizers can prevent erosion. Mulching protects the soil from the rainfall impact and overland flow, and also promotes the growth of vegetation by protecting the seed and fostering germination.
- Mulch slopes as grading operations proceed. If timing of the grading operations doesn't allow vegetation establishment due to weather or season, apply mulch to stabilize slopes until seasonal conditions improve and the timing is right for permanent stabilization.
- When temporary drains are to be placed on fill slopes, construct a temporary earth berm along the 1:6 to 1:3 breakpoint with additional berms constructed as necessary to guide water into the drain. Where possible, place the drain at a low point, with the spacing between drains no more than 500 feet along the fill slope.
- For drains spaced at 500 feet intervals along a fill, use an 8-inch diameter or larger smooth conduit or corrugated metal pipe.

- Construct the inlet end of a drain and berm system to channel water into the temporary drain.
- Provide metal inlet aprons.
- Provide a means for energy dissipation at the outlet ends of all temporary drains to control erosion at the outlet. Dissipaters could be dumped rock riprap and/or a tee installed attached to a cross pipe or other devices which would slow the water.
- Anchor all temporary drains to the slope to prevent disruption by the force of the water flowing in these drains. If the drain consists of flexible pipe such as plastic pipe or rubber hose, it must be securely anchored to the ground. Figure 5-3 shows a temporary drain placed on a fill slope.

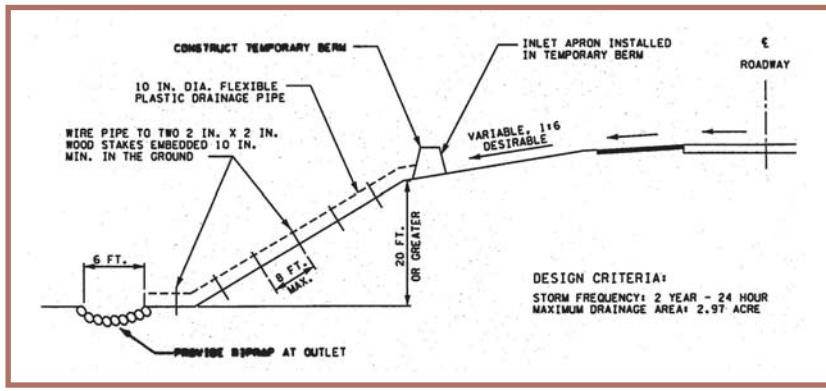


Figure 5-3. Temporary Drain on a Fill Slope.
See Mn/DOT Road Design Manual Chapter 8.

Triangular Silt Dikes

Description

Triangular silt dikes intercept and pond sediment-laden runoff, slow the incoming flow velocity, and allow most of the suspended sediment to settle out. Water exits the dike by flowing over the top. They are made of triangular urethane foam, enclosed in a woven geotextile fabric.

Design

- Place triangular silt dikes perpendicular to the ditch flowline.
- The dike should extend far enough so that the bottoms of the end dikes are higher than the top of the lowest center dike, which prevents water from flowing around the dike.
- Dikes should not be placed in ditches where high flows are expected. Use rock checks in those areas.
- Use in ditches with a slope of 6% or less.
- Place one dike every for every 1% grade at evenly spaced intervals of 100 feet.
- Use only during construction.
- Triangular silt dikes are reusable.

Installation

- Can be removed and replaced as work requires.
- Use over bare soil or erosion control blanket.
- Do not place triangular silt dikes in front of a culvert outlet. They will not withstand the concentrated flow.
- The upstream apron of the triangular silt dike must be dug into the soil and anchored, or water will flow under the check base.
- Follow prescribed spacing guidelines. Exceeding the spacing guidelines will cause erosion between the ditch checks.
- Do not allow water to flow around the dike. Make sure that the dike extends far enough so that the bottoms of the end dikes are higher than the top of the lowest center dike.

Maintenance

Inspect triangular silt dikes every seven days and within 24 hours of a rainfall of one-half inch or more.

Check the following during each inspection:

1. **Does water flow around the silt dike?** This is usually caused by insufficient dike length.
2. **Does water flow under the triangular silt dike?** This is usually caused by not properly anchoring the dike. Make sure that the upstream apron is trenched in and that an adequate number of staples have been used.
3. **Does water flow through spaces between abutting dikes?** This is caused by poor connections between adjoining dikes. Connect dikes at their ends with the connecting sleeves. If spaces exist between adjoining dikes, reconnect them properly.
4. **Does sediment need to be removed from behind the dikes?** Remove accumulated sediment when it reaches one-half of the dike height. When removing sediment from behind a triangular silt dike with a bulldozer or backhoe, make sure not to hook the upstream apron with the blade. This will damage the dike and require it to be replaced.

A triangular silt dike slows water and allows sediments to settle. ***Source: ACF Environmental***

6.0 Sediment Control During Construction

Off-site damage frequently occurs from sediment flowing into streams, lakes, reservoirs, and adjacent lands. Best practices for reduction or control of sediment during construction include:

1. Use perimeter control practices, such as berm dikes, filters, and sediment basins.
2. Manage stormwater to reduce velocities and runoff volume.
3. Detain sediment laden runoff long enough to let soil particles settle out.

Mn/DOT standard specifications allow the Engineer to direct the contractor to remove sediment trapped in retention devices or deposited in retention ponds at any time. This consists of excavating and other operations to remove sediment and restore the capacity of the temporary erosion control device. Standard Specification item 2573.520, Sediment Removal, Backhoe can be included in the Plans and paid for by the hour. About 1 hour/300 lineal feet of silt fence on a project is an acceptable estimate.

Temporary sediment control methods described in this chapter are summarized in Table 6-1.

Sediment control during construction will prevent off-site damage.

Table 6-1. Temporary Sediment Control Devices

Name	Application Areas
Biorolls or hay bales	Use in wetlands or cattail areas with limited access. Do not remove at construction completion.
Drainage Swales	To trap sediment in ditch bottoms.
Inlet protection	Place around drop inlets throughout construction.
Perimeter control	Includes fence, silt fence, bales or biologs used to intercept sheet flow toward off-site adjacent property.
Sediment basin	To retain runoff so that sediment is trapped and can be removed later. Use for disturbed drainage areas of 5-100 acres for up to 18 months.
Sediment trap	To trap sediment in ditch bottoms and/or for areas where runoff leaves the right-of-way. May need a flocculant in soils with high clay content.
Silt curtain	Use during construction in open standing water and to protect water bodies from sediment.
• Moving water	Use in streams and rivers with flow less than 5 ft/second and a depth of 3-12 feet.
• Work area	Use in areas of moving or still water to confine a work area, and also for containing overflows from a weir, settling pond, or standpipe. Use to block off work areas, and as a last line of defense.
• Still water	Use on lakes or water bodies with no current.
Silt fence*	Use at construction perimeter, toe of slopes, around stockpiles, near wetlands to protect adjacent areas.
Standpipes	Use at culvert inlets and at catch basins to trap sediment and keep the culvert from plugging.
Treatment Basins	Act as sediment and nutrient traps and can provide stormwater quality treatment and rate control.

**Use in combination with other erosion control devices. Not to be used for snow or perimeter control.*

A temporary sediment basin can trap sediment prior to storm water discharge.

Biorolls

Description

The bioroll consists of straw or wood excelsior enclosed in polyester or plastic netting, 6" in diameter.

Design

- Place bioroll on top of a Category 3, Spec. 3885 erosion control blanket.
- Use in wetlands or cattail areas with limited access.
- Use in ditches and over bare soil.
- Biorolls can be removed and replaced as work requires, or left in place permanently. They typically last one season.
- Used as energy dissipater on inlets.

Installation

- Place one roll for every 1% of grade, evenly spaced at an interval of 50 feet.

Maintenance

- Leave in place, and do not remove at construction completion.

Bioroll application on TH 200 near Bemidji.

Drainage Swales

Description

A drainage swale is a ditch that is designed to trap sediment. They can be used to intercept surface runoff and direct it to a desirable collection or discharge point.

Design and Installation

Variations in channel alignment should be gradual, particularly if the channel carries high velocity flows. Sharp bends and sudden changes to steeper gradients should be avoided as these conditions increase the scour potential of the channel.

Channel cross-sections are generally determined for a particular location by considering the terrain and flow quantity to be conveyed. Channels located adjacent to roadways should conform to recommended shapes which will minimize the shock of impact by errant vehicles and provide a traversable section. The natural processes of erosion and siltation will usually shape an unlined trapezoidal channel to an approximate parabolic shape. V-shaped channels are susceptible to erosion and may not meet roadside safety requirements.

The swales ability to filter sediment can be greatly enhanced by creating a trench in the ditch bottom, lining it with a non-woven geotextile fabric and backfilling with filter media. The filter media can consist of any number of items including rock, wood chips and brush cuttings. If woodchips, brush cuttings and similar material is used, it is recommended to place a non-woven geotextile fabric and minimum six inch layer of rock rip rap over the media to keep it from washing out under high flow conditions.

These filters are best constructed just prior to drainage flows entering creeks, lakes, wetlands, etc. If being included as part of a new construction project, they should not be constructed until the permanent erosion control items have been installed. This will prevent them from clogging prematurely with silt.

Other recommendations for swale design are listed below:

- Avoid irregular profiles and steep gradients.
- Provide drainage swales with wide, rounded cross sections that reduce the erosion potential.
- Minimize channel changes. When channel changes are required, adjust the new channel cross-section alignment and/or length to match the existing flow velocity.
- Avoid problems associated with locating swales at the toe of fill slopes. These swales frequently fill in with sediment from the fill slope during construction and require additional clean-out and maintenance even after the fill is stabilized.
- Line swales as soon as possible to prevent erosion and to maintain the profile.

Maintenance

Cleaning or replacement of these filters will depend on silt loading. However, it is anticipated that they should last several years.

Other maintenance considerations are as follows:

- Clean channels when they become clogged with sediment or debris to prevent overflows and washouts.
- Check swales after major storm events for obstructions, erosion or bank collapse.
- Regrade swales only when necessary and line with vegetation or stone as soon as possible.

Inlet Protection

Description

Runoff can carry large amounts of sediment. Storm drain inlet protection is meant to intercept and retain sediment to minimize the amount that enters the storm sewer system. It may include a temporary barrier, with the capability to filter or settle out sediment before it enters the storm sewer.

Design

- See Mn/DOT Standard Specification 3891.
- Manufactured devices are listed in the approved products list located on the Mn/DOT Environmental Services or MnROAD web sites. Materials include clean rock, filter fabric, straw bales, slotted riser pipe, concrete block, wire screen, stakes, and silt fence.
- Mn/DOT Standard Plan 5-297.405 gives several alternatives for temporary inlet protection using silt fence or aggregate filters.
- Every inlet in urban areas should have inlet protection.

Installation

- It is not practical to control drainage areas larger than one acre with this measure alone.
- Leave the inlet protection in place and maintain it until adequate vegetative cover is established. A variety of designs have been tried and found to be acceptable for retaining sediment. Select the material to satisfy local conditions.
- The storm drain inlet requires periodic inspection, and after each storm event. Repair or replace the measures as necessary, and remove sediment when its level reaches half of the design depth. Proper sediment disposal prevents clogging the inlet protection device.

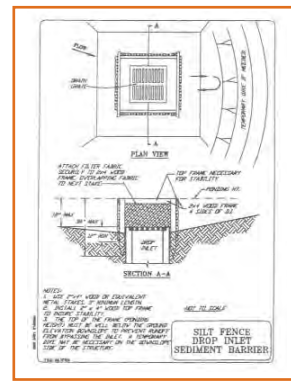


Figure 6-1. Silt Fence Barrier Installation.

Maintenance

- Periodic inspection as required by the permit, as well as after each storm event.
- Inlet protection should be repaired or replaced as necessary.
- Remove sediments after each rain.
- Remove sediment when the level reaches half of the design depth. Proper sediment disposal will prevent clogging the inlet protection.
- Clean outlets frequently to prevent water from backing up into traffic lanes.

Perimeter Control

Description

Perimeter control can include fence, silt fence, bales or biologs, and is used to intercept sheet flow running toward adjacent property or the work site. Vegetative debris from clearing and grubbing operations can also be used. These devices may be used on cut or fill slopes, and areas where runoff should be slowed or diverted. These controls prevent any off-site damage by minimizing the amount of sediment leaving the site. In most cases, the controls will remain in place throughout construction.

Design

- When large amounts of sheet flow from undisturbed areas intercept the construction area, the runoff may be diverted around the site, minimizing the erosion and amount of runoff. This can be done by constructing diversion berms or using bales around the site (see Figure 6-2.).

Installation

- Figure 6-1 shows the installation of bales as perimeter control. Bales can be used in areas that are too wet for silt fence, but not wet enough to use silt curtain.

> ***Caution:*** **When inlet protection is used on areas with traffic, consideration must be made for emergency overflow. Backed up water may create hazardous conditions.**

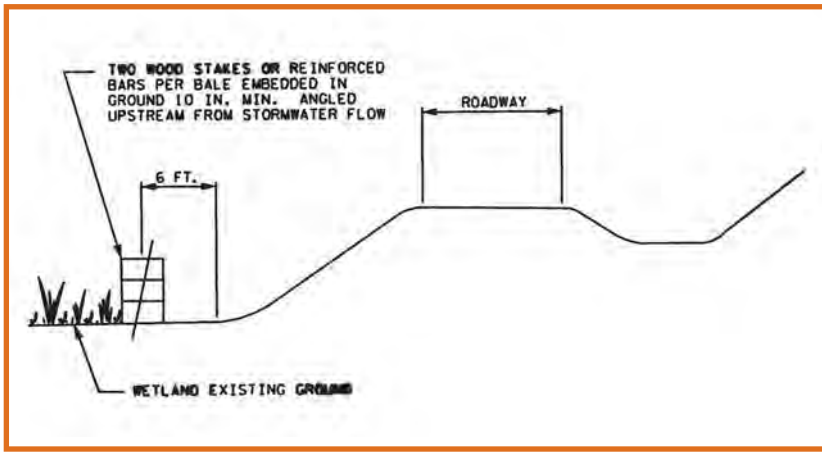


Figure 6-2. Bale Diversions as Perimeter Control. See Mn/DOT Road Design Manual Chapter 8.

Sediment Basins

Description

Sediment basins and sediment traps retain runoff so that sediment can settle out and be removed later. Sediment basins have a longer design life (the length of the construction project or, in some cases, permanent) than sediment traps and, therefore, benefit from individual design and good construction practices. Design usually provides flow control section details using durable construction materials.

Sediment basins can be used for disturbed drainage areas of 5-100 acres, and are effective for up to 18 months. They can be used to manage the sediment until permanent drainage or vegetation is in place. In some cases, permanent basins may be converted into small recreational lakes and, therefore, may have to be designed considering specifications of other agencies.

Design

- For maximum effectiveness, a sediment basin should have a permanent pool of water. Figure 6-3 shows the components and storage volumes associated with sediment basins. *Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota, MPCA, March 2000* gives detailed design information for sizing and designing settlement basins and emergency spillways.
- Locate sediment basins where failure will not cause loss of life or property.
- Locate sediment basins to avoid impact by later phases of construction.

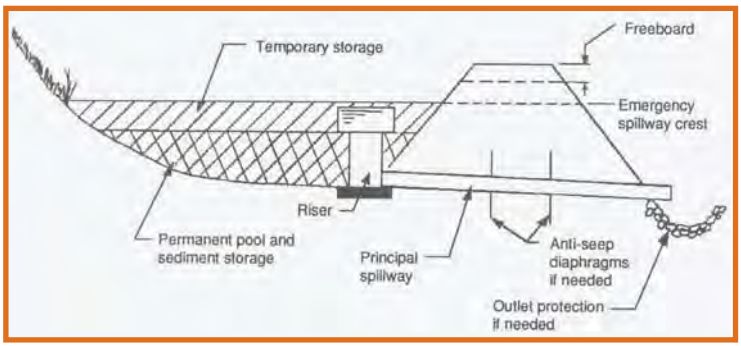


Figure 6-3. Typical sediment basin cross section.

Source: Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota, MPCA, 2000

Maintenance

- Extend the life of a basin by periodic cleaning.
- Inspect immediately after a storm, and complete needed repairs right away.
- Maintain the basin until the area is permanently stabilized.
- Clean out when sediments fill the basin to 50 percent of its storage volume.

Note:Sediment basins attract children and can be very dangerous. Fence the perimeter, or make them inaccessible unless it is deemed unnecessary due to the remoteness of the site or other circumstances. In any case, adhere to the local ordinances and regulations regarding health and safety.

Sediment Traps

Description

Sediment traps are small excavated sediment storage areas without flow control sections or defined side slopes. They are often field located and temporary. Use them when it is necessary to protect downstream sensitive areas, or as velocity checks on a long ditch run. Temporary sediment traps are intended to detain sediment-laden runoff from small disturbed areas long enough to allow the majority of the sediment to settle out.

Design

- Typical locations for sediment traps are at the foot of embankments, at the downgrade end of a cut section, in ditch bottoms steeper than 3 percent, in medians, and in depressions within the right-of-way.
- The length, width and depth of the trap are dependent on project conditions.
- Sediment traps are limited to drainage areas of size 6 acres or less.
- In severe areas, place a series of traps, spaced at a minimum of 300 feet between traps. All traps may be fenced to prevent unwanted access.

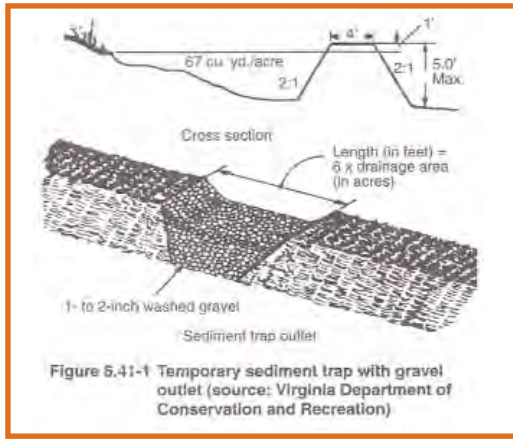


Figure 6.41-1 Temporary sediment trap with gravel outlet (source: Virginia Department of Conservation and Recreation)

Temporary sediment traps are useful as velocity checks and treatment areas. ***Source: Minnesota Polution Control Agency Best Management Practices Manual, 2000***

Installation

- Sediment traps must have an outlet to carry runoff through the structure, which can be a pipe outlet, gravel outlet or other suitable device. It must be capable of handling the runoff from a 10-year frequency, 24-hour duration storm without failure or significant erosion.
- Failures are typically caused by installation in high-flow situations, where the trap is inadequate to contain runoff from the drainage area.
- Remove sediment when it fills half of the capacity of the sediment trap. If the outlet becomes clogged with sediment, it should be cleaned to restore its flow capacity.

Maintenance

- Clean out when sediments fill the basin to 50 percent of its storage volume.
- Inspect after significant rainstorms to check for damage or operational problems.
- Remove structure after the contributing drainage area has been stabilized.

Silt Curtain

Description

A flotation silt curtain is a silt barrier for use within an area of open water, consisting of a filter fabric curtain weighted at the bottom and attached to a flotation device at the top. It is used to isolate an active construction area within a lake or pond to prevent silt-laden water from migrating out of the construction zone.

Design

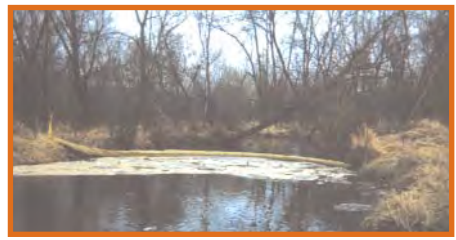
- See Mn/DOT Standard Specification 3887.

Installation

- See Table 3887-1 in the Standard Specifications for Construction for placement and installation guidelines.

Maintenance

- Maintain the silt curtain until the construction area is stabilized and turbidity is reduced to acceptable levels.



Do not use silt curtain across streams.

Silt Fence

Description

Silt fence is used to retain sediment and prevent off-site sheet flow sedimentation. The following types are provided for specific uses:

- **Standard Machine Sliced** - for general use during site grading, to protect critical areas. Can be used in ditch check applications.

- **Heavy Duty** - use in locations where extra strength is required, such as near water bodies, unstable wetland soils, steep slopes, highly erodible areas, areas inaccessible to equipment, and high runoff areas.
- **Preassembled** - use for light duty application to protect temporary construction or to supplement the other types of silt fence.

Silt fence is used to protect adjacent areas at the construction perimeter, toe of slopes, around stockpiles, and near wetlands. It should be used in combination with other erosion and sediment control devices. Do not use silt fence for snow or perimeter (access) control.

Design

- See Mn/DOT Standard Specification 3886 and 2573.

Installation

- Use silt fence where the drainage area is less than 2 acres, the maximum uncontrolled slope length above the silt fence is 150 feet, and water reaches the silt fence as sheet flow. Do not use in channels, waterways, or other areas with concentrated flow.
- Silt fence should be placed convex to flow, have ends tied into the landscape, be accessible to remove sediment, have a stabilized outlet for large storms, and be able to hold shallow pool
- See Table 3886-1 in the Standard Specifications for Construction for placement and installation guidelines.
- Place silt fence where it is unlikely that it will be over topped. Water should flow through a silt fence ditch check, not over it.
- Standard specification 2573 outlines the installation of sliced in silt fence.
- Install silt fence on the contour and so that the flow cannot bypass the ends. “J-hook” sections can also be used.
- If the silt fence is longer than 600 feet, it should be constructed in separate independent units, with each unit having a length less than 600 feet.

Maintenance

Silt fence should be inspected every seven days and within 24 hours of a rainfall of ½ inch or more. Check the following during each inspection:

1. **Are there any points where water is concentrating?** When the fence is not placed along contours, water concentrates at low points. This concentrated flow usually causes a failure. Even if a failure doesn't occur, the concentration of flow drastically reduces the overall storage capacity of the fence. To solve this problem, reinstall the fence so that it is level.
2. **Does water flow under the silt fence?** This is usually caused by posts that are too far apart, a trench that is too shallow, or an improper burial procedure. If guidelines for proper installation haven't been met, the fence should be re-installed.
3. **Does the fence sag excessively?** Sagging silt fence is caused by excessive post spacing and/or overtopping of the silt fence. Water should flow through the silt-fence, not over it.
4. **Has the silt fence torn or become detached from the posts?** If a tear develops, replace the silt-fence.
5. **Does sediment need to be removed from behind the fence?** Sediment must be removed when it reaches one-half of the original exposed height of the silt fence. When removing sediment from behind silt-fence, take care not to under mine the entrenched silt fence.

Many tiers of silt fence can be useful in steep slope situations.

Standpipes

Description

Intakes for incomplete permanent drainage structures should be protected from the inflow of sediment-laden runoff. This can be accomplished with a standpipe.

During construction, roadway embankments with a culvert may be converted into a sediment trap by installation of a standpipe at the inlet end, as shown in Figure 6-3. This temporary type of installation should be used when critical areas are exposed, when a large amount of sediment is expected to accrue, and/or when it is necessary to protect off-site areas at the culvert outlet.

Design

- Because of the freeboard required, standpipes on culvert inlets are used only in deeper ditches (those deeper than 3 feet and/or in off-take ditches where a small ponding area can be developed without danger to upstream areas.)
- Sediment traps can be used in shallow ditches when it is necessary to protect sensitive areas.
- Perforated standpipes can also be used to protect drop inlets, see Figure 6-4.
- Because of the degree of damage that could occur as the result of failure, standpipes are not recommended when the plan culvert diameter exceeds 36 inches.

Installation

- Installation is as shown in Figures 6-4 and 6-5.

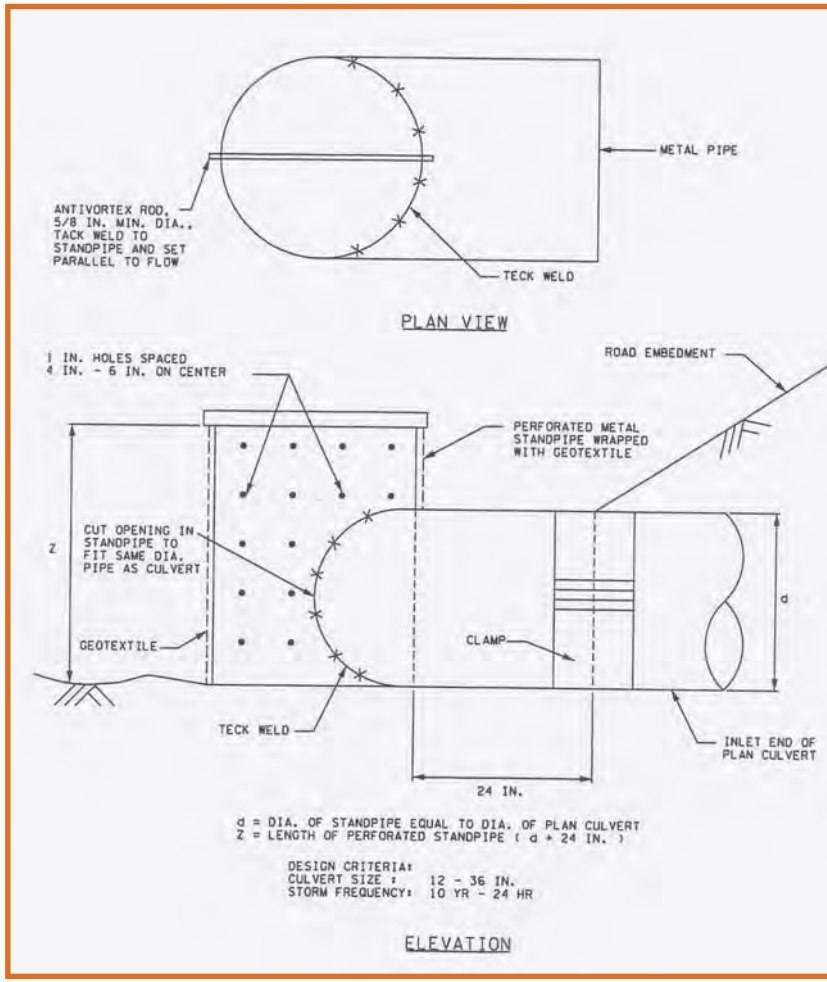


Figure 6-4. Temporary Standpipe for Sediment Control on Culvert Inlet. See Mn/DOT Road Design Manual Chapter 8.

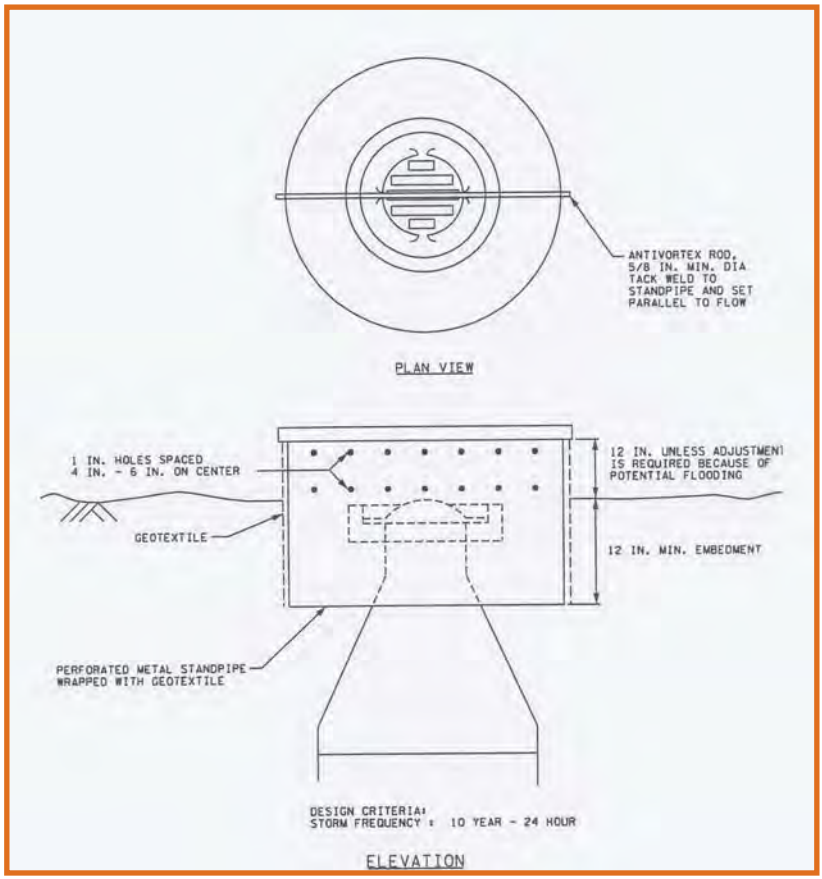


Figure 6-5. Temporary Standpipe for Sediment Control to Protect Drop Inlet. See Mn/DOT Road Design Manual Chapter 8.

Treatment Basins - NURP Ponds

Description

Treatment basins can provide stormwater quality treatment and rate control. They are designed based on the objective they need to meet. Nationwide Urban Runoff Program, or NURP ponds are designed to meet the NURP guidelines. Pond design generally provides for 60% removal of phosphorus and 70-95% removal of suspended solids in storm water runoff. These ponds can also be designed to provide rate control.

Design

- A permanent pool ("dead storage") volume below the principal spillway (normal outlet) greater than or equal to the runoff from a 2.5 inch storm event over the entire contributing drainage area assuming full development.
- Permanent pool average depth (basin volume/basin area) greater than or equal to 4 feet, and less than or equal to 10 feet.
- An emergency overflow (emergency outlet) adequate to control the 1% frequency/critical duration rainfall event.
- Basin side slopes above the normal water level no steeper than 3:1 and preferably flatter. A basin shelf at least 10 feet wide and 1 foot deep below the normal water level is recommended to enhance wildlife habitat, reduce potential safety hazards, and improve access for long-term maintenance.
- To prevent short-circuiting, maximize the distance between major inlets and the normal outlet.
- Provide a flood pool ("live storage") volume above the principal spillway so that the peak discharge rates from the 1-, 10-, and 100-year critical duration storms are no greater than pre-development conditions.

Treatment Basins - NPDES Ponds

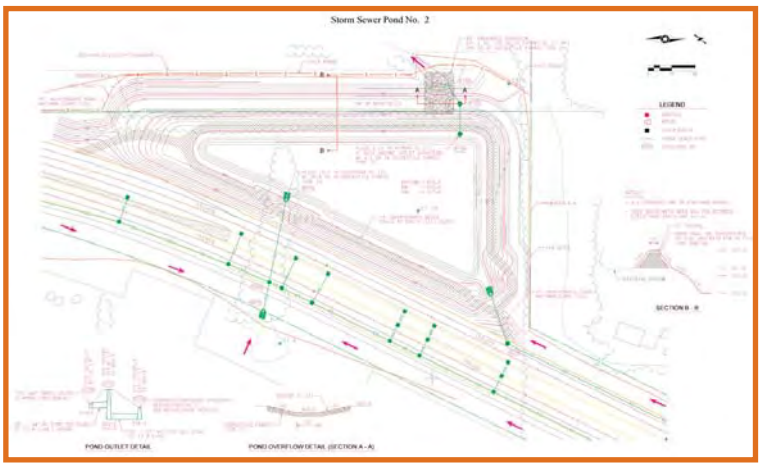
Description

In many situations in road design, NURP ponds are not practical due to space limitations. However, NURP ponds may be required from local Watershed Districts or local cities and townships. Check with the local permitting agencies for requirements. For situations where NURP ponds are not feasible or not required, ponds can be designed to temporary or permanent NPDES (National Pollutant Discharge Elimination System) standards. The NPDES standards are outlined below:

Design

Temporary NPDES basin standards:*

- Basins shall provide 3,600 ft^3 per acre drained of hydraulic storage below the outlet pipe. For roadways, the use of adjacent drainage ditches with riser pipes is acceptable.
- Design basin outlets to prevent short-circuiting and the discharge of floating debris. The outlet should consist of a perforated riser pipe wrapped with filter fabrics and covered with crushed gravel. Design the perforated riser pipe to allow complete basin drawdown.



Typical NURP pond design.

Permanent NPDES basin standards:*

- The basin's hydraulic volume (dead pool) must be sufficient to capture 0.5 inches of runoff from the new impervious watershed area.
- The basin must provide a minimum of 250 ft^3 of dead sediment storage below the basin's volume/impervious acre drained.
- Place basin inlets above the sediment storage volume.
- Design of the basin outlets must remove all suspended solids greater than 5 microns with a settling velocity of 1.3 x 10-4 ft/sec.
- Design basins to prevent short-circuiting and discharge of floating debris.
- Basins must provide spillways to accommodate storm events in excess of the basin's hydraulic design.

Information from the General permit: Authorization to discharge storm water associated with a construction activity under the National Pollutant Discharge Elimination System/State Disposal System Permit Program (i.e. NPDES permit)

Storm Water Ponds are an excellent way to control and treat runoff.

Chapter 7: Permanent Erosion Control

Permanent erosion control measures are designed primarily to function after projects are complete and vegetation is established. They include consideration of proper earthwork shaping, rounding and transitioning, as well as the proper preparation of surfaces for expected flow quantities and velocities. Avoiding areas, slopes and formations where restabilization or revegetation will be difficult is also a very important and effective erosion prevention technique.

Table 7-1. Permanent Erosion Control

Device	Application Areas
Design elements	The entire project area can be positively affected by good design.
Ditches and liners	Ditches
Detention pond	Regional ponds with larger drainage areas are generally most cost effective than site basins.
Riprap	At pipe outlets, in ditches
Runoff spreaders	On shoulder slopes at super-elevated curves. Adjacent to shoulder on vertical curves. Broken-back safety fill slopes
Soil bioengineering and Streambank or shoreline protection	Along streams or shorelines
Turf establishment	Everywhere on a project, including temporary stockpiles and borrow locations.

Design Elements

Description

Proper design features and natural materials or methods are the most effective means of erosion control. Many erosion problems can be simply avoided by good design practices. The Mn/DOT Road Design Manual, Chapter 8, outlines many detailed best practices for design.

Design

Design features that minimize erosion potential are listed below:

Right-of-way and Construction Limits

- Obtain adequate right-of -way to avoid steep, unstable slope grades. Weight the initial cost of additional right of way against the long-term costs of construction and main tenance. Appearance is also improved when adequate right-of-way or slope easements for rounding and blending is obtained.
- Obtain right-of-way for sediment basins and other erosion or sediment control devices.
- Set construction limits that provide for slope rounding, pre serve trees and shrubs, and prevent over-clearing.

Smoothing and Rounding

- Proper shaping includes slope and ditch rounding, cut-to-fill blending, built-in gully elimination, and feathering cuts.
- Use a smooth grade line with gradual changes to avoid numerous breaks, minimize the number of cut-to-fill roundouts, and avoid short lengths of grade.
- Round slope edges where cuts or fills intersect the natural ground line.
- Construct slope angles to insure slope stability, and conserve existing vegetation and topographic features to reduce erosion.

Fit Alignment to Existing Terrain

- Preserve the natural and existing drainage patterns.
- Avoid placing low points of vertical curves in cut sections.
- Avoid low grade lines requiring ditch sections in areas that are swampy, or have a high water table.
- Avoid or minimize earthwork balancing that requires hauling dirt across streams. Avoid placement of sediment-generating haul roads in stream areas.
- Leave stabilized steep slopes of rock debris, soil or stream banks undisturbed. 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 slope easement and obliterate the critical areas using current vertical and horizontal design standards.
- Use independent alignments on divided highways to fit the highway to the terrain and to adjust grades.

Materials

- Maximize the use of natural materials such as soils, sod, seed, mulch, and riprap, which reduce costs and increase the likelihood of achieving permanent erosion control.
- Avoid the use of open metal, concrete, or bituminous flumes, as they are costly to install, subject to undermining, deteriorate with freezing and thawing, and frequently fail over time. Consider natural materials and topographic features first for preventing erosion.

Plan Review

- Review the plans by watershed area for coordination of erosion control work with grading progress.
- Evaluate the grade line and cross-sections for possible erosion problems, especially in ditches, cut runouts, at vertical curve low points, and any other area where water may concentrate.

Ditches and Liners

Description

Ditches prevent water from reaching the roadway base or sub-base by disposing of surface runoff from the roadway surface and roadside areas. In addition, roadside ditches provide for drainage of the roadway base to prevent saturation and loss of support.

Ditches direct water away from the roadway base.

Design

- A parabolic rounded trapezoidal ditch cross section is hydraulically efficient, meets safety standards, and is easy to construct. In addition to cross-section rounding, both alignment and surface treatment (lining) are significant in the control of erosion in ditches.
- 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.
- Provide vegetated ditches and drainage channels with wide, rounded cross sections that reduce the erosion potential.
- Minimize channel changes. When they are required, adjust the new channel cross-section alignment and/or length to match the existing flow velocity.
- Locate and align culverts to avoid erosion at the inlet and outlet. Place structures as nearly as possible at 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.
- Avoid problems associated with locating ditches at the toe of fill slopes. These ditches frequently fill in with sediment from the fill slope during construction and require additional ditch clean-out and maintenance even after the fill is stabilized. A toe ditch may be necessary along fills to keep water from draining out onto adjacent fields.

Liners

- Erosion damage to drainage ways and ditches can be substantially reduced or prevented with the proper ditch liner treatment. Ditch liners should be selected based on the ditch gradient and soil type. Liner selection is outlined in Table 7-2.
- Use the ditch gradients listed in Table 7-3 as a guide under normal conditions. Several variables in flow quantities and velocities may affect the design determination as given. Do not sod when the flow velocity exceeds the maximum per missible velocity given in Table 7-2.

- Line ditches flatter than 5% with grass in order to filter sediments.
- Line ditches steeper than 5% slope with rock riprap or high flow stabilization blanket. If rock lining is used, underlay the lining with geotextile.

Table 7-2. Ditch Liner Selection

Liner Type	Use	Notes
Granular	Streambeds Match existing conditions. Use angular for high flows and rounded in low flow areas.	Described in NCHRP report 108
Clay	To replace highly erodible soils, such as sands and silts	Must be ½ foot thick compacted
Riprap	Runoff velocity >6.5 ft/sec	A geotextile filter may be required
Sod	Runoff velocity <6.5 ft/sec	Can use erosion control netting over the top
Erosion stabilization mats	Runoff velocity >6.5 ft/sec Must be topsoiled, seeded and blanketed	Considered experimental; results mixed at this time
Reno blankets	Extremely high flow Poor soils High bed shears	
Interlocking blocks	Extremely high flow Poor soils High bed shears	
Cabled concrete	Extremely high flow Poor soils High bed shears	Several sizes are available
Root rap	Use in areas where rip rap is needed, but a softer look is desired	Described in MnDOT Specification 2577.3H

Table 7-3. Ditch Gradients Requiring Sod or Erosion Control Blankets

Soils	Gradient (%)
Seed/mulch	0-2
Sod	2-7
Category 3 erosion control blanket	2-3
Category 4 eroison control blanket	2-4
Category 5 erosion control blanket	2-7

Notes:

1. Ditch gradients are based on Mn/DOT parabolic cross section where R=16.3 feet.
2. With a ditch bottom radius is 32.5 feet, the maximum gradient listed can be increased by 25%.
3. Category 1 blanket is not recommended as a ditch liner.

Installation

Several biological/vegetative stabilization techniques can be used to control erosion and stabilize ditches. Some of those techniques are listed below:

- Using granular liners in conjunction with special vegetation
  in seeping ditches and areas of high water table.
- Using clay ditch liners in conjunction with sod for stabilizing ditches in erodible soils such as loamy sand and sand soils.
- Using riprap mixed or covered with soil and then seeded.
- Line ditches as soon as possible to prevent erosion and to maintain the ditch profile.

Maintenance

- **Steep ditch gradients are very susceptible to erosion and require extra design effort.**
- **Overlap sod (See Mn/DOT Standard Plan 5-297.406) in ditch bottoms.** Overlap the sod in areas of concentrated flow, and place the sod strips parallel to the water flow.
- **Shingle the sod in areas of sheet flow.**
- **Staking overlapped sod will also increase its effectiveness.** See Mn/DOT Standard Specification 2575 and Standard Plan 5-297.406.
- **Sod ditches to a width and depth (1 foot minimum depth) that will convey the expected runoff quantity within the sodded section.** When the ditch sodding is too narrow, water will flow along each edge of the sod, causing erosion, undermining the sod and preventing its growth. Therefore, the bottom of the ditch section must be sodded to a width sufficient to create a sodded waterway with a depth of at least 1 foot. To accomplish this where the front or back slope is flat (less than 4%), the ditch should be notched and then rounded before placing sod as shown in Standard Plan 5-297.404.
- **Place a piece of sod approximately 18 inch square at approximately 20 feet intervals along the outside edge** (see Mn/DOT Standard Plan 5-297.404).
- **Clean ditches when they become clogged with sediments or debris to prevent overflows and washouts.**
- **Check ditches after major storm events for obstructions, erosion or bank collapse.**
- **Regrade ditches only when necessary and line with vegetation or stone as soon as possible.**

Detention Pond

Description

Detention ponds have a permanent pool of water and the capacity to temporarily store storm water runoff until it is released from the structure. This capability to hold runoff and release it at lower rates than incoming flows has made it a popular practice for flood and storm water management.

Detention ponds are most effective for treating urban runoff. After a storm, fine suspended solids in the pond have a relatively long time to settle out until the next storm occurs. In addition to efficient settling, this time allows some removal of dissolved nutrients through biological uptake. This process results in good pollutant removal from small storms. Runoff from larger storms will also receive treatment, but not to the high level of smaller storm runoff.

Removing, hauling and disposing of the sediment in the pond can be costly due to the pollutants it contains.

Structural alternatives, such as the Stormceptor, filtered catchbasins or grit chambers are available for use in many areas.

Detention ponds temporarily store and treat storm water until it is discharged.

Design

- Design factors include the type of facility desired, variability of the rainfall and runoff, soil and cover type. The site should have suitable soils to prevent excessive seepage. If permeable sandy or silty soils exist in the area, a liner constructed of compacted clay may be needed.
- The drainage area above a detention pond must be large enough to maintain a permanent pool. Generally, 4 acres of drainage area are recommended for each acre-foot of pond storage.
- Regional detention ponds with larger drainage areas are generally most cost effective than on-site basins. The drainage area of regional ponds should be small enough to minimize unprotected areas, but large enough to allow cost savings and meet overall storm water management goals.
- If the detention pond is used for water quality improvement, as well as for flood control, additional planning and design considerations, such as size and shape of the permanent pool need to be incorporated.
- Elements of design include the pool volume, pond depth, pond shape, slopes, inlet and outlet, flood routing, and structure design.

Pond size, shape, and revegetation plan need to be considered during design.

To ease maintenance, consider the following:

- Keep all slopes 1:3 or flatter so that vegetation can be maintained easily
- The principal spillway intake should be protected with a trash rack to prevent clogging
- Vehicle access to the pond should be at least ten feet wide and the access should not be steeper than 15 percent. Maintenance access should never cross an emergency spill way unless the spillway has been designed for vehicular traffic.
- Provide on-site sediment disposal sites where possible, which will drastically reduce the cost of sediment cleanout.
- Provide a drawdown device to drain the permanent pool, which can eliminate the need for pumping if the pool is drained for sediment cleanout or other maintenance.
- Construct the principal spillway of materials that will resist failure from corrosion or deterioration for the design life of the structure.

Specific design criteria, procedures and standards are outlined in Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota, MPCA, March 2000.

Maintenance

- **Routine maintenance includes mowing grass, controlling weeds and woody vegetation, repairing eroded areas and removing debris from the pond.**
- **Non-routine maintenance includes sediment cleanout and major structural repairs.** Remove sediment before it becomes excessive, to preserve the efficiency of the pond from a water quality standpoint. That efficiency is severely impaired if too much sediment is allowed to accumulate.
- **Prompt action can minimize remedial action cost.**

Riprap

Description

Riprap is generally used for energy dissipation to prevent erosion, and acts by slowing the flow of water to reduce the water's erosive force. It is a designed gradation of large rocks designed to remain stationary under the force of water. Filter material can be an aggregate mixture or a geotextile designed to prevent the riprap from sinking into the underlying soil.

Design

- See Mn/DOT Standard Specification 3601.
- Riprap is available in a variety of sizes and classes. The size and amount of riprap to be used at a location depends on the velocity of water anticipated to be flowing through the area. As the water's velocity increases, larger riprap should be used to dissipate the water's energy.
- Riprap should be designed with an underlying filter. Geotextile fabric an be used, provided it is tied into the ground upstream of the discharge point.

Riprap provides energy dissipation of storm water at outlets, thus reducing erosion potential.

Installation

- Riprap placement is outlined in Mn/DOT Standard Specification 2511.
- Energy dissipation devices such as riprap can be used at many locations including storm sewer inlet and outlet structures, along the side slopes or the bottom of drainage swales or ditches, or other areas that are anticipated to be impacted by the force of flowing water. Use a riprap basin in areas where a standard riprap apron or other energy dis sipators are inadequate.
- If the velocity of the water leaving the pipe is greater than 4 ft/sec, constructed a protected transition between the pipe and the ground.
- Thickness of riprap should be 1-1/2 times the maximum stone diameter.
- Place filter materials immediately after the foundation is prepared.
- Place riprap on a filter layer of either granular material or a geotextile fabric when velocities of greater than 6 feet per second are anticipated.
- Riprap can also be grouted in place, covered with fencing, or placed as a gabion to prevent it from washing down stream for areas that experience very high water velocities.
- Form a dense, well-graded mass with no clusters of stones of one size.
- Large stones should dominate, with smaller stones filling in voids.
- The elevation of the riprap should be the same as its surroundings.
- Mn/DOT Standard Plate 3133 and 3134 detail the recommended installation for riprap.

Maintenance

- Riprap may be subject to vandalism, and degrades over time (especially if limestone is used.)
- **Periodic maintenance is required.**
- **Inspect riprap annually and after major storms.** If riprap has been damaged, repairs should be made promptly to prevent progressive failure. If repairs are needed repeatedly at one location, evaluate the site to see if original design conditions have changed.

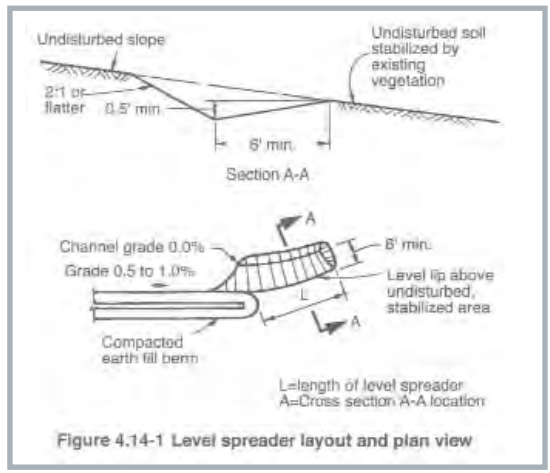
Runoff Spreaders

Description

The purpose of sodded runoff spreaders is to convert concentrated flow into lower velocity sheet flow by spreading the flow out within a stabilized area. Their most common applications are at super-elevated curves and vertical curves, and they can also be used at broken-back safety fill slopes.

Design and Installation

Chapter 8 of the Mn/DOT Road Design Manual outlines the design procedure for runoff spreaders at super-elevated curves, at vertical curves, and on broken-back safety fill slopes.



Typical runoff spreader design. ***Source: Minnesota Pollution Control Agency Best Management Practices Manual 2000***

Soil Bioengineering and Streambank or Shoreline Protection

Description

Bioengineering involves the use of vegetation as the structural and mechanical elements in soil stabilization. Live cuttings and rooted plants are imbedded in the ground to serve as soil reinforcements, hydraulic wicks, drains, and barriers to soil movement. This practice works best when used as a system of various bioengineering measures or with hard-armor engineering practices. Bioengineering treatments provide sufficient stability so native vegetation can establish and stabilize the soil.

Wattling

Wattling is the method trenching bundles of tied live, easily rootable woody plants such as willow along the contour, usually of a slope. The process is as follows:

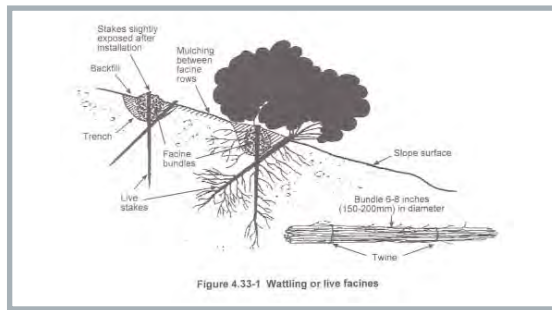
- Cut the woody plant while it is dormant, in the spring before leaf-out or the fall after leaf-drop.
- Prevent plants from drying out, and form them into cigar-shaped bundles, wattles tied with twine.
- Stake the wattles into trenches dug on the slope contour and covered over, except for the top two inches of the bundle. The wattles root and grow controlling water runoff velocities, stabilize the surface layers of the slope, and increase water infiltration.

Contour wattling with willows is best on a cut or fill slope with surface or subsurface moisture, and also on streambanks. A coconut/straw blanket can be placed over the soil, into the trenches before the wattles are installed to protect the bare seeded soil.

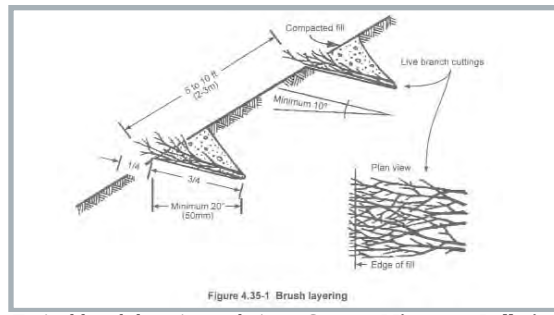
Brush layering

Brush layering consists of embedding live branches of shrub or tree species that will root easily (e.g., willow, dogwood, alder), on contours in the face of a slope. Brush layering is more effective than wattling in preventing shallow movements. It works well when done in conjunction with the construction of a conventional fill slope operation. The process is as follows:

- Place the branches in a crisscross or overlapping pattern, so that tips of the branches protrude just beyond the face of the slope, which slows runoff velocity and retains sediments.
- The vegetation act as small horizontal slope drains.
- The brush layers are embedded between successive lifts of fill, or in a ditch dug at an angle.



Typical Wattling Technique. ***Source: Minnesota Pollution Control Agency Best Management Practices Manual 2000***



Typical brush layering technique. ***Source: Minnesota Pollution Control Agency Best Management Practices Manual 2000***

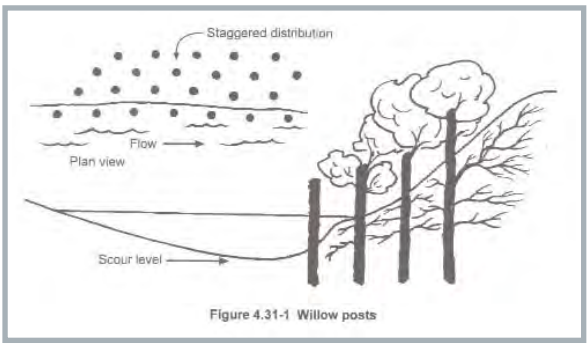
Live Stakes

Live stakes are live, rootable woody vegetation cuttings inserted into the ground. It may be the primary treatment or used with wattling, brush layering, or other treatments. Plant materials that root easily include species of willow, dogwood, cottonwood, alder. The type chosen should be indigenous to that site.

Other important notes about live stakes include:

- Live stakes placed in rows (2 feet o.c.) across a slope help control shallow mass movement.
- Jute or coir netting tamped through streambank areas helps stabilize the soil. Installed through a straw blanket (or if an erosive site, a straw/coconut blanket) will stabilize the bare seeded soil.
- Willow stakes can be placed in a clustered array along the sides of gullies for slowing velocity, retaining sediments and controlling erosion. The clusters are installed in chevron-like rows that point downstream.
- The rows should start at the top of the bank directed downstream to the toe.

Placed in joints between riprap and gabions into the soil, livestakes will root beneath the riprap, reinforcing the soil, anchoring the riprap and improving drainage by extracting soil moisture. They can be used to anchor the wattles in a trench, adding additional rooting to a slope.



Live staking with willow stakes is an effective means of bank stabilization. ***Source: Minnesota Pollution Control Agency Best Management Practices Manual 2000***

Root-rap

Root-rap consists of placing a gravel channel lining or riprap and overseeding or planting the completed channel.

Streambank Erosion Control

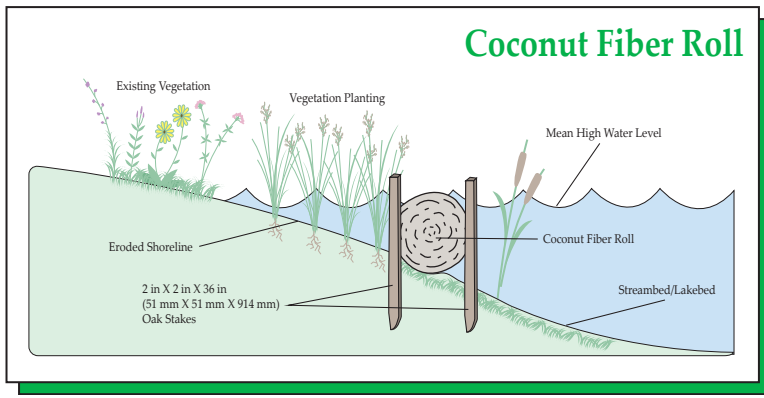
Streambank erosion control uses the techniques outlined above in conjunction with each other along with erosion control blankets. Erosion control blankets protect the bare soil until the seeding and vegetation has established.

Fiber Roll

The fiber roll (Mn/DOT Standard Specification 3895) is used along edges of streams, rivers, lakes, and reservoirs. It is a tube of coconut fiber (coir) placed to reduce the water's forces and retain soil so vegetation is allowed to establish. Factors to be considered in design include:

- bank steepness
- wave height
- stream velocity
- low-flow conditions
- human and animal traffic.

This technique is very successful in creating wetland and riparian habitats when used in conjunction with pre-planted pallets of aquatic species.

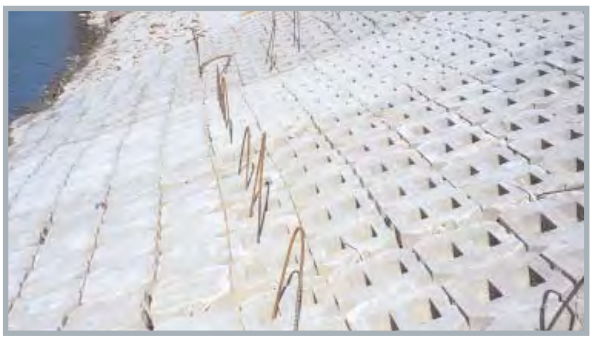


Concrete Armor Units

Concrete Armor Units (Mn/DOT Standard Specification 3602) are made of two pieces of concrete that fit together and form a structure similar to a 'jack'. Placement is as follows:

1. Place armor units at the toe of a stream bank to support the toe-of-slope and protect the slope from the water forces on the outside of a bend.
2. Interlock the units together and stuff netting between them to keep water from eroding out behind them.

The units are able to withstand high flow velocities. Mats pre-planted to form an aquatic species sod are also good for vegetating drainageways that are continuously moist.



Concrete armor units are useful for stormwater erosion control in high volume and high velocity situations.

Turf Establishment

Description

This section will outline general turf establishment policies and recommendations. Note that each site has a different set of conditions affecting turf establishment materials and needs, such as soils, topography, and traffic. Turf establishment recommendations for a particular project are based on the types of soils present. The Mn/DOT Seeding Manual is available from the Turf Establishment unit, or online at www.dot.state.mn.us/environment.

A summary of turf establishment recommendations is as follows:

1. Topsoil

Topsoil is a valuable natural resource. All existing topsoil should remain on site, and be salvaged to the extent possible. On slope easements, topsoil should be removed to the bottom of the "A" horizon (see the Mn/DOT Geotechnical and Pavement Manual, Section 2-2.02) and reapplied uniformly within the easement area. Plans and specifications should require that topsoil stockpiles receive temporary seeding after they are formed and graded.

Design Consideration

- Mn/DOT Standard Specifications section 2105.5 outlines topsoil borrow acceptance. To increase turf's chances for survival, test borrow material to determine that it meets topsoil requirements before accepting or placing it.
- Conduct earthwork finishing and topsoil covering operations concurrently with the grading operations so as to permit completion of the erosion control items as early as practical.
- Complete topsoil covering operations as soon as possible after the subsoil has been finished to grade on any significant area.
- Place topsoil on all areas to be seeded or sodded.
- Require a minimum of 3 inches of topsoil.
- If salvageable topsoil quantities are limited, plastic subsoils or organic and muck soils (up to 20 percent organic matter) can be used. Peat is undesirable because it may dry up, blow away, settle, consolidate, and/or will not support mowing equipment.
- When the topsoil is placed, the subsoil should be loose and friable for a minimum depth of 3 inches, and there should be no erosion rills or washouts in the subsoil surface deeper than 3 inches.

Some projects may require greater depths of topsoil depending on subsoil textures and/or the nature of the area:

- greater depth on coarse textured subsoils
- as much as 8 inches in hydraulic sandfills
- less depth on plastic subsoils.

2. Fertilizer

Fertilizer used is dependent on the soil composition and time of application.

- Use fertilizer on areas to be seeded or sodded, and base quantities on computed seeded areas
- Obtain a soil analysis from your local University Extension Service to determine the correct fertilizer type and application rate for a desired vegetation cover.
- Do not use product containing phosphorous next to wetlands.

3. Seeding

Table 7-4 lists Mn/DOT's seed mixes by type, purpose and maintenance requirements (such as mowing).

- Seed all disturbed areas that are not sodded including storage sites, stockpile sites, field office sites, and other miscellaneous areas.
- On grading projects when the paving is to be let as a separate future contract, provide for seeding the median from grading PI to grading PI and to the outside ditches and slopes.
- Use the seed mixture and/or vegetation which best fits the nature of the project area and its soil condition. The following may serve as a guide:

Table 7-4. Mn/DOT Basic Design Recommendations for Seeding

Type and Purpose	Mix	Maintenance Needs
Introduced Mowed Turf	60B	High
Introduced/native General Ditch	50B	Medium
Introduced/native General Wet Ditch	80B	Medium
Native General Wet/Dry Ditch	28B	Low
"Urban" Prairie	30B,30B-WF (contains forbs)	Low
Native Wet/Dry Woodland Edges	5B	Low
Native Tallgrass Prairie (general)	15B	Low
Native Western Tallgrass Prairie	10B	Low
Native Sand Tallgrass Prairie	20B	Low
Native Wetland Sedge Meadow	25B	Low
Native Wetland Prairie Meadow	26B	Low
Native Western mixed-height Prairie	33B	Low
Native Mixed-height Dry Prairie	38B	Low
Temporary Mixes		
Fall seeding, cover following season	100B	NA
Spring seeding, cover that season	110B	NA
Fall seeding cover following 2 seasons	120B	NA
Fall seeding, cover 2 seasons (legumes)	125B	NA
Spring-fall seeding, cover 1 season	130B	NA
Introduced/native, 1-5 yr. Cover	90B	Medium
Special		
Sedimentation pond basins	25 or 26B	Low
Sedimentation pond upland buffers	use appropriate native mix	Low

Note: The Mn/DOT web site can provide updated seeding designs and recommendations.

4. Sodding

- Use sod to protect slopes at structures such as bridge abutment slopes, culvert ends, at the lower side of superelevated curves, and around hydraulic structures.
- Use sod to protect drainageways such as ditches steeper than 2.5 percent, cut runout ditches.
- Use sod to re-establish lawn areas adjacent to farmsteads, businesses, and/or residents.
- Provide adequate sod quantities for critical drainage areas.

Case Study 1
Crow Wing County CSAH 11, MN

The CSAH 11 Improvement Project in Crow Wing County consisted of grading, surfacing, realigning, and addressing drainage issues for approximately 7 miles of rural section road. Issues associated with the reconstruction of this road included:

- Numerous wetlands adjacent to the roadway
- Major realignment of portions of the road
- Sandy soils

To address the erosion potential during and after the project, a number of erosion control measures were implemented. Each major erosion control measure is outlined below with a discussion of the effectiveness of some measures in relation to this project.

TEMPORARY EROSION CONTROL MEASURES

Bale ditch checks: Hay bales were placed on edge and butted tight within the ditches to reduce flow velocity and trap sediment. Bale checks were anchored to the ground with wood stakes at a 10" minimum.

Heavy Duty Silt Fence: Heavy duty silt fence was used throughout the project area to help reduce the amount of sediment leaving the construction site. Silt fence was generally placed at the toe of the slope with the anchor located on the upstream end of the flow.

Hale bales were used in the ditches to reduce flow velocity.

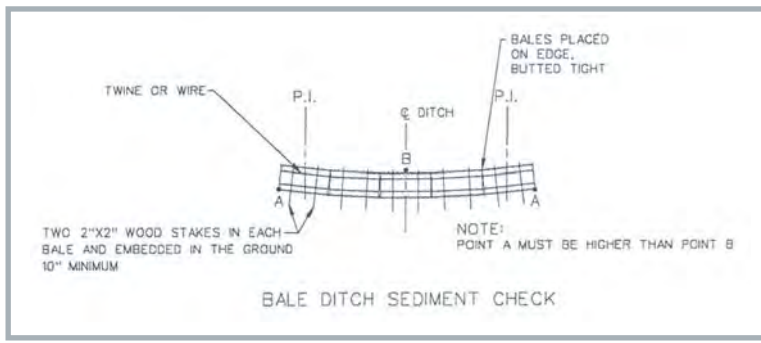
PERMANENT EROSION CONTROL MEASURES

Erosion control blanket: Erosion control blanket, in conjunction with the seeding, was used along the sides and bottom of the ditch sections to prevent erosion caused by water flowing within the ditch after construction. The blanket was anchored into the top of the slope by trenching it into the ground.

Seeding, sodding, and mulching: Seeding, sodding, and mulching were used along the entire length of the project as a permanent erosion control method. Different techniques were used for different purposes and uses of the area. The seeded areas were either mulched, disc anchored or protected with an erosion control blanket.

When water was anticipated to flow in a channelized fashion, sod was placed parallel to the direction of water flow with edges overlapping on the downstream end. When sheet flow was expected, sod was placed perpendicular to the direction of water flow in a shingling pattern.

Riprap: Riprap at the larger culvert outfalls was used to reduce the velocity of water flowing from the culvert.



Typical detail for bale ditch sediment check.

Discussion

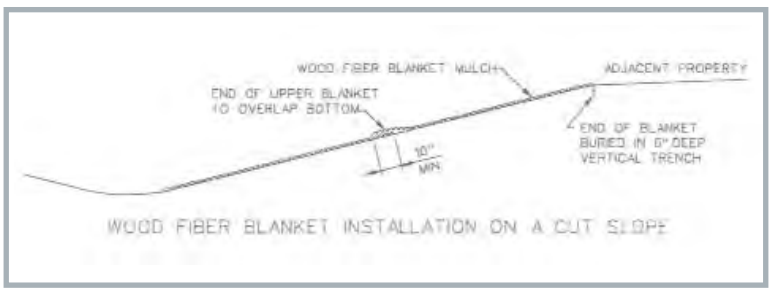
- The erosion control blanket was successful at anchoring the steep ditch slopes, assisting in vegetation establishment, and preventing erosion in the ditches.

- The bale checks were not as successful as the erosion control blanket. The bale checks had a tendency to be damaged in storm events, or the water would flow around the checks.

- The timing of the turf establishment and work completed by the utility company was an issue on the project. The utility company completed work after some of the areas had vegetation established. This utility work created erosion problems within the project area that had not been anticipated. Additional turf establishment work was needed after the project was completed.

- The riprap at the culvert ends has been successful in reducing erosion at these outlets.

Portions of the plan sheets for this project are attached.



Typical detail for erosion control blanket.

Case Study 2
Chisago County CSAH 22, MN

The CSAH 22 Improvement Project in Chisago County consisted of grading, surfacing, and addressing drainage issues for approximately 4 miles of rural section road. Issues associated with the reconstruction of this road included:

- Numerous wetlands adjacent to the roadway
- Ditches/streams and a DNR stream running through the project
- Agricultural runoff impacting water quality
- Large drainage areas
- Moderately sloping topography
- Erosion within the ditches

To address the erosion potential during and after the project, a number of erosion control measures were implemented. Each major erosion control measure is outlined below with a discussion of the effectiveness of some measures in relation to this project.

TEMPORARY EROSION CONTROL MEASURES

Heavy Duty Silt Fence: Heavy duty silt fence was used throughout the project area to help reduce the amount of sediment leaving the construction site. Silt fence was generally placed at the toe of the slope with the anchor located on the upstream end of the flow.

Bale Checks: Bale checks were used along chosen sections of the ditch to assist in reducing erosion and sedimentation within the ditch. Bale checks were placed on edge and tied together with twine or wire.

Silt Fence Ditch Checks: To assist in reducing water velocity in areas of the ditch during construction, silt fence ditch checks were placed within the ditch.

PERMANENT EROSION CONTROL MEASURES

Seeding, sodding, and mulching: Seeding, sodding, and mulching were used along the entire length of the project as a permanent erosion control method. Different techniques were used for different purposes and uses of the area. The seeded areas were either mulched, disc anchored or protected with an erosion control blanket.

When water was anticipated to flow in a channelized fashion, sod was placed parallel to the direction of water flow with edges overlapping on the downstream end. When sheet flow was expected, sod was placed perpendicular to the direction of water flow in a shingling pattern.

Erosion Control Blanket: Erosion control blanket, in conjunction with the seeding mentioned above, was used along the sides and bottom of the ditch sections to prevent erosion from water flowing within the ditch after construction. The blanket was anchored into the top of the slope by trenching it into the ground.

Side Slopes: Along areas not adjacent to wetlands, side slopes in the ditches were generally graded to 1:4 and back slopes were 1:3. Erosion control blanket was added to the 1:3 slopes to prevent erosion.

Riprap Weir: Riprap weirs with Class II riprap were used along the project near the Sunrise River. Type III geotextile fabric was also used for the base of the weir structure to prevent undercutting.

Concrete Drainage Flume: Concrete drainage flumes were used as one of the permanent erosion and sedimentation control measures to address runoff from the edge of roadway where the curb-and-gutter ended and the rural section started. Class III riprap was placed at the outfall of the flume.

Rock Ditch Check: The rock ditch checks consisted of Class IV riprap underlain with a Type IV geotextile fabric liner. These ditch checks were placed in the bottom of the ditch.

Discussion

- The erosion control blanket worked well along the ditch channels and the steeper side slopes. It successfully prevented erosion within the ditch channels, prevented the seed mix from floating away, and prevented the steeper side slopes from eroding.

- The silt fence ditch checks worked better than bale checks. The silt fence ditch checks held together better than bale checks over time, were easier to clean and remove, and held back silt and sediment better than bale checks.

- The concrete flumes had mixed success. Some worked while others failed. One or two catch basins with outlets to the ditch in areas where the flumes were used may have worked better overall.

Portions of the plan sheets for this project are attached.

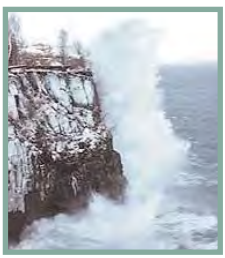
Chapter 8: Erosion Control For Coastal Areas

Coastal erosion occurs as a result of the impact of constant waves and tides along the east or west coast of the United States, as well as in the great lakes. About 200 miles of Lake Superior shoreline borders Minnesota. Erosion of some areas of this shoreline, especially the tall clay bluffs, has accelerated due to runoff from impervious surfaces, clearing existing vegetation, and increased weight at the top of the bluff from development. Over 70,000 tons of sediment erode annually from the clay bluffs along Lake Superior in Minnesota.

There are four general factors that lead to an increased rate of erosion on high bluff shoreland:

- **Wave action at the base:** Wave action at the toe of the bluff removes the soil base and decreases the bluff stability.
- **Weight or pressure from the top:** When roads or other development occur at the top of the bluff, the additional weight that pushes down on the bluff causes pressure and instability within the bluff.
- **Increase runoff and groundwater seepage:** The addition of runoff from impervious surfaces infiltrating the ground further acts to weaken the internal strength of the bluff.
- **Vegetation removal:** Often, development removes existing vegetation from the shoreline or bluff. Removing this vegetation eliminates the natural stabilization factors, resulting in erosion.

These factors lead to instability of the bluff, which eventually causes the bluff to slump down and the bank erodes.



Wave action is one cause of coastal erosion. Source:Minnesota State Historical Society

Several methods for preventing erosion along coastal and shoreland bluffs are listed below:

- **Prevent development along the top of the bluff.** Aligning roads or placing other development away from the top of the bluff eliminates the problem created by placing too much weight on the bluff.

- **Redirect runoff away from the bluff.** Reducing the amount of water directed to the bluff can reduce erosion in two ways. First, redirecting surface water runoff away from the bluff will reduce the water's erosive potential as it flows over the bluff. Second, redirecting surface water that would infiltrate into the ground at the top of the bluff will also reduce erosion of the bluff. Surface water that infiltrates into the ground near the bluff can weaken the bluff's strength and cause slumping or erosion as the groundwater seeps from the bluff.

- **Prevent vegetation removal.** Vegetation plays a vital role in anchoring soil and preventing erosion in any system, but this is especially true of coastal shoreline areas. An easy way to prevent erosion is to allow existing vegetation to remain and prevent disturbance of these areas.

- **Revegetation.** If a bluff or shoreline has already experienced erosion or existing vegetation needs to be removed for a project, stabilizing the area with native plants is one method to reduce erosion and restore the area. Ground cover, shrubs, and trees can be used to revegetate the area. Ground cover plants stabilize the soil's surface, while the deeper roots of shrubs and trees anchor the slope deeper in the ground.

- **Planting design.** Prior to planting, evaluate the site, select the plant species, and design a planting scheme. When evaluating the site, take into consideration the steepness of the slope. If the slope is greater than 1:1.5, other structural erosion control measures may also be needed. When selecting plant species, select native ground covers, shrubs, and trees. Planting container or balled and burlapped shrubs and trees allows for more mature plants to be used and causes less stress on the plant during transplanting. However, this may be cost prohibitive. Site constraints may also make it difficult to use containers or balled and burlapped plants. In these situations, bare root stock should be used.

- **French drains.** If surface water cannot be directed away from a bluff or steep slope, French drains can be used to intercept the water before it reaches the bluff. Install them on the back side of the bluff. The drain contains a perforated plastic pipe that is wrapped in a filter fabric and placed at the bottom of the drain parallel to the bluff. The drain is then filled with sand or gravel to cover the pipe. Water will filter through the sand or gravel and collect in the pipe. The pipe should drain water away from the bluff or slope and the outfall should also be protected from erosion.

- **Rip-rap.** In areas with severe wave action where vegetation alone will not work, the shore or bluff can be armored with rip-rap. Place a geotextile fabric under the rip-rap to prevent undercutting of the rock from the waves. Rip-rap size will depend on the force of the waves. Use sufficient material at the toe of the slope to protect this area. For additional discussion on rip-rap placement, see Chapter 7.

- **Rock buttresses.** In areas that vegetation alone will not work due to very steep slopes, installing rock buttresses at the base of the slope is an effective way to reduce the erosive potential of wave action.

Case Study
Coastal Erosion on Lake Superior

The Board of Water and Soil Resources completed the Lake Superior Sucker Bay project just east of the Sucker River with grant money from the Environmental Protection Agency and the Great Lakes Commission. This project utilized an innovative approach to address erosion along 1,050 feet of tall clay bluff of Lake Superior. It was estimated that this site was producing 4,820 tons of eroded material into Lake Superior every year. To stabilize the bluff, a number of techniques were used:

- **Rock buttresses:** Approximately 6,800 cubic yards (cy) of buttress rock were used along the toe of the bluff to provide weight and protection to the bottom of the bluff. This buttress was further protected by approximately 3,070 cy of 1-3 ton armor stone on the lake side of the buttress.

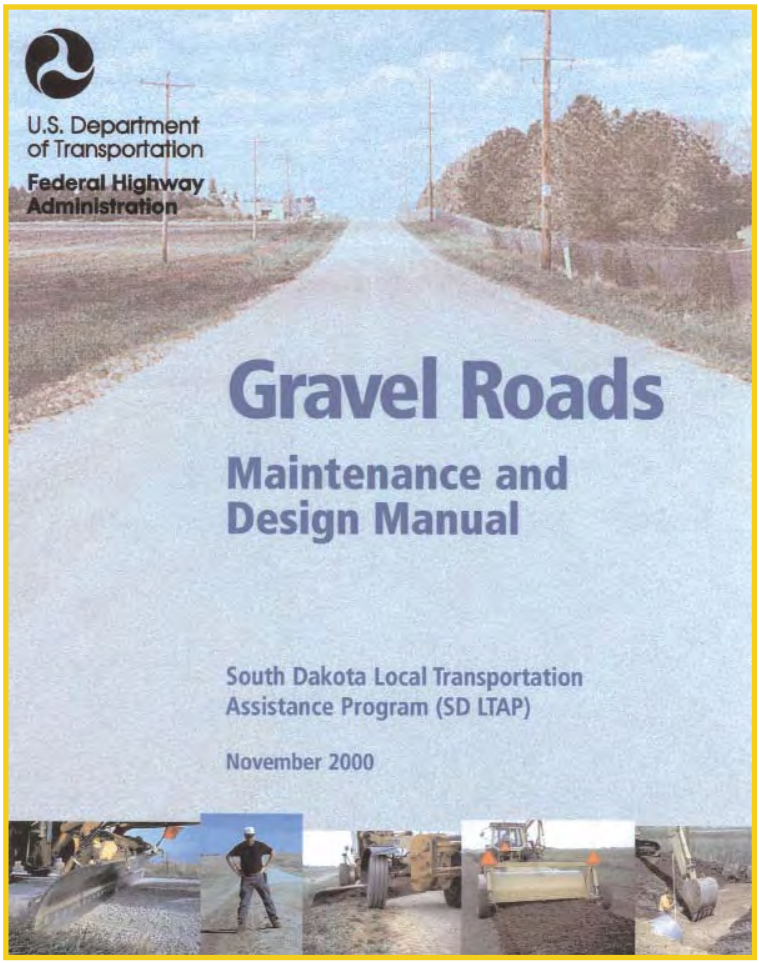
- **French drains:** Along the top of the bluff, a 640 foot long French drain system was installed to collect surface water and some shallow groundwater. This system had three surface intakes and was placed in a trench with granular material and a perforated pipe.

- **Revegetation:** Although not completed yet, this project also includes revegetating the slope to prevent erosion as funds become available.

Placing buttress rock and armor stone at toe of slope. Photo courtesy of BWSR.

Chapter 9: Gravel Road Maintenance

This chapter will outline suggestions for controlling or repairing erosion on gravel roads. Most of the information from this chapter was taken from the Gravel Roads Maintenance and Design Manual developed by the South Dakota Local Technical Assistance program. That manual is available on line at *www.ltapt2.org/gravel/gravelroads.htm.*



Typical gravel road maintenance includes routine blading and adding gravel as needed. Over time, additional work may be required as berms or secondary ditches that build up along the shoulder line develop, and as material shifts from the surface to the shoulder area or grade inslope. These problems cause disruptions to the drainage patterns and lead to erosion.

Surface and shoulder reshaping can be completed with the motorgrader alone. This is best completed in the spring when there is minimal vegetative growth and moisture present. Compact the aggregate material after it has been cut and repositioned, which will leave a denser, stronger, smoother surface that is easier to maintain.

Reshaping the entire section may be required when severe rutting, loss of crown, excessive gravel loss, or deep secondary ditches are present. When these factors are present, reshaping must be done immediately regardless of the vegetative growth. Equipment includes motorgraders, disks, pulverizers/mixers and rollers. It is important to put enough pressure on the blade to cut shoulders and washboard ridges, to rebuild a uniform cross section, and restore the drainage patters to their designed conditions. Scarify the surface when necessary, and note that more than one pass may be needed. Place new surface gravel after the road has been totally regarded. Again, compact the aggregate material after it has been cut and repositioned, which will leave a denser, stronger, smoother surface that is easier to maintain.

Erosion control is an important element of gravel road maintenance. When major reshaping is completed and extends beyond the gravel surface, vegetation and ground cover are disturbed, which can cause erosion. This is especially true in areas with rolling or rugged terrain, heavy precipitation, and where the soil is highly erodible. Grading outside the gravel surface also causes increased sediment to enter the drainage system, clogging ditches and culverts and affecting water quality. And, eroded slopes can require additional grading and maintenance.

Some considerations for erosion control on gravel roads are listed below:

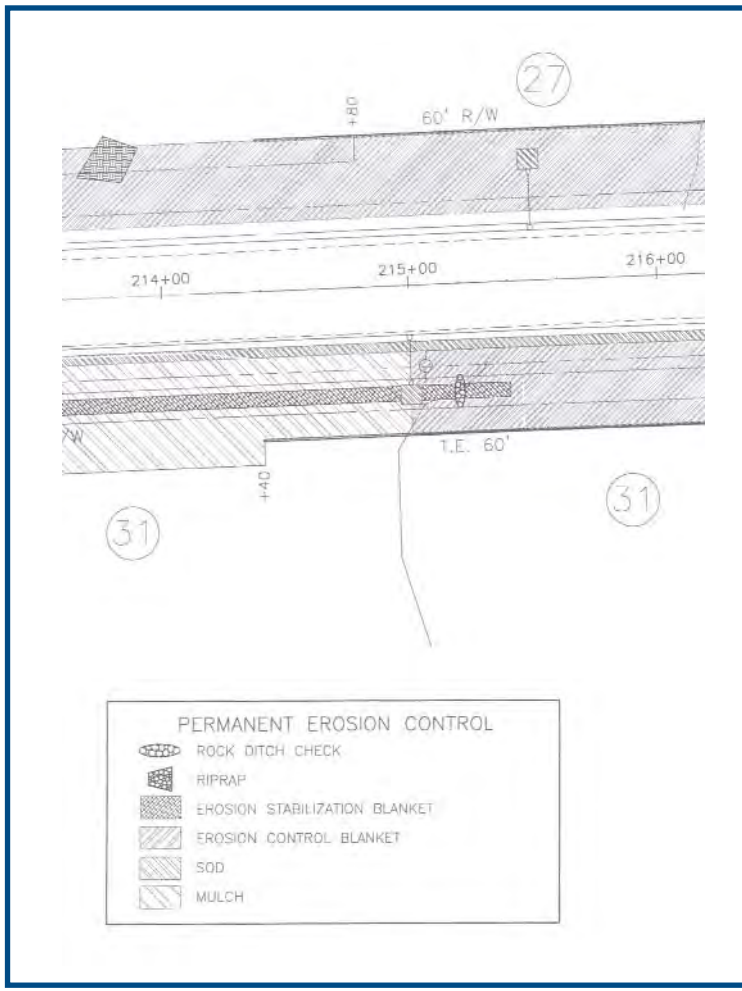
- **Avoid major reshaping work during times when frequent or heavy rainfall rainfall is expected.**
- **Minimize disturbed areas.** Set work boundaries and don't let work crews go beyond them.
- **Consider stabilization of disturbed areas.** This includes using silt fence, mulching, or erosion control blankets.
- **Keep water velocity low.** Removing vegetative cover and topsoil increases the runoff amount and velocity. Keeping slopes as shallow and smooth as possible also reduces water velocity. Shorten drainage runs and work to establish vegetative cover as soon as possible after completing maintenance work.
- **Contain sediment within work boundaries by using a silt fence or ditch checks to filter water or slow it down until soil particles can settle out.**
- **Inspect recent work to make sure channels haven't formed in ditch bottoms or on slopes,** or around and under controls that were used. This is especially important after heavy rains.

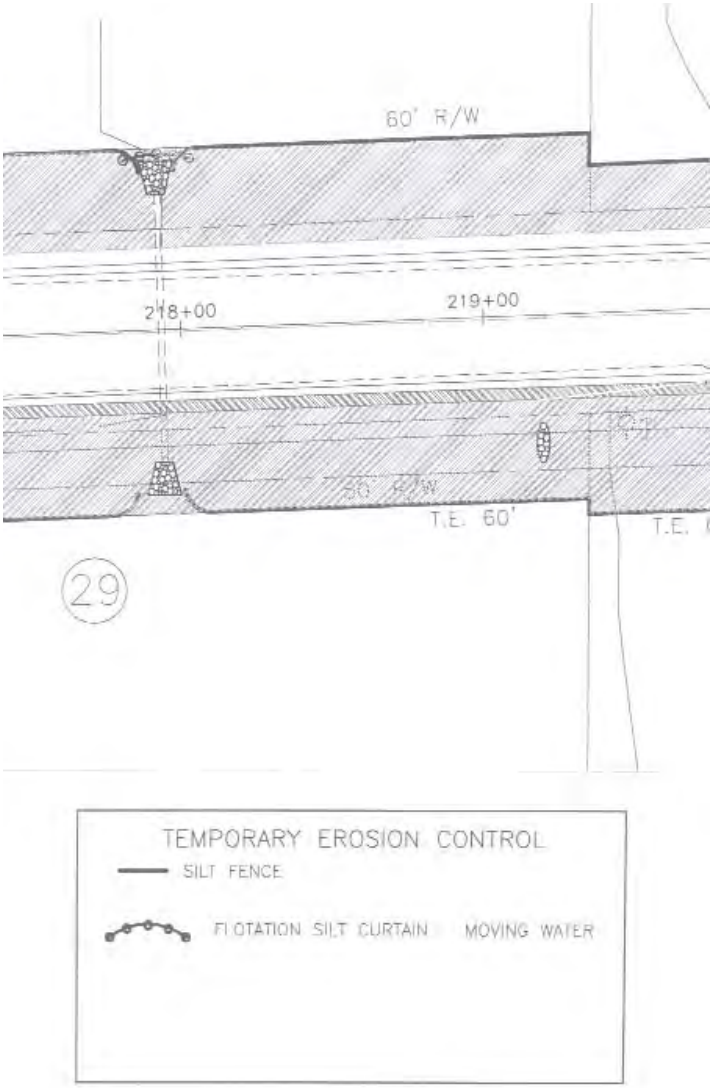
Erosion control is an important element of gravel road maintenance.

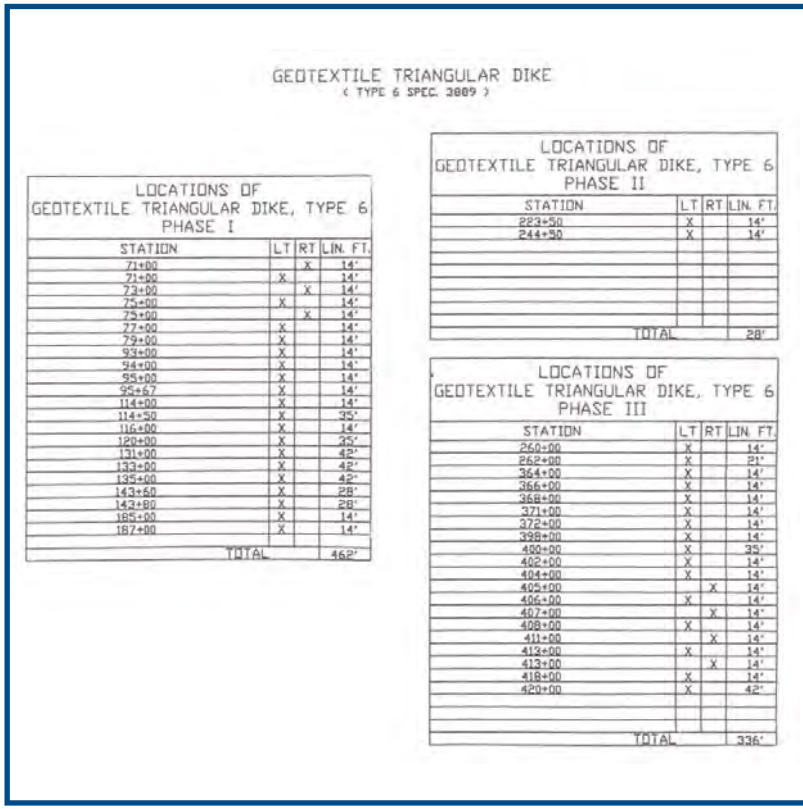
Appendix - Sample Plans

Plan 1

This plan illustrates how one Minnesota county includes the erosion control requirements into their own **plan view** for the project. Plan sheets are developed specifically for erosion control.




60' R/W
218+00
219+00
50' R/W
T.E. 60'
T.E.
29
TEMPORARY EROSION CONTROL
SILT FENCE
FLOTATION SILT CURTAIN
MOVING WATER



GEOTEXTILE TRIANGULAR DIKE
(TYPE 6 SPEC. 3889)

LOCATIONS OF
GEOTEXTILE TRIANGULAR DIKE, TYPE 6
PHASE I

STATION	LT	RT	LIN. FT.
71+00		X	14'
71+00	X		14'
73+00		X	14'
75+00	X		14'
75+00		X	14'
77+00	X		14'
79+00	X		14'
93+00	X		14'
94+00	X		14'
95+00	X		14'
95+67	X		14'
114+00	X		14'
114+50	X		35'
116+00	X		14'
120+00	X		35'
131+00	X		42'
133+00	X		42'
135+00	X		42'
143+60	X		28'
143+80	X		28'
185+00	X		14'
187+00	X		14'
TOTAL			462'

LOCATIONS OF
GEOTEXTILE TRIANGULAR DIKE, TYPE 6
PHASE II

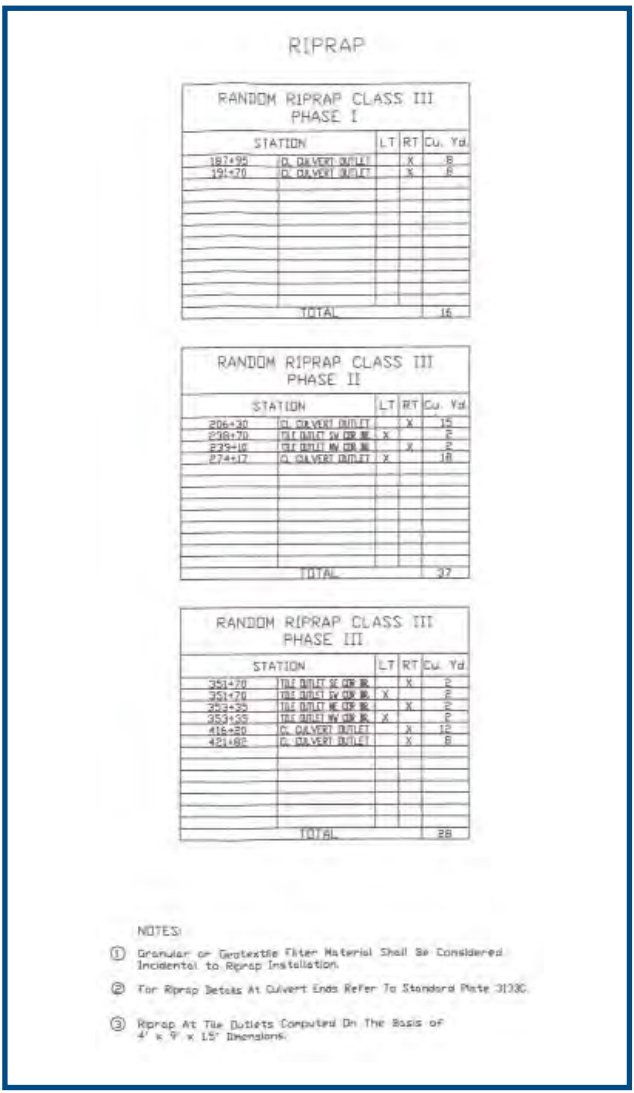
STATION	LT	RT	LIN. FT.
223+50	X		14'
244+50	X		14'
TOTAL			28'

LOCATIONS OF
GEOTEXTILE TRIANGULAR DIKE, TYPE 6
PHASE III

STATION	LT	RT	LIN. FT.
260+00	X		14'
262+00	X		21'
364+00	X		14'
366+00	X		14'
368+00	X		14'
371+00	X		14'
372+00	X		14'
398+00	X		14'
400+00	X		35'
402+00	X		14'
404+00	X		14'
405+00		X	14'
406+00	X		14'
407+00		X	14'
408+00	X		14'
411+00		X	14'
413+00	X		14'
413+00		X	14'
418+00	X		14'
420+00	X		42'
TOTAL			336'

Plan 2

This plan illustrates how another county incorporates erosion control requirements in tabular form. Tables summarizing placement of various erosion control techniques and products, along with standard details are provided that correlate to project plan view drawings.



RIPRAP

RANDOM RIPRAP CLASS III
PHASE I

STATION		LT	RT	Cu. Yd.
187+95	CL CULVERT OUTLET		X	8
191+70	CL CULVERT OUTLET		X	8
TOTAL				16

RANDOM RIPRAP CLASS III
PHASE II

STATION		LT	RT	Cu. Yd.
206+30	CL CULVERT OUTLET		X	15
230+70	TILE OUTLET SW CORNER	X		2
235+15	TILE OUTLET NW CORNER		X	2
274+17	CL CULVERT OUTLET	X		18
TOTAL				37

RANDOM RIPRAP CLASS III
PHASE III

STATION		LT	RT	Cu. Yd.
351+70	TILE OUTLET SE CORNER		X	2
351+70	TILE OUTLET SW CORNER	X		2
353+35	TILE OUTLET NE CORNER		X	2
353+35	TILE OUTLET NW CORNER	X		2
416+20	CL CULVERT OUTLET		X	12
421+82	CL CULVERT OUTLET		X	8
TOTAL				28

NOTES:

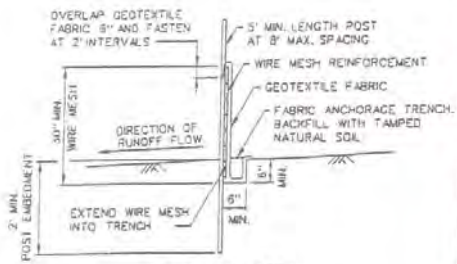
① Granular or Geotextile Filter Material Shall Be Considered Incidental to Riprap Installation.

② For Riprap Details At Culvert Ends Refer To Standard Plate 3133C.

③ Riprap At Tile Outlets Computed On The Basis of 4' x 9' x 1.5' Dimensions.

Plan 3

This plan illustrates erosion control shown in plan views for the project outlined in Case Study 1.



SILT FENCE DETAIL

SILT FENCE		
STA. TO STA.	LOC.	LIN. FT.
130+00 - 138+00	RT.	800
133+75 - 137+25	LT.	350
138+00 - 138+75	LT.	75
144+00 - 149+00	RT.	500
160+50 - 164+50	RT.	400
163+75 - 164+75	LT.	100
233+00 - 240+75	LT.	775
233+00 - 239+50	RT.	650
370+00 - 375+00	LT.	500
370+00 - 375+00	RT.	500
391+75 - 405+00	LT.	1325
391+75 - 405+00	RT.	1325
47+50 - 49+25	LT.	175
TOTAL		7475

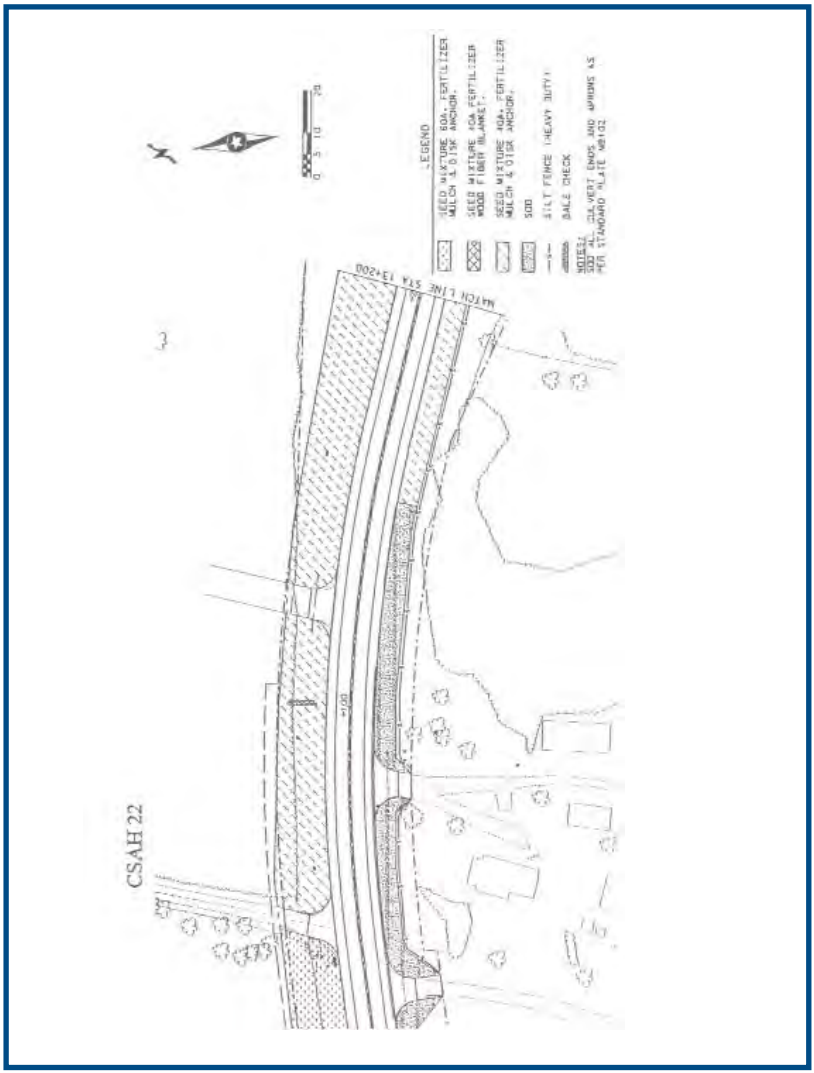
ROADWAY EMBANKMENT

SILT FENCE TO PROTECT ADJACENT CRITICAL AREAS

AREA SODDING			
STA. TO STA.	LOC.	SQ. YD.	REMARKS
100+75 | 107+00	RT.	1100	DITCH BOTTOM
102+97 | 110+69	RT.	315	INSIDE CURVE
127+00 | 132+00	LT.	890	DITCH BOTTOM
132+24 | 144+91	LT.	845	INSIDE CURVE
168+00 | 171+00	LT. & RT.	1070	DITCH BOTTOM
179+00 | 185+00	LT.	1070	DITCH BOTTOM
182+00 | 183+00	RT.	180	DITCH BOTTOM
230+00 | 232+00	LT. & RT.	360	DITCH BOTTOM
285+40 | 305+18	RT.	1320	INSIDE CURVE
329+00 | 337+00	LT. & RT.	2850	DITCH BOTTOM
355+57 | 382+89	LT.	1820	INSIDE CURVE
387+00 | 390+50	LT. & RT.	1240	DITCH BOTTOM
406+81 | 426+17	RT.	1310	INSIDE CURVE
455+68 | 471+00	LT.	1020	INSIDE CURVE
38 15" CMP @ 17		986	CULVERT ENDS
65 ENTRANCES @ 43		2795	RADIUS
8 APPROACHES @ 80		640	RADIUS
40 YARDS @ 560		22400	YARDS
TOTAL		42421	

Plan 4

This plan illustrates erosion control for the project outlined in Case Study 2. This erosion control plan was implemented through the use of details and tables.



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