

Section 5: Engineering and Design for Erosion Control

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5.1. Introduction

This section describes the plan sheets and documentation needed to meet the SD DENR requirements for coverage under the General Permit for Storm Water Discharges Associated with Construction Activities (General Permit). Erosion and sediment control design considerations, the BMP selection process, engineering design methods, and permit submissions related to the Storm Water Pollution Prevention Plan (SWPPP) submissions are discussed here. The documents and procedures covered in this section are related to available standard plates, and revised Section D Plan Notes which are now the template for the SWPPP.

5.2. South Dakota Department of Transportation Policy

SDDOT has adopted policies and conventions to be used in the preparation of the SWPPP. Those charged with preparation of the plan must be familiar with these policies, as well as the requirements of the SD DENR General Permit.

5.2.1. The Plan

The SWPPP consists of the Section D SWPPP (formerly the Sediment and Erosion Control Plans) and the SWPPP plan sheet. This set includes the project cover sheet and may include other drawings in the construction document set. Together, these sheets fully describe and control erosion and sediment control work to be performed for the project.

The SWPPP is bound with the construction documents to ensure that they are clearly considered part of the work to be performed. However, the package is also designed so that the SWPPP materials can be detached and used as a stand alone document to meet the permit filing requirements. In so far as possible, all repetitive items that apply to every construction project have been included in the new SWPPP as boiler plate. This limits the plan preparation time to the technical concerns related to the unique erosion and sediment controls of each project.

5.2.2. The Notice of Intent (NOI)

The NOI is a three page form provided by SD DENR. Complete and file this form at least 15 days prior to the beginning of construction. It is recommended that a copy of the SWPPP documentation that is included in the plan set be submitted and attached by reference as a part of the NOI.

5.3. Preparing the Storm Water Pollution Prevention Plan (SWPPP)

5.3.1. Introduction

The SWPPP is only one part of meeting all the water quality mandates. Other requirements may exist for both water quantity and quality controls. Therefore, preparation of the SWPPP should begin during the early stages of the design process. For new construction, a preliminary review of water quality issues should be conducted just prior to selecting the final roadway alignment so that, to the extent possible, the alignment will minimize areas that will be difficult to stabilize, or minimize alignments that may involve costly temporary and permanent measures to meet long term water quality issues. For reconstruction projects, planning for water quality should be part of the preliminary project design review. Many times there may be a need to retrofit existing structures to provide more or better water quality and quantity controls, which may require additional right-of-way or consideration of underground structures. Likewise, the needs for temporary erosion and sediment controls should be evaluated to ensure that the appropriate field information is gathered and available as the detailed design process proceeds.

The issue of maintenance projects is sometimes problematic since any activities considered “maintenance” are excluded from the requirements of the General Permit. On the other hand, designers and maintenance engineers need to be alert to potentials for accelerated erosion and take appropriate steps to prevent potential discharges into water bodies adjacent to the state’s right-of-way.

5.3.2. Planning the Temporary Erosion and Sediment Controls for the Project

Temporary and permanent erosion and sediment controls are one part of the broader considerations of NPDES storm water quality issues. Therefore, it is important to consider the information in this section within the broader context of storm water quality. This includes the full package of structural and nonstructural controls utilized to achieve the storm water quality goals of a project. While the focus will be on temporary erosion and sediment controls related to the construction period, when relating this to the overall Road Design Process, reference will be made to other closely related storm water quantity and quality issues.

The SWPPP should begin in the early stages of project development. As the project progresses through the SDDOT Road Design Process, storm water quality issues and needs should be evaluated at each stage of development. There are specific points in the SDDOT process where, depending on the scope of the project, storm water quality and quantity review is recommended. The following section discusses considerations in the context of the SDDOT Preconstruction Engineering scheduling system referring to each step or activity of the process.

5.3.2.1. Project Scope (Activity 3023)

During this part of the process a preliminary review of all storm water quality issues is suggested. This would include, but not be limited to, both temporary and permanent erosion and sediment controls, as well as permanent storm water quality and quantity needs, particularly with respect to potential need for additional ROW and special site conditions such as the potential presence of historic properties or endangered species. These considerations may also impact final alignment selection.

5.3.2.2. Field Survey (Area Office Activity 3137)

The data needs for every project will be different in terms of the detail and extent. However, there are some basic storm quality data that should be collected for most projects of any significant scope. These data support the entire project development process, but may include additional details to support water quality management.

- **Vicinity map.** This map should have topography and hydrography so that offsite runoff contributions and potential problem conditions (such as adjacent wetlands or other sensitive habitat) can be identified, and proper measures designed to avoid conflicts.
- **Drainage Information.** Drainage information, such as channel cross sections, field drainages, potential off site discharges, or run-on potentials should be collected. Where significant flows may be encountered, information should be developed for flow depths and peak discharge rates.
- **Existing Erosion and Sediment Control Practices.** Any existing erosion and sediment control measures should be identified. These might include diversion terraces on slopes, energy dissipaters at culvert outlets, stone riprap, or other channel protection measures.
- **Soils Data.** Collect general engineering soils data and erosiveness properties of the soils on the project. This information is available from the South Dakota office of the National Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS). Review of this information is important for selecting the most cost-effective erosion controls for the project.
- **Field Review.** Conduct a field survey of the project corridor. Use a map to delineate special conditions and problem areas that will need special treatment. Be alert to the subtleties of the site such as potential neighbor problems, sites with possible historic connections, channels connected to pristine waters, or existing vegetation that will be very difficult to re-establish, etc.

5.3.2.3. Preliminary Design Activities

These sections of the preliminary design process need to be reviewed carefully to be sure that erosion and sediment controls, both temporary and permanent, are being taken into account. The amount of detail and the extent that any part of the project may be affected depends on the scope and the complexity of the project at hand. Not every project will require each action noted here.

- **Review/Update Scope (3053).** This should note any special provisions for storm water quality and/or erosion and sediment control in the Roadside Development section and the Environmental section of the scope summary. The Right-of-way (ROW) and Environmental Needs section should also be used if there are any special considerations.
- **Develop ROW Strip Map (3080).** This would note any special allocations of land for permanent sediment or storm water quality structures.
- **Develop Preliminary Gradeline (3055).** This should be evaluated for issues such as the potential need for velocity controls, troublesome slopes, and special conditions, such as step bridge abutment slopes, that may require special stabilization.
- **Develop Preliminary Roadway Design (3056).** This contains specific provisions for review of drainage channels, erosion control, and other issues such as permanent storm water quality and quantity needs.
- **Revise Preliminary Roadway Design (3057).** This step includes an on-the-ground site inspection. This should be used to identify any problem areas for erosion and sediment control needs that may not yet have been identified in the design process. The information gathered here should be the basis for developing the .DGN level(s) that will carry the SWPPP erosion and sediment control requirements.
- **Develop Erosion Control Plans (3085).** This is the period when the detailed preparation of the SWPPP would take place.

5.3.2.4. Final Design Plans

These are the tasks involved in developing the finals plan sets that will go to letting. The new [SWPPP template](#), formerly Section D Plan Notes, the standard erosion and sediment control plates, and the temporary sediment and erosion control plan sheets are incorporated into the project drawing set, and the Notice of Intent (NOI) is completed for submission to SD DENR.

- **3060, Final Roadway Design 2.** This continues the review and preparation of the SWPPP and the NOI documents.
- **Develop Final Roadway Design and Conduct Inspection (3059).** This is the final opportunity to meet on-site with the design team and incorporate all revisions made from meetings and reviews by the design squad. This review should integrate the guidance of the SWPPP preparation checklist with the Final Design Inspection checklist in Chapter 18 of the Roadway Design Manual.
- **Complete Erosion Control Plans (3086).** This is the final preparation for plans prior to review.
- **Revise Erosion Control Plans (3087).** This is to make revision from review comments and to complete the plans for release to the Bid Letting office.

5.4. Design Methods for Temporary Sediment and Erosion Controls

Field conditions during construction change constantly from day to day and weather events are unpredictable. For these reasons designing temporary erosion and sediment controls can be considered part art and part science. It is helpful if those

charged with developing water quality plans, including temporary and permanent erosion and sediment controls, have good professional judgment and an understanding of erosion processes, materials and methods of erosion control as well as working knowledge of soil mechanics, hydraulics, hydrology. The following section discusses the tools that are available to guide the design and selection of erosion and sediment controls. As appropriate, references will be made to existing SDDOT manuals and methods appropriate for design and selection of materials and methods.

This discussion of design methods will be divided into the two primary categories of erosion control and sediment control. Each of these categories will be further divided based on the design considerations and design methodologies.

5.4.1. Modeling Erosion

Often the decision about the appropriate types of controls requires some estimate of the potential sediment load a site may generate. The Revised Universal Soil Loss Equation (RUSLE) is a model used to estimate annual sheet and rill erosion rates caused by rainfall and the associated overland flow. RUSLE is the result of a tremendous amount of data collection and evaluation from the 1930s through the 1970s. It was originally developed in the 1930s as the Universal Soil Loss Equation (USLE) for farmers and the agriculture profession as a tool to manage their soil but its limited application led to the development of RUSLE. The need for this USLE revision, which took place in the 1980s, became apparent as users demanded more flexibility in modeling erosion which was not offered in the original equation. RUSLE is represented by the following equation:

$$A = R \times K \times LS \times C \times P$$

where:

- A = Average annual soil loss in tons per acre, per year across entire site.
- R = Rainfall Runoff Erosivity Index is a statistic calculated from the annual summation of rainfall for a given area. It is calculated using the following equation:

$$R = E \times I/n$$

where:

- E** = Kinetic energy of raindrop
- I** = Maximum 30-minute storm intensity
- n** = Number of rainfall events

This equation indicates that the greater the intensity and duration of the storm, the higher the erosion potential. While *total* rainfall is important, *intensity* most affects the amount of erosion in that a slow, steady, gentle rain will not be as erosive as a short, intense torrential downpour. As expected, the R value varies geographically.

- **K** = Soil Erodibility Factor. This is a measure of the ease with which soil particles are detached by raindrop impact and tractive force of surface flow (runoff). The two most significant soil characteristics affecting soil erosion are infiltration capacity and structural stability. Tight clays do not allow infiltration as soils with high organic content. Structural stability, or the resistance of soil particles to breaking off, determines the amount of sediment displaced by the overland flow. This erodibility value is calculated by determining the amount of soil loss after placing a particular soil in a plowed but unseeded condition in a test plot with a slope length of 72.6' and slope steepness of 9%. K factors are available from South Dakota Department of Agriculture, SSURGO Soil Reports.
- **LS** = Slope Length-Gradient Factor. The LS factor is based on the fact that the steeper slopes produce higher overland flow velocities. Longer slopes accumulate runoff from a larger area and also results in higher overland flow velocities. Thus, both result in increased erosion potential, but in a nonlinear manner. The LS factor represents a *ratio* of soil loss of a particular slope, possibly at a construction site, with the 'standard' slope length of 72' and a steepness of 9%. For convenience L and S are grouped together into a single term.
- **C** = Crop Management Factor indicates the influence of cropping systems and other management variables on soil loss. It is the most computationally complicated of the RUSLE factors, yet it is the factor over which we have the most control. The C value for a specific location depends on a number of factors including the crop (vegetation) being grown, crop stage, tillage and other management factors. Technically, the C value is the ratio of soil loss under the conditions found in the field in question to that which would occur under clean, tilled, yet unseeded conditions. The C value will be high (approaching 1.0) with bare soil. It will be low (<0.10) where large amounts of vegetation or crop residue are on the surface of the ground. These values are typically computed by experienced scientists with knowledge of the effects of vegetative cover and management practices in a given area. Actual values are available through the USDA Soil Conservation Service.
- **P** = Support Practice Factor (sometimes called Conservation Practice Factor) indicates the effects of practices that will reduce the amount and rate of the runoff thus reducing the amount of erosion. The P-factor is defined as the ratio of soil loss with a given surface condition to soil loss from up-and-downhill plowing. This factor accounts for the erosion control effectiveness of such land treatments as slope roughening, establishing sediment basins, and other control structures. Terracing, vegetated buffer strips, and contour plowing all reduce P values. If there are no support practices the P-factor is 1.0.

The biggest problem with RUSLE is that the C and P factors have not yet been calibrated for use in transportation construction applications. The Support Practice Factor, **P**, does not allow for evaluating combinations of practices in a way that will allow optimization of design. However, there are no better tools currently available that are as simple and rely on commonly available data.

The Modified Universal Soil Loss Equation (MUSLE) is a derivative of RUSLE. MUSLE follows the structure of the Universal Soil Loss Equation with the exception that the rainfall factor is replaced with a runoff energy factor. This form allows the estimate of the sediment yield for a single storm event rather than the annual loading. The estimates obtained with MUSLE are generally reliable within a watershed that does not exceed 5 square miles.

RUSLE has been derived empirically and has been used internationally because of its relative simplicity and because of the small amount of input required. However, one of the limitations of using the RUSLE model is that it predicts erosion across the entire site, but it does not account for deposition. In addition, it can not account for complex topography even when integrated with complex GIS analysis. Though updated, the main focus of RUSLE is to predict long-term sheet and rill erosion on disturbed hill-slopes. As such, RUSLE does not provide estimates for gully erosion, streambank erosion, or sediment yield from watersheds or single rainfall events.

5.4.2. Public Domain Software for Modeling Erosion

RUSLE 2 (2000)

RUSLE 2 is an advanced, user-friendly software program that predicts average annual erosion by water for construction, farming, mining and forestry use. It is a public domain Microsoft Windows® based program and can be downloaded from: ftp://fargo.nserl.purdue.edu/pub/RUSLE2/RUSLE2_Program_File/.

The Water Erosion Prediction Project (WEPP)

The USDA Water Erosion Prediction Project (WEPP) erosion model is a continuous simulation erosion prediction model implemented as a set of computer programs for Windows® based personal computers. Continuous simulation means that the computer program simulates a number of years with each day having a different set of climatic conditions. On each simulation day, a rainstorm may occur, which may or may not cause a runoff event. If runoff is predicted to occur, the soil loss on the site (erosion), sediment deposition, and sediment loss off-site will be calculated. This value can then be divided by a time interval which allows erosion to be predicted on a daily basis.

WEPP represents a new generation of technology for estimating soil erosion and sediment delivery from slopes, channels and small watersheds based on the fundamentals of weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics. It allows users to simulate runoff, erosion, and sediment delivery from entire watersheds (up to 2000 acres) or portions of the watershed. The program also allows the user to compare management practices under different scenarios. It offers a *Landscape Profile* application which provides a major advantage over existing erosion prediction technology. The advantages of this application include capabilities to estimate net soil loss for an entire hill-slope on a daily, monthly, or annual basis. Since the model is process-based it can be used to calculate a broad range of conditions that are not practical or economical to field test. In watershed applications, sediment yield from an entire watershed can be estimated.

The following erosion processes are simulated by the WEPP erosion model:

- detachment and transport by *raindrop impact*
- detachment, transport, and deposition by *overland rill flow*
- detachment, transport, and deposition by *concentrated channel flow*
- deposition by *impoundments*

Factors used to calculate these processes include rill erosion (caused by water flowing over the land) and inter-rill erosion (caused by raindrop impact and splash), sediment transport and deposition, surface sealing, rill hydraulics, surface runoff, plant growth, evaporation, transpiration, snow melt, frozen soil effects, and soil roughness, among others. WEPP takes into account both spatial and temporal variability in topography, surface roughness, soil properties, and land use conditions of hill-slopes. Almost all of these factors used for hill-slopes are duplicated for concentrated channel flow. Impoundments such as check dams, culverts, and filter fences can be simulated and evaluated to remove sediment from the flow. The model has been validated against approximately 1,000 plot years of natural rainfall from 15 different watersheds across the United States.

Included in the WEPP system is a climate database, a soil database, and user interface programs which allow end users to 'customize' and save information. The above mentioned factors and databases make the WEPP model a very powerful tool for users involved with natural resources or environmental issues.

The WEPP software and tutorial can be downloaded at:
<http://www.ars.usda.gov/Research/docs.htm?docid=10621>

WEPP is an evolving tool and requires data at the watershed level. These data are seldom available for rural highways which may cross several watersheds within the limits of a single project. However, in time, the NRCS, cities, counties, and transportation agencies will continue to develop detailed geographic information systems. Therefore, the data required to effectively utilize WEPP and other hydrology software will be increasingly available. Until that time, WEPP remains a tool of limited use in most transportation applications.

However, it is important that those in SDDOT charged with design of sediment and erosion controls for construction sites are familiar with these basic modeling tools. At this time RUSLE and WEPP are the most widely recognized and defensible tools available for estimating sediment loads. When projects involve particularly sensitive waters or habitat these program are the best tools for addressing how decisions will be made regarding appropriate BMPs and how they will be maintained.

5.4.3. Designing Erosion Controls for Shoulders, Borrow Ditches, and Slopes

The design and selection of materials and methods for erosion control on shoulders, borrow ditches, and slopes focuses on minimizing the forces of wind, rain drop impact, and concentrated flows that can detach and transport soil particles. Some proprietary applications have been developed based on the RUSLE. These applications have been developed by manufacturers of erosion control products to guide the selection of their products. However, there is no similar public domain tool available other than RUSLE 2 and WEPP. Because of the wide range of materials and methods available for controlling general erosion, as well as sediment designers need to consider several site related factors:

- slope
- soil type, and
- material longevity.

Slope: represents part of the energy component of driving the erosion process. The greater the slope the greater the shear stress will be on the soil surface. As water sheets over the surface of a slope it will accelerate down the slope, therefore the longer the slope the greater the velocity and the greater the stress.

Soil Type: The most significant property of a soil that affects erosivity is the soil texture. Soil texture refers to the particle size distribution of the soil horizons in terms of the percent of sand, silt and clay. The relationships between the particle sizes are usually most often displayed in a three sided matrix called the “Soil Triangle” (see Figure1). Each side of the matrix represents the percent of sand silt or clay particles in a soil. The shaded part of the matrix represents soils that for erosion control purposes will behave as sands or non-cohesive soils. The soils in the unshaded area will behave as clays or cohesive soils.

Material Longevity: The life of a material or method of erosion control affects selection in two ways. First, it is important that a material last for as long as needed. That is generally the period of time that it will take to establish enough permanent vegetation so that the temporary cover is no longer needed. The second consideration is cost. Materials that last longer are generally more expensive than shorter lived materials. The tendency to select a longer lived material as a measure of safety is not a particularly good choice. If a material persists after achieving a stand of vegetation it can interfere with maintenance activities and particularly mowing machinery. So it is critical to select materials that will degrade at about the same rate as vegetation establishment. In cases where planting can be done in season, that is spring or fall planting erosion controls that last for a single season are preferred. The only time longer lived materials are usually warranted are in high elevations or in drought prone areas where it may take two or three seasons for the vegetation to mature to a sufficient height and density to provide protection.

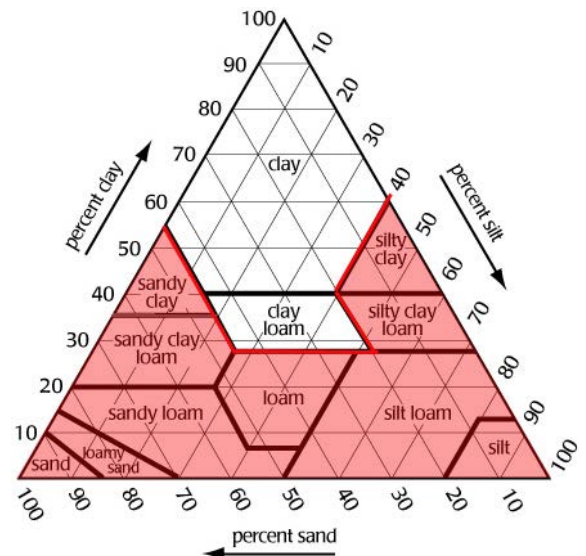


Figure 1: Soil Triangle

Because there are so many materials and methods from which to choose, a simple decision tree was developed that can be used to guide users through the selection process. The selection tool includes commercial products, mulches, blankets, turf reinforcement mats (TRM), bonded fiber matrices (BFM), as well as non-proprietary materials and methods, such as straw mulch and surface roughening. The tool is

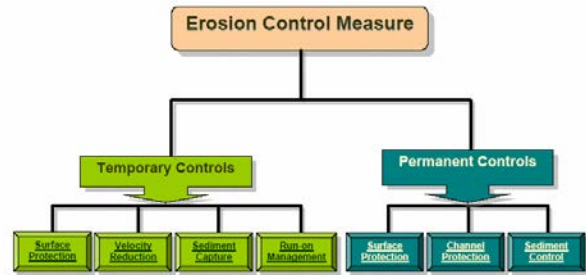


Figure 2: BMP Selection [Process](#)

introduced in Section 3 of the Design Manual. The decision tree was developed based on over 15 years of research and field testing of erosion control products. It takes into account the primary considerations of soil type, slope steepness, and general function of erosion control or sediment control. It does not directly consider material longevity. Because of the variation in materials, the lack of any testing or ranking standards, and the impact of climate on breakdown, designers will have to exercise judgment in making decisions about longevity. As noted earlier, materials that will degrade over the period of a single season are usually sufficient except in very special cases where climatic extremes are encountered.

One word of caution about surface protection materials; in highly erosive soils it is important to select a material that is sufficiently flexible to maintain intimate contact with the soil, otherwise the material does little more than cover up the erosion below the blanket. Rigid materials, such as heavily tacked straw, stiff synthetic materials, and heavy coir fibers sometimes lack flexibility and will simply span rills which continue to grow with each succeeding rainfall event.

5.4.4. Temporary and Permanent Channel Liners

Channels require a more sophisticated design consideration. In general, the selection of the lining material should be based on the shear stress rating of the material and the design shear stress of the road side channel. The design procedures for determining channel shear stress are in the Chapter 9 of the SDDOT Drainage Manual.

In Chapter 9 of the SDDOT Drainage Manual the use of the HEC-15 program to compute the shear stress on the channel bottom is recommended. However, the calculation is quite simple and for the selection of a channel liner the calculation can be done manually. Equation 1 is used to determine the shear stress on the bottom of a straight line channel. This is the most practical form of the equation since channels are usually parallel to straight line pavement sections so a value of one (1) is used for the bend coefficient.

As an example, the shear stress on the roadside channel that has a longitudinal slope of 0.043 and an estimated depth of flow of 18 inches.

$$\tau = gDS_f K_b$$

τ = Shear in #/ft²
 g = Unit weight of water (62.4#/ft³)
 D = The depth of flow in feet
 S_f = Friction slope or bed slope of Channel
 K_b = Bend Coefficient (K_b is 1 for straight channel)

Equation 1: Shear Stress on Straight Line Channels

$$\tau = gdS_f K_b$$

$$\tau = 62.4 \frac{lb}{cf} \cdot 1.5^f t \cdot 0.043^{ft/f} t \cdot 1$$

$$\tau = 4.02 \frac{lb}{ft}$$

The channel will have a peak shear stress of 4^{lb/sf}. Working through the selection tool for channel protection, you determine that Type 1 Turf Reinforcement Mat (TRM) is the minimum product that will meet this need.

5.5. Design Checklist

This [SWPPP Checklist](#) was developed to guide the preparation of the SWPPP document. This tool ensures the requirements are met to secure approval of the Notice of Intent (NOI) and SWPPP under the SD DENR General Permit for Storm Water Discharges Associated with Construction Activities. The list can be used in either paper or electronic format. The first column of the checklist is a series of check boxes to indicate a task is complete. The second column of the checklist cites the section of the General Permit that task relates to. The third column is a description of the task or product to be produced, and the fourth column is used to provide quick references to the specific page in the SWPPP plan set that addresses the requirement of the permit. The check list follows the section organization of the SD DENR General Permit for Storm Water Discharges Associated with Construction Activities.