CHAPTER 8
DRAINAGE DESIGN AND EROSION CONTROL

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8-1.0 INTRODUCTION

It is the goal of this chapter to equip MnDOT designers and engineers with a reference on drainage design and erosion control that will see them through the highway design process in a majority of the projects they encounter. To achieve this, in some instances procedures are covered by reference to MnDOT's Drainage Manual or other publications.

8-1.01 Manuals

The Department's system of manuals includes MnDOT's Drainage Manual. It will be necessary for the designer to refer to both the Road Design Manual and the Drainage Manual for information.

8-1.02 Importance of Drainage

1. Drainage
   Drainage is designed for and installed into highways to direct surface and subsurface flow away from structural elements of a roadway, and to then convey it to a safe outfall without damage to the highway or adjacent property.
2. Erosion Control
   Erosion control is provided to prevent soil damage done by moving water, either the displacement of soil by water in motion or the deposit of soil by sedimentation at points of low flow velocity.

The importance of drainage and erosion control cannot be over-emphasized. Relatively insignificant errant flows over time can do great damage, while conversely, storms not properly anticipated can suddenly endanger lives and property. Proper hydrologic calculations accompanied by adequate hydraulic design can avert such damages at a cost acceptable to the highway agencies.

8-1.03 Drainage Law

Highway design personnel have a responsibility to anticipate and prevent, to the greatest extent possible, damage to public and private property resulting from changes they make in natural drainage patterns. An evaluation is required when the flow of several small streams is to be concentrated into a single structure or channel. This responsibility extends to locations downstream and elsewhere, wherever damage may occur as a direct result of drainage from a project in question. The most common effects brought about by deficiencies in drainage design are excessive erosion, sedimentation, and flooding. Legal action by affected property owners is not uncommon and has increased in recent years.

There are limits to the designer's responsibility. Flows generated by an unprecedented storm or other flows beyond normal control cannot be accommodated in the drainage design. Overall, the designer should strive to develop drainage designs that are complete and that affect natural drainage patterns to the least possible degree, thus avoiding the many potential problems and consequences associated with inadequate designs. An extensive discussion of the subject with references appears in the latest edition of Highway Drainage Guidelines, (The Legal Aspects of Highway Drainage, Vol. V), published by AASHTO. One other document with legal implications in the area of drainage design is "Federal Wetlands Executive Order 11988 on Flood Plain Management".

8-2.0 HYDROLOGY

Hydrology is generally defined as a science dealing with the interrelationship between water on and under the earth and in the atmosphere. For the purpose of this manual, hydrology will deal with estimating flood magnitudes as the result of precipitation. In the design of highway drainage structures, floods are usually considered in terms of peak runoff or discharge in cubic feet per second (ft^3/s) and hydrographs as discharge per time. For structures which are designed to control volume of runoff, like detention storage facilities, where flood routing is used, the entire discharge hydrograph will be of interest.

For information regarding hydrology, the designer should refer to the MnDOT Drainage Manual.

The major subjects covered in the Hydrology chapter of the Drainage Manual are:

1. Design frequency
2. Hydrologic procedures
3. Time of concentration
4. Rational method
5. SCS method
6. USGS regression equations
7. Analysis of stream gauge data

8-3.0 MEANS OF DRAINAGE CONVEYANCE

8-3.01 Roadway Typical Section and Alignment

A roadway must be carefully shaped and graded to remain "high and dry". The combination of: (1) centerline grade (with respect to existing ground), (2) typical section (the shape of the roadway structure including ditches), and (3) vertical alignment (the succession of centerline grades) must be established to prevent inundation of the roadway and its supporting structure.

This grading and shaping of the roadway and roadsides is the first step in drainage design and serves to get runoff started toward the other more explicit drainage collectors and conveyances. The discussions of alignment and typical section in Chapters Three and Four, respectively, provide guidelines for this initial work.

An additional step should be taken when reconstructing an existing roadway. Where the roadway embankment represents a berm which might retain runoff (act as a dam) at the occurrence of a severe storm, a risk assessment for the revised alignment with regard to possible flooding should be done, and the implications for affected properties assessed.

8-3.02 Open Channels or Ditches

Open channels or ditches are the simplest and cheapest means for collecting and conveying flows which are to be drained. These channels or ditches are extremely variable in size and shape and have many different applications. Included below are the several different functional types as established in FHWA Hydraulic Design Series No. 4, titled <u>Introduction to Highway Hydraulics</u>. For design of channels, the designer should also refer to the Drainage Manual.

1. Gutters - These are used in the urban areas or on parkways. They are formed using a curb at the edge of the pavement or shoulder.
2. Roadside Ditches - These are channels parallel to the edge of the roadway which collect runoff from pavement and cut slopes and conduct it longitudinally to an outfall. A discussion of the most desirable slopes and widths to be provided for safety considerations appears in Chapter Four.
3. Toe of Fill Channel - Located at the toe of fill, these channels, when required, provide a course for water to an outfall or to a location where the flow can be diffused overland without ill effect.
4. Intercepting Channels - These channels are located at the top of cut slopes. They intercept flows above the cut to prevent excessive flows down the cut slopes. Multiple channels are sometimes used in areas where percolation of water into the soil is desirable. These installations should only be undertaken, however, with the approval of the Soils Engineer, since the establishment of excessive ground water flows at cut slopes may cause slope instability.
5. Median Ditches - These gently sloped shallow courses conduct runoff to the intermittent collection points in median areas. Since medians in road sections are generally not curbed, all runoff from lanes between the divided roadway crowns and the median area itself must be handled by these ditches. Median ditch grades may vary from roadway longitudinal slope to achieve the desired drainage.
6. Channel Changes - In the past, natural waterways have often been realigned, straightened and/or combined with other streams or natural outfall channels. Downstream erosion damage, ditch failures and other negative environmental impacts, including damage to natural habitats, have occurred when the many effects of such changes were not adequately anticipated. Channel changes should not be considered as an option for convenience or short-cut. Changes to stream alignments should only be made when they are unavoidable, and then only with complete analysis and discussion with other appropriate agencies.
7. Off-take Ditches - This type of ditch is used when runoff collected along the roadway must be conducted in a direction more or less perpendicular to the roadway to some parallel outfall such as a river or lake shore. Property lines often provide a convenient alignment. These ditches can provide an economical alternative where carrying significant flows parallel to the roadway is difficult or impossible.

8-3.03 Culverts

Culverts are open-ended conduits which carry runoff and other flows under a roadway or roadways. Pipes of a storm drain system are not considered culverts. They will be treated separately. Culverts for highway applications may be of many materials and of many shapes, sizes and lengths or may be custom constructed on-site from plans requiring unique shapes, sizes and appurtenances. There are also prefabricated products which are made-to-order for assembly in the field.

The common materials of which culverts are currently made are corrugated metal, with several coatings and treatments available, and reinforced concrete. Common sectional shapes include round, box, and arches of different geometric proportions. MnDOT's Standard Plates Manual 3000 series provides details for many standard culverts and culvert appurtenances. Selection of materials for each application should be made with information from the Drainage Manual in accordance with the materials selection policy. Information regarding culvert design is available in the Drainage Manual.

8-3.04 Storm Drain Systems

Systems of inlets and pipe sewers which serve to collect and carry storm and surface water from the right of way to an outfall (or to a culvert leading to an outfall) form a storm drain system. These systems are used in urban, suburban, and other built-up areas where roadway channels are undesirable and/or there is insufficient right of way.

Water enters these systems through inlets, drop inlets, and catch basins. Curb and/or gutter are often used to direct surface flow towards inlets and are also conversely the location beneath which the systems are often located. Manholes are built to facilitate pipe intersections where a surface water inlet is not needed. Manholes also provide opportunities for vertical and horizontal directional changes. They are also installed on straight runs of pipe over 400 ft in length to provide for maintenance and other needed access. The MnDOT Standard Plates Manual provides plans for the many types of pipe sewer, inlets, manholes, and other appurtenances. The Drainage Manual provides information regarding storm drain systems.

8-3.05 Definitions of Pipe Culverts and Storm Drain Systems

For clarity, the following definitions are provided.

1. A pipe culvert is defined as a conduit with open ends through which surface water flows transversely under one or more roadways. It may include intermediate median drains or junctioning conduits, but such junctioning conduits shall be classified as pipe culverts only if they consist of a single conduit with an open end.
2. A storm drain system is a conduit or interconnected complex of conduits that conveys storm water runoff. Water is admitted to the system primarily through drains and catch basins. An open-end conduit is classified as a storm drain if it connects to a system of conduits.

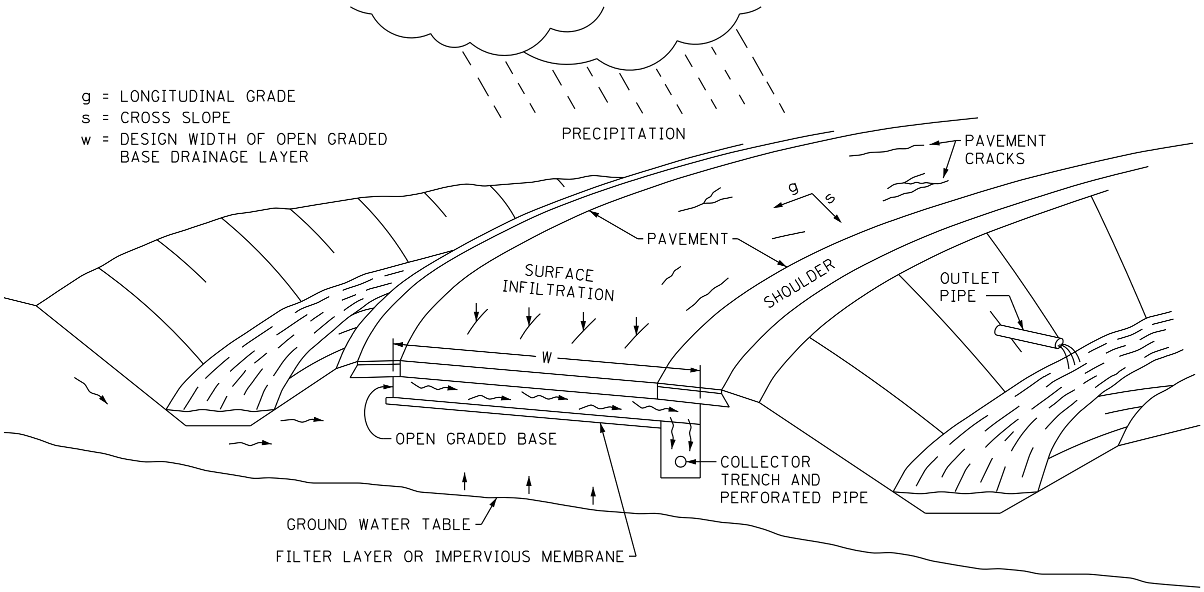
An enclosed pipe flume is a term used to describe a conduit designed to convey water down a steep slope. Pipe flumes should be considered as storm drains or culverts according to the above definitions.

Where practical, in accord with the foregoing definitions and explanations, any interconnected system of conduits should be classified wholly as pipe culvert or storm drain system.

8-3.06 Subsurface Drainage

The structural integrity of a roadway's base is greatly reduced by inundation, since water reduces the necessary friction between adjacent gravel particles. Properly installed subsurface drains provide an outfall for water in the roadway base, whether it originated from subsurface flows or seepage through pavement and shoulders. See Figure 8-3.06A or an example. The removal of this water allows the required high friction between particles to be retained.

Subsurface drainage (sometimes called under-drainage) consists of perforated pipe placed in a highly permeable layer of granular material where inflow seepage or high ground water occur. The effectiveness of the subsurface drainage will be directly related to (1) the ability of the base layer to transmit inflows to the subsurface drainage pipes and (2) the ability of the pipes to transport the flows to a safe outfall. As long as the combination of the permeable base and subsurface drainage pipes continues to conduct water away faster than the base is inundated, a high percentage of the dry strength of the aggregate base will be retained.



SUBSURFACE DRAINAGE SYSTEM

Figure 8-3.06A

The configuration of perforated pipe is variable, depending on the magnitude and location of the inundation. Proper operation can be expected if the following are provided and maintained:

1. Permeable material in base layer and perforated pipe trench for transmission of inflows
2. Adequate pipe and outfalls
3. Positive slope in permeable layer and pipes

8-3.07 Stormwater Holding Ponds

It may be necessary to construct ponding areas in conjunction with roadway projects. Ponding areas typically provide for peak flow attenuation and/or water quality improvements. Ponding may be required due to a limit in downstream conveyance capabilities of a culvert or storm drain, the requirements of a regulatory agency, or other reasons. The District Hydraulics Engineer should determine the need for stormwater ponding areas. The district should also determine if a need exists to provide fencing around the perimeter of the pond. Ponding sites should be identified early in the design process, as purchase of additional right of way may be needed.

8-4.0 HYDRAULIC DESIGN

The drainage facilities designed for any highway will probably include a mixture of open channels, ditches, culverts, perhaps storm drains and underdrain. For each of these components, adequate hydraulic design should be done to assure that each has the capacity to handle the flows anticipated and that the design chosen is the most economical use of resources. The many design methods and aids embodied in charts, graphs, nomographs and computer programs reduce the effort required to generate alternate designs sufficiently to allow for multiple designs.

A short section follows on hydraulic design for each of the types of drainage means.

8-4.01 Open Channel Flow

8-4.01.01 Design Discharge

Commonly, a design discharge Q will be determined and an inlet and outlet location chosen such that approximate slope can be calculated. From these data, a channel is designed to handle the flow, avoid erosion and satisfy any safety requirements.

8-4.01.02 Channel Grade

Open channels should be graded to a desirable minimum gradient of 0.005 ft/ft so that some slight settlements will not create large areas of standing water. Maximum slopes should reflect the type of soil and linings to be used especially for grass lined channels.

8-4.01.03 Channel Alignment

Changes in alignment should be made as gradually as possible so as to introduce the least amount of unstable flow. When possible, locate horizontal curves where profile is flattest.

8-4.01.04 Channel Cross Section and Side Slopes

Trapezoidal shaped channels are recommended for their relative economy, safety, ease of construction and hydraulic effectiveness. MnDOT has adopted the trapezoidal shape as standard for roadside ditches. Hydraulic considerations must be made recognizing that the front slope of the ditch will also be the side slope of the roadway section. For this application, side slope criteria per design standards and Section 4-6.01 apply.

Similarly, back slopes at roadside ditches are constrained to be as flat as practicable for safety and erosion reasons. Right of way width and adjacent topography, in addition to hydraulic efficiency, will force the designer to make a judgmental compromise in many cases. Alternative compromise solutions can be tested with the solution of Mannings equation for hydraulics and Figure 4-6.03C for safety and traversability.

Channel cross sections at other than roadside locations should be determined by hydraulic and erosion considerations to achieve a channel that has adequate capacity for the flow quantity to be handled, will require little or no maintenance, will fit in the space available and will be economically acceptable to construct.

8-4.01.05 Channel Linings

Channel lining is needed when the velocity of the design flow exceeds that permissible as shown in Table 8-4.01A. Lining types include grass of many types, concrete, bituminous materials, stone and others.

The combination of advantages and disadvantages for each material may complicate the designer's choice. A listing of characteristics for each lining material follows:

Grass Lining:

- n values vary due to type and height (n is Mannings' roughness coefficient)
- inexpensive to build
- self healing
- require protection until turf established

Concrete:

- low n value
- expensive to build
- susceptible to heaving, undermining and buoyancy
- rigid
- often requires energy dissipation at outlet

Bituminous Material Lining:

- n similar to concrete
- flexible under settlement, heave, and buoyancy
- susceptible to weed ingrowth
- energy dissipation often necessary
- susceptible to undermining
- generally, these are more expensive to build than grass linings

Riprap Linings:

- n quite variable based on stone size and whether dumped, placed, or placed and grouted
- can be inexpensive where stone plentiful
- usually require filter blanket base
- offer designer broad flexibility, although expense varies significantly
- where ungrouted, adjusts well to settlement
- low maintenance

Expanded discussions useful in design applications are available in Introduction to Highway Hydraulics, HDS No. 4, from FHWA, and in Design of Roadside Channels with Flexible Linings, HEC No. 15, also from FHWA.

Table 8-4.01A
PERMISSIBLE VELOCITIES IN GRASS-LINED CHANNELS

Maximum permissible velocities in channels lined with uniform stands of various grass covers, well maintained. [1,2]

COVER	SLOPE RATE Percent	Maximum Permissible Velocity On …	
		Erosion Resistant Soils ft/s	Easily Eroded Soils ft/s
Bermudagrass	0 – 5 5 – 10 Over 10	8 7 6	6 5 4
Buffalograss Kentucky Bluegrass Smooth Brome Blue Grama	0 – 5 5 – 10 Over 10	7 6 5	5 4 3
Grass Mixture	0 – 5[3] 5 – 10[3]	5 4	4 3
Lespedesa Services Weeping Lovegrass Yellow Bloestem Kudzu Alfalfa Crabgrass	0 – 5[4]	3.7	2.7
Common Lespadeza[5] Sudangrass[5]	0 – 5[4]	3.7	2.7

[1] From Handbook of Channel Design for Soil and Water Conservation.

[2] Use velocities over 5 ft/s only where good covers and proper maintenance can be obtained.

[3] Do not use on slopes steeper than 10 percent.

[4] Use on slopes steeper than 5 percent is not recommended.

[5] Annuals, used on mild slopes or as temporary protection until permanent covers are established.

8-4.02 Culvert Design

The objective of any culvert design effort is to provide the most economical means of passing peak flows from one side of the roadway embankment to the other within the physical constraints provided.

The principles of design for culverts include treatments for several different cases that fall into two distinct categories based on the controlling location along the flow alignment through the culvert. One category is denoted "Inlet control" and includes those cases where the depth and geometry of the flow at the culvert inlet determine the capacity of the culvert. The other category, denoted, "Outlet control", includes the remainder of cases where the culvert slope, length and roughness, in conjunction with the geometry, and depth of flow at the outlet, control the flow capacity of the culvert.

The MnDOT Drainage Manual provides information regarding culvert design. The primary information in the Drainage Manual includes:

1. Design criteria
2. Culvert Analysis
3. Design procedure

8-4.02.01 Entrance Culverts

Entrance profiles should be designed with a depression below the shoulder of the highway, as indicated in Standard Plate 9000. In conjunction with this depression, entrance culverts are normally designed for a ten-year frequency discharge under the assumption that higher flows will overtop the entrance at the depression and continue flowing in the roadside ditch.

In instances where physical conditions or restricted right of way make it impossible to develop this depression, the adverse effects of diverting water onto the highway should be evaluated. In some cases it may be necessary to design the entrance culvert for a fifty-year frequency discharge to prevent frequent flooding of the roadway.

8-4.02.02 Large Culverts

Large culverts are defined as structures or set of parallel structures (i.e. two barrels) where the total width is equal to or greater than 10 ft.

Structural design responsibility for these structures, whether, prefabricated or fabricated on-site, belongs to the Office of Bridges and Structures. For projects containing such structures, early coordination should be established to reserve adequate space in the plans and provide the designer(s) adequate lead time with design constraints and criteria. Hydraulic design should be done in consultation with District Hydraulics personnel or the Office of Bridges and Structures, Hydraulics Section.

8-4.03 Culvert Design Policy

The Culvert Chapter of the Drainage Manual provides design criteria and general policy regarding highway culverts.

8-4.03.01 Safety Design Policy

It is the design objective to create a reasonably wide roadside recovery area for vehicles that may leave the roadway. The criteria for the determination of that variable width, sometimes called the "clear zone", are presented in Section 4-6.04. The following minimum guidelines should apply to the placement of drainage structures.

1. Centerline Culverts: Centerline culverts are culverts perpendicular to the roadway. All centerline culverts should be of sufficient length to provide a clear zone distance equal to the distance provided by the roadsides ahead and behind the culvert. This clear zone may be achieved using safety grates on centerline culverts, but only after an evaluation is made of the flood hazard to upstream property and the highway should the grates plug with debris. Guardrail should be considered in lieu of grates where the debris and flood damage potential are high. Grates should never be used at the outlet of a pipe unless they are also used at the inlet.
   Where roadsides ahead and behind a proposed centerline culvert do not give a clear indication of appropriate clear zone width, a determination should be made with the criteria provided in Section 4-6.04.
2. Side Culverts: Side culverts are culverts parallel to the roadway. All side culverts, including PC-Catch Basins in medians, should either be placed beyond the clear zone ahead and behind the culvert or protected by grates.
3. Median Drains: Flush median drains should be used wherever possible because of their safer performance.

8-4.03.02 Safety Guidelines for Culverts

The attached guidelines were compiled from the Texas Transportation Institute, Transportation Research Board, Roadside Design Guide, MnDOT manuals and meetings with the FHWA, and the Final Design Advisory committee.

The application of these guidelines assumes use on trunk highways and the clear zones appropriate to them. For urban areas with lower speeds, judgment should be used as to their application. Clear zone criteria may also be applied at locations where auxiliary roadways such as frontage roads are involved. They normally will not require the use of these guidelines because of the shorter clear zones but the designer should use judgement on their application. Although pipes outside of the clear zone do not require safety aprons, the latter may be installed to match slopes better. In general, if a safety grate is needed on a pipe outlet, a light duty grate should be installed at the inlet.

DEFINITIONS

Safety Aprons:

An apron for the end of pipe culverts or pipe sewers that has mitered sides. The width of safety apron = the pipe diameter. Standard Plates 3022, 3128 and 3148.

Safety Grate:

A bar system used over the culvert or sewer apron opening to allow vehicles to pass over the opening safely. Standard Plates 3128, 3132, 3148 and an unapproved detail available from the Standards Server.

Trash Guard:

A bar system used over the culvert or sewer apron opening to keep out trash, and in some cases, mammals that seek shelter. This bar system is not childproof if the spacing of the bars exceeds 6 in. This bar system is not considered a safety grate.

Critical Clear Opening:

The clear distance a culvert or sewer apron opening that a vehicle can safely transverse before a safety grate is required.

CLEAR ZONE

Any culvert end outside of the clear zone does not need a safety apron or safety grate.

The following criteria are for culverts within the clear zone.

A. Cross-Drainage Structures (Centerline Pipes)
Critical clear opening = 30 in. pipe placed perpendicular to the roadway

Without Safety Apron (Flared End)

Round Pipe
15 in. or less - no safety grate required
18 in. or greater - safety grate required

Span Pipe
All sizes - safety grate required

All multiple pipes - safety grate required

With Safety Apron (Mitered End)

Round Pipe
36 in. or less - no safety grate required
42 in. to 72 in. - safety grate required.
78 in. or greater - no safety apron available, use flared end with grate

Span Pipe
36 in. span or less - no safety grate required. Equivalent round = 30 in.
44 in. span to 102 in. - no safety apron available, use flared end with safety grate. Equivalent round = 36 in. to 84 in.
115 in. or greater - use Standard Plate 3114 with safety grate. Equivalent round = 90 in.
Multiple Pipe

Round 30 in. or less - no safety grate required
Span 28 in. or less - no safety grate required. Equivalent round = 24 in.

Note: Pipe sizes are based on concrete pipe.

New Construction

- Use safety aprons whenever possible.
- Concrete safety aprons (Standard Plate 3022) can be used for concrete pipe. There are safety grates available for 42 in. to 72 in. size pipe. Standards is developing a grate for the 1:6 designs.
- Whenever the apron on Standard Plate 3022 is considered for use, Hydraulics should review each location to determine if it will work hydraulically.

Retrofit:

- Replacement of inplace flared aprons with safety aprons may not work because of limited right-of-way, etc. Each location should be checked to determine if a safety apron will fit. Where the flared apron is used or left inplace, follow the guidance about the use of safety grates.

B. Parallel - Drainage Structures (Parallel Pipes)
Pipe placed parallel to the roadway for entrances and median crossovers.

Without Safety Aprons (Flared End)
It is recommended that flared end aprons not be used on parallel pipes within the clear zone.

With Safety Aprons (Mitered End)
Round Pipe
24 in. or less - no safety grate required
27 in. or greater - safety grate required

Span Pipe
24 in. span or less - no safety grate required
28 in. span or greater - safety grate required

All Multiple Pipes - safety grate required

Note: Pipe sizes are based on CS pipe

Median crossovers require 1:10 slopes and all safety aprons require a safety grate.
Entrances require 1:6 slopes.

New Construction

- Use safety aprons whenever possible.
- Metal safety aprons (Standard Plate 3128 and 3148) can be used on both concrete and metal pipes. It is recommended that Standard Plate 3128 be used and that Standard Plate 3148 be included in the list of plates as an available option.

Retrofit

- Replacement of inplace flared aprons with safety aprons may not work because of limited right-of-way, etc. Each location should be checked to determine if a safety apron will fit. Where the flared apron is used or left inplace, follow the guidance about the use of safety grates.

8-4.03.03 Permits for Construction of (or Changes to) Drainage Facilities

Because of the State's responsibility to construct and maintain transportation systems, MnDOT may change drainage patterns and facilities. As checks on the exercise of that power, however, MnDOT must coordinate with and/or obtain approval in writing (a permit) from several agencies before making certain changes. The following is a list of agencies and their areas of coordination and/or approval.

1. Department of Natural Resources (DNR) - Any project or work affecting "public or private water." Reference: Minnesota Statutes, Chapter 105.
2. Watershed Districts - "Regulate improvements of the beds, banks, and shores of lakes, streams, and marshes...to preserve the same for beneficial use." Reference: Minnesota Statues, Chapter 112.
3. County Commissions and Joint County Ditch Authorities - Drainage ditch systems located respectively: (1) completely within county limits or, (2) in two or more counties or servicing more than one county. Reference: Minnesota Statutes, Chapter 106.
   Note: In some cases Watershed Districts have begun representing the county commissions and Joint County Ditch Authorities on these matters.
4. U.S. Army Corps of Engineers
   Section 10 permits: "for all work in, over or under navigable waters of the United States." Reference: River and Harbor Act of 1899.
   Section 404 permits: "for work affecting the 'waters' of the United States." Reference: Federal Water Pollution Act of 1972.
   Note: Nationwide permits by the Department of the Army were granted in 1977 for certain "noncontroversial, environmentally insignificant activities." These permits exempt certain activities from further involvement in the Sections 10 and 404 permit process.
5. U.S. Coast Guard - Bridges, causeways, overhead pipelines, and work affecting Coast Guard navigational aids.
6. NPDES Permit: Technical memorandum 00-07-ENV-02, or subsequent issues, describes the process to obtain the permit.

8-4.03.04 Boat Clearances

Recreational trends have increased the boating and canoeing demands, especially where lakes are linked together with channels or rivers. These connecting passages should be preserved where it is economically feasible.

Hydraulically, it may be possible to replace a large, natural waterway opening with embankment construction and a culvert that operates under head during stages of high water. This type of installation may require a portage across a highway with high traffic volumes. This condition would present a safety hazard. In some cases, it may be possible to design a culvert with adequate head clearance. In addition to vertical clearance, adequate width must be provided for operation and steerage of the watercraft.

The minimum of 4 ft head clearance above normal water elevation will be provided on all rivers or channels where boat traffic is expected. In waterways where use of pontoon boats is anticipated, consideration should be given to providing for an adequate (10 ft more or less) vertical clearance between normal water elevation and the low member of the structure.

8-4.03.05 Artesian Conditions at Culvert Sites

The following procedures should be followed in order to determine artesian flow in subsurface sands (quicksand) at culvert sites:

1. Soils Investigation: After setting the location and flow line of proposed culverts along natural or improved natural drainage-ways (county ditches, judicial ditches, etc.), the designer should request that the District Soils Engineer investigate ground water levels as well as soil conditions at the site.
2. Borings: At least three auger holes should be taken at or along the proposed culvert site (center and ends). The holes should extend at least thirty feet below the proposed flow line. If a potential aquifer is encountered, at least one piezometer should be set and the water level recorded over a period of time. Any natural evidence of springs should also be noted.
3. Undisturbed Borings: If it appears that natural springs, excess piezometer head above the natural ditch water level, or soft soils are present, the Foundations Unit should be contacted to schedule

"undistributed" borings and the placement of piezometers to evaluate the foundation in the proposed site. Additional auger borings may also be necessary.

8-4.03.06 Anti-Seepage Diaphragm

Anti-seepage diaphragms should be considered for use with pipes that are placed on steep grades. They should also be used at culvert installations where the headwater at the culvert inlet will be above the top of the pipe for an extended period of time. Typical examples would be ponding areas and sedimentation basin outlets. An anti-seepage diaphram is shown in Standard Plate 3146.

8-4.03.07 Inlet and Outlet Aprons and Improved Structures

With increased emphasis on roadside safety and beautification over the years, culverts have been extended in both directions so as to enter and exit the roadway embankment flush with the side slope on all but the most minor roads. Standard designs for these inlets and outlets (often called "aprons") appear in Standard Plates, 3000 series. These aprons (or special designs having the same effect) should be employed in all culvert inlets or outlets at roadside embankment locations. Special inlet protection for metal pipes are shown on Standard Plates 3125, 3126, and 3127.

Erosion protection at outlets applies to both culverts and storm sewer outfalls. When, at these outfalls, the velocity of flow exceeds an acceptable level for the soils involved, it must be reduced or erodability reduced. Velocity reduction is achieved by dissipating some of the energy of the flow against non-erodable materials. Outfalls in erodable soils can be protected by lining the area. Sections 8-4.01 and 8-5.0 address channel liners and erosion control, respectively. The Drainage Manual also provides information on these subjects.

8-4.04 Storm Drain Design

The objective of storm drain design is to develop the most economical system of closed drainage that will drain the pavement and prevent flooding and damage to adjacent properties for a given segment of highway right of way at the occurrence of a design storm.

The MnDOT Drainage Manual provides information regarding:

1. Design criteria
2. System planning
3. Hydrology
4. Pavement drainage
5. Gutter flow
6. Inlets
7. Manholes and inlet structures
8. Storm drains
9. Hydraulic grade line

Figure 8-4.04A and Table 8-4.04A indicate the more common manhole and catch basin structures in their various combinations with castings and grates. Note that Figure 8-4.04A and Table 8-4.04A are also located in the Standard Plates Manual at the beginning of the Sewer Appurtenances Section.

8-4.05 Subsurface Drainage

The presentation of a design method for subsurface drainage design on MnDOT projects is beyond the scope of this manual. When required on a MnDOT project, the District Materials/Soils Engineer will supply the necessary design information for incorporation into the construction plans. The following brief notes on the subject are offered to inform and orient designers and engineers.

8-4.05.01 Subsurface Drainage Design Process

As part of the Soils Report for each MnDOT project, the Materials/Soils Engineer identifies locations where flows into the roadway base material might be significant enough to warrant installation of subsurface drainage, and prepares the necessary design information for the subsurface drainage facilities for incorporation into the final construction plans. Design personnel should recognize that time is required to prepare the information, and should coordinate with the Geotechnical Engineering Section to assure that the appropriate design and location information is available for the plans when it is needed.

8-4.05.02 Designer Awareness of Subsurface Drainage Needs

Changes in project limits and design concept after completion of the Materials Design Recommendation could lead to situations where the need for subsurface drainage facilities might go undetected by the Office of Materials & Road Research. As those most familiar with the design of any given project, design personnel should be aware of conditions which warrant further investigation in the area of subsurface drainage. The following are some locations of potential concern:

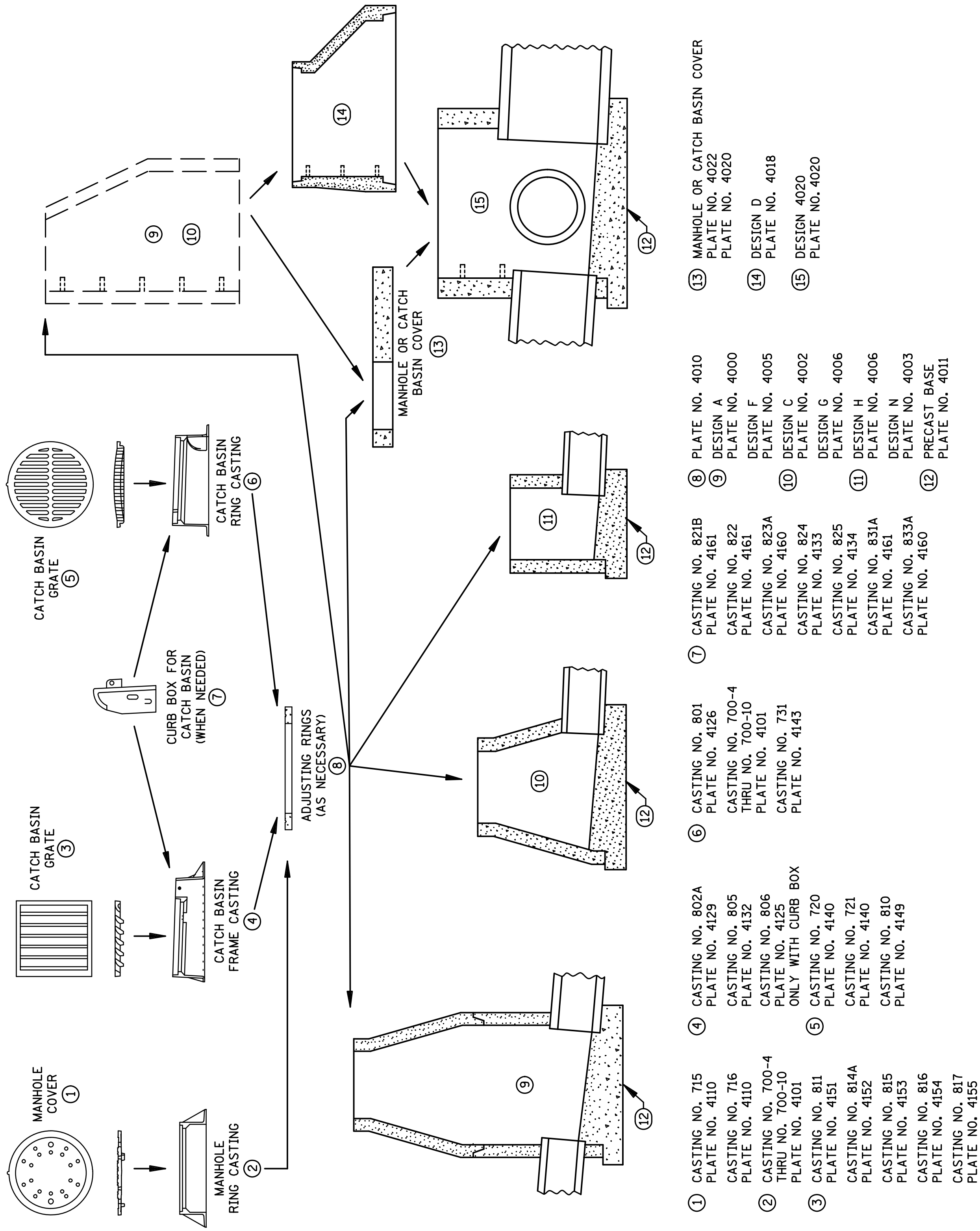
1. areas where springs are observed;
2. areas where existing pavement cracks show continued drainage long after other areas are dry;
3. areas where cross sections and/or profiles show no means of positive drainage from the pavement structure; and
4. any location where there is evidence that water entering the pavement structure may exceed that structure's ability to drain the water quickly while maintaining its ability to support traffic.

Evolution in pavement structure design has brought increasing emphasis on highly permeable roadway bases in recognition of the fact that water in the structure cannot be effectively prevented. Because of the cost and magnitude of potential problems, it is important to locate and provide facilities that can adequately handle subsurface flow.

Table 8-4.04A
STANDARD CASTING ASSEMBLIES

INLET CASTING ASSEMBLIES												
TYPE	RING OR FRAME CASTING NO. (Std. Plate No.)	CURB BOX NO. (Std. Plate No.)	GRATE CASTING NO. (Std. Plate No.)									
			810 (4149)	811 (4151)	814A (4152)	815 (4153)	816 (4154)	817 (4155)	720 (4140)	721 (4140)	731 (4143)	REMARKS
B-Curb	801 Round (4126)	821B (4161)	**B-1**									
	802A Square (4129)	823A (4160)		**B-2**	**B-3**	**B-4**	**B-5**					
	805 Square (4132)	N/A		**B-6**	**B-7**	**B-8**	**B-9**					
	806 Square (4125)	824 (4133)		**B-10**	**B-11**	**B-12**	**B-13**					
	806 Square (4125)	825 (4134)		**B-14**	**B-15**	**B-16**	**B-17**					
D-Curb	805 Square (4132)	N/A		**D-1**	**D-2**	**D-3**	**D-4**					
V-Curb	801 Round (4126)	831A (4161)	**V-1**									
	802A Square (4129)	833A (4160)		**V-2**	**V-3**	**V-4**	**V-5**					
	805 Square (4132)	N/A		**V-6**	**V-7**	**V-8**	**V-9**					
S-Curb	801 Round (4126)	822 (4161)	**S-1**									
	805 Square (4132)	N/A		**S-2**	**S-3**	**S-4**	**S-5**					
ADA	805 Square (4132)	N/A						**ADA-1**				
Misc.	700-4 Round (4101)	N/A							**M-1**	**M-6**		720 convex
	700-7 Round (4101)	N/A							**M-2**	**M-7**		721 concave
	700-8 Round (4101)	N/A							**M-3**	**M-8**		
	700-9 Round (4101)	N/A							**M-4**	**M-9**		
	700-10 Round (4101)	N/A							**M-5**	**M-10**		
	Round Conc. (4143)	N/A									**M-11**	731 Stool

MANHOLE CASTING ASSEMBLIES		
RING CASTINGS (Std. Plate No.)	COVER CASTING NO. (Std. Plate No.)	
	715 (4110)	716 (4110)
700-4 Round (4101)	**A-4D**	**A-4**
700-7 Round (4101)	**A-7D**	**A-7**
700-8 Round (4101)	**A-8D**	**A-8**
700-9 Round (4101)	**A-9D**	**A-9**
700-10 Round (4101)	**A-10D**	**A-10**



TYPICAL CONCRETE MANHOLE OR CATCH BASIN AND CASTING COMBINATIONS
Figure 8-4.04A

8-5.0 EROSION AND SEDIMENT CONTROL

Erosion and runoff can be a serious problem along roadsides, both during and after construction. In addition to losing valuable soil resources, erosion results in an unhealthy environment for growing vegetation, pollutes waterways with sediment, and results in costly maintenance activities to repair damage. Damage at a site may include rilled and gullied slopes, washed-out ditches, damage to pavements and drainage structures, clogged pipes, and flooding. Damage to water bodies occurs when they become filled with polluting sediment, making them susceptible to flooding and stream bank erosion.

Erosion is caused when wind or water blows or washes away the land surface and results in sediment as a byproduct. The presence of vegetation retards erosion. A recent study showed in a given rainfall episode, an acre of bare soil can lose up to 45 kg (**100 lbs**) of sediment, mulched soil up to 9 kg (**20 lbs**), but well vegetated soil only about 0.45 kg (**1 lb**). Clearly, the presence of well-established vegetation, or even a mulch cover**,** will preserve the soil and reduce the effects of erosion on an area.

The six types of erosion are listed in Table 8-5.01A.

Table 8-5.01A Types of Erosion

Type of erosion	Description	Technique for Minimization
Raindrop splash	The impact of the raindrop dislodges soil, causing bare soil to splash into the air. The effect of the splash also increases compaction and destroys open soil structure.	Stabilize the soil with mulch or permanent cover to prevent raindrop impact**.**
Sheet erosion	The transporting of soil loosened by raindrop splash and removal of soil from sloping land in thin layers. It is a function of soil type, depth**,** and flow velocity.	Divert overland flow away from the slope or break up long slopes with terraces.
Rill erosion	When sheetflow becomes concentrated in small, defined channels. Most rainfall erosion occurs this way.	Stabilizing slopes and divert flow. Repair damage immediately with disking or tilling.
Gully erosion	When concentrated flow occurs in unrepaired rills, gullies form.	Same as Rill Erosion but, gully erosion requires extensive repair.
Channel erosion	Channel erosion occurs at streambanks and causes sediment scar along the channel bottom.	Proper design through stream geomorphology.
Wind erosion	Wearing away of soil by wind.	Cover bare soil.

Soil erosion and the resulting sedimentation are principal causes of water pollution. By volume, sediment exceeds the national sewage load 400 times. Studies show that erosion during highway construction is 10 to 500 times greater than that produced by farming, which in turn is 25 times greater than that of natural geologic processes. Erosion not only has detrimental effects on the environment, but it also causes damage to highway drainage systems, roadside and adjacent areas, and even to the pavement structure itself. Considerable public resentment can be expected if the resulting sedimentation occurs in scenic ponds, reservoirs, residential yards, rivers, or streams. Soil erosion during highway construction increases costs, and causes needless delays and repairs.

There are many serious consequences of soil erosion and they cannot be overemphasized. Agencies imposing restrictions and requirements during construction activities include the FHWA, the Pollution Control Agency, the Department of Natural Resources (DNR), Corps of Engineers, and local Watershed Districts.

Shaping and re-establishing vegetation are the basic erosion prevention methods. If performed properly, the resulting erosion potential will be minimized in some situations. At times, vegetation will not withstand the anticipated flow conditions. In these areas, bioengineered and/or hard-armored structures or channel liners may be needed.

For implementation, see the Standard Plan Manual. These sheets are also available on the MnDOT Technical Support Web Site. The applicable Standard Plan Sheets should be included in grading and surfacing construction plans with the temporary and permanent erosion and sedimentation plan sheets.

8-5.01 Construction Activity NPDES Stormwater Permit

Application instructions to the General Permit can be found online under the construction activity link at www.pca.state.mn.us/water/stormwater/index.html.

MnDOT is a primary customer of this program. More information about the permit and a sample application form are located online under the technical memorandums at www.dot.state.mn.us/tecsup/.

The following section describes temporary devices that control erosion and sediment. A Temporary Erosion Control plan is needed for a NPDES permit.

8-5.02 Temporary Erosion And Sediment Control

8-5.02.01 General

Of all phases of highway development and maintenance, the construction phase produces the most erosion and sediment. During construction, vegetation is stripped, areas are opened up, drainage channels and ditches are dug and left open, fills are placed and cuts are made. During the time when vulnerable areas are unprotected, rain and winds can occur and cause erosion. As erosion removes soil from the construction site, gullies in slopes and ditches will form to the extent that reshaping is required. Sediment can also plug culverts and drainage structures.

In addition to the erosion damage that occurs on the project, off-site damage can occur in the form of siltation in streams, lakes, reservoirs, and adjacent lands. On a geologic time scale, the duration of a construction project is relatively short, but this limited period of accelerated erosion can have irreversible effects at the site, in rivers and streams, and on land downstream. Poor public relations between the contracting agency and adjacent residents can also develop. Thus, it is important to control erosion and limit its negative impacts. Preventing problems before they occur will cost less than fixing them later.

8-5.02.01.01 Important Elements of Temporary Erosion and Sediment Control

1. Plan packages that includes grading must have a temporary erosion and sediment control plan that contains pay items with estimated quantities for temporary erosion and sediment control items. The temporary plan should contain general guidance for ongoing erosion and sediment control during construction.
2. Identify critical areas on the temporary erosion/sediment control plan. Measure the size of the areas and state the method of rapid stabilization. Each critical area should also be listed in tabulated form by location, size and method of rapid stabilization. The statement of estimated quantities should list the total area for each method of rapid stabilization and reference the tab sheet number.
3. Use a silt fence as a last method of defense for sediment control. Do not rely solely on a silt fence to protect a site.
4. Although temporary mulching and temporary seeding/mulching are very effective at controlling erosion, they are temporary measures. Mulch quantities must be sufficient to allow for more than one mulching, depending on staging or project duration.

8-5.02.01.02 Staging

Staging is an important part of erosion control on a project. As provided in the plans over the duration of the project, controlling erosion during construction hinges on the timely installation of the permanent erosion protection materials. Placing sod, mulch, and seed promptly as the project progresses reduces the length of time areas are left unprotected and susceptible to excessive erosion.

In addition to the timely placement of permanent erosion control measures, temporary measures must also be provided during construction. These measures may include temporary devices to route drainage and collect sediment during construction.

When designing a project, the designer should account for final locations of detention ponds and their purpose. If temporary ponds are required as part of the permit, they should be constructed and stabilized first. Drainage should then be routed to the ponds.

8-5.02.02 Temporary Erosion Control Best Management Practices

Temporary erosion control best management practices are devices and methods needed to control erosion. Erosion control is protecting and preventing the exposed soil from eroding, with correct shaping, temporary seed, mulch, blanket**,** and other needed devices. These other devices may include sandbag barriers, temporary drains for fill slopes or temporary flumes to safely carry water down a slope.

8-5.02.02.01 Shaping

See the shaping discussion in Section 8-5.03, "Permanent Erosion Control.**"**

8-5.02.02.02 Temporary Slope Stabilization

During construction, temporary erosion controls may be necessary to comply with the NPDES permit and MnDOT's Specification 1803.5 in order to protect exposed slopes left idle, drainage ditches and critical areas.

- For a slope not at final grade with exposed soil and not being worked on, apply Type 1 mulch.
- For a slope that is to final grade**,** will not be permanently seeded**,** will be left idle longer than one month, apply Type 1 mulch and a temporary seed mixture.
- For slopes steeper than 1:3 or sandy soil areas use erosion control blankets over a temporary seed mix for temporary slope stabilization.
- For stockpiles, apply Type 1 mulch disc anchored or tackified with temporary seed, or apply Type 6 Hydraulic Soil Stabilizer and temporary seed to prevent erosion if it will be undisturbed for periods longer than one month.

8-5.02.02.03 Temporary Mulching

Mulch protects the soil from rainfall impact and overland flow, and also promotes the growth of vegetation by protecting the seed and fostering germination. Mulch, Type 1 should be held inplace by disc anchoring. If this is not possible a tackifier should be sprayed over it. Temporary and permanent seeding should be mulched within 24 hours after applying the seed.

Temporary mulching with Type 1 mulch should be specified on stockpile areas, exposed slopes near environmentally critical and staged construction areas. Type 6 Hydraulic Soil Stabilizer can be used on slopes 1:2 or steeper or areas with limited access instead of Type 1 mulch.

8-5.02.02.04 Temporary Seeding

Graded areas where the permanent seeding cannot be performed will require temporary seeding, i.e. temporary by-passes. Stockpiles may require temporary seeding if they will be there for periods longer than one month.

8-5.02.02.05 Temporary Erosion Control Blankets

Temporary erosion control blankets should be specified for the last 61m (**200 ft**) of all ditch bottoms in which the ditch drains directly into a surface waters.

8-5.02.02.06 Temporary Down Drains

Temporary down drains consisting of enclosed metal pipe, plastic pipe, or flexible rubber pipe may be used to carry concentrated runoff from the top of a slope to the bottom and thus reduce erosion. The temporary drains may be used on fill slopes, cut slopes, cut-to-fill transition swales, drainage ways**,** bridge ends and other locations where a temporary structure may be required to carry water prior to the installation of permanent stormwater facilities, or while vegetation is establishing. The design limits are a 2-year, 24 hour storm and can usually handle a maximum drainage area of 1.2 hectares (**3 acres**). When a temporary drain is placed on a broken back fill slope, a temporary soil berm should be constructed along the slope breakpoint with additional berms constructed to guide water into the drain as necessary. Where possible, the drain should be at a low point, with the spacing between drains at a minimum interval of 150 m (**500 ft**) along the fill slope. For drains spaced at 150 m (**500 ft**) intervals along a fill, a 250 mm (**10 in**) diameter smooth conduit or corrugated metal pipe may be used.

The outlet ends of all temporary drains must have some means of dissipating the energy to control erosion at the outlet. Dissipaters can be rock riprap and/or a tee attached to a cross pipe**,** or another device that would slow the water.

8-5.02.02.07 Bituminous-Lined Flumes, Rock Flumes, and Sod Flumes

Bituminous, rock, and sod flumes can convey drainage on temporary fills, bypasses, or ditches. They can also remain inplace to become permanent flumes. The sod flume method is the best in terms of safety. Sod flumes with netting underneath the sod add enough strength to the roots to allow them to sustain shear stresses comparable to rock and bituminous flumes.

8-5.02.02.08 Diversion Mounds

Diversion mounds divert runoff away from a work area and/or to protect slopes. Diversion mounds can be used on drainage areas up to 2 hectares (**5 acres**) and where the grade of the diversion will be less than five percent. A detail is included in the Standard Plan sheet.

Diversion mounds constructed of soil should not be used near bodies of water or wetlands.

Erosion can be controlled by some of the best management practices in Table 8-5.02B. These practices include, but are not limited to, shaping, mulching, temporary seeding, perimeter control, and installing devices to transport runoff down the slope.

Table 8-5.02B
Temporary Erosion Control Best Management Practices

Practice	General Effectiveness	Application Areas
Shaping and grading	Good to excellent	• Slopes and ditches as construction progresses • See Section 8-5.03.02.01.
Mulch/seed	Excellent	• Bare soil • Areas with exposed soil 61 m (**200 ft**) from a surface water • Idle areas, including stock piles
Erosion control blanket	Excellent	• Slopes steeper than 1:3 • Erosive ditch bottoms (v-shaped) • Ditch bottoms 61m (**200 ft**) up from a surface water • Highly erodible areas such as bridge slopes, pipe outlets, high volume exit points
Temporary Drain-on Slope	Good	• To convey drainage down cut or fill slopes
Bituminous Flume	Good	• To convey concentrated drainage on temporary fills, temporary bypasses, or temporary ditches • Use on projects with erosive potential longer than one season.
Rock Flume	Good	• Use on projects with erosive potential longer than one season.
Sod Flume	Good	• Use on projects longer with erosive potential than one season.
Diversion Mound	Good	• For use at the top of backslope or fill slope • Can be used to divert runoff from a work area • Shoulder work perimeter control

8-5.02.03 Temporary Sediment Control Best Management Practices

Temporary methods and devices to contain sediment that has eroded from within the project limits will be covered in this section. Many permits require the installation of sediment control devices before land disturbing activities begin. These devices include, but are not limited to silt fence, sandbags, traps and temporary basins, flotation silt curtains, and soil berms.

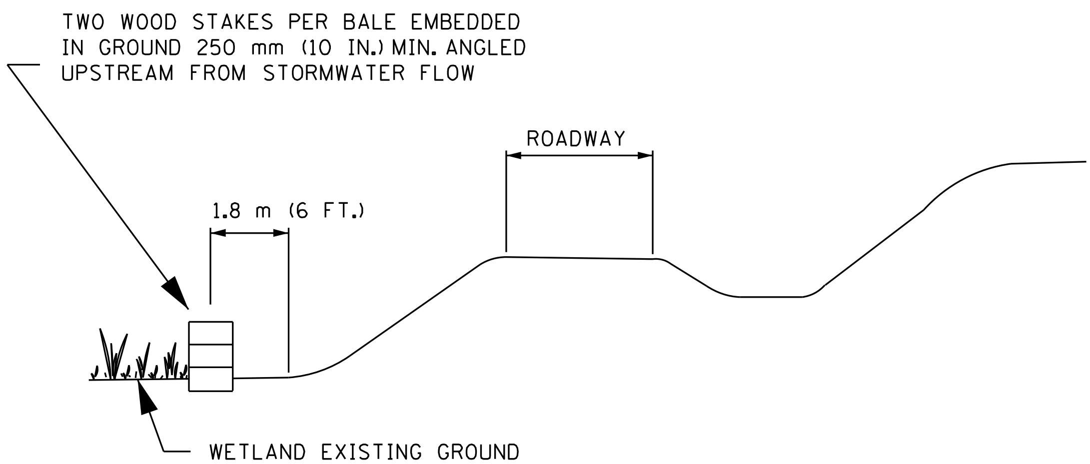
8-5.02.03.01 Perimeter Control

Perimeter control should be used to protect surface waters and other adjacent critical areas, such as wetlands and sensitive-use areas such as golf courses. The purpose of these controls is to prevent any off-site damage by preventing the amount of sediment leaving the site. In most cases, the controls will remain in place throughout construction. In order to be effective, do not use these controls over the total project length, but in strategic locations.

When large amounts of sheet flow from undisturbed areas enter the construction area, prevent erosion and runoff by diverting the runoff around the site. Soil, silt fences, and bales are effective tools for this diversion.

Machine-sliced silt fences are effective for perimeter control when located and installed correctly. When used correctly, these fences will control sheet flow, but not concentrated flows. Silt fence should be located to protect environmentally sensitive areas, such as surface waters, and to keep sediment-laden sheet flow from leaving the project.

Bale berms can be used to protect wetlands or standing water, where silt fence would be very difficult to place, and/or the water is too shallow for a silt curtain. See Figure 8-5.02A. They can also be used for sediment control (Table 8-5.02D). See also section 8-5.02.02.08 for use of diversion mounds to control runoff.



BALE DIVERSIONS
FIGURE 8-5.02A

8-5.02.03.02 Sandbag Barriers

Sandbag barriers can be used as inlet protection, temporary weirs, and in bridge construction as barriers between bridge abutments and water. See Section 8-5.02.04, "Working in or Near Streams."

8-5.02.03.03 Temporary Ditch Checks

Temporary ditch checks may be used to trap sediment and/or reduce runoff velocities in ditches and drainage ways. Typically**,** ditches with grades of 1.5 to 5 percent should be considered for velocity control. The four types of ditch checks that are outlined in Standard Specification are listed in Table 8-5.02C. The Application of these products is based on the expected and desired runoff flow.

Table 8-5.02C
Temporary Ditch Check Selection

Type	Name	Description (see Standard Plans)	Use
1	Sliced-in silt fence	The sliced-in silt fence consists of a high-flow geotextile fabric secured to posts, and sliced into the ground.	• 2-3% ditch grade, less than 0.40 hectare (**1 acre**) of drainage area entering the ditch • The above criteria also applies to bale checks and biorolls[1] • Must be removed before permanent seeding
3	Bioroll blanket system	The bioroll consists of straw or wood excelsior and is enclosed in polyester or plastic netting, 150 to 178 mm (**6 to 7 in**) in diameter. The bioroll is placed on top of a category 3, specification 3885 erosion control blanket.	• 1.5-2% grade, with less than 0.80 hectares (**2 acres**) of drainage entering the ditch • Can be permanently left in place • Lasts one season • Can be used for inlet protection.[1]
6	Geotextile triangular dike	The geotextile triangular dike consists of triangular urethane foam enclosed in a woven geotextile fabric.	• 2-3% grade with less than a 1.6 hectares (**4 acre**) drainage area entering the ditch • Use on rough grading. • Reusable • Must remove before permanent seeding
7	Rock check	Class I – IV riprap is placed over a secured geotextile fabric liner-across the ditch in a berm approximately 0.60 m (**2 ft**) high. Riprap size is dependent on expected flow quantity, velocity, and duration.	• 3-5% ditch grade with a 0.80± hectare (**4+ acres**) drainage area entering the ditch. • Use in high flow areas • Long duration • Remove rock once ditch is stabilized.

[1] Use bioroll without blanket, which will require a different pay item.

Spacing for ditch checks is generally = (height of the check x 100)/(ditch grade as a percent). For example, with a 1.5% ditch grade and a bioroll blanket system, the ditch checks would be placed every 33 feet [(0.5ft)(100)÷1.5% = 33 feet].

8-5.02.03.04 Sediment Traps

Sediment traps are small, excavated sediment storage areas without flow control sections or defined side slopes that are often field-located and temporary in nature. See Standard Plans. Sediment traps should be used when it is necessary to protect downstream sensitive areas, or to reduce flow velocity on a long ditch run. Typical locations include the downgrade end of a cut section, ditch bottoms steeper than three percent, medians, depressions within the project limits, and other associated areas.

The length, width, and depth of the trap can vary according to project conditions. Sediment traps are limited to drainage areas of 0.8 hectares (**2 acres**) or less. In highly erodable areas, a series of traps may be placed, with a minimum spacing of 90 m (**300 ft**) between traps. Questions and a review of the adequacy of proposed installations at critical or sensitive locations should be referred to the District Hydraulics Engineer.

8-5.02.03.05 Temporary Sediment Basins

Temporary sediment basins serve functions similar to those of sediment traps, but do so on a larger scale. Sediment basins have a longer design life (the length of the construction project or, in some cases, permanent). Basins are needed to capture runoff from 4+ contiguous hectare (**10+ contiguous acres**) of exposed soil before the runoff leaves the project limits or enters surface waters. Basins are located where they will not be impacted by later phases of construction and are designed to be drained and cleaned out when half the sediment storage capacity has been filled up.

The District Hydraulics Engineer can provide assistance and advice on the design of both temporary and permanent sediment basins.

8-5.02.03.06 Inlet Protection

Storm drain inlet protection measures are designed to minimize the amount of sediment that enters a storm sewer system. A storm drain inlet protection measure includes a temporary barrier that has the capability to filter or settle out sediment before it enters the storm sewer. Exposed soil around the inlet, and slopes that drain to the inlet, must have temporary cover within 61m (**200 ft**) of that inlet if the pipe outlets to a surface water.

It is not practical to control drainage areas larger than 0.4 hectare (**1 acre**) with this measure alone. The inlet protection should be left in place and maintained until a uniform 70% vegetative cover is established. The designer must select a device that satisfies local hydraulic conditions such that hazardous conditions are not created.

The Standard Plans gives several alternatives for temporary inlet protection using silt fence or aggregate filters. Standard Specifications describes each type that may be needed on the project. Some inlets may require two different types of inlet protection depending on the phase of construction; both types need to be specified in the plan. Manufactured devices are listed on the approved products list on the MnROAD web site or a link from MnDOT's Office of Environmental Services home page and can be listed in the project's Special Provisions.

8-5.02.03.07 Standpipes

Intakes for incomplete**,** permanent drainage structures should be protected from the inflow of sediment-laden runoff. During construction, a roadway embankment with a culvert may be converted into a sediment trap when a standpipe is installed at the inlet end. This temporary type of installation should be used when critical areas are exposed, a large amount of sediment is expected to accrue, and/or it is necessary to protect off-site areas at the culvert outlet. Because of the freeboard required, standpipes on culvert inlets are used only in deeper ditches (those deeper than 900 mm (**3 ft**) 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. Riser standpipes can also be used to protect drop inlets. Because of the damage that could occur as the result of failure, standpipes are not recommended when the plan culvert diameter exceeds 915 mm (**36 in**), or for more than a 10-year, 24 hour storm.

Table 8-5.02D
Temporary Sediment Control Devices

Device	General Effectiveness	Areas to Use
Perimeter control- Silt Fence[1]	Fair to Good	Toe of slopes, around stockpiles, near wetlands to protect adjacent areas See Section 8-5.02.03.01
Sandbag Barrier	Good	To protect excavations, for culvert replacements To dike channel changes and to serve as sumps during de-watering
Sediment Trap	Good	Ditch bottoms or areas where runoff leaves the project limits.
Temporary Sediment Basin	Good	Where 4+ contiguous hectares (**10+ contiguous acres**) of exposed soil contribute to a point of discharge before leaving the project limits, or entering a surface water
Inlet Protection	Good	Catch Basins, street inlets
Riser Standpipe	Good	Catch basins, culvert inlet, temporary sediment trap outlet
Flotation Silt Curtain		Open standing water during construction
▪ Moving water	Poor	Streams and rivers with currents less than 1.5 m/s (**5 ft/s**) and depths of 0.9 to 3.3 m (**3 to 11 ft**).
▪ Work area	Good	Areas of moving or still water (to confine a work area and for containing overflows from a weir, settling pond, or standpipes)
▪ Still water	Fair to Good	Lakes or large bodies of water with no current
Bale Berms	Fair	Wetland areas with limited access Ditch bottoms on rough graded sites (for turf establishment) Slope diversions (as shown in Figure 8-5.02A) See Section 8-5.02.03.01**.**
Diversion Mounds	Good	The perimeter of construction, toe of slopes, around stockpiles See Section 8-5.02.02.08**.**

[1]Use silt fence in combination with other erosion control devices.

Sediment can be contained by some of the best management practices in Table 8-5.02D. These practices include, but are not limited to silt fence, sandbags, traps and temporary basins, flotation silt curtains, and soil berms. These practices are needed to contain sediment within the project limits.

8-5.02.04 Working In or Near Streams

Four sediment control devices are described for working in or around streams: sediment mats, sandbags, flotation silt curtains, and temporary stream crossings. Each is outlined in the following sections.

8-5.02.04.01 Sediment Mats

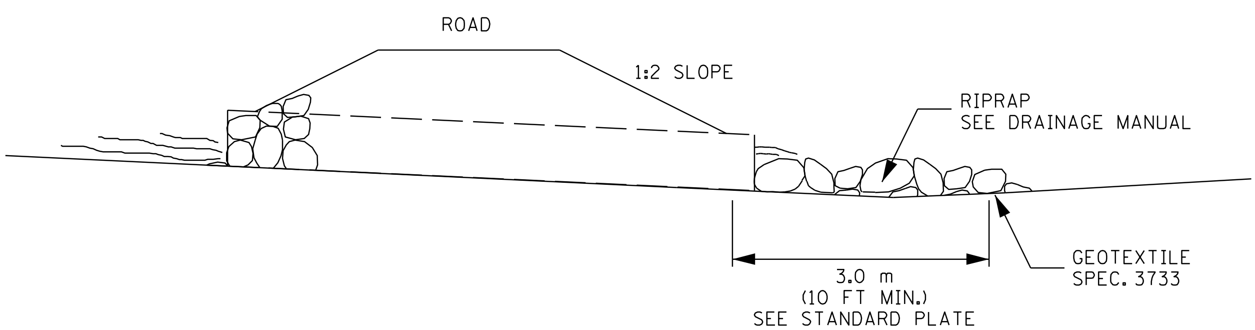
A sediment mat is a temporary erosion control device used in the streambed to collect sediments that enter the stream during construction. The sediment mat is used effectively during culvert replacements and bridge work. When construction is complete, the mat is removed and placed onto the stream bank and seeded. The sediment mat is restricted to streams having a maximum flow velocity of 1.5 m/s (**5 ft/s**) and a maximum water depth of 0.6 m (**2 ft**).

8-5.02.04.02 Sand Bags (Specification 3893)

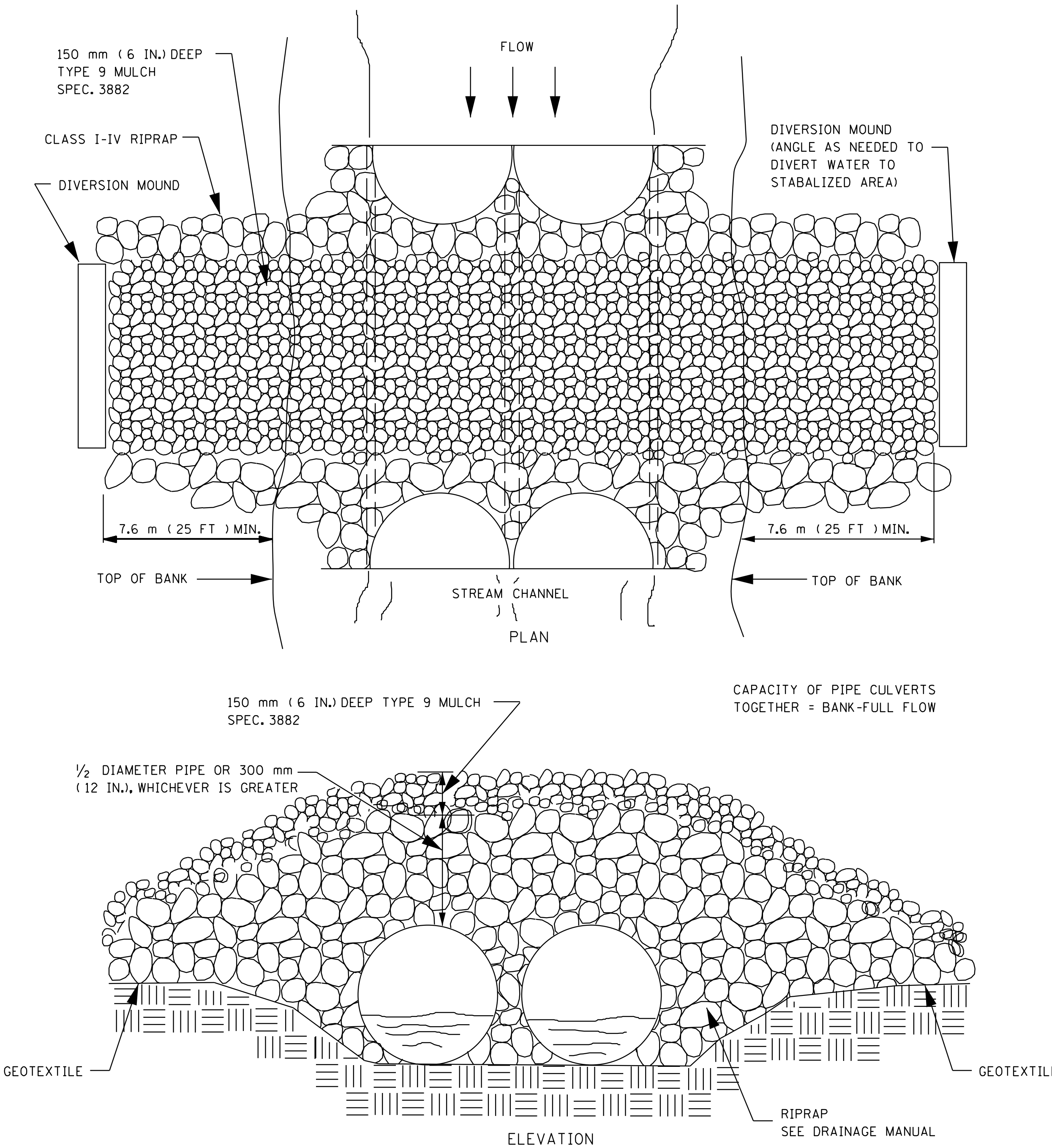
Sandbags can be used to dike off areas to help settle out sediments from dewatering, and to block off areas with erosive soil from a body of water. They can also be used to protect inlets.

8-5.02.04.03 Temporary Stream Crossings

Temporary stream crossings, such as haul roads and work roads across major streams and rivers**,** may be designed and included in the plans. These plans should show a profile grade, culvert end locations and the minimum size of culvert or temporary bridge. Use clean rock fill, and in most instances, provide riprap on the temporary crossing to prevent erosion. A geotextile should be used to cover the streambed and streambanks to reduce settlement and improve stability of the ford or culvert crossing. The geotextile should extend a min. of 6" beyond the end of the rock. Approaches should be covered with aggregate or wood chips to prevent tracking on to the crossing. A ford crossing consists of clean rock on top of the geotextile placed in the stream allowing the stream to flow over it. A temporary stream crossing may be able to be constructed certain times of the year if it does not impact fish spawning. See DNR or Corps of Engineer permit. Figures 8-5.02B and 8-5.02C show temporary stream crossings. Temporary bridge stream crossings are most applicable to narrow and deep channels. Bridge crossings are preferable to other types of stream crossings because they cause the least disturbance to the stream. Consult the District Hydraulics Engineer when designing temporary stream crossings.



PROFILE VIEW TEMPORARY STREAM CROSSING
FIGURE 8-5.02B



TEMPORARY STREAM CROSSING
FIGURE 8-5.02C

8-5.02.04.04 Flotation Silt Curtains

Flotation silt curtains can be used in moving water, still water, or in an area containing both moving and still water. It can be used in moving streams and rivers with currents less than 1.5 m/s (**5 ft/s**) and a depth from 0.9 to 3.3 m (**3 to 11 ft**). Silt curtains placed in moving water should not extend across the water from shore to shore. Curtains should divert sediment to the shoreline for removal. Curtains can be placed close to a disturbed river shoreline to protect it from the water currents erosive forces.

This product can confine a work area or contain overflows from weirs, settling ponds, or standpipes. See also Standard Plan Sheet. See Table 8-5.02D.

8-5.02.04.05 Bridge Abutments

Figure 8-5.02D shows sediment control during bridge construction. When used during construction, riprap can act as a barrier between the exposed soil and the water when it is keyed into the toe. When ready, the contractor can perform slope protection on the end slope and pull up the rock berm on the slope.

The three types of temporary bridge abutment protection practices are shown on the Standard Plans. They are:

1. Buffers in areas with low embankment, (silt fences are used and wrapped around the toe of the embankment);
2. Buffers in areas with a high embankment (3.0 m (**10 ft**) or greater), (sand bags are used as a barrier adjacent to the water, along with silt fence); and
3. Sheet piles on short bridges, sensitive areas, or areas with small working space.

Figure 8-5.02E shows runoff control measures at bridge abutments to direct runoff from the bridge deck into catch basins or temporary drop inlets. This will prevent the concentrated runoff from flowing over the inslope and eroding the bank.

8-5.02.04.06 Dewatering

Dewatering sediment-laden water directly back into surface waters, or into a drainage pipe or ditch that flows directly to surface waters should not occur. A sediment trap or other means should be used to settle the sediments before the dewatering water enters these areas.

Some sediments are too small to be settled or filtered out of the sediment-laden water. These silt and clay particles can end up entering a critical surface water and cloud the water turning it to a murky brown color. To settle out these fine particles a flocculant can be specified. For further information contact the Erosion Control Engineering Unit.

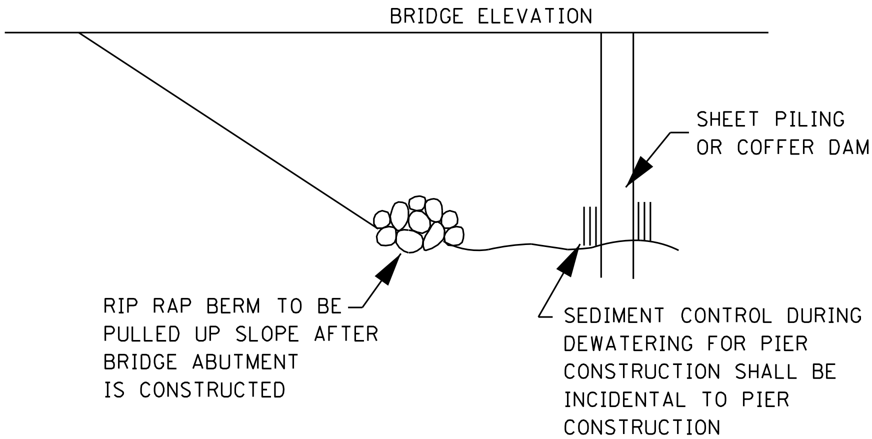
8-5.02.04.07 Rock Construction Entrances

At construction access locations, a rock construction entrance pad will reduce the amount of mud transported onto paved roads by vehicles or surface runoff. Rock construction entrance pads provide an area where mud can be removed from vehicle tires before entering public roads.

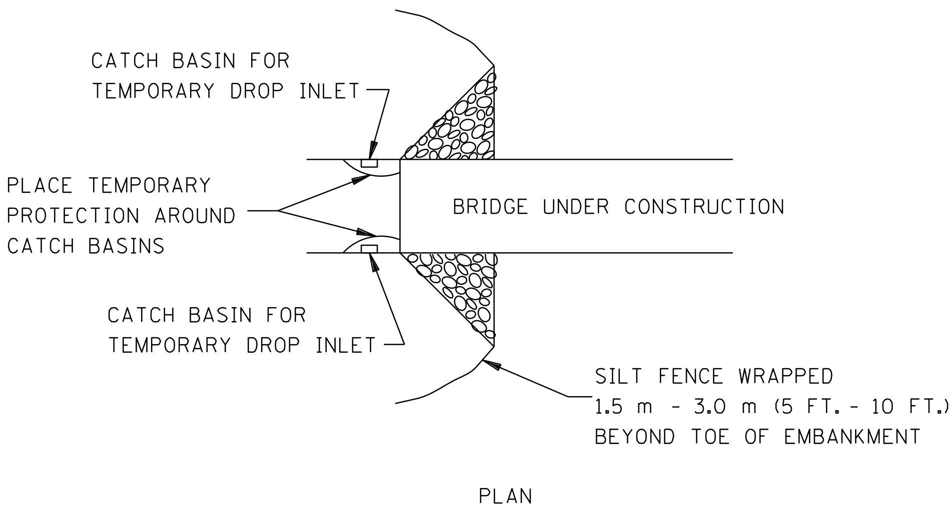
The rock pad, which should extend the full width of the access location, should contain 25 to 50 mm (**1 to 2 in**) size washed rock, with a 152 mm (**6 in**) minimum thickness. A geotechnical fabric may be used under the aggregate to minimize the migration of stone into the underlying soil. A wash rack installed on the rock pad may make cleaning more convenient and effective.

To prevent the tracking of mud onto paved roads, the rock entrance pad will need maintenance. This maintenance may require periodic topdressing with additional rock, or removal and reinstallation of the pad. Street sweeping to remove sediment from paved surfaces is required to prevent dirt from entering catch basins and water bodies.

See Standard Plan sheet for more information.



SEDIMENT CONTROL DURING BRIDGE CONSTRUCTION
FIGURE 8-5.02D



TYPICAL CONTROL MEASURES AT BRIDGE ABUTMENTS
FIGURE 8-5.02E

8-5.02.04.08 Sediment Removal

At any time during construction, the contractor may have to remove sediment trapped in retention devices or deposited in retention ponds. Sediment removal shall consist of excavating and other associated operations to restore the capacity of any temporary sediment control device. When sediment reaches one-third of the height of a silt fence device or equivalent, remove the sediment or replace the device if it is not functioning properly. Sediment basins must be cleaned out when sediment reaches half of the storage volume.

Because of weather conditions, field changes, and other unpredictable situations, estimated quantities for temporary erosion and sediment control can be hard to predict. Table 8-5.02E provides some guidelines to use.

Table 8-5.02E
Estimated Quantities Guidelines for Temporary Erosion Control

Practice	Material	Estimated Quantity
Temporary Mulching, Type 1	Mulch Type 1, 3	100% of the permanent seed quantity
Temporary Mulching, Type 6	Hydraulic Soil Stabilizer, Type 6	20% of the total permanent seed quantity
Temporary seeding and mulching	Seed mixes 100B, 110B, 130B, 150	20% of the total permanent seed quantity area
Ditch stabilizing	Category 3 erosion control blanket	100% of first 61 m (**200 ft**) from surface waters
Concentrated runoff prevention	Category 3 erosion control blanket, sediment basin	Where needed in concentrated flow areas
Protecting Inlets	Inlet Protection	Count each inlet that drains to surface waters, off project limits, or to a ditch that drains to a surface waters
Controlling Ditch Velocity	Temporary ditch checks	See Table 8-5.02C
Maintaining Devices	Sediment removal, backhoe	1hr/90 m (**1 hr/ 300 ft**) Silt fence; 2 hours per sediment basin per construction season

8-5.03 PERMANENT EROSION CONTROL

8-5.03.01 GENERAL

Permanent erosion control measures are different from temporary measures because they are primarily designed to function after projects are complete. They include proper earthwork shaping, rounding, and transitioning, and properly prepare surfaces for expected flow quantities and velocities. Avoid disturbing areas where restabilization or revegetation will be difficult.

8-5.03.01.01 Important Elements of Permanent Erosion Control

A summary of design guidelines that minimize erosion potential follows.

1. Avoid steep, unstable slope angles. Weigh the initial cost of additional right of way against the long-term costs of construction and maintenance.

2. Design sediment basins and other erosion or sediment control devices, temporary and permanent.

3. 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.

4. Preserve the natural and existing drainage patterns to the greatest extent possible. Avoid placing the 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.

5. Set construction limits that provide space for slope rounding, preserve trees and shrubs, and prevent excessive clearing.

6. Avoid or minimize earthwork balancing that requires hauling dirt across streams.

7. Do not disturb steep stabilized slopes of rock debris, soil, or stream banks. If the project is "short of dirt," obtain borrow instead of disturbing these critical areas.

8. Consider using independent alignments to fit divided highways to the terrain and to adjust grades.

9. Avoid irregular ditch profiles and steep ditch grades. Adjust grades with special ditch grades. If steep ditches are necessary, locate the steep section at the head of the ditch instead of at the outlet.

10. Provide a note in the plan that states ditch bottoms should be graded to a radial shape to reduce erosion.

11. Minimize channel changes. When channel changes are required, adjust the new channel cross section alignment and/or length to match the existing flow velocity.

12. Locate and align culverts to avoid erosion at inlets and outlets. To allow direct entrance and exit conditions, place structures as near to the natural flow line as possible, and in line with the flow direction. Avoid placing outlets at curved sections or channels, or where the outflow can drop and cause scour.

13. Where possible avoid problems associated with locating ditches at the toe of fill slopes.

14. Maximize the use of natural materials such as soils, sod, seed, mulch, and riprap to 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 to prevent erosion.

15. Review the plans by drainage area to assure erosion control work practices are adequate.

16. 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 accumulate.

17. Request and use available technical assistance. A quick detail review with additional Department input can save hours of costly changes and minimize problems. Technical assistance in each respective area is available from the Geotechnical Engineering Section (http://www.mrr.dot.state.mn.us/geotechnical/geotecheng.asp), Office of Environmental Services (www.dot.state.mn.us/environment), the Hydraulics Section or District Hydraulics Section, or the District Materials Section.

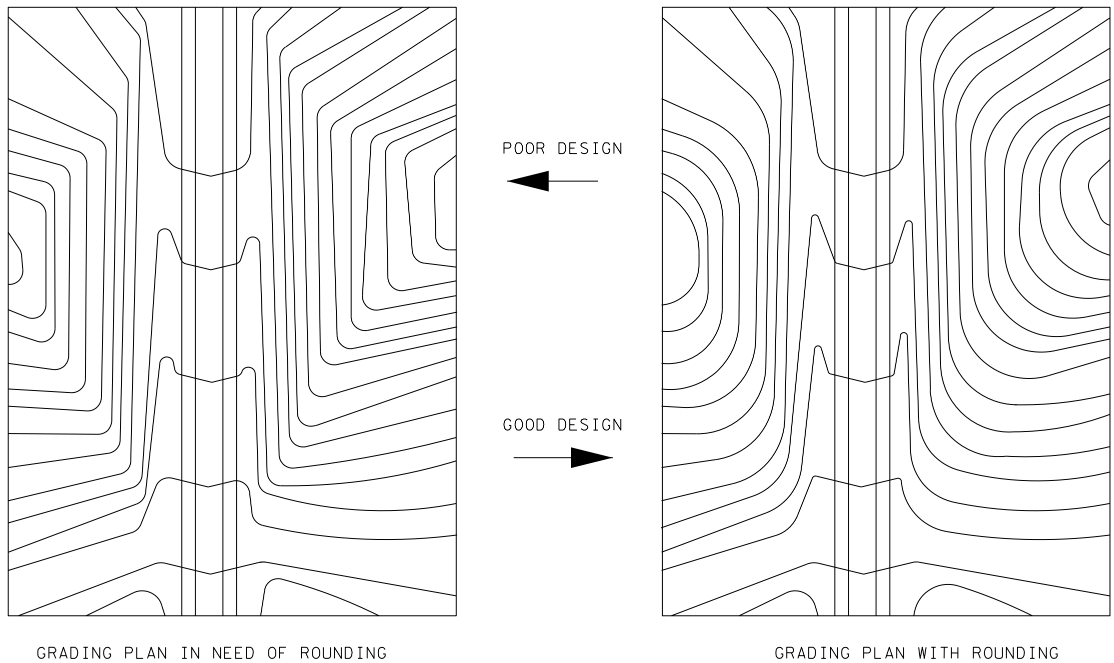
8-5.03.02 Permanent Erosion Control Best Management Practices

Permanent erosion control best management practices are devices and methods that prevent erosion on an on-going basis. Proper design features and natural materials or methods are the most effective means of erosion control.

8-5.03.02.01 Shaping

One of the most important erosion prevention techniques is proper shaping and/or contouring. Proper shaping methods include rounding slopes and ditches, blending cuts and fills, eliminating built-in gullies, and feathering cuts. The edges of slopes where cuts or fills intersect the natural ground line should be rounded. See Figure 8-5.03A. Construct slope grades to insure slope stability and conserve existing vegetation and topographic features to reduce erosion.

Many erosion problems can be avoided by good design practices. Avoid hill side locations where steep, deep cuts are required because they are difficult to stabilize, especially in rock cuts with loose sloughing overburden, in water-bearing strata, or in soils high in silt content. Before slopes can be stabilized, the foundation soils or geologic formations must be stable. In general, the degree of the slope must be flatter than the natural angle of the weakest soil or rock formation in the slope area. Vegetation can only stabilize and control surface erosion, which is normally in the top 1.0 m (**3 ft**) of the soil. Revegetation depends directly on slope stability. If slope grades are constructed to insure stability, plant establishment can usually follow.



SHAPING FOR EROSION CONTROL
FIGURE 8-5.03A

8-5.03.02.01.01 Cross Section Slope Rounding

The gentle rounding at the intersection of different roadside slopes should be specified and constructed to make the highway section safe, erosion resistant, and compatible with the landscape. For the location of rounding areas see the Standard Plan Sheet.

8-5.03.02.01.02 Cut-to-Fill Transitions

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

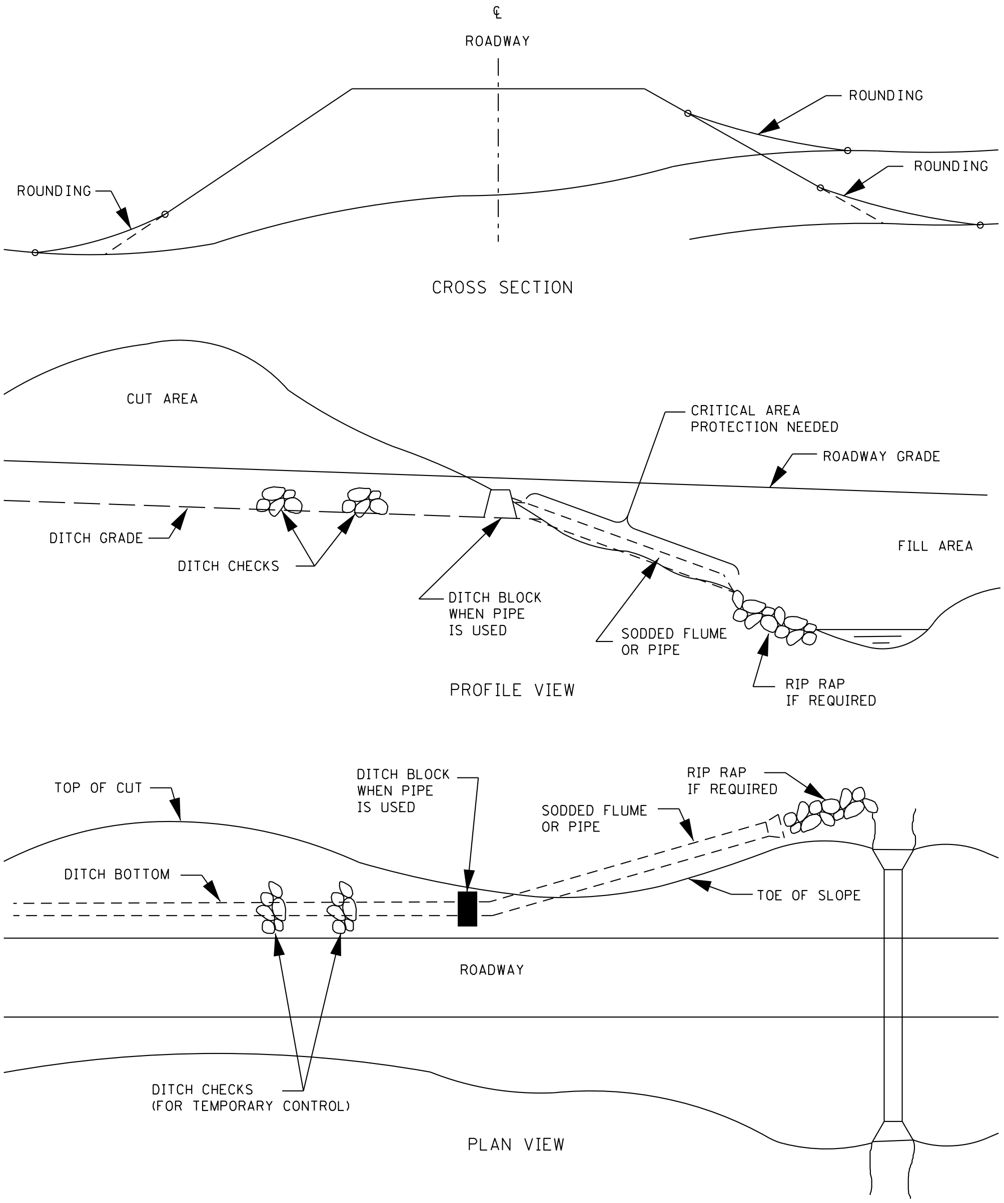
From the cross section shown in Figure 8-5.03B, there are two conditions that affect the shape of the drainage channel at the toe of the fill:

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

If the natural ground is level or slopes away from the fill, the toe of the fill should be rounded to blend the fill into the terrain and to divert drainage onto vegetated areas.

If the natural ground slopes toward the fill, a special ditch grade should be constructed along the toe of the slope to reduce the erosion potential and to provide the desired rounded cross section for sodding. At ditch grades less than 2 percent, it is generally assumed that the special ditch can be stabilized by providing seeding and mulching and adequate cross-section rounding, however; if drainage is conveyed long distances or if the runoff quantity is large, the designer should request assistance from the District Hydraulics Section. An erosion control blanket lining the ditch bottom may be needed, or if shear stresses are large an erosion stabilization mat may be more appropriate.

If the design indicates that a sod flume is inadequate to convey the runoff flow quantities down the special ditch, the designer should contact the District Hydraulics Sections for assistance.



EROSION CONTROL AT CUT-TO-FILL TRANSITIONS
FIGURE 8-5.03B

8-5.03.02.02 Ditches

Ditches prevent water from reaching the roadway base or sub-base by disposing of surface runoff from the roadway surface and roadside areas. Roadside ditches allow the roadway base to drain and thus prevent saturation and loss of support. For highway application, MnDOT uses a radial, rounded ditch cross section as standard. This cross-section is hydraulically efficient, and is very easily constructed. Besides cross section rounding, both alignment and surface treatment (lining) are significant ways to control erosion in ditches.

Ditch alignment, both horizontal and vertical, should be kept as simple as possible, with smooth curves and transitions to minimize the erosion potential. Although construction is cheaper and less lining is required with a broken-back profile, a uniform ditch profile is more desirable and is comparable to natural channels. Broken-back profiles are comparable to gullies that erode progressively upstream.

8-5.03.02.02.01 Culverts Outletting to Ditches

Properly placed culverts will alleviate ditch maintenance problems by allowing the free flow of drainage runoff. Culvert outlets should be as close to the toe of slope as possible. To divert as much road runoff as possible, outlet ditch culverts to vegetated areas where possible. Also, protect culvert outlets from erosion and undermining by placing rip rap or surge basins at the outlets.

Where auxiliary outlets are needed to prevent large concentrations of water, protected outlets must be constructed utilizing sod, level spreaders, metal pipe flumes**,** or plastic pipes. To reduce water velocity at pipe outlets, the last section of the pipe should be as flat as possible. If relatively flat pipes are impractical, use riprap surge basins. Surge basins must be installed correctly at the bottom of the slope and have a filter under the riprap. See Drainage Manual. Contact the District Hydraulics Section for recommendations of outlets.

8-5.03.02.02.02 Ditch Liners

Erosion damage to drainage ways and ditches can be substantially reduced or prevented by providing proper ditch-liner treatment. Ditch liners should be selected based on the ditch grade and soil type.

The ditch grades listed in Table 8-5.03A are guides under normal conditions in the design and treatment of ditches. Sodding should not be used when the ditch grade exceeds the maximum permissible ditch grade given in Table 8-5.03A. When exceeded, consult with the District Hydraulics Section for recommendations concerning design of special liners or energy dissipaters.

Table 8-5.03A
Ditch Grades Requiring Sod or Erosion Control Blankets

Ditch protection type	R ≥ 9.75 m (**32.5 ft**)	R ≤ 4.97 m (**16.3 ft**)
Seed/mulch	2.5%	0-2%
Sod	8.75%	2-7%
Category 3 erosion control blanket	3.75%	2-3%
Category 4 erosion control blanket	5%	2-4%

Notes:
The Category 1 or 2 blanket is not recommended as a ditch liner.
R is the ditch bottom radius

Several biological/vegetative stabilization techniques can be used to control erosion and stabilize hydraulic channels. These techniques include, but are not restricted to:

1. granular liners in conjunction with special vegetation in seeping ditches and areas of high water table;
2. clay ditch liners in conjunction with sod for stabilizing ditches in erodible soils such as loamy sand and sand soils**;**
3. Erosion Stabilization Mats, as described in the Standard Specifications
4. ditch linings of sod over topsoil; and
5. riprap mixed or covered with soil and then seeded.

The above techniques are based on increasing the characteristics of the channel to withstand erosion. See Table 8-5.03B for more details. Further recommendations in regard to these techniques are available from the Erosion Control Engineering Unit.

8-5.03.02.02.03 Sodded Ditches

Steep ditch grades are very susceptible to erosion and require extra design effort. The Standard Specifications and Standard Plans offer additional information.

8-5.03.02.02.04 Level Spreaders

The purpose of sod or seed-and-blanket 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 superelevated curves. See Table 8-5.03C for other applications of level spreaders.

Table 8-5.03B
Ditch Liner Selection

Liner type	**Application**	**Notes**
Granular Liner	Streambeds Seeping ditches High water table areas	See the District Hydraulics Engineer
Clay Liner	To replace highly erodible soils, such as sands and silts	Must be 0.15 m (**0.5 ft**) thick and compacted
Erosion Stabilization Mat	Runoff velocity > 2 m/s (**6.5 ft/s**) Should be top soiled, seeded and blanketed	Spec. 3888
Riprap	Runoff velocity > 2 m/s (**6.5 ft/s**) Use angular for high flows and rounded in low flow areas	Must provide filter material Spec. 2511
Reno Blanket, Interlocking Block	Extremely high flow Poor soils High bed shears	Look up on Internet
Cabled Concrete Mat	Extremely high flow Poor soils High bed shears	Several sizes are available Look up on Internet
Root Rap	Use in areas where rip rap is needed, but a softer look is desired	Spec. 2577.3H

8-5.03.02.02.05 Superelevated Curves

Shoulder slopes on the inside of superelevated curves where mowing will take place should have Category 1 blanket over the seed for the length of the curve, including transitions at both ends, at a minimum width of 2 m (**6 ft**) from the edge of the shoulder. In areas where mowing will not be done specify a category 3 blanket.

Table 8-5.03C
Protection Adjacent to Shoulders

Condition (Areas Contributing Runoff to 1:3 Slope Area)	**Treatment**
Bridge deck, roadway and 1:6 safety inslope	Provide a catch basin or flume to intercept bridge runoff in conjunction with sod runoff spreader.
Roadway and 1:6 safety slope	Provide a runoff spreader on all soil types (category 3 blanket and seed).
Only 1:6 safety slope	Spreader is not required unless it is in erodible conditions, such as erodible silty soils and fills over 7.5 m (**25 ft**) high.

8-5.03.02.02.06 Broken-Back Safety Fill Slopes

Because of the complex slope shape, broken-back safety fill slopes have a high erosion potential. Runoff from the roadway may be either sheet or concentrated flow upon entering the steeper inslope. As the runoff flows over the slope, it becomes concentrated by wheel tracks, clods, clumps, minor surface settlement of the topsoil layer, or ridges of soil from the finishing operation. As a result, runoff frequently exits off the steeper slope to the point of intersection as concentrated flow, thus eroding the less steep portion of the inslope. Adding a sod run off spreader will prevent erosion, see Standard Plan sheet.

8-5.03.02.03 Erosion Control Dike

Water flowing over disturbed earth will erode the soil and either deposit it as sediment in lower areas or pollute waters with its sediment-filled runoff. This erosion must be avoided if possible. One practical method of reducing erosion and the resultant sedimentation or pollution is to prevent storm water from flowing across cut slopes by constructing a permanent slope protection dike.

Since the quantity of runoff is dependent on the rainfall intensity, duration, drainage area, topography, type and quantity of vegetation, and the permeability of the soil, the designer will need information from the District Hydraulics Section to determine whether or not a dike is needed. See Standard Plan sheet.

Dikes can be constructed by placing erosion-resistant embankment material. This method is preferred over using cut and fill or plowing a furrow. If slight rises in the natural ground occur over relatively short distances, shallow cuts may be made, but these cuts must be sodded to prevent erosion. Where swales occur that would cause flooding beyond the right of way, provide flumes to carry the water down the slope.

8-5.03.02.04 Storm Water Basins

Storm water basins are needed to collect the increased water runoff due to the increased impervious surfaces. Storm water basins may be required by various permitting agencies with special design guidelines. These guidelines should be referred to and followed for the specific project situation. Along with storm water basins grassed swales and vegetative filter strips can help reduce sediment from runoff and allow infiltration of runoff. Refer to the hydraulics manual for additional design guidance or contact District Hydraulics Engineer.

8-5.03.03 Turf Establishment

The purpose of this subsection is to generalize turf establishment policies and recommendations for the designer. Each site has a different set of conditions that will affect turf establishment materials and needs. Soils, topography, and traffic have a great effect on the needs to prepare the turfed areas and their continued maintenance. Although this section does not include detailed recommendations, it does summarize them so that the designer can analyze his or her particular project, detect inconsistencies, or locate critical areas requiring additional protection.

The Office of Environmental Services, Erosion Control Engineering Unit will provide turf establishment recommendations for particular projects as outlined in the Technical Memorandum. If the designer detects inconsistencies or feels that additional protection may be required in critical areas, he or she should contact the Erosion Control Engineering Unit.

8-5.03.03.01 Important Elements of Turf Establishment:

8-5.03.03.01.02 Topsoil

a. Topsoil is a valuable natural resource. **All inplace topsoil should remain on site, and be salvaged to the greatest extent possible.** On slope easements, remove topsoil to the bottom of the “A“ horizon and reapply it uniformly within the easement area. Provide topsoil information, such as average depth**,** location**,** and depth of deep deposits in the soils letter. Consult with District Maintenance personnel regarding the stockpiling of topsoil when a surplus exists.
b. Use topsoil on all areas that will be seeded or sodded.
c. If there is a shortage of salvageable topsoil, use plastic subsoils or organic and muck soils that are up to 20 percent organic matter. Do not use peat because it may dry up, blow away, settle, consolidate, and/or will not support mowing equipment. Before specifying either the subsoils or muck soils to use as topsoil, consult with the District Soils Engineer.
d. Depending on subsoil textures and/or the nature of the area, some projects will require different depths of topsoil. A few include:
   - coarse textured subsoils, which may be deeper;
   - hydraulic sandfills, which may need as much as 200 mm (**8 in**); and
   - plastic subsoils, which may be shallower.

8-5.03.03.01.03 Fertilizer

The fertilizer applied depends on the soil composition. Soil tests are always recommended to determine the appropriate fertilizer analysis and application rate. Soil samples for fertility should be collected according to the Geotechnical and Pavement Manual.

a. Use fertilizer on areas that will be seeded or sodded.
b. Provide half the fertilizer rate of seeded areas for sodded areas.
c. Refer to the District seeding recommendations for general recommendations.

8-5.03.03.01.04 Seeding

MnDOT has seed mixes that grow best in specific soils. The seed mixes are also designed for the long-term function; mowed turf, reclamation areas, wetland mitigation. Refer to the District seeding recommendations for general recommendations or contact the Erosion Control Engineering Unit.

8-5.03.03.01.05 Mulching

Mulching provides a cover over the seed and bare soil. It keeps soil cooler and moister, allowing for better germination and plant establishment, and provides for temporary erosion control while the vegetation is establishing.

8-5.03.03.01.06 Erosion Control Blankets

Standard Specifications includes descriptions of erosion control blankets. Blanket selection is based on slope steepness and length. These two factors have the greatest effect on the increase in energy caused by runoff velocity.

8-5.03.03.01.07 Hydraulic Soil Stabilizers

Standard Specifications includes different descriptions of the different type of soil stabilizers, and Standard Specifications outlines application rates. Generally, hydraulic soil stabilizers are used in areas with limited access and steep slopes. They may be sprayed over the top of other mulches, but should not be used on ditches or seeping slopes.

8-5.03.03.01.08 Erosion Stabilization Mats

Erosion Stabilization Mats are permanent mats that add additional shear strength to the vegetation and allow it to withstand higher shears in concentrated flow areas, such as ditch bottoms. Depending on the bed shear, these mats can be used as an alternative to riprap.

8-5.03.03.01.09 Turf Weed Control

Remove weeds prior to restoring wetlands and prairies. Contact the Erosion Control Engineering Unit for guidance and recommendations.

8-5.03.03.01.10 Shoulder Mulch Tacking

Shoulder mulch tacking consists of Type 1 hydraulic soil stabilizer sprayed onto Type 1 mulch on a 0.9 m (**1 yd**) wide strip immediately abutting the roadway surface. During placement, the area should be seeded, the seedbed firmed, Type 1 mulch placed and the area must be disk-anchored, and oversprayed with Type 1 hydraulic soil stabilizer as a continuous process.

8-5.03.03.01.11 Protection Adjacent to Bituminous Shoulders or Curbs

If areas adjacent to the shoulder are not going to have gravel placed then vegetation is needed. After bituminous shoulders have been placed, the aggregate surfacing extending beyond the bituminous edge should be bladed to provide greater depth of topsoil adjacent to the bituminous shoulder. See Standard Plan Sheet. If the foreslope must be protected by sod, the top of the topsoil should be 25 mm **(1 in)** below the top of the bituminous so that it will not act as a curb or pond water on the roadway**,** causing water to concentrate after the sod is placed. When sod is placed at the back of a curb the topsoil should be 25 mm **(1 in)** below the top of curb. See also Table 8-5.03C.

8-5.03.04 Soil Bioengineered Systems

Soil bioengineering entails the use of vegetation as the structural and mechanical elements in soil stabilization and to be used with hard-armor methods. Stream bank stabilization is best accomplished utilizing these methods to leave a naturally stabilized site. Live cuttings and rooted plants are imbedded in the ground to serve as soil reinforcements, hydraulic wicks, drains, and barriers to soil movement. Bioengineering treatments provide sufficient soil stability so native vegetation can further establish and stabilize the soil. For additional information, see MnDOT Standard Specification and Standard Plan Sheet.

- **Wattles**
  The wattling method trenches bundles of tied live, easily rootable woody plants**,** such as willow**,** dogwood, and alder along the contour of a slope. The woody plant must be cut while in its dormant stage in the spring before they leaf out or the fall after they drop their leaves.

The wattles root and grow, control water runoff velocities, stabilize the surface layers of the slope, and increase water infiltration. Contour wattling with willows is best on cut or fill slopes with surface or subsurface moisture, and also on streambanks. A coconut/straw blanket can be placed over the soil in the trenches before the wattles are installed to protect the bare seeded soil.

- **Brush Layering**
  Brush layering involves embedding live branches of shrub or tree species that will root easily on the contours in the face of a slope. They slow runoff velocity and retain sediments from the runoff. Brush layering is more effective than wattling at preventing shallow mass movements. They reduce moisture in seep slopes and assist in stabilizing them. The vegetation extends deeper into the slope rooting along their lengths, and act immediately as small horizontal slope drains. Brush layering works well with the construction of a conventional fill slope operation.

- **Live Stakes**
  Live stakes are live, rootable woody vegetation cuttings inserted into the ground. Live stakes can be placed in clusters that are installed in chevron-like rows that point downstream. The rows should start at the top of the bank and be directed downstream to the toe. Also placed in joints between riprap and gabions down into the soil, live stakes will root beneath the riprap to reinforce the soil, anchor the riprap, and improve drainage by extracting soil moisture. They can also be used to anchor the wattles in a trench, adding additional rooting to a slope.

- **Root Rap**
  Root rap involves placing a gravel or riprap channel lining and over seeding or planting the completed channel. The root rap can also be used to stabilize a seeping slope by transporting water down to the toe of the slope

- **Fiber Rolls**
  The fiber roll is a device used along the edges of streams, rivers, lakes, and reservoirs. It is a tube of coconut fiber (coir) placed to reduce the water's forces at the toe of the bank and retain soil so vegetation is able to establish and stabilize the soil. Factors to consider when designing include bank steepness, wave height, stream velocity, low-flow conditions and human and animal traffic.

- **Concrete Armor Units**
  Concrete armor units are two pieces of concrete that fit together and form a structure similar to a jack. They are placed 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. The stream alignment may need moving to the stream center and off the erosive streambanks. Specifying rock vanes, bendway weirs or a system of pools and riffles can do this. Streambank protection using hard armor (riprap, boulders) protection should be carried up the slope to bankfull width for a 1.5 year storm. Consult your District Hydraulics Engineer for specific information.

8-6.0 APPLICATIONS POLICY AND CRITERIA

8-6.01 Culverts and/or Storm Drain Pipes

8-6.01.01 Selection of Material Types for Drainage Facilities

The policy for selecting material types for drainage facilities is outlined in the Drainage Manual.

8-6.01.02 Joint Tying

Unless conditions dictate otherwise, provide ties on concrete pipe per Standard Plate 3145.

8-6.01.03 Joint Sealing and Gasketing of Concrete Pipe

All storm drains and sanitary sewers are required to have flexible watertight joint seals. No specific reference is required in the plans except when the gasket type (shown in Standard Plate 3006) is the only acceptable joint seal. Exclusive use of the gasket type seal should be specified for the following general cases (round pipe only):

1. When the design flow velocities exceed 10 ft/s, and in cases where fine material surrounds the pipe.
2. Where the pipe will be placed below the ground water table.
3. In cooperatively constructed sewers where, as a general rule, the local government agency uses this type of gasket.
4. All sanitary sewers.

Plans should list Standard Plate 3006; use separate pay items and indicate locations where this type of joint is required.

8-6.01.04 Sewers and Culverts (Metal Pipe)

Corrugated metal pipe shall be either helically corrugated or have all seams caulked (in accordance with the manufacturer's recommendations), using a permanent type waterproofing material approved by the Engineer. In the general cases listed below, the contractor shall obtain the Engineer's approval of the waterproofing material prior to placing the order. Also, pipe section connecting bands shall consist of the rod and lug type coupler (i.e., two ½ in. diameter galvanized threaded rods with lugs, installed with the same permanent type waterproofing material as above) or the "hugger type" band coupler with O Ring rubber gaskets properly installed (Standard Plate 3221). Any other equally effective connecting device approved by the Engineer may be employed.

The following are several cases for the requirement of the above criteria:

1. when the design flow velocities exceed 10 ft/s;
2. when fine material surrounds the pipe;
3. when the pipe will be placed below the ground water table; or
4. when a metal storm sewer system is used that does not have any of the three conditions above, the Hydraulics Section should be consulted to determine the possible need of the specifications for some other reason.

8-6.01.05 Elbows and Bends on Plans

When elbows are required in metal pipe structures, the number of elbows and the degree of bend shall be shown in the drainage tabulation for each line of pipe.

When bend sections are required in concrete pipe structures, the number of short-radius bends or long-radius bends shall be shown in the drainage tabulation for each line of pipe.

8-6.01.06 Bedding

The various types of bedding in general are described in the Drainage Manual. Also, bedding should only be specified with full knowledge of Specification 2451, Structure Excavations and Backfills.

8-6.01.07 Corrugated Steel Pipe Protection

There are many means and materials available for the protection of corrugated steel pipe. Information on these means and materials is available in Chapter 2 of MnDOT’s Drainage Manual.

8-6.01.08 Treatment of Center-Line Culverts in Plastic Soils

Center-line culverts placed in plastic soils may need to be treated with special aggregate bedding and granular backfill tapers to help to reduce the differential heave at the roadway surface caused by frost penetration into the soil around the pipe. This treatment is shown on four different cases of pipe depth in Figures in the Technical Manual. These treatments for centerline culverts in plastic soils should always be used unless otherwise recommended by the District Materials and/or Soils Engineer in consultation, if necessary, with the C.O. Geotechnical Section.

When treatments are planned for use, a detail similar to that given the Technical Manual must be shown in the plans for each necessary case. Treatment quantities for the various treatments are given in the Technical Manual.

Figure 8-6.02A & B show the treatment for box culverts in plastic soils.

8-6.01.09 Backfill for Sewers

MnDOT’s Technical Manual as well as Specification 2503 provide instructions for the construction and backfilling of sewers. The main purpose for backfilling sewers with granular materials is to provide for good compaction around the pipe, particularly for deep corrugated metal pipe sewers where pipe strength is heavily dependent upon the compaction of the surrounding soil.

Backfill of small diameter, shallow sewer lines, however, may result in a granular block wholly within plastic soils and within the frost zone, which can cause a differential frost heave. In addition, on urban highways with numerous small diameter shallow storm sewer lines crossing at intervals of 300 ft or less, the backfilling with granular materials becomes quite costly and may create construction difficulties.

Based on the above, all small sewer pipe (24 in. diameter and smaller) backfill will be "selected material" as defined under Specification 2451.3D unless otherwise recommended by the District Materials and/or Soils Engineer. Selected material may be either plastic or granular soil as long as it is "acceptable mineral soil which is free of clods, stones over 3 in. in greatest dimension, sod and roots."

For larger sewer pipe (greater than 24 in. diameter), backfill will be granular materials as defined in Specification 3149 unless otherwise recommended by the District Materials and/or Soils Engineer.

When granular backfill is required, a detail similar to that shown in the Technical Manual shall be shown in the plans. Each plan shall indicate if the granular backfill is available on the project or must be imported from an outside source.

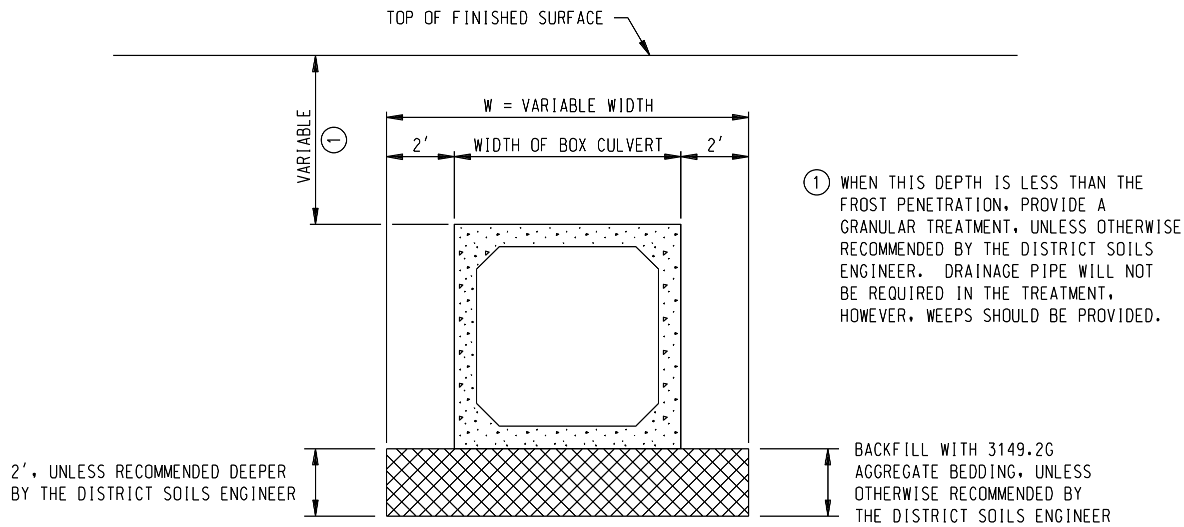
The treatments shown in the Technical Manual should not be used for closed-ended storm sewers. However, they may be used on open-end (i.e., outlet apron) sewers upon recommendation of the District Materials and/or Soils Engineer.

8-6.01.10 Plastic Soil Cap Treatment at the End of Large Drainage Structures

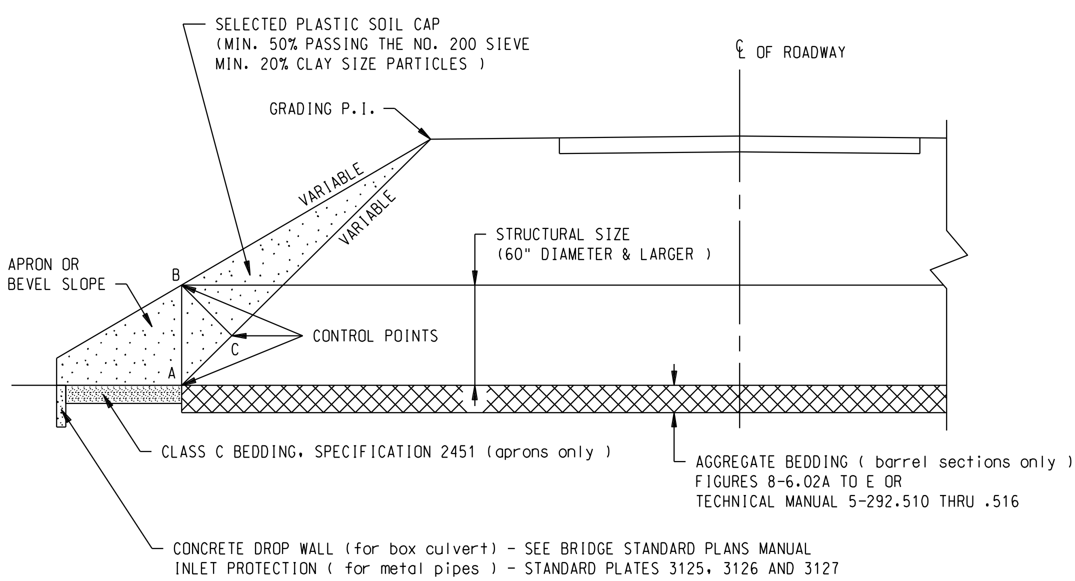
Erosion and piping of the granular bedding and/or the backfill of large drainage structures has occurred on both the inlet and outlet ends. Generally, the problem is most prevalent at the inlet end. Scour is generally less of a problem when flare-type aprons are provided for the structure.

Although large metal pipe and precast box culverts normally have straight-type aprons, they have concrete drop walls to protect the bedding from erosion (see Standard Plates 3125, 3126, and 3127, and Bridge Stand Plans Manual). However, these treatments may not be sufficient to prevent erosion around the structure, especially with flooding conditions and granular embankments.

To alleviate this potential problem, a plastic soil cap as shown on Figure 8-6.02H should be provided over large drainage structures (60 in. diameter and greater) when recommended by the District Materials and/or Soils Engineer. The treatment normally will only be required at the inlet end of the structure; however, when deemed necessary it may also be used at the outlet end. The treatment may be recommended for use with either granular embankments or plastic soil embankments when granular treatments are provided.



TREATMENT OF BOX CULVERTS IN PLASTIC SOILS
Figure 8-6.02A



NOTES:

THE TREATMENT SHALL BE RECOMMENDED BY THE DISTRICT MATERIALS AND/OR SOILS ENGINEER.

WIDTH OF PLASTIC SOIL CAP:
a) FOR PLASTIC SOIL EMBANKMENT - FULL WIDTH OF THE GRANULAR TREATMENT PLUS 2′ ON EACH END
b) FOR GRANULAR SOIL EMBANKMENT - A MINIMUM OF ONE DIAMETER OR WIDTH OF STRUCTURE ON EITHER SIDE OF THE STRUCTURE.

THE TREATMENT IS NORMALLY REQUIRED ONLY ON THE INLET END.

THE THICKNESS OF THE PLASTIC SOIL CAP (B-C) IS 3′ MINIMUM AND 6′ MAXIMUM.
a) FILL HEIGHTS LESS THAN 15′. NORMALLY EXTEND THE LINE THRU (A-C) TO THE GRADING P.I. HOWEVER, IF THIS RESULTS IN A THICKNESS (B-C) GREATER THAN 6′, REDUCE B-C TO 6′ OR LESS AND INTERSECT THE FILL SLOPE RATHER THAN THE P.I.
b) FILL HEIGHTS GREATER THAN 15′. THE LINE THRU A-C NEED NOT INTERSECT THE GRADING P.I. INSTEAD INTERSECT THE FILL SLOPE AT A POINT NOT LESS THAN 5′ ABOVE THE STRUCTURE MAINTAINING AT LEAST A MINIMUM THICKNESS (B-C) OF 3′.

PLASTIC SOIL CAP TREATMENT AT LARGE DRAINAGE STRUCTURES
(60" DIAMETER OR EQUIVALENT PIPE-ARCH AND LARGER)
Figure 8-6.02B