Tennessee Department of Transportation (TDOT)

Statewide Storm Water Management Program

Program Rationale, Evaluations, and Recommendations for Erosion Prevention and Sediment Control Materials and Practices for TDOT Construction Projects

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May 2007

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1 Evaluation of Environmental Division Procedures and Roadway Design (A.1)

1.1 Evaluation of Current Interdepartmental Coordination (A.1.c)

This section describes TDOT's current project development process and interdepartmental coordination. Based upon interviews with staff and document review, TDOT's past processes for highway planning did not consistently integrate interdisciplinary participation throughout the lifecycle of project planning, design, construction, and maintenance. Although the project planning and development process is now moving towards a more coordinated interdisciplinary approach, procedures do not appear to be consistently applied from project to project. In addition, the level of detail in information available or used in highway planning varies considerably among projects and divisions.

1.1.1 Past Planning Practices Evaluation

Often in past highway project planning, ecological information was not included in decisions on corridor or alignment selection. Rather, selections were made and then provided to environmental staff for studies necessary to produce documents under the National Environmental Policy Act (NEPA) to evaluate impacts of the chosen corridor and support the decision for the project. Later in the process, detailed studies were performed to acquire information needed to complete permit applications.

TDOT is not unique in this regard. According to the National Cooperative Highway Research Report 480 (NCHRPR 480):

> For many years, planning, design, and construction of highways and streets have been left mostly to the 'professionals' – highway and traffic engineers. Selection of routes, the design of the alignment, location of intersections, and the roadway features were based primarily on engineering considerations, with the objective being to provide the highest quality service at the lowest construction cost.

In February 2005, the Federal Highway Administration (FHWA) provided guidance on linking transportation planning and the NEPA processes. This guidance stated that, despite the statutory emphasis on transportation planning, the environmental analyses produced to meet the requirements of NEPA were often disconnected from the analyses used to develop long range, statewide, corridor, and feasibility studies or Federal Transit Administration (FTA) planning alternatives analyses. The FHWA guidance further stated that the transportation planning process should work in tandem with the analyses required by NEPA. Some other relevant contents of the guidance included:

- A planning level analysis need not be conducted at the level of detail required in the NEPA process.
- Transportation planning processes would benefit substantially from early involvement of federal, state, and local environmental, regulatory, and resource agencies. Consideration of the concerns raised by these agencies

early in the process could facilitate consideration of permit applications for projects that implement transportation plans.

- A robust scoping and early coordination process should play a critical role in leading to informed decisions on the suitability of transportation planning information, analyses, documents, and decisions.
- The NEPA process should be used early in transportation planning to establish purpose and need, as well as providing a basis for objectively screening alternatives from detailed analysis.
- Existing information should be used to identify current and projected conditions that might affect alternative considerations (demographic trends, environmentally sensitive areas, land use or natural resource management plans, etc.); GIS was suggested as a possible tool for this level of analysis.
- Results from environmental planning can be used to streamline transportation planning processes, including development of mitigation strategies. Streamlining the planning process will help to meet transportation and conservation goals.
- A variety of possible mechanisms should be used to facilitate working partnerships within transportation departments and with other environmental, regulatory, and resource agencies.

Consideration of sensitive resources early in project development will reduce development time and overall costs of highway projects. Furthermore, incorporating such factors into project planning can reduce the impacts of highway projects and will result in projects that are more compatible with natural and cultural environments while serving the public in a safe and efficient manner.

Storm water management planning should begin with initial phases of transportation project planning. As described in NCHRPR 480, in environmental terms, the concept of Context Sensitive Solutions (CSS) is to ensure that a project "lays lightly on the land." To accomplish this, environmental considerations must be a meaningful part of the solutions generating process, not add-ons, or after-the-fact steps.

Early incorporation of environmental considerations makes it easier to accommodate project changes from the outset such that cost and schedule impacts are minimal. In essence, the NEPA and CSS processes are very similar, and the two can merge very easily. It is within this concept that storm water management planning, along with other considerations, must be incorporated into early project planning. Inherent in the idea of early consideration of environmental information is the premise that more options exist early in the process before there is an over-commitment of resources through project development.

According to NCHRP 480,

> Successful and efficient project development and delivery almost always require synchronicity between the level of detail in the engineering and environmental analysis. Failure can be expected when the level of engineering greatly exceeds the level of

> environmental analysis or vice versa. For example, not having enough information about the affected environment while advancing a design concept can lead to the discovery of a deal-breaker late in the process and the need to go back and search for another alternative. Conversely, having adequate information about the surrounding environment, but failing to consider the feasibility of tying in an interchange to a freeway corridor can also lead to backing up and looking for another alternative. It is also critical that construction feasibility be kept in mind as attempts to avoid, minimize, or mitigate environmental issues are pursued.

It is important to note that, while NEPA is required only for projects that include federal funding, the same early planning processes should apply to projects that do not include federal funding to ensure they are also compatible with environmental protection goals. Furthermore, most projects that do not include federal funds will ultimately include federal actions, such as Tennessee Valley Authority (TVA) Section 26a and/or U.S. Army Corps of Engineers (USACE) permits under sections 404, 401, and/or 10, which will require these agencies to invoke NEPA. However, applying NEPA (or the basic tenets of NEPA) only when federal permits are sought for the planning and development of a specific project can seriously restrict the range of options for TDOT to select alignments that avoid or minimize adverse impacts. This often leaves an in lieu fee payment as the only means of accomplishing mitigation. TDOT should use the NEPA process to provide a uniform structure under which all environmental laws, regulations, and policies are considered in a coordinated fashion during planning and development decision-making. It is important that resource and regulatory agencies, as well as the public, have meaningful opportunity to contribute ideas for solutions to transportation problems early in the planning process.

1.2 Recommendations for Developing an Interdisciplinary Project Planning Team (IPPT)

NCRHP 480 states that an important characteristic of the process to yield excellence in highway project development includes establishing a multi-disciplinary team early in project planning with disciplines based on the needs of the specific project and should include the public. Another important attribute would be to understand the landscape, the community, and valued resources that may be impacted by the proposed project before beginning engineering design. Further, every project has a context as defined by the terrain and topography, the community, users, and the surrounding land use.

For these reasons, it is essential that an interdisciplinary team become involved in transportation planning from the very beginning of the process. TDOT has previously used interdisciplinary teams for project planning but found that a set team made up of staff members from various interdepartmental groups that followed a project from planning through design was too demanding on staff resources. **As an alternate application, we recommend that an interdisciplinary team be developed, consisting of staff from interdepartmental groups that provides input on project planning and development at key steps during the process,** instead of every team member being involved at each project development step. This type of project planning process can easily be facilitated through the SEMS project under development by Dye Management.

The remainder of this section describes the disciplines that should be included on the interdisciplinary team and the key points for input to be considered.

1.2.1 Interdisciplinary Project Planning Team Make-up

The following groups throughout TDOT should be represented on the IPPT:

- **Project Manager (Project Management Division)**
- **Ecology (Natural Resources Office, Ecological Services Section)**
- **Geotech (Materials and Test Division)**
- **Design (Roadway Design Division)**
- **Hydraulics Section (Structures Division)**
- **Project planning (Project Planning Division)**
- **Environmental planning (Environmental Division)**
- **Environmental permitting (Natural Resources Office Environmental Design Group)**
- **Construction (Construction Division)**
- **Right of Way (Right of Way Division)**

The above list should be viewed as a "core" team, as it provides a good starting point for most transportation planning and development processes. However, depending on characteristics of any specific project, the IPPT should be supplemented with other specialized expertise as necessary. The IPPT should be considered dynamic in that it may be joined by other professionals with expertise in differing areas as appropriate for the project. In addition, the IPPT, not an individual, should sign off on each key step (see below). This dissemination of information and responsibilities will prevent an over-reliance on one individual and will allow responsibilities to shift within a professional group to prevent a bottleneck in the project development process. Determining the make-up of the IPPT early in the project planning and development processes, and identifying key issues early in the process will allow limited resources to be prioritized to focus on critical issues as the planning and design processes evolve. Finally, bringing outside resource agencies into the IPPT to supplement the team's expertise should be a priority. Coordinating with resource agencies early in the project planning and development process develops interagency trust, facilitates communication, and identifies critical issues early in the process, leading to a more cost-effective and efficient project development process.

1.2.2 Key IPPT Input Steps

As noted above, not all IPPT members should be saddled with having to follow all project development paths and attending all project development meetings. Instead, **each IPPT member should provide input on the following points through limited project development meetings and a built-in checks and balances process** (see 1.3.1 below). Project development should not be allowed to bypass or skip steps.

a. **Project Commitments**. Each commitment (environmental or otherwise) should be reviewed by the IPPT to evaluate how the commitment could impact other aspects of the project. For example, agreeing to a boulevard roadway layout with a wider corridor may significantly impact environmental permitting and mitigation if stream segments or wetlands are impacted. Alternative alignments could be evaluated to avoid or minimize impacts to receiving waters while meeting a commitment to provide a specific roadway design. Failing to include other team members in commitment review early enough in the process could result in time delays and inefficiencies with permitting and/or re-design requirements.

b. **Corridor Evaluation**. Each IPPT member should understand the alternatives evaluated for each project and know the rationale for choosing the final alignment. The NEPA evaluation should be made available to all team members. Understanding this background information will give each team member a better understanding of the project goals, limitations, and drivers.

c. **Environmental Boundaries.** Since environmental boundaries define mitigation, permitting, design, and ROW needs, the team should review environmental boundaries, once developed.

d. **Onsite Mitigation Design.** TDOT's project-related stream and wetland mitigation approach is shifting focus towards more onsite mitigation. In order to facilitate onsite mitigation, potential mitigation areas must be identified earlier in the project development process and must be incorporates into the project commitments tracking process.

Each of these components can easily be integrated into a digital document and project development tracking process to ensure that steps are not skipped or bypassed without approval from each IPPT member's group or Division.

1.3 Planning Process Recommendations:

This section describes recommendations related to early project planning and development activities. Generally, it appears that the planning and project development processes are comprehensive and complete. The following recommendations are mostly concerning the **communication** between Divisions and groups during planning and development.

1.3.1 Recommendations to incorporate checks and balances into the PPRM

Current project planning and development follows TDOT's *Project Development Activities - Program, Project, and Resource Management (PPRM) Manual.* The manual describes each planning and development activity within the Department and seeks to coordinate activities within Divisions and Sections within each Division so all of the planning and design aspects are addressed. To fully evaluate the PPRM activities relative to their sequence and application, the process would need to be audited, following several projects through the process to determine if the steps were appropriate and in sequence. Based upon discussions with staff, it was generally felt that the PPRM activities are appropriately sequenced and that the process is inconsistently followed. After reviewing

the PPRM process, it does appear that environmental data is being collected early enough in the project planning and development process to facilitate incorporation into the project design. In reviewing several existing TDOT projects that the RBF Team had under other contracts, numerous examples of process failures were encountered. Failures were more often caused by communication disconnections between the Design Division and Ecological Survey Section when streams or mitigation design were encountered but not fully incorporated into design plans, causing either re-designs or field problems for Construction. Such disconnects can increase project development costs. **We recommend incorporating checks and balances into the project planning design and construction processes to ensure the PPRM is being followed. In addition, the PPRM process should be fully integrated into the SEMS database under development by Dye Management, and it should include Division or IPPT sign off prior to advancing to the next project planning or development milestone.**

1.3.2 Recommendations to include environmental attributes of each alternative alignment, including low-impact corridor alignments, in the evaluation of each project or corridor alignment

This section outlines how GIS data sets should be incorporated into the alternative alignment analysis for new roadways.

The current project planning process collects and begins the analysis of environmental data for the NEPA process at Activity 285 in the PPRM. Each alignment alternative considers the same set of environmental data. The environmental GIS datasets described in Product 4 should be incorporated into the analysis of each corridor or alignment alternative. Those datasets include:

- Hydrology
- Impaired, Tier II and Tier III streams
- TMDL watersheds, including an identification for each TMDL pollutant
- Impervious surfaces
- NPDES CGP dischargers
- Public lands
- Q3 flood data
- Known sinkholes and Class V injection wells
- Soils
- Federal and state threatened and endangered species data, and state species deemed in need of management, including habitat for T&E species
- Known water quality monitoring stations maintained by USGS, TDEC or other agency where monitoring data is collected by USGS or TDEC
- Wetlands

- Buffer zones, as they relate to the NPDES CGP
- Cultural features
- Topography
- Caves
- State and federally owned parks, natural areas, and wildlife refuges

These GIS datasets and their attributes are described more fully in Appendix A.

1.3.3 Recommendations on interdisciplinary team protocols to predict the impact of discharging increased flows during and after construction.

1.3.3.1 During construction

Standard measures incorporated into typical roadway designs address discharging runoff in a non-erosive manner during and after construction. These measures include

Energy dissipaters at pipe outlets. The function of this control is to decrease velocities from pipe outlets from erosive velocities to non-erosive velocities.

Stabilized (non-stream) channels. The industry standards for channel design are the 2- and 10-year (for temporary and permanent, respectively) storm events. These design storms produce the most erosion. Channels are designed to be stable for the 2- and 10-year storm events. Therefore, installing and stabilizing channels early in construction activities and then protecting them from runoff from active construction areas with sediment controls constitute protection for the receiving system.

All perimeter EPSC measures should be installed before land disturbing begins and additional EPSC measures installed as appropriate for each phase of grading and then maintained throughout the life of the construction project. Ditches and pipe outlets should be stabilized as soon as possible and adequate outlet protection provided so runoff discharged onto adjacent properties or into streams occurs in a non-erosive manner.

1.3.3.2 After construction

In January of this year, TDOT adopted Chapter 8 of the TDOT Design Division Drainage Manual. Chapter 8 is entitled "Stormwater Storage Facilities" and covers detention design. However, this chapter does not currently address when to include stormwater mitigation measures or detention on a TDOT project, only how to design detention facilities.

We recommend that TDOT consider adding the following criteria to Chapter 8 to evaluate the need for detention or other stormwater mitigation in the design phase:

Projects that affect 1 acre or more should have hydraulic evaluations prepared for each outfall collecting runoff from the TDOT project. (Note that the 1 acre threshold aligns with the current TN CGP requirements for coverage and the upcoming threshold for the post-construction stormwater quality treatment requirements in TDOT's MS4 permit. Keeping the thresholds for hydraulic evaluation, CGP coverage, and post-construction stormwater quality treatment the same will identify these projects as needing a higher

level of stormwater design.) Each hydraulic evaluation should consider the following factors that influence the receiving drainage system's ability to handle increased flows:

- The receiving drainage system immediately downstream from the project does not have the capacity to carry the required design storm events (as defined in the Design Division Drainage Manual).
- Significant portions of the receiving channel are degraded or unstable, based upon field investigation (in the Ecology report).
- The project impacts a sinkhole drainage basin with limited capacity (if known) for increases in peak flow or volume.
- The project impacts an existing detention facility.
- The project discharges to environmentally sensitive areas, such as wetlands or critical habitat, as identified by the Environmental Division or in the Ecology report.

The evaluation should also take into consideration the following items:

- Existing and proposed land use
- Change in peak discharge and volume in the before and after project conditions
- Description of the downstream receiving channel
- An evaluation of the receiving channel's ability to accommodate the proposed design, with on focus on channel stability.

Furthermore, numerous communities in TN are instituting detention and storm water quality treatment standards in response to the NPDES Phase I and II requirements. Most TDOT projects are linear and have the potential to cross numerous watersheds and several different municipal jurisdictions. If TDOT followed each jurisdiction's storm water design requirements, each project could have numerous design goals, causing confusion and inconsistent design throughout the project. Instead, TDOT should follow their own guidance on storm water design and communicate these design standards and goals to each jurisdiction crossed by the project.

1.3.3.3 Recommendations for predicting the impact of increased flows

While the existing TDOT Drainage Manual contains information on design storms for detention structures, it does not include information to help the designer determine **when** to include detention. In an effort to gauge the impact from increased flows from TDOT roadway projects and develop a step-wise process to determine when storm water mitigation is needed, we have the following recommendations.

The Interdepartmental Project Planning Team should include hydraulic impacts as a component of the initial project screening process. During the project-planning phase for new roadway alignments, storm water discharges should be a consideration in the identification of the final alignment. **We recommend that the following criteria be incorporated into TDOT procedures for determining when storm water runoff mitigation measures will be required.**

To determine the impact of increased flows on the receiving storm water system, the following criteria should be used:

Initial screening. In early planning phases, a project should be screened for the potential to impact downstream systems. The total watershed impervious cover should be evaluated with the proposed project included in the impervious cover calculation. Each watershed crossed should be evaluated. Where the total impervious cover for each watershed exceeds 10%, a full hydraulic evaluation and report will be necessary, as outlined below. Where the total impervious cover within the project for each watershed is less than 10%, detention should not be included.

Hydraulic evaluation criteria. The criteria outlined below should be used to determine when storm water mitigation should be incorporated into the project:

- ✓ Roadway construction produces a 10 % or greater increase in peak flow volume for the design year storm event at any outfall;
- ✓ In areas where existing storm drain systems downstream of the project have been determined not to have sufficient capacity to carry the required design event (as defined in Chapter 10 of the Drainage Manual, using the Rational Method or the NRCS TR55 Method);
- ✓ At outfall locations where significant portions of the receiving channel are in a degraded or unstable condition, based upon field review;
- ✓ Where the project impacts an existing detention facility; or
- ✓ At outfall locations where the receiving channel is located in or leads to an environmentally sensitive area (wetlands, habitats, etc.).

Furthermore, numerous communities in TN are instituting detention and storm water quality treatment standards in response to the NPDES Phase II requirements. Most TDOT projects are linear and have the potential to cross numerous watersheds and several different municipal jurisdictions. If TDOT followed each jurisdiction's storm water design requirements, each project could have numerous design goals, causing confusion and inconsistent design throughout the project. Instead, **TDOT should follow their own guidance on storm water design and communicate these design standards and goals to each jurisdiction crossed by the project.**

1.3.4 Recommended methods, processes, and criteria for evaluation of the no-build option

TDOT's current practice for evaluating the no-build alternative follows the National Environmental Policy Act (NEPA) and the Environmental Impact Statement (EIS) process. First, a well-defined purpose and need is developed for each project. FHWA notes that

> ...a clear, well-justified purpose and need section explains to the public and decision-makers that the expenditure of funds is necessary and worthwhile and that the priority the project is being given relative to other needed highway projects is warranted. In addition, although significant environmental impacts can be caused by a project, the purpose and need section justify why impacts are acceptable based on the project's importance.

The Council on Environmental Quality (CEQ) regulations requires that the EIS address the no-build alternative and "rigorously explore and objectively evaluate all reasonable

alternatives." A well-justified and defined purpose and need are vital to meeting the requirements of Section 4(f) (49 U.S.C. 303) and the Executive Orders on Wetlands (E.O. 11990) and Floodplains (E.O. 11988) and the Section 404(b)(1) Guidelines. Once the purpose and need are identified for a project, the project alternatives, including the no-build alternative, can be more comprehensively analyzed for overall impacts to the cultural, natural, and social environments.

Generally, the no-build alternative is used as the basis for evaluating other alignments. A summary of how other DOTs consider the no-build option in evaluating the merits of each project alignment can be found in the table below. The information for each state DOT was based upon interviews with each DOT staff and review of any planning documentation provided.

DOT	**No-Build evaluation**
NCDOT	The no-build is considered not to meet the purpose and need for the project. It is a basis for comparison for the build alternatives. NCDOT does not specifically look into the positive aspects of not doing the project.
FDOT	The no-build alternative is considered a viable alternative through the public hearing. The DOT will determine which viable alternative(s) will be evaluated further through the public involvement process and environmental analysis. The possibility exists that the no-build alternate may be selected at this point and the project abandoned.
GDOT	Consideration of the no-build alternative is not consistent. It is always considered, but not usually selected (however, GDOT does not consider it only a checkbox). For Categorical Exclusion (CE) and Environmental Assessment (EA) projects, a brief discussion is given. The severity of impacts may warrant a more detailed discussion. A template-type statement is usually provided in the document as to how the no-build alternative does not meet the need and purpose of the project. For EIS projects (GDOT doesn't do many of these, currently only six EIS projects), greater discussion will be given for the no-build alternative. From the GDOT Environmental Procedures Manual: Discussion of the No Build Alternative is required to address CEQ guidelines. Typically, the text will identify the disadvantages of this alternative. Technically, the No Build Alternative is defined as a "do nothing" alternative, although it can include minor construction activities such as pavement maintenance and safety measures. No modifications to the roadway network would be included (i.e., no new access roads, extensions, or increases in capacity). The discussion should include acknowledgement of impacts and costs that would be avoided by the No Build Alternative. These advantages are weighed against the disadvantages from failing to meet the project's purpose and need.
Caltrans	The no-build alternative does not satisfy the project purpose and need. It is presented and evaluated as a basis of comparison with the reasonable alternatives.
TDOT	The no-build alternative provides the basis for comparison of all other alternatives. However, the no-build alternative does not satisfy the purpose and need for the project.

TDOT's process is detailed in the draft "TN Environmental Procedures Manual." This manual contains a comprehensive, stepwise approach to project planning, including the development of a project need and purpose, alternative alignments, and environmental analysis. **The "TN Environmental Procedures Manual" should be finalized, adopted,**

and used by Environmental Division staff as guidance in evaluating all project alternatives, including the no-build option.

1.4 Tools to Incorporate into the Planning Process (deliverables 2A.1.b, 3A.1.c, 5A.1.e, 6A.1.f, 7A.1.g)

The planning process is the initial alignment option evaluation process that involves many facets of roadway development (i.e., transportation needs analysis, safety, environmental). This section will provide tools that are recommended to be included in the project planning process from the initial planning stages through design and construction. The following sections provide rationale and recommendations for improvements to the planning, development, and implementation processes to avoid, minimize, and/or mitigate impacts to sensitive environmental features (i.e., streams, springs, wetlands, or protected species).

1.4.1 Mitigation

The following sections describe recommendations related to stream mitigation planning, design, and application.

1.4.1.1 Mitigation guidance and design

Routine mitigation measures are already in place, and suggested recommendations to improve the mitigation process are presented in the Mitigation Chapter developed as Product 2. The NCDOT manual entitled *Best Management Practices for Construction and Maintenance Activities* (BMP Manual) was used as a guide in developing mitigation measures for routine construction in and around water resources. The NCDOT BMP Manual appears to have been used by TDOT when developing the scope of work for Section A.1.b. **We recommend finalizing and adopting the Environmental Procedures Manual, with the inclusion of the mitigation chapter provided as Product 2, to be used by the mitigation design group and the Ecology Section for work in and around water resources. This guidance should be incorporated into project planning, development, and implementation.**

The Mitigation Chapter should be used by TDOT Environmental Division (ED) Ecology Section and the Environmental Design Group (EDG) staff when preparing natural resource assessments for transmittal to the Planning Division so that protection of sensitive areas (i.e., high quality streams, wetlands, E&T species) can be considered early in the process. The information can be provided to the planners within the Ecology Report (Scope A of the Ecology Studies scope of work). Mitigation measures should likewise be considered during the planning process so that the Design and ROW Divisions can incorporate and plan for inclusion of mitigation into the project plans Mitigation measures should be developed and implemented early in the process to ensure that the proper amount of right-of-way is acquired to perform the required mitigation. Additional information on mitigation is presented in more detail in Product 2a and will be developed as a guide for the Ecology Section within the ED and the Environmental Design Group to use when designing and reviewing projects that require mitigation.

Natural resource features, such as streams, springs, wetlands, and protected species, should be identified and measures evaluated to avoid these sensitive areas early in the planning and design process so that costly delays are not encountered once construction begins. If these sensitive environmental features cannot be avoided, impacts must be mitigated. TDOT has developed procedures for mitigating impacts to streams, wetlands, and protected species in accordance with the Ecology Section *Scope of Work for Ecology Studies*.

When mitigation is required (e.g., stream relocation, on-site wetland mitigation, or protected species), TDOT ED and Design Division staff should work together closely from the initial conceptual design phase through detailed mitigation plans for construction. Conceptual mitigation plans should be developed during the planning process of the project. The ecologists should then expand upon the conceptual plan with the Designer during development of the preliminary, ROW, and final construction plans. The proposed EDG should prepare mitigation design based on consultation with the Ecology Section and Roadway Design staff. It is recommended that the EDG be housed within the ED. Stream relocations and other mitigation activities, which are a part of Section 404 and Aquatic Resource Alteration Permit (ARAP) permitting, must be consistent with the Erosion Prevention and Sediment Control (EPSC) Plan and SWPPP development. The EPSC plan cannot conflict with terms of the ARAP (e.g., no check dams in streams) or conditions of the Corps of Engineers permit.

Whenever a project requires stream mitigation, an analysis should be performed to determine whether natural channel design is feasible for the project. Natural stream channel design should be used for all stream relocations greater than 50 ft. to avoid payment into the in-lieu-fee program for relocations. TDEC currently allows TDOT a 50 ft. transition zone to direct stream flow into a newly constructed culvert. A full-scale geomorphic stream assessment is not necessary in all instances (see Mitigation Chapter in Product 2). The installation of habitat such as rock and log structures, riffles and pools, and establishment of native vegetation will prevent payment of fees into the in-lieu fee mitigation program. The use of riprap lined stream channels (which requires the payment of $200/ft for 0.75 x the length of stream lined) should be avoided except in extreme cases. When riprap must be used, live stake willows and dogwoods should be used to establish a vegetated stream bank. Riprap can be used in transitional zones (up to 50 ft. on either end of the culvert). It should be noted that some projects would be located in highly urbanized areas where designing natural channels for mitigation will not be appropriate or feasible.

1.4.1.2 Stream Determinations and Mitigation

One of the most difficult aspects of project planning and development is identifying streams in the field. While many streams are obvious, headwater streams that may not have all of the typical characteristics of a stream may not be easily identified in the field. When streams are not identified in plans and prior to construction, costly delays and violations can occur. Currently, TDOT ED and their ecology consultants identify streams in the Environmental Boundaries Study and/or in the Ecology Reports. **It is recommended that TDOT use the Statewide Stream Determination Protocol defined**

by TDEC. If there is not a current standard stream determination protocol, it is recommended that TDOT, in consultation with TDEC, take a leading role in developing a stream determination protocol to be used across the state.

TDEC recently provided TDOT with an updated stream determination protocol that will be used on future projects in conjunction with an adapted version of the North Carolina protocol. TDEC developed the "Hydrologic Determination Guidance Key and a Hydrologic Determination Field Data Sheet. In reviewing protocols developed by other neighboring states, the North Carolina Department of Environment and Natural Resources, Division of Water Quality has one of the most comprehensive rating systems. The system is detailed in their guidance manual, *Identification Methods for the Origins of Intermittent and Perennial Streams, Version 3.1 (2005)*. This manual provides an objective procedure for performing a stream determination based upon the identification and scoring of geomorphic, hydrological and biological stream features that distinguish between ephemeral (wet weather conveyances), intermittent, and perennial streams. This numerical rating system provides for an objective method of stream identification and would provide a comprehensive approach for identifying streams in TN.

It is recommended that TDOT place a priority on natural stream channel design wherever feasible and practical. Initially, the RBF Team investigated the feasibility of initiating dialogue with the Tennessee Stream Mitigation Review Team (SMRT) to develop a functional and value assessment for streams. Following discussions with TDOT and others, it was determined that a multi-tiered in-lieu-fee program based on a stream's function and value would be difficult to administer. Furthermore, it is anticipated that the in-lieu-fee program will be phased out in the next few years. TDOT's priority in the planning and NEPA process will first be avoidance of wetland and stream impacts, second to minimize these impacts, and finally to mitigate for stream and wetland impacts. Nationwide, the trend for stream mitigation is to follow a stepwise approach to mitigation with the highest priority placed upon onsite mitigation. When onsite mitigation is not possible, mitigation banks or mitigation within the same watershed is the next highest ranked mitigation option, and where this option is not feasible, in-lieu-fee programs are accepted. As noted in Section 1.4.1.1, we recommend that the focus of TDOT ED will be on natural stream channel design for all relocations. Payment of in-lieu-fee funds should be reserved for culvert and filling impacts only. The goal is to incorporate stream mitigation design when practical into projects as a general practice rather that paying the in-lieu-fee. The current program and cost structure ($200/ft.) should be used for all types of streams.

1.4.2 Identification and Labeling of Natural Resources

The ED Ecology Section currently transfers environmental boundaries to the Design Division via Form G. The Ecology Field Study, Design Phase (Scope G) is prepared primarily for the ED to relay information about natural resources permitting requirements to the Design Division. This study is performed within the proposed ROW or easement limits shown on the plans provided by the Design Division. The natural resource features are identified as inside or outside the proposed ROW. The deliverable provided by this study includes the marking of the present and proposed layout sheets, features identified

on a USGS 7.5-minute quadrangle map, and photographic documentation of all natural resources identified during the field study. This information is provided to the Design Division for inclusion and incorporation onto the plan sheets. The intent of this Design level ecology study is to identify all natural resource features so the appropriate permitting can be applied. Likewise, the incorporation of these natural resources on the plan sheets, including erosion control plan sheets, should alert the Construction Division and contractors that a permitted resource is present at a certain location.

There does not appear to be a consistent procedure currently in place for identifying and labeling potentially impacted waters of the state. The problem encountered with the use of Form G is that once plans are completed, there is not a clear procedure for identification or placement on the present and proposed layout or on the erosion control plans that a stream or other sensitive area is present. Wetlands are typically well labeled on the plans with standard wetland hatching, as are known springs, but streams and sensitive areas (i.e., endangered species or critical habitat) are not clearly identified. It is recommended that all streams, springs, wet weather conveyances, and sensitive areas be clearly labeled and identified on the present layout sheet and on the EPSC plan. **All features labeled and described on Form G should be clearly shown on the Design Plans with the same designation as used on Form G. The following symbology used on Form G is an alphanumeric code with each successive feature described in ascending order (for example, STR1, STR2, etc.).**

CAV	Cave
LAK	Lake
PND	Pond or quarry
PSP	Protected species
RKS	Rock shelter
SEP	Seep
SNK	Sinkhole
SPG	Spring
SPH	Specialized habitat, management area
STR	Perennial or intermittent stream
WFL	Waterfall/cascade
WTL	Wetland
WWC	Wet weather conveyance

Other plan labels recommended to be included on the erosion control plans are any designated High Quality Waters (Tier II) or impaired waters (303(d)) listed streams. **It is recommended that all permitted streams be clearly identified with the symbology above and denoted as impaired or High Quality Waters.** These types of labels should clearly identify to the construction staff and the contractor that there are jurisdictional Waters of the State present and that precautionary measures should be employed around these sensitive environmental resources. Streams should also be labeled with names and symbology from Form G (i.e., STR-1, Sinking Creek, STR-2, Sugar Branch, Unnamed Tributary to Browns Creek).

The Environmental Boundaries study should be performed prior to development of the EPSC plans. It has been documented on past projects that some items and measures placed on the EPSC plans prior to the Environmental Boundaries Study tend to carry through to construction and has resulted in past violations due to measures being placed in streams or permitted waterbodies. If streams and other sensitive natural resources in need of protection are clearly identified and labeled on the plans prior to development of the EPSC plans, then the designer would know that in-stream measures could not be used for erosion prevention and sediment control.

The Georgia Department of Transportation (GDOT) labels all wetlands, streams, and protected animal and plant species habitats as specially designated Environmentally Sensitive Areas (ESA). These areas are shown on the plan sheets and labeled "ESA." In addition, if these areas extend beyond the right-of-way they are clearly labeled on the plans. During construction, all ESAs within the Project ROW and within easement limits are marked with orange plastic safety netting placed around the perimeter of the areas. The safety netting is removed only at the direction of the Engineer when permitted work is authorized. The Contractor shall advise all personnel on the project of locations that are designated as "Environmentally Sensitive Areas (ESA)." The purpose of designating ESAs is to protect receiving waters from impacts associated with erosion and sedimentation by prohibition of unnecessary activities in wetlands and within stream buffer areas.

It is recommended that prior to initiation of construction that all permitted areas and other environmentally sensitive areas be clearly delineated in the field with highly visible barriers, such as orange safety fencing. Historically, violations have occurred for unpermitted work or discharges to wetlands, streams, and other environmentally sensitive areas because of a lack of contractor awareness. To lessen the risk of an equipment operator unknowingly impacting a permitted area, high visibility safety fence, or other highly visible barrier, should be placed around all permitted and sensitive areas before initiating the clearing and grubbing phase of construction. The demarcation of these areas with high visibility fencing is a means to minimize the chance for violation. These areas should be marked before the Environmental Pre-Construction meeting (see Section 1.4.4.). Resource agencies in other states (i.e., Washington, Georgia, and North Carolina) have mandated that this type of fencing be implemented on all projects where wetlands and streams occur.

The intent of the high visibility fencing is to provide positive identification of wetlands, streams, and sensitive areas where equipment is not allowed to work, material may not be placed except as allowed by permit, or normal activity is otherwise restricted by permit conditions. Installation of high visibility fence as the first order of work is expected to keep encroachment into sensitive areas to a minimum. The high visibility fencing is for all streams, wetlands, and sensitive areas, even if there is a permit to impact the resource. Marking these areas prior to disturbance will prevent inadvertently impacting an area prior to initiating the work that was permitted to occur.

1.4.3 PPRM changes relative to mitigation design

The current tool used by ED NRO to transmit mitigation plans to the Design Division is using Form J. Currently this procedure does not occur in the PPRM process until Activities 565 and 570. To assist the ED Ecology and Permits Sections in obtaining the necessary permits as quickly as possible, it is necessary to know the extent to which mitigation procedures will affect Design and Construction. To achieve this goal, it is recommended that the ED Ecology Section and the mitigation design group within the Design Division become involved earlier in the Project Development Process. Currently, according to the PPRM, mitigation procedures (Activities 565 and 570) are scheduled to begin after the preparation of the ROW plans (Activity 535) and ROW PS&E meeting (Activity 540) and certainly later than preliminary EPSC plans. The ED should be integrated into the Project Development Process at an earlier time frame (prior to Activities 535 and 540), the ED NRO and Design Division should have adequate time to work together and incorporate the mitigation plans into the ROW planning process. **It is recommended that the Development and Preparation of Mitigation Plans be incorporated into the process around Activities 285 – 305**. This could be a preliminary mitigation with fine-tuning of the plan for permits occurring at its present Step in the process. This early involvement should aid in avoiding problems late in the project development process post permit application submittal (see Section 1.4.3.). This should assist TDOT with obtaining permits in a timely manner as well as provide for adequate preparation of the mitigation plans. It is further recommended that Activity 370 – Provide Environmental Boundaries for Avoidance – be separated into distinct disciplines (i.e. Ecology, Historic, and Archaeology). Each discipline within ED should sign off on the review prior to project continuation. A geotechnical investigation (currently Activity 225 – Conduct Initial Geotechnical Study) should become an automatic study to be done near Activity 210 in the PPRM process to capture geotechnical issues early in the process such as acid producing rock problems.

The Environmental Scoping Process occurs at Step 190 and the preparation of the Ecology Report occurs at Activity 210. This process appears to be sufficiently early in the overall project development process. However, there appears to be a major gap in the transfer of environmental data from the Planning stage to the Design stage. **It is recommended that the Ecology Report, which identifies jurisdictional natural resources that will require permitting and mitigation, be attached to the project and tracked** (See Section 1.4.4.) throughout the life to completion of construction. The Ecology Planning document should be forwarded to the Design Division so that the natural resources identified during the planning level study can be included on the preliminary plans, prior to ROW review and certainly prior to the development of the EPSC plans.

At the time of project alignment selection (Activity 265), there appears to be a split in the tracking of environmental data and actually two separate paths are taken: one track by Design beginning at Activity 315 and another track by NEPA at Activity 280. There may be environmental commitments determined during this process that need to be incorporated into the Design plans prior to ROW decisions. These two paths do not meet up again until Activity 595, after ROW plans. This appears to be late in the process for

meeting many environmental commitments on large projects. The Environmental Boundaries Study for Avoidance (Activity 370) appears to be in the right sequence.

Permits are applied for in Activity 675, which is when there are sufficient drawings and data available for the regulatory agencies to review. **However, there must be another Activity inserted into the process near the development of Preliminary Plans Review (Activity 390) to get early buy in from TDEC and the Corps of Engineers** (Section 1.4.5, Early Interagency Coordination).

1.4.4 Environmental Pre-Con

It is recommended that TDOT conduct an environmental pre-construction meeting for all projects that involve Clean Water Act permitting (i.e., Section 404, Nationwide, CGP, and/or ARAP). Currently, the environmental components of most projects are incorporated into the overall project pre-construction meeting, and are given a very small amount of time for discussion. Some regions are moving towards a separate pre-erosion meeting to discuss EPSC measures. However, this pre-erosion meeting does not always cover items other than EPSC, such as ARAPs, and is not standard across the state. Furthermore, few TDOT ED representatives attend the pre-con because of the time commitment. Conducting a separate environmental pre-construction meeting will place a focus on environmental compliance, set the stage for contractor expectations, and ensure that all parties involved with the project are aware of environmentally sensitive areas and permit boundaries. All regulatory agencies with permits on the site should be invited to the environmental pre-con. The environmental pre-con should be held on-site to review all permits and sensitive areas. Project commitments should also be reviewed during this meeting. It is also recommended that the newly appointed Storm Water Coordinator and Ecology Staff conduct this meeting with the TDOT Construction Project Supervisor and Contractor.

For most projects requiring Clean Water Act permits, NCDOT conducts environmental pre-construction meetings with contractors to educate those involved in the construction process about environmental commitment expectations, avoidance of environmentally sensitive areas, and construction permit mitigation details.

1.4.5 Early Interagency Coordination

TDOT has experienced project delays and re-designs due to lack of early inter-agency acceptance of project alternatives and mitigation. Interagency coordination and early "buy-in" on project alignments, impacts, and mitigation is essential to the planning process. The North Carolina Department of Transportation (NCDOT) has developed a Memorandum of Understanding (MOU) with various regulatory and resource agencies (*Section 404/NEPA Merger 01 Process Information, April 25, 2005*) to review, evaluate, and comment on projects as they are developed. Primarily, the Merger 01 Process involves the NCDOT, U.S. Army Corps of Engineers Wilmington District (USACE), and North Carolina Department of Environment and Natural Resources (NCDENR). In Tennessee, the agency equivalents would be TDOT, USACE (both Memphis and Nashville Districts), TWRA, TVA, and TDEC. **It is recommended that TDOT consult these agencies early in the project development process and apply screening criteria**

to identify specific projects that will follow this process of integrating NEPA and Section 404 for transportation projects.

1.4.5.1 NCDOT's Coordination Efforts

In North Carolina, this integrated approach is part of an effort to streamline the project development and permitting processes. The objective is to ensure that the regulatory requirements of Section 404 of the Clean Water Act are incorporated into the decision-making process for transportation projects. The intent of the streamlined process is to ensure that agency concurrences are obtained before proceeding to the next step or concurrence point. Concurrence points are defining points in the NEPA project development and Section 404 permitting process. This process is called *Merger 01 Concurrence Points.* NCDOT coordinates with the USACE, FHWA, and NCDENR to identify team members for each project that may include the following:

- U.S. Army Corps of Engineers, Wilmington District
- Federal Highway Administration
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- North Carolina DENR, Division of Water Quality
- North Carolina Wildlife Resources Commission
- North Carolina Department of Cultural Resources

Concurrence provides buy-in of team members at each decision point, and once decisions are concurred upon, they are not revisited. *Merger 01 Concurrence Points* for new location projects are summarized below. There are seven strategic decision (concurrence) points in the Section 404/NEPA project development and permitting process:

1. Purpose and Need and Study Area Defined: The foundation upon which justification for the project is established.
2. Detailed Study Alternatives Carried Forward: Alternatives that satisfy the purpose and need for the project. These alternatives will be studied and evaluated in sufficient detail to ensure good transportation and permit decision-making.

2A. Bridging Decisions and Alignment Review: Identification of bridge locations and approximate lengths and a review of the preliminary alignment for each alternative

3. LEPDA/Preferred Alternative Selection: The alternative selected as the "least environmentally damaging practicable alternative" or LEDPA (NEPA preferred alternative), through the project development and permitting process.

4A. Avoidance and Minimization: Wetlands and streams are delineated. A detailed, interdisciplinary, and interagency review to optimize the design and benefits of the project while reducing environmental impacts to both the human and natural environment.

4B. 30 Percent Hydraulic Review: A review of the development of the drainage design.

4C. Permit Drawings Review: A review of the completed Permit drawings after the hydraulic design is complete and prior to permit application.

A more in-depth overview of NCDOT's Merger 01 Process is provided below.

Implementation procedures which provide detailed information that have been developed to provide guidance for the Section 404 / NEPA Merger 01 Process. These implementation procedures have been developed for three basic types of projects as follows:

- Process I - Projects on New Location
- Process II - Widening and Other Improvement Projects
- Process III - Bridge Replacement Projects Processed as a Categorical Exclusion

The Section 404 / NEPA Merger 01 Process will generally apply to all new location projects and all projects that will likely require an individual permit under Section 404 of the Clean Water Act. The guidance listed below is used in determination of projects to be moved through the Merger 01 Process:

New location and widening projects:

- Projects will be placed in the Merger 01 Process if an Individual Section 404 permit is likely.
- If a Section 404 regional or nationwide permit is likely and the project potentially impacts:
  - Critical Water Supply Area or
  - Total Direct Impacts > one acre of wetlands or > 500 feet of stream, then:
    - FHWA, USACE, NCDENR and NCDOT will consult before scheduling the Concurrence Point No. 1 meeting to determine if the project should be placed in the Merger 01 Process.

NCDOT noted that in the past it was difficult to get collaborating agencies to take risks and make commitments early in the planning process. To surmount interagency differences, NCDOT has worked to establish close partnerships and a sense of trust by garnering the involvement of all related agencies. Interagency consultation and cooperation is helping NCDOT succeed in its pre-Transportation Improvement Program (TIP) planning activities. NCDOT is piloting a pre-TIP process that engages resource agencies at the systems planning stage; the purpose of the process is to identify and avoid the adoption of corridors on a transportation plan that may have "fatal flaws." NCDOT and the resource agencies are also working to finalize a High Quality Resources (HQR) policy that will ensure that such resources are avoided to the maximum extent practicable during the systems planning stages. NCDOT then is better equipped to develop schedules

and cost estimates, including mitigation costs, with increased predictability. Most importantly, the policy will result in transportation projects that are less environmentally disruptive.

1.4.6 Tracking Environmental Commitments

The process of tracking environmental commitments appears to be lacking in the current TDOT program development. The PPRM flow process does not identify or establish a specific item or order that will be followed to ensure that environmental commitments that were agreed to early in the planning process were actually provided to Design or implemented during construction. Federal Highway Administration convened a consortium of several state DOTs to review the tracking of environmental commitments and published the work in *Domestic Scan: Environmental Commitment Implementation, Innovative and Successful Approaches* (Domestic Scan). The state DOTs that participated in the Domestic Scan included New York, New Jersey, Indiana, Kentucky, Texas, Colorado, and Wyoming. Numerous other states provided information on tracking environmental commitments such as North Carolina, California, Georgia, Montana, Maryland, Nevada, Ohio, Pennsylvania, Wisconsin, Utah, and Washington. The Domestic Scan can be a useful tool for TDOT to adopt for tracking not only environmental commitments but also other project commitments such as historical, safety, MPO requests, etc.

During the project development process, the environmental impacts of proposed projects are identified and evaluated. These impacts to sensitive resources should be avoided or, if unavoidable, minimized and mitigated. Many decisions are made throughout the project development process in relation to environmental impacts. A project's environmental commitments – which are contained in either the document required by the NEPA or in the project's mandated permits – represent how these environmental impacts will be avoided, minimized, and mitigated. Environmental mitigation and enhancements have become integral parts of the preliminary project-planning component of Section 404 / NEPA process. However, it is in the implementation of these commitments that the benefits of an environmentally based planning process are realized.

The processes and methodologies observed in the seven participating State DOTs proved that communication and environmental stewardship are the most essential elements in assuring successful environmental commitment implementation. The following recommended approaches summarize the lessons learned from the Domestic Scan:

- ✓ Proactive efforts at all levels of an agency are imperative for effective compliance.
- ✓ Cradle-to-grave communication (from planning through construction and maintenance) is an essential mechanism for achieving successful commitment compliance.
- ✓ Education and training at all levels are critical elements in promoting environmental stewardship and commitment assurance within an organization.
- ✓ Strong stakeholder relationships foster the development of transportation projects that are in harmony with the environment.

- ✓ Learning from experiences encourages future implementation successes.

The Domestic Scan Team observed several common themes that contributed to successful environmental commitment implementation. The following themes are key tools in the successful planning and implementation of environmental commitments:

1. Environmental Ethic / Stewardship
2. Staffing
3. Training
4. Guidance Documents
5. Commitment Assurance
6. Tracking Mechanisms
7. Public Involvement
8. Interagency Coordination
9. Resource Specific Initiatives
10. Tools and Technology

Washington Department of Transportation (WSDOT) has included Tracking of Environmental Commitments in their Environmental Procedures Manual, similar to TDOT's PPRM Manual. WSDOT includes Step 490 as the Tracking of Environmental Commitments during Environmental Documentation, Step 590 as Tracking Environmental Commitments during Permitting and PS&E, and finally Implementing Environmental Commitments during Construction (Step 690). Environmental Commitments become part of the contract documents for construction.

Georgia Department of Transportation (GDOT) tracks environmental commitments with the use of a "Greensheet." GDOT uses a tabular format to list environmental commitments and mitigation. The Green Sheet runs with the project from planning development through construction and is signed off on by the responsible party.

North Carolina DOT also uses a Project Commitments "Greensheet" that runs with the project from planning, through permitting, design, and construction. NCDOT also aims to minimize environmental impacts through its "Project Commitments Greensheet" process. Green Sheets, prepared by NCDOT's Project Development and Environmental Analysis (PDEA) branch, list and summarize all of the environmental commitments made for a specific project. Along with listing commitments, each NCDOT branch or division responsible for an individual commitment is designated on the Green Sheet. The PDEA Branch distributes the NEPA commitments to design staff for inclusion in the Preliminary Field Inspection Plans. After regulatory review and design input, the revised commitments are distributed again and included in the Final Field Inspection Package. The final version of the commitments is combined with the permit special conditions to make up the Project Commitment Greensheet, which is distributed by the PDEA Branch as part of the permit package, and distributed to all agencies on the distribution list.

TxDOT has web-based Environmental Tracking System (ETS). ETS was developed to resolve permit-tracking issues the Department was having. With the system, all dates and communications are tracked and time stamped, and explanations for delays are provided. Now, TxDOT is able to understand what the problems are and where and why they are occurring.

1.4.7 Staffing Requirements for Ecology and Permits Section

Based upon a review of current ED staffing and workloads, additional TDOT Ecology staff is recommended to facilitate project planning and mitigation design review. Currently the ED has one Ecologist per TDOT region dedicated to coordinating all Environmental Planning Ecology Reports, Environmental Boundaries Studies, and Environmental Mitigation Design and Coordination. In addition to coordinating the routine ecology and mitigation studies, the ED staff is responsible for addressing water quality violations that arise throughout the state in various regions.

Comparisons of workloads with comparable units within NCDOT and GaDOT were made to TDOT's ED, noting that each state has a different roadway system size with unique needs. The NCDOT Natural Environment Unit currently consists of five groups. Presented below are the names of the group, responsibilities, and number of funded staff positions.

- Biological Surveys Group – Conducts field surveys for E&T species and water quality sampling; 14 staff positions
- Project Management Group – Responsible for coordinating and conducting environmental boundaries studies and permitting, 32 funded positions
- Program Operations – Responsible for scheduling and business aspects of the Natural Environment Unit, 6 positions
- Indirect Cumulative Impacts (ICI) / On-site Mitigation Group – Responsible for preparing cumulative impact assessments and preparing on-site mitigation plans, 9 funded positions
- Engineering Group – Responsible for providing construction oversight and permitting compliance for on-site mitigation projects (i.e., stream relocations), 6 funded positions

NCDOT currently maintains more than 78,000 miles of roadway, including county roadways, where TDOT maintains over 13,500 miles of roadways. TDOT manages about 25% as many roadway miles as NCDOT, which was taken into consideration when evaluating each program. Currently TDOT has no staff dedicated to coordinating Endangered or Threatened species review and surveys and does not have an engineering group or anyone dedicated to providing oversight of on-site mitigation projects. Currently, one position in the Ecology Section is responsible for all TDOT wetland mitigation banking.

A further review was conducted comparing TDOT and NCDOT budgets. The FY 2005/2006 NCDOT overall budget was $3.6 B whereas TDOT has an overall budget of

$1.8 B, roughly half the size of North Carolina. It was very difficult to compare construction budgets between the two departments since numbers are tracked differently. The FY 2005/2006 construction budget for TDOT was approximately $1.1B whereas NCDOT Transportation Improvement Program (TIP) construction budget was $1.4 B. This does not include total construction for North Carolina.

GDOT maintains over 144, 800 miles of roadway. The current GDOT staffing and organization chart is very similar to TDOT in responsibility and number of staff. In discussing the staffing needs and organization with both Georgia and North Carolina, each ecologist at any given time will have a dedicated list of 80 to 150 projects. Many of these are not active projects. This is very similar to TDOT ED ecology staff that process around 500 projects per year (100 projects per ED ecologist).

Using NCDOT and GDOT as models for environmental procedures, the following staffing and organizational recommendations are provided to facilitate ED review of projects for submittal from the Design Division for environmental boundaries, mitigation, and permitting. Staffing requirements for the Environmental Design Group (EDG), EPSC, and SWPPP are presented in Section 1.6.3.3 of this document.

ED Position	Current Staff	Recommended Total Staff
Biological Survey Group - Endangered Species Coordinator, TIER determinations, water quality surveys	0	3
Ecology Group (Planning Ecology Reports, Environmental Boundary Studies)	4	8 (2 per region)
Mitigation Group – Mitigation Banks and On-site Mitigation and Stream Relocations	2	4
Section 404 / ARAP Permits	4	8 (2 per region)

1.5 Recommendations procedure for ID of impacted waters (A.1.f)

1.5.1 GIS recommendations - 303(d) list, labeling streams/rivers with TMDLs along with qualifier for limiting constituent, HQW streams/rivers

TDEC maintains and updates a listing of impaired streams within Tennessee. These data, contained in the 303(d) list of impaired streams, are reviewed and updated every 2 years by TDEC. Once the list has been completed by TDEC, it must be submitted to and approved by EPA. **TDOT should monitor the 303(d) list revisions and include any revisions that have been approved by EPA in a GIS data layer on TDOT's internal server. The data layer should clearly indicate the stream reach impaired and the pollutant impairment.**

TDEC also develops TMDLs. Each draft TMDL must be submitted to EPA for approval and contains specific language related to pollutant load reductions, based upon the pollutant and land use. Multiple TMDLs can be developed for one stream or river if that stream or river is impaired by more than one pollutant. An example would be the Harpeth River, which has approved TMDLs for siltation and metals. Because TMDLs can impact the design or construction of the project and the post-construction BMPs chosen for the

site, **TMDLs should be monitored and incorporated into a data layer for the interdepartmental GIS system. The data layer should clearly indicate the limiting constituent for ease of use.**

Streams that have been identified as Tier II, Tier III, Exceptional Tennessee Waters, or high quality waters, should also be tracked and developed into a GIS layer, as the Construction General Permit requires specific design criteria for EPSC measures on construction sites within Tier II / III watersheds.

1.5.2 Recommendation on streams under CGP

The TN CGP requires that a 60-foot wide buffer or equivalent measure be maintained between an active construction site and any stream included on the impaired streams list (303(d) list) or identified as high quality waters. (Note that any stream with valid ARAP or equivalent federal permit is exempt from the buffer requirements within the permit area.) The buffer zone should average 60 ft. with the minimum at any one place being 25 ft. While the CGP does not specify, discussions with TDEC staff have indicated that the buffer is required along streams impaired due to siltation and habitat alteration.

A GIS layer should be developed and maintained on TDOT's internal server identifying the streams where 60-foot wide buffers must be protected.

1.6 Environmental Compliance

This section examines the existing methods used within TDOT for the review of EPSC Plans, per Consent Order requirement § XXXIV.C.6 (g), and presents recommendations for improving the overall internal processes and logistics related to the quality assurance review of these designs. Due to the interwoven relation between EPSC Plans, stream mitigation designs, and SWPPPs, recommendations are also given relative to the development of SWPPP documents.

This section also presents recommendations related to the existing QA/QC site assessment and inspections programs. Note that more comprehensive recommendations can be found in the Comprehensive Inspections Program document.

1.6.1 Current TDOT Procedures for EPSC Plan Review, SWPPP Preparation, and Stream Mitigation Design

The design of EPSC plans is currently handled through the Design Division. Stream mitigation design is prepared by the Environmental Division's consultants.

Currently, the review of all EPSC Plans and the development of all SWPPPs are performed by outside consultants. The process is initiated when the TDOT Roadway Design Manager submits plans to the Environmental Division (ED). This action triggers the assignment of a SWPPP consultant to independently review the EPSC Plans. The role of the TDOT Roadway Design Project Manager is to submit roadway design and EPSC plans to the ED Permit Office for review by the SWPPP consultant. The TDOT Roadway Design Project Manager submits Preliminary Plans, R.O.W. Plans, and Construction Plans that have been prepared by the Design Engineer. EPSC plans are not included at the Preliminary Plans stage but are included with the R.O.W. and Construction Field Review

meeting plans. The Design Engineer is responsible for incorporating and/or addressing comments made by the SWPPP consultant concerning the EPSC plans. The SWPPP Consultant prepares the Notice of Intent (NOI) and submits it to the ED Permits Office, which in turn submits it to TDEC.

The ED assigns projects to independent SWPPP consultants and conveys EPSC plans and comments between the Design Engineers and the SWPPP consultants. If there is a dispute concerning recommendations about the EPSC plans, the ED facilitates the issues between the two parties in working toward a solution. The ED submits the NOI (initial NOI without the contractor's information, and a final NOI with the contractor's information) to TDEC as well as to act as the go-between for the Roadway Design Project Manager and SWPPP consultant.

The SWPPP consultant prepares a cost/man-day estimate; independently reviews EPSC plans, attends field review meetings, and submits EPSC plan comments and recommendations to the ED. The ED prepares a cover letter and electronically distributes this information to the TDOT Design Project Manager, who then distributes it to a Division staff designer or consultant designer. The Design Engineers use these comments when developing the final EPSC plans. Once the EPSC plan is satisfactorily completed, the SWPPP consultant will seal and sign a 'Finding of the EPSC Plans'.

Typically, the initial task for the SWPPP consultant is to attend the Preliminary field review meeting (or, for smaller projects, a combined Preliminary/R.O.W. field review meeting). Following the meeting, to assist the Design Engineer in the development of the EPSC plans, the SWPPP consultant emails recommendations and comments to the ED within two weeks after the initial field review meeting. The ED Permits Office prepares a cover letter in an email and distributes it to the TDOT Project Manager and appropriate parties within TDOT.

If the initial field review meeting has already taken place when the Work Order is issued to the consultant, the SWPPP consultant will provide comments to the ED Permits Office within two weeks of the Work Order. Comments are distributed by the ED Permits Office as outlined above. If it is determined at the initial field review meeting that no SWPPP will be required (due to less than one acre of disturbance), the consultant is to notify the ED immediately.

TDEC requires submission of the SWPPP, which includes the EPSC plan, with the NOI for projects covered under the CGP.

Currently, all EPSC plans, whether prepared by a Design Division Roadway Design Engineer or consultant, are independently reviewed by a SWPPP consultant through the ED Permits Office. An approved SWPPP consultant is chosen from a selected list of consultants. Typically, the SWPPP consultant conducting the independent review will be the consultant that will prepare the SWPPP.

The independent EPSC plan review process begins when the TDOT Roadway Design Manager submits a set of Preliminary Plans, to the ED Permits Office. It should be noted that some projects require early Preliminary Plans for grade approval. Grade approval is requested only for projects on which a grade crossing structure is proposed or has

drainage structures with a Q_{50} of 500 cfs or greater. Early preliminary plans are still under development and are submitted to the TDOT Structures Division for review and, based on this review, the line or grade may change. If the project does not require grade approval, the process begins with Preliminary or combined Preliminary/Right of Way Plans.

The ED Permits Office assigns and mails the plans to the SWPPP consultant. An independent EPSC Plan review man-hour estimate is prepared by the SWPPP consultant and submitted to the ED Permits Office for review and approval. Once the Work Order is issued, the SWPPP consultant may commence work.

Under the current system, the use of multiple consultants as EPSC Plan reviewers leaves the process fraught with inconsistencies. This produces frustrations for the Design Engineers of the EPSC Plans. In addition, certain disagreements can occur between the Design Engineer and SWPPP consultant. The use of consultants in this review role appears to complicate the resolution process for these disagreements.

1.6.1.1 Review of Other State DOTs

A review of other selected state DOTs regarding their practices associated with SWPPP development and EPSC Plan review was performed and is summarized as follows:

Alabama

SWPPPs are developed in-house or, in some cases, by consultants. The EPSC Plan is prepared by the road designer and reviewed by the Storm Water Coordinator.

California

Construction contractors prepare SWPPPs and submit to Caltrans (CA DOT) for approval before beginning a job. The SWPPP is usually read and commented on by the Resident Engineer and the District Construction Storm Water Coordinator to make certain that the proposed plan meets the contract requirements (permit). In certain cases, Caltrans will have a consultant read and comment on the SWPPP as well. The preparer of the SWPPP must have formal storm water management training or certification as a CPESC.

Florida

SWPPPs are done by the roadway designer as a part of the roadway plans. Roadway plans are done by in-house staff or, if needed, consultants. Roadway plans are reviewed by the Florida DOT Office of Construction. Designers of the roadway are expected to prepare the SWPPP and EPSC Plans. In-house staff uses a template in MicroStation to prepare the SWPPP. Erosion control plans are checked by the Florida DOT Office of Construction who oversees environmental issues.

Georgia

SWPPPs are prepared by in-house designers or, in some cases, by consultants. If the design is performed in-house, the DOT group responsible for geometric design will prepare the SWPPP and drainage plans.

North Carolina

The EPSC Plan serves as the SWPPP for construction projects by the NC DOT. The NC DOT designs 80-90% of the Plans in-house. The remainder are handled by consultants, but are approved by NC DOT before implementation.

Virginia

A consultant or the VDOT Location and Design Division (L&D) will develop the SWPPP and/or EPSC Plan according to the ESC & SWM Program Manual. The plan is reviewed and commented on by a Certified Plan Reviewer or L&D Hydraulics P.E. The designer incorporates and/or negotiates changes and resubmits the plan for approval. The SWPPP/EPSC Plan then must approved by the VDOT Resident Engineer.

1.6.1.2 Recommendations

Based on the review of the current TDOT process for EPSC Plan review and SWPPP development and a review of the systems in place within other selected state DOTs, the following recommendations are presented.

1.6.2 EPSC Plan Review, SWPPP Development, Stream Mitigation Design Process Structure

The primary recommendation is for TDOT's Environmental Division to establish a new, specialized group for Environmental Design. The Environmental Design Group (EDG) would be responsible for:

- **Review of EPSC Plans**. This involves only the review of EPSC Plan documents. The preparation of EPSC Plans should remain under the direction of the Design Division and their consultants.
- **Development of all SWPPPs**.
- **Stream mitigation design**. Currently, natural channel design is not a priority emphasis in project development. In addition, there does not appear to be a specialty group trained for natural channel design either within the Design Division or within the Ecology Section. Incorporating this responsibility into the EDG would place an emphasis on natural channel design and environmental stewardship; coordinate EPSC measures with mitigation designs around streams; and lessen the potential for conflicts between mitigation, EPSC/SWPPP designs.
- **Other mitigation design, as necessary and appropriate**.

The EDG would consist of a specialized group of engineers, with training and experience in erosion and sediment control design, storm water quality, and stream mitigation design (including geomorphology). This group would have sole responsibility for all EPSC Plan reviews, SWPPP document development, and stream mitigation designs for all TDOT projects. Members of this group will work closely with the ED ecologists in designing stream relocations. Members from this group responsible for SWPPP and EPSC Plan reviews should attend field review meetings. In addition, staff members from this specialized group will also be responsible for preparation of the NOI.

The proposed work flowchart for the EDG is presented in Figure 1-1. The EPSC Plan for a given project will be prepared by the Design Division or one of its consultants. In addition, Chapter 10 of the TDOT Design Division Drainage Manual should be used as the guidance document for the design of EPSC Plans.

Once the EPSC Plan has been prepared, the plan is submitted to the EDG within the Environmental Division for review. The EPSC review process should incorporate a checklist for review of EPSC Plans to insure that minimum requirements are being met and that all plans are consistent in their content. An example checklist is given in Figure 1-2.

The EDG or Designer will calculate the disturbed acreage potential for the proposed project and, based on the calculation, determine if the project will require an NPDES permit. If the calculated disturbed acreage is less than 1 acre, the plan will not require an NPDES permit and will, therefore, not require the preparation of a SWPPP and the NOI. However, if the calculated disturbed acreage is equal to or greater than 1 acre, an NPDES permit will be required, along with the required documents.

If the disturbed acreage for a project is less than 1 acre, the EPSC Plan for the given project will be initially reviewed by the EDG. If the plan is inadequate based on the EDG review, comments should be provided to the TDOT Design Division to address.

If the disturbed acreage for a project is equal to or greater than one acre, SWPPP documents and the NOI must be prepared. The submitted EPSC Plan will be initially reviewed by the EDG. If the plan is inadequate based on the EDG review, comments should be provided to the TDOT Design Division to address. The EDG will also prepare the SWPPP and prepare the NOI for the given project. Once the SWPPP has been developed, and the N.O.I. has been prepared, the entire package of permit documents would be submitted to the ED Permits Office for final review and submittal to TDEC.

In addition, it is recommended that an EPSC Plan Review Committee be formed, consisting of representative at least one Storm Water Coordinator and one EPSC Inspector (see the Comprehensive Inspections Document) within TDOT ED. The purpose of this EPSC Plan Review Committee will be to provide guidance and comments to the EDG and Design Division for EPSC Plan design relative to construction issues, including constructability, field observations of BMP performance, and maintenance. This committee will meet periodically with EDG and Design Division staff as an advisory group to provide guidance and make recommended adjustments to the program.

1.6.3 Training

Internal training is recommended for the members of the EDG to bring all staff up to speed regarding TDEC requirements and internal TDOT requirements for the preparation and review of permit documents. This training must be carried out annually to re-calibrate the staff and introduce any new permit or internal requirements. In addition to the internal training program within TDOT, mechanisms such as bulletins, directives, and guidance documents should be used to communicate changes in the permit document requirements.

Under the current system, there appears to be little consistency regarding the EPSC design application and implementation. Training and periodic calibration for the design of EPSC plans is strongly recommended.

Figure 1-1: Design Divisions Environmental Design Group Flow Chart

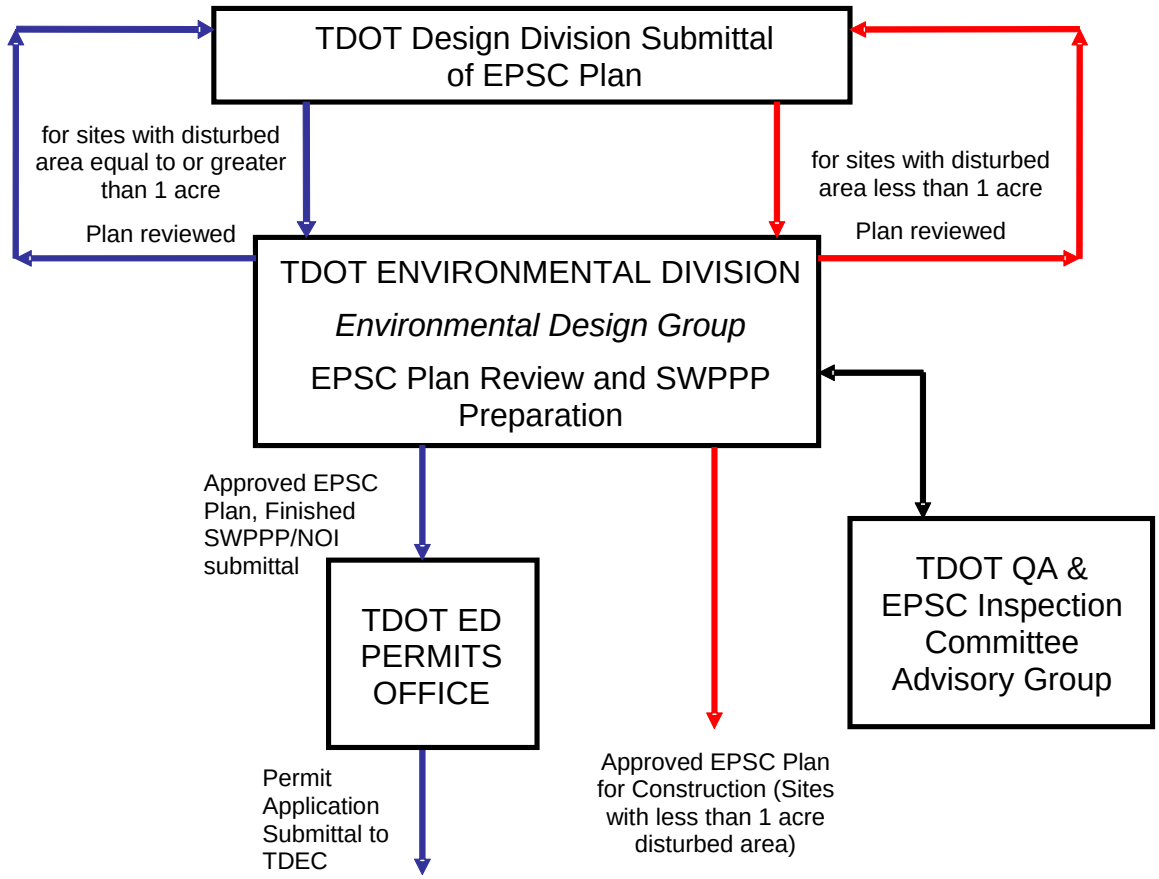

Figure 1-2: Example Erosion and Sediment Control Plan Review Checklist

Project Name: _____

Project Number: _____ PIN: _____

Reviewer Name: _____

Date Submitted for Review: _____

Date(s) Reviewed: _____

Drainage Area Size: _____

REQUIRED INFORMATION FOR SEDIMENT CONTROL PLAN

____ All sheets of final EPSC package numbered consecutively:

____ Sealed by P.E., L.S., or architect on the first page of the plans, with date and signature.

____ Construction R.O.W. designations.

____ Match lines corresponding sheet to sheet.

____ Disturbed area outlined and labeled.

____ Existing and proposed tree lines or individual trees labeled on all EPSC plan view sheets.

____ Offsite drainage area (acres) entering site on EPSC plan view sheets.

____ Show and label existing and proposed roadway improvements on EPSC plan view.

____ Any designated wetlands (including buffer) delineated on the EPSC plan view sheets.

____ Label all EPSC devices.

____ Sediment trap(s): inflow erosion protection, proper outlet location (maximizing flow length from inflow points). Provide trap data information on the EPSC plan sheet as follows: trap type; existing drainage area; developed drainage area; storage required; storage provided; weir crest elevation; storage depth; bottom dimensions; cleanout elevation; channel depth of flow; maximum sideslopes (specify cut and/or fill); bottom elevation; embankment elevation.

Figure 1-2 (continued)

____ Sediment basin(s): include sediment basin design and construction information; barrel outfall cross-section; dewatering device detail; inflow erosion protection. Show and address construction access and stockpiling on the EPSC plan and address sediment control during basin installation. Limit initial disturbance to installation of the principle spillway. If there is a base flow, provide a clean water diversion; if there is no base flow; provide run-on diversion above the disturbed area.

____ Designated undisturbed areas shown on plans.

____ Temporary stream diversion: detail in Sequence of Construction, show profile, give invert elevations of temporary pipe into trap on plan view, profile, and details.

____ Sequence and Phasing of Construction.

____ Standard Sediment Control Notes.

____ Standard details for EPSC devices.

____ Adequate access, staging, and stockpile areas shown on the plan with appropriate sediment control for each.

____ All outfalls must release runoff to an adequately stable receiving channel/ditch. Provide profiles of outfalls showing riprap slope, length, d50 at pipe outfall.

____ Provide outfall cross-section detail(s) with the following information specific to each outfall: outfall dimensions, riprap size (d50); embedded depth (2.0 x d50); and geotextile underneath.

____ Provide ARAP information including the permit numbers, special conditions, and other pertinent information on the plans.

1.6.4 Staffing Requirements and Qualifications of EPSC Plan Review and SWPPP-Development Staff

In Fiscal Year 2005, there were 45 projects with less than five (5) acres of disturbance, and 35 larger projects with greater than five (5) acres of disturbance. Of these larger projects, nine (9) had greater than 100 acres of disturbance. The number of full time TDOT positions that would be required within the Environmental Division to take over the independent EPSC plan review work is estimated to be 2 to 3 full time positions, including a supervisory position. The man-hours for reviewing EPSC plans for a project with less than 5 acres disturbance are 8 to 16 hours and for greater than 5 acres are estimated at 16 to 24 hours.

For the preparation of SWPPPs, an additional 6 to 10 employees will need to be added. It is also recommended that at least two of these 6 to 10 employees have experience and training to perform stream mitigation work, with specific training in geomorphological approaches to stream mitigation.

Therefore, the total estimate of additional Environmental **Division staff for this specialized group is 8 to 13.** The estimate of 8 to 13 full time in-house positions takes into account vacation time, sick time, and training.

The Tennessee CGP currently does not specify training and certification requirements for those reviewing EPSC Plans. However, the new Tennessee CGP requires that the SWPPP be prepared and signed by a P.E. or registered landscape architect if any structural, hydrologic, or hydraulic design is involved that requires engineering calculations. **Therefore, these additional employees for the** Environmental **Division should be either registered civil or environmental engineers or EITs working under the direct supervision of a registered P.E. in civil and/or environmental engineering. In addition, the employees should have, at a minimum, experience and training that is equivalent to what is required for a CPESC-IT.** Again, regular internal training as set forth in the Statewide Storm Water Management Plan will also be mandatory.

1.6.4.1 Consultants

As seen in other state DOTs, in cases of excessive overflow of workload, **it is recommended to have on-call contracts with consultants as a back-up plan for handling the additional load for EPSC Plan review, SWPPP development and stream mitigation designs. Consultants used for this work must have qualified staff that meet or exceed the qualifications set forth for working in the EDG within TDOT.**

1.6.5 Construction inspection program recommendations

TDOT currently has two separate and distinct inspection programs: inspections performed to comply with the TN Construction General Permit and Quality Assurance/Quality Control (QA/QC) site assessments as required by the Consent Order. The separate document entitled "Comprehensive Inspections Program: QA/QC and Weekly Inspections Program Recommendations" contains our recommendations to develop and implement a self-monitoring program for TDOT, similar to NCDOT's program. **We recommend that this approach be adopted by TDOT and implementation begins immediately.**

Furthermore, several efforts are underway either nationally or on a regional basis towards developing programs that may benefit TDOT in the future. Two of these efforts are described below:

- The Colorado Storm Water Excellence Program is a pilot program developed to help the state agency tasked with construction site inspections prioritize inspections. The program places the responsibility for construction site self-policing on the construction industry, while allowing the state regulator to focus on more problematic sites.

- An initiative is underway to develop a national EPSC inspector certification program called "Certified Inspector of Sediment and Erosion Control (CISEC)." The goal of this certification program is to develop a national baseline training program for erosion and sediment control inspections.

We recommend that TDOT continue to monitor the progress of these two initiatives, and other related initiatives, to determine their applicability to TDOT programs in the future.

1.7 References

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2 Sediment and Erosion Control Practices for TDOT Construction Projects – A.2.a (2)

This section assesses the current and evolving design practices used by TDOT to develop the Storm Water Pollution Prevention Plan (SWPPP) for construction projects. Sound practices are cited and recommendations are made for improvements in design procedures. Issues and practices for implementing "low-impact" design practices that will minimize erosion and reduce sediment loads to be captured are discussed. Additional methods for documenting the selection of structural temporary erosion controls using the Revised Universal Soil Loss Equation (RUSLE) and tractive force theory will be introduced. The focus is on the erosion and sediment control functions to be performed, and not on specific erosion prevention and sediment control (EPSC) technologies or methods.

Current TDOT documents that guide the design and selection of EPSC measures for construction projects include:

- Standard Specifications for Road and Bridge Construction (2006);
- Qualified Products List (QPL);
- Standard Drawings for Erosion Control and Landscaping (ECSTR1—ECSTR60); and
- TDOT Design Division *Drainage Manual*, Chapter 10 —Erosion Prevention and Sediment Control.

These four documents, in combination with appropriate checklists and the SWPPP boilerplate documentation, provide the suite of tools needed to prepare EPSC plans and SWPPPs for TDOT projects. Each of the current documents has been reviewed for content, coverage, and fit with the other documents. Some specific deficiencies are cited in each section and several recommendations are made for additions to the materials list in the Standard Specifications, the Drainage Manual, and the QPL.

2.1 Assessment of Current Sediment and Erosion Control Planning and Design Practices (A.2.a)

2.1.1 Standard Specifications for Road and Bridge Construction

There are three sections in the Standard Specifications that cover materials, methods, installation and maintenance of temporary EPSC measures:

- Section 209-Project Erosion and Siltation Control;
- Part 8-Roadside Development and;

- Section 918, Miscellaneous Materials

2.1.1.1 Section 209 - Project Erosion and Siltation Control

Section 209's title, "Project Erosion and Siltation Control," is inconsistent with the general terminology of Erosion Prevention and Sediment Control or EPSC that is used in most other TDOT literature and correspondence. Many of the terms found in the Standard Drawings, Chapter 10 of the Design Division *Drainage Manual*, and the QPL do not appear in the specifications. A review of the terms used in the four design guidance documents found 92 different terms. Of these terms, no term was common in all four documents; only two terms were common to any three documents, and only 22 terms were common to any two documents. Each of the remaining 68 terms was found in only a single document.

This inconsistency can lead to confusion during the design, bidding, and construction periods. To avoid confusion, it is suggested that a standard terminology be adopted that is generally consistent with the current products and methods common to the erosion control industry and grouped by function.

In addition, some of the actual specifications are unnecessarily limiting. For example, 209.07(c) specifies that "asphalt binder" be used as the tackifier for mulch rather than simply an approved tackifier. Although asphalt emulsions are effective as tacking agents they are no longer considered environmentally friendly and should no longer be used for EPSC purposes.

To further diversify the terminology used for EPSC measures they should be grouped by the function they perform. The three primary functions involved in designing for the prevention of storm water pollution are:

- Surface protection: materials and methods for keeping the exposed soil surface in place, whether on a slope or in a channel
- Sediment Capture: materials and methods for removing suspended sediments from storm water runoff
- Flow Control: materials and methods for reducing the energy in sheet and concentrated flows, which in turn minimizes the amount of sediment that can be suspended and transported and materials and methods used to divert and convey clean or excess runoff around exposed surfaces as a means of minimizing accelerated erosion.

Grouping the EPSC practices into these three categories, and keeping all terms uniform in all documents emphasizes the function, which aids both the design and selection processes. Consequently, secondary design considerations (such as size, class, and type) become a function of the design and not of the terminology.

To simplify the terminology and to embrace some of methods and technologies that are not covered in any of the current documents, a list of generic terms is summarized in Table 2-1.

Table 2-1: Summary of Recommended Terms and Applications of EPSC Materials and Structures[1]

Surface Protection	Sediment Capture	Flow Controls
Bonded fiber matrix (BFM) (class)	Erosion wattle	Earth berm
Erosion control blankets (type & class)	Enhanced silt fence	Interceptor ditch
Temporary channel liners	Sediment trap (type)	Temporary slope drain
Turf reinforcing mats (class)	Sediment basin (type)	Temporary flume
Soil binder	Inlet protection (type)	Slope drain
Erosion control mulch (crimped straw)	Sediment filter bags	Diversion ditch
Erosion control mulch with tackifier	Berm	Temporary berm
Hydraulic mulch	Windrow	Berm
Hydraulic mulch with tackifier	Check dam	Slope drain
Rock riprap (size/weight)	Silt fence	Enhanced silt fence check
Temporary seeding	Filter sock	Triangular silt dikes
Permanent seeding	Sediment basin	Enhanced silt fence
	Silt fence with wire backing	Silt fence with wire backing
	Enhanced silt fence check	Filter sock
	Triangular silt dikes	Silt fence
	Temporary berms	Windrow
	Rock sediment dam	Erosion wattle
	Gabon check dam	

There is a substantial library of standard drawings for structural EPSC measures. The initial sheet EC-STR-1 has a list of pay items that is significantly more extensive than the terms used in either the specifications or the QPL. Most of the differences in terms are a function of size, type, or class of material. The following list includes terms used to describe sediment-trapping devices. It is recommended that these terms and definitions be adopted and used to replace the various sediment control device terms found on the standard drawings, in the specifications and Design Division Drainage Manual Chapter 10.

Table 2-2 (Summary of Suggested Sediment Control Terminology) summarizes the current terms used and the recommended replacements. Full definitions are provided in the following text section.

[1] Note that several term are repeated in the sediment capture and flow control columns of Table 2-1 because they can be used to serve both functions.

Table 2-2: Summary of Suggested Sediment Control Terminology

Current Term	Location	Recommended Replacement Term
Temporary filter barrier	EC-STR-3a	Silt fence *Recommend deleting the standard drawing, since EC-STR-3B covers all the conditions.*
Temporary silt fence	EC-STR-3b	Silt fence
Silt fence with backing	EC-STR-3c	Silt fence with wire backing
Enhanced silt fence	EC-STR-3d	Enhanced silt fence
Straw or hay bale or fabric temporary erosion checks	EC-STR-5	*Recommend dropping this detail from use in favor of other methods, such as wattles, filter socks, and fabric checks.*
Temporary erosion ditch check using enhanced silt fence	EC-STR-4	Enhanced silt fence check (trapezoidal ditch section) *In the standard drawings EC-STR-4 and -4A, there is no difference between these terms other than Note E, which indicates that the length includes the ditch bottom.*
Temporary erosion check/filter using enhanced silt fence (in a triangular ditch section)	EC-STR-4a	Enhanced silt fence check (triangular ditch section)
Rock check dams	EC-STR-6	Check dam *Several materials can be used for check dams (such as rock and gabion check dams), and the standard drawings will take care of the difference.*
Temporary sediment trap with temporary silt screen check dam	EC-STR-7 EC-STR-11	Silt trap type A, B, C… *Recommend adding other types and designating them as Type A, B, C, etc., such as the silt trap shown in EC-STR-11.*
Rock silt screens *This drawing has both" in-channel sediment control measures" and" inlet protection devices." Recommend separating them to distinguish between them.*	EC-STR-12	Rock inlet protection *Recommend using EC-STR-6 for all rock check dams, regardless of whether the dam is used for velocity control or as a sediment trap; any rock check dam will act as a sediment trap.* *Recommend combining EC-STR-12 for all inlet protection.*
Temporary rock sediment dam	EC-STR-12	Rock sediment dam
Sediment basin	EC-STR-15	Sediment basin
Gabion check dam	EC-STR-55	Check dam
Temporary sediment trap with temporary gabion check dam	EC-STR-60	Check dam *A check dam provides both velocity control and sediment trapping functions, regardless of the primary purpose.*
Brush barrier (No standard drawing)	209.07(f)	*A brush barrier is of questionable value as a sediment control practice, unless it is dense enough to provide filtration (e.g., wood chip fill), and should be eliminated.*

Current Term	Location	Recommended Replacement Term
Sediment structure (No standard drawing)	209.07(c)	*Recommend dropping "sediment structure" and replacing it with " sediment trap," and designating a type (A, B, C, etc.).*
Temporary berm (No standard drawing)	209.07 (a)	*No replacement; recommend continuing to use "temporary berm*."

2.1.2 Recommendations for 209.02 Classification

Several changes should be made to the definitions to clarify the purpose of the measures and to eliminate practices that are not effective. These are described below.

2.1.2.1 Check Dams

Recommend adding the purpose, i.e., "to reduce the velocity of flow in the channel and to trap sediment." While checks may initially be designed as velocity controls, as suggested in the Drainage Manual, they also provide a significant sediment trapping function. Because they do trap sediment, they also need to be inspected and trapped sediment removed as needed. Failure to do so will reduce the velocity control effectiveness and result in resuspension of excess sediments.

2.1.2.2 Temporary Seeding and Mulching

Recommend eliminating the term "mulching" from the title. Seeding may be either permanent or temporary, depending on the species, time of year, and whether or not continuous disturbance is necessary. Therefore, this section should be titled simply "Seeding." Mulching should be a separate section entirely.

Recommend removing the terms mulching and matting from this section, since they are different materials and their methods of application and costs differ significantly.

2.1.2.3 Baled Hay and Straw Checks

Recommend deleting this practice. Hay and straw bales are not generally cost-effective or technically effective, particularly when compared to the performance and longevity of other alternatives such as wattles, rolls, and triangular silt barriers.

In addition to the modifications described above, several additions to these classifications have been identified and are described below.

2.1.2.4 Recommended Additions to Classification

1. Erosion Control Blankets (Erosion Control Blankets and Mats) – Rolled materials used for temporary erosion control and vegetation establishment may consist of open weave textiles, or combinations of natural or synthetic fibers
2. Turf Reinforcing Mats (TRMs) – A rolled erosion control product composed of natural or synthetic fibers, filaments, nets, or other elements used to prevent the erosion of channels carrying concentrated flows. Products composed of 100% organic materials are considered temporary while those composed of synthetics may be considered permanent per the QPL.

3. Erosion Wattles, Rolls and Socks – Synthetic mesh tubes or socks filled with straw, excelsior fibers, compost or other approved material used to reduce velocity and trap sediment on slopes or in channels.
4. Triangular Silt Barriers – Triangular foam covered with filter fabric or plastic forms used to reduce velocity of surface or channel flows and to trap sediment.

2.1.2.5 209.06-Construction Requirements

The language regarding the beginning of grading activities is inconsistent with the requirements of the TDEC General Permit and should be modified. "Areas to be graded shall not be cleared and grubbed more than 20 calendar days prior to the beginning of grading..."; however, the General Permit specifies 15 days see 3.5.3.1 (h) and (i).

2.1.2.6 209.07-Construction of Structures

2.1.2.6.1 209.07-(a) Temporary Berms

This section is difficult to understand and possibly should have a standard plate to clarify the use and proper installation of temporary berms. Windrows server a similar function and much simpler in construction.

2.1.2.6.2 209.07-(c) Sediment Structures

In general, the term "sediment basin" is used to describe any earthen structure designed with a metering outlet to extend the residence time so sediment will fall from suspension. These structures are also designed with an overflow spillway to pass events greater than the designed capacity. It appears that this category is generally described as "silt basins." The difference between "sediment structures" and other silt trapping devices is not clear, even though some of the other devices are called out in 209.07 (f), (g), and (h). The Standard Plates also use a slightly different terminology, which could be confusing.

2.1.2.6.3 Sediment Trap:

Any device used to collect and detain runoff from a slope or in a channel for allowing sediments to precipitate out of suspension. Sediment traps include, but are not limited to, fabric fences; rock check dams; sand or gravel bags; compost or wood- chip- filled socks; straw, excelsior, or coir wattles; and foam or plastic dikes.

2.1.2.6.4 Sediment Basin:

A structure, usually earthen, designed to detain and store the sediment from a selected design storm. The structure will consist of an earthen basin either excavated or confined by an earthen dam having a control structure to extend the residence time for a period sufficient to precipitate sediment held in suspension. There must also be a spillway designed to pass flows greater than the design storm with out overtopping the dam or flooding the adjacent roadway. A sediment basin must be designed by a registered engineer.

2.1.2.6.5 Sediment Filter Bag:

A fabric container used to filter sediment from storm water or other sediment-laden sources on a construction site.

2.1.2.6.6 Berm:

An earthen structure 12 in (300 mm) in height, with side slopes of up to 3:1 and a top width of 24 in (600 mm).

2.1.2.6.7 Windrow:

A low soil berm approximately 12 inches high used to prevent offsite discharge of storm water and as a means of providing containment around stockpiles of material stored onsite. If windrows are to be used for an extended period of several weeks, they should be seeded to enhance stability and prevent sediment loss.

2.1.2.6.8 Check Dam:

A velocity control or sediment-trapping device placed in a ditch or waterway. Check dams can be made of, but are not limited to, rock, rock riprap, gravel bags, or gabions. Check dams must be composed of materials of sufficient weight and durability to withstand the peak discharge rate of the channel for a design storm of an appropriate return frequency.

2.1.2.6.9 Erosion Wattle:

Natural fiber or synthetic fabric tubes filled with straw, excelsior, coir, or other fibers; or a tightly rolled and stitched mat or blanket. Wattles may be used in ditches or shallow channels to trap sediment and/or to reduce flow velocities. (Note that in bio-technical engineering literature a brush barrier composed of live branch bundles bound together in rolls is also called a “wattle”.)

2.1.2.6.10 Filter Sock:

A synthetic fiber tube filled with compost or a proprietary mix of compost-like materials that is used to filter sediment from storm water. Filter socks may be used in ditches or shallow channels to trap sediment and/or to reduce flow velocities.

2.1.2.6.11 Silt Fence:

Woven or non-woven fabrics set into the ground and supported by wood or metal posts. Silt fence is generally intended to capture the sediment carried in surface sheet flows or on level areas near the toe of soil stockpiles, hills, or embankment slopes. Fabrics have flow rates that range from around 5 to 35 gpm/sf.

2.1.2.6.12 Enhanced Silt Fence:

Fabric barrier with wire backing and closely spaced posts to add vertical stability in concentrated flow conditions where soils are likely to become saturated and cause failures by overturning.

2.1.2.6.13 Silt Fence with Wire Backing:

Fabric barriers used in moderate concentrated flow conditions to trap sediment. Wire backing is used to reinforce the fabric so it can withstand heavier loads.

2.1.2.7 209.07-Construction of Structures Other Terms That Should Be Added

2.1.2.7.1 Erosion Control Blanket:

A fabric net of natural or synthetic fibers, or straw, curled wood fibers (excelsior), or coir fibers bonded together with net, glue or other binding material to form a mat. Products are furnished in rolls of various length and widths. Weights, net types, and binders vary depending on the intended application. Erosion control blankets are temporary biodegradable products.

2.1.2.7.2 Soil Binders:

Chemicals that can be used to temporarily bind the surface soil particles together so surface flows will not transport loose soil down slope. These materials include asphalt emulsions, copolymers, acrylamides, vegetable based materials and cementitious products.

2.1.2.7.3 Tackifier:

Materials used to bind mulches together to prevent them from blowing or migrating down slope. Materials include asphalt emulsions and vegetable based products.

2.1.2.7.4 Bonded Fiber Matrix:

A bonded fiber matrix is a hydraulically applied mix of elongated cellulose fibers bound together by a water-resistant tackifing agent. It is completely biodegradable with a functional life of one growing season.

2.1.2.7.5 Hydraulic Mulch ("Hydro-mulch"):

Hydraulically applied cellulose wood fibers or other approved materials used to foster germination of seed, moderate surface temperatures and help conserve soil moisture. Hydraulically applied mulches are not for erosion control.

2.1.2.7.6 Hydraulic Seeding: ("Hydro-seeding"):

Seed or seed and fertilizer applied to the soil surface by hydraulic means.

2.1.2.7.7 Broadcast Seeding:

Seed applied to a prepared seedbed by hand, aerial application, or mechanical rotary spreaders. Broadcast seeding is used only in very small areas with no access for equipment or where mobilization of hydraulic or drill seeding operations are not practical.

2.1.2.7.8 Drill Seeding:

Drill seeding uses a mechanical apparatus to place seed into the seedbed. Drills are of two

types, standard drill, and a no-till drill. The standard drill places seed into a prepared seedbed while a no-till drill requires no special bed preparation other than a reasonably level surface.

2.1.2.7.9 Erosion Control Mulch:

Mulches may be approved wood chips, straw, hay, or suitable compost materials placed on the soil surface to prevent erosion, conserve soil moisture, and foster seed germination. To be an effective erosion control BMP, mulch must be applied in sufficient quantity to cover the surface and to form a mat that will not blow or wash away in a significant storm event. Straw materials should be crimped or bonded with an approved tackifier. Hydraulically applied cellulose fiber mulches are not considered effective erosion controls. The preferred mulch material is clean straw or hay at the rate of 100lb/1000sf (75kg/100m^2), for slopes up to 2:1 and crimped with a serrated disc or an approved erosion control blanket.

2.1.2.7.10 Temporary Channel Liners:

Temporary channel liners are rolled materials composed of biodegradable materials used to temporarily protect the surface of a channel during revegetation. Temporary channel liners must be rated to withstand shear stresses of 2lb/sf and greater.

2.1.2.7.11 Temporary Seeding:

Temporary seeding is the installation of small grains, forbs and other annual herbaceous materials that provide temporary erosion protection for a single growing season.

2.1.2.7.12 Permanent Seeding:

Permanent seeding is the installation of mixes that contain perennial grasses and other herbaceous materials that will establish a permanent, sustainable vegetative cover.

2.1.2.7.13 Rock Riprap:

Rock or coarse crushed stone 5-8 inches in diameter placed on the surface to prevent erosion from sheet and shallow concentrated flows. Rock riprap should be underlain with an approved filter fabric to prevent the mobilization of fine materials below the riprap cover.

2.1.2.7.14 Turf Reinforcing Mat (TRM):

A permanent rolled erosion control product composed of non-degradable synthetic fibers, filaments, nets, wire mesh and/or other elements, processed into mat which may be filled with degradable components, to provide immediate erosion protection, enhance vegetation establishment. Turf reinforcing mats provide long-term functionality by acting with the vegetation and reinforcing the soil root matrix.

2.1.2.7.15 Permanent Erosion Control:

This definition is recommended for inclusion in the specifications and other documents to clearly establish the difference between permanent and temporary erosion controls.

Permanent erosion control includes the revegetation of disturbed areas with native and adapted grasses, forbs, and other herbaceous species that will provide a continuous sustainable surface cover, and any structures or addition of permanent reinforcing materials to stabilize slopes and drainage ways.

2.1.2.7.16 Temporary Construction Entrances

Temporary construction entrances may be constructed of coarse rock, pipe, logs, or timber for removing sediment from vehicle tires as they leave the construction site.

2.1.2.8 Part 8 – Roadside Development

The following sections describe the review and recommendations for modification of Part 8 of the guidelines.

2.1.2.9 Section 801.07 Mulching

Section 801.07 is somewhat limiting in its language in that it does not mention crimping as an option to using a tackifier to anchor mulch. On non-cohesive soils, crimping has been demonstrated to be more effective than using tackifiers are. The third paragraph allows tackifiers other than emulsified asphalt, which is inconsistent with 209.07 above. The mulching rates seem adequate. However, the generalized specification requiring a tackifier in all installations is probably not the most cost-effective means of achieving good erosion control. On non-cohesive soils, straw applied at the specified rate of 100lb/1000sf (1.25kg/100m^2) forms a significant surface cover and, when bound by the tackifier, becomes a relative stiff surface mat. Because of this stiffness, it will bridge microrills, allowing significant rill erosion under the cover.

Research and testing in studies in both California and Texas have shown that the most effective way to control erosion with straw and hay mulches on non-cohesive soils is to crimp the material with a serrated disc or crimping tool. Crimping prevents blowing of the mulch, provides good surface cover, and ensures continuous contact with the soil. For this reason, it is very difficult for rills to form and significant erosion is effectively prevented. In addition, crimping is generally less expensive than are tackifiers.

However, on clay soils, it is very difficult to effectively prevent erosion using straw or hay mulch; in most cases, research has shown that blankets and bonded fiber matrix materials are more effective.

2.1.2.10 Section 801.06 Seeding

This section covers the materials and methods to be used for reestablishing vegetation. TDOT currently uses a very limited mix of species for roadside planting. The plant list includes only seven grass species of which only four would be considered perennial species and four small grains and clover. These are sprinkled among nine different mixes dominated by either Kentucky 31 Fescue or Bermudagrass that are differentiated only by planting season. Given the harsh conditions of the roadside, heat, droughty, compacted soils, and no supplemental irrigation, it is doubtful that any cool season species will likely persist for an extended period or form sustainable community, thus leaving the roadside to be colonized by other weedy pioneer species.

The seeding specification suggests the use of a rotary (broadcast) seeder, hydraulic seeding, or other approved means. For highway practice, broadcast and hydraulic seeding have been shown to be far less effective than drill seeding. Seed drills place the seed in the soil, which helps provide better access to moisture and less fluctuation in temperature, which helps speed germination and establishment.

While rotary and hydraulic seeding methods have a place in transportation practice, they are not recommended as the primary seeding technologies for several reasons:

1. Rights-of-way generally have slopes greater than 10:1 and are slow to take on moisture, which creates a persistent droughty condition
2. When seed is spread on the surface on steep slopes the seed will migrate down slope in significant, pre-germination, rainfall events.
3. In areas adjacent to the pavement, soil temperatures tend to be elevated, which causes rapid drying which further exacerbates the droughty condition.
4. Rainfall, while generally considered adequate for maintenance of vegetation seed applied at the surface, will dry quickly and can be easily blown away or eaten by birds. May to August is a period of lowest and sporadic rainfall in most parts of the State.
5. The seed mixes employed consist of very different seed types some are very small while others are large and fluffy. Using rotary and hydraulic seeding methods make it difficult to get uniform distribution of these differing seed types.

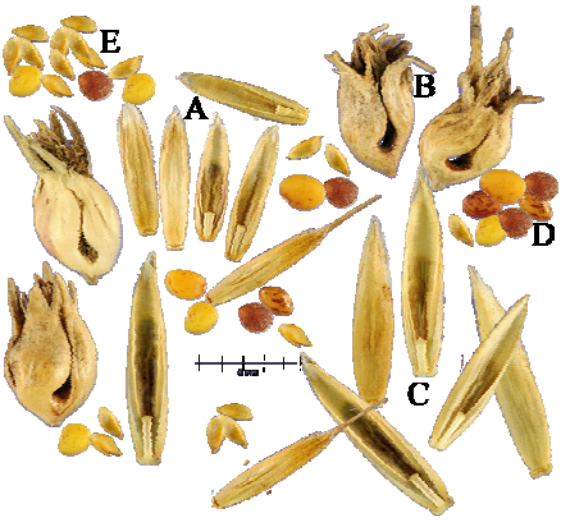

Figure 2-1: Seed Types and Sizes

It is recommended that rotary seeding be removed as a primary seeding option in favor of drill seeding. In cases where drill seeding is not possible because of limitation on the use of equipment due to slope and terrain, then hydraulic seeding should be used. See suggested definition in the "Terminology" section. When hydraulic seeding is used, it

should include a cover of hydraulically applied mulch or a bonded fiber matrix (BMF), depending on slope and soil conditions. Seeding and mulching should be done in a two-step process seed and fertilizer first followed within 24 hours by mulch or BFM application. The two-step process may provide better soil contact for the seed; research suggests that the better success rate of the two-step process is related to the extra moisture applied and not necessarily to the contact between seed and ground.

Sections 801.01 through 801.06 are generally sufficient; however, there does not appear to be a definition of what constitutes suitable topsoil in Section 209. In general, topsoil should be a friable material that contains a minimum of 10% organic matter. Sandy clay loams to clay loams are preferred to sands or clays.

The general requirement for the use of tackifiers for mulch applications should be changed by including crimping of straw mulch on sandy soils. To get effective control of clay soils, the combined use of crimped straw, blankets, BMF-type of materials, or other soil-binding materials need to be considered in light of the site-specific conditions. Clay particle sizes are small and usually negatively charged; therefore, once they are suspended, it is difficult to remove them from suspension without using chemical flocculants.

2.1.2.11 Section 803.02 Sod

Section 803.02 allows the use of block sod. It is recommended that block sod not be allowed for roadside stabilization. Rolled sod is a preferred material for sodding of linear projects because it has fewer edges and maintains moisture better than sod blocks. Likewise, machines can be used to lay rolled sod, which makes it somewhat less expensive. When irrigation water is available, sodding can be a cost-effective alternative to some erosion control blankets. It will still be necessary to staple or pin sod materials on steep slopes. Reinforced sod, sod that is grown with a TRM material embedded, has also been demonstrated an effective tool in providing erosion control in new channels with concentrated flows.

2.1.2.12 Section 801.07 Mulching

Crimping should be the preferred option for straw and hay mulch on non-cohesive. On cohesive soils crimping, soil binders and/or tackifiers may be required to get effective control.

2.1.2.12.1 Section 805 Erosion Control Blankets

The review of Section-209 raised several terminology issues that affect the specification of erosion control blankets. A significant concern is with the appropriate application and longevity of the different types of blankets or approved alternatives. These materials have different performance characteristics that require better differentiation. The issues to be addressed relate to soil type and distinguishing between blankets, temporary channel liners, and bonded fiber matrices, which are an alternative to blankets. In addition, the terms describing materials (covered by this section) need to be expanded and better defined as described in the discussion of Section 209. Also, see the discussion of the QPL.

2.1.2.13 Section 918 Miscellaneous Materials

There are several erosion prevention and sediment control related materials specified in this section including:

- 918.14 Grass Seed
- 918.15 Commercial Fertilizer,
- 918.16 Ammonium Nitrate,
- 918.17 Agricultural Limestone,
- 918.18 Mulch Material,
- 918.19 Staples,
- 918.24 Inoculants for Legumes,
- 918.25 Crown Vetch Sprigs,
- 918.27 Geotextile Material, and
- 918.29 Erosion Control Blankets.

The specifications for all these materials are sufficient with the exception of grass seed and erosion control blankets. Recommended changes for this section area described below.

2.1.2.14 Section 918.14 Grass Seed

The specification of seed materials as to delivery, inspection, and testing are vague in that there is no mention of minimums for germination and purity, or presence of weed seed While the Tennessee Department of Agriculture seed standard is cited, there is no guidance on how it is to be used. Because purity and germination varies with seed source and variety, the percentages of seed in a mixture need to be specified as Pure Live Seed (PLS), which is the product of the percent purity and percent germination, not simply percent. For example, a bag of seed with a purity of 0.87 and a germination of 0.84 contains only 73% pure live seed. If this represents 80% of the specified seed mix and the seeding rate specified is 7 lb/ac then the current specification would allow for 5.6 lb of seed/ac (7 lb/ac x 0.80 = 5.6 lb/ac). However, since the PLS is only 73%, the actual seed rate is only 4.08 lb/ac (5.6 lb/ac x 0.73 = 4.08 lb/ac). The actual seed that would be needed to meet the specification would be 7.67 lb/ac (5.6 lb/ac/0.73 = 7.67 lb/ac).

In addition, the current seed mixes, with respect to species and applications, need further consideration; and are discussed in detail in Section 3.4 of this report.

The fertilizer specification should be a separate item and should be changed to the effect that “fertilizer shall be provided in accordance with the analysis shown on the plans or in the plan notes.” This way the chance of creating nutrient pollutant hazards is minimized. Fertilizer in this section is also specified as a uniform mix (10-10-10) of active ingredients: nitrogen, phosphorus, and potassium. While this is common, it does not acknowledge that different soils have different nutrient needs. Applying nutrients that are not needed is wasteful and can be environmentally harmful. For example, if soils are

already high in phosphorus, adding any phosphorus could present a nutrient threat to adjacent waters. This practice needs to be revised so the percentages of active ingredients are appropriate for the site-specific soil requirements.

2.1.2.15 918.28 Erosion Control Blankets

The reference to the QPL is appropriate; however, the definitions and methods for developing the QPL need further consideration as noted in the recommendations for Section 209.02 above. See the discussion for Section 805-Erosion Control Blankets, 209.02 Classification, and the Qualified Products List: QPL's 17 Mulch and Erosion Controls.

2.1.3 The Qualified Products List (QPL)

The materials for erosion prevention and sediment control are so vast that most all transportation agencies have developed approved or qualified product lists to ensure the quality and performance of materials used on construction projects. TDOT's current QPL List, Section 17 Mulch and Erosion Controls, has three sections of approved products: Section A: Erosion Control Matting and Blankets for Slopes; Section B: Alternates to Matting and Blankets; and Section C: Flexible Channel Liners.

In its current state, the QPL is limited and does not recognize some good products that are available for a variety of EPSC applications. The term "mulch" in the title is somewhat inappropriate because there is really no category for mulch materials. The following discussion explains the basic deficiencies in the current QPL procedures. The following paragraphs provide several suggestions for expanding the Qualified Products List as well as the standard specifications. An in-depth discussion of product testing is provided in Section 3 of this report. Detailed recommendations for product qualification are in Section 3.3.4 Recommendations for TDOT QPL Evaluation Program.

2.1.3.1 Section A: Erosion Control Matting and Blankets for Slopes

The material list is divided into four types (Type I – Type IV) by material type and slope height and steepness. This classification is somewhat lacking because does not take into account the soil type. Non-cohesive soils are more erosive, and many products that perform well on steep slopes with cohesive soils do not have the strength or flexibility to maintain good soil contact on non-cohesive soils. Longevity is also a factor that is often overlooked, but can have significance in areas where climatic conditions lead to slower establishment of vegetative cover, such as at higher elevations.

The materials descriptions comprise four principal types of material: straw, curled wood fiber (excelsior), jute, and coconut fiber (coir). These specifications are so specific with respect to index qualities that many other materials that perform well are technically disqualified.

Numerous products such as erosion nets and synthetic-fiber-based materials are effectively eliminated from the QPL, Section B notwithstanding. Part of the problem is the rapid change in and marketing of materials for erosion control, but it is also confounded by the lack of a broadly accepted method of testing performance. This

problem is addressed in a separate section that specifically describes the issues of testing, material selection, and performance.

Since there are several recommendations related to this section, they are provided in bulleted format. It should be noted that the rational for these recommendations is provided in other sections of this report.

- Index testing should be adopted as a means of quality assurance. That is, that the products being supplied in the field meet the material standards of the products that were performance tested. Index testing of erosion control materials does not predict performance. The tests simply document the character of the material so it can be compared for quality control purposes.
- Performance testing methods are recommended as the basis for design purposes and for developing and classifying the QPL.
- If the performance testing methods are adopted there will be no need for the Section B provisions for Alternates to Matting and Blankets as the focus will be on the slope protection performance function and not materials properties

2.1.3.2 Section B: Alternatives to Matting and Blankets

Section B covers the family of materials that are generally not traditional rolled erosion control products. The current QPL includes one non-traditional rolled material and several products that are generally referred to as Bonded Fiber Matrices or BFMs. The current list has products that fall into the categories to be substituted for Type I and Type II erosion control blankets. These and other materials have demonstrated good performance on steep slopes with cohesive soils, particularly when combined with some slope roughening. Because they are applied hydraulically, they may have a broader application than given in the current list.

If the combined program of index and performance testing is adopted as suggested elsewhere, this category will not be necessary as all products will be rated by performance measures. There are hydraulically applied materials that have been shown to perform in a range that would fit Types III and IV.

2.1.3.3 Section C: Flexible Channel Liners

This section divides materials into four Classes, Class I - Class IV, based on the materials ability to withstand horizontal shear caused by surface flow. There are currently no products listed in Class I, which is for shear stresses of less than 2lb/sf. Two pounds per square foot is generally considered the upper stress limit for grass-lined channels. For this reason, it is recommended that the Class I channel liners should populated with biodegradable flexible channel lining materials. These materials should be performance tested to resist shear stresses of 2 lb/sf and greater. While a number of the biodegradable materials will withstand shear stresses greater than 2 lb/sf, they should not be grouped with higher performance classes because they do not provide long-term reinforcing of the vegetation-soil matrix.

The other categories include materials rated for stress ranges of 2 lb/sf to 5 lb/sf, 5lb/sf to 8 lb/sf and, greater than 8 lb/sf. Using shear as the means of qualifying flexible channel lining materials is consistent with current national practice. However, there is a need to distinguish between temporary and permanent flexible channel lining materials. Biodegradable materials should only be used to line channels having sheer stress of 2 lb/sf or less during the revegetation process.

2.1.3.4 The Drainage Design Manual: Chapter 10.

The *Drainage Manual's* Chapter 10 that has been developed for the design of EPSC applications is an extensive, well-considered work that brings together much of the theory needed for EPSC design decisions. The document is fully illustrated with pictures, diagrams, tables, and other information necessary to objectively select and design EPSC measures. However, the section covering the selection of surface protection methods, such as blankets, mulches and BFMs could be improved by providing some defensible numeric methods for design. Pitt and Clark, 2002, at the University of Alabama, have recently proposed a methodology that now allows the use of some simple hydraulics theory to be linked to the Revised Universal Soil Loss Equation (RUSLE) as a means of testing the selected EPSC measures against targeted thresholds of design. Adding these methods to Chapter 10 would give TDOT one of the most objective and comprehensive EPSC design manuals in transportation practice. The recommended additions are presented in a later section of this report; see Section 2.6.1—Modeling Erosion.

2.2 Recommendations for TDOT Sediment and Erosion Control Planning and Design Practices (A.2.a)

While TDOT has a reasonably developed set of tools to guide development of EPSC plans and Storm Water Pollution Prevention Plans (SWPPPs), the documents are not well coordinated with respect to terminology and application. This can be attributed in part to rapid changes in the regulatory framework that require transportation agencies like TDOT to change the way they have traditionally managed construction projects and by changes in the palette of materials available to the designer to meet EPSC needs.

In presenting the recommendations related to TDOT erosion prevention and sediment control design practices it is important to place the discussion in the context of the regulatory framework. By thinking in terms of EPSC measures as defined in the "Standard Specifications," "Standard Drawings," and QPL it is possible to forget that the broad focus of the regulatory framework which, is to manage the construction site so the state's water resources are protected from pollutants that can be carried in storm water. Since soil is the number one pollutant it tends to be the focus while other equally harmful pollutants such as solvents, pH modifying materials, solid waste, sanitary waste and others may be overlooked.

Although the recommendations for changes are addressed in the context of the Standard Specifications, Design Division Drainage Manual, Standard Drawings, and the Qualified Products List, they should be understood in the context of the SWPPP, and not just the documents themselves. The reasons for this are:

1. TDOT's practice of preparing SWPPP documents as part of the construction document package aims to accomplish two specific goals:
    a. To educate TDOT contractors regarding the requirements of, and the extent of effort required to meet, the General Permit and Aquatic Resources Alteration Permit (ARAP) requirements of TDEC and EPA; and
    b. To ensure more uniformity in the bidding of EPSC measures for TDOT projects.
2. The structural EPSC measures are only one part of the management tools that need to be in place to ensure that water resources are protected. Other nonstructural measures must be considered in the overall planning and design process, including: spill prevention and clean up planning, solid waste storage and management, hazardous materials storage and containment, and sanitary waste management plans.

All of these issues must be considered as part of the planning and design process leading up to the preparation and execution of the EPSC plans and SWPPP for a project. Given this as the overarching concern the following recommendations are made in relation to the principal documents used to guide the process of developing SWPPPs.

2.3 Recommended Design Methods

This section discusses the review of Chapter 10 being developed for the Design Division of TDOT. The document is intended to guide the selection and design of EPSC measures for TDOT construction sites in the future. Chapter 10 includes sections covering:

- Documentation Procedures;
- Fundamentals of Erosion and Sediment Control;
- Control Measures and Practices;
- The Erosion Prevention and Sediment Control Plan;
- Utilities;
- Phasing of EPSC Plans;
- Guidelines and Criteria for EPSC Measures;
- Acceptable Software; and
- Appendices.

It is recommended that before final adoption of the Manual that all the terminology in the manual, standard specifications, standard drawings and the QPL be reviewed and standardized. Recommendations for the standard terminology are given in the previous section. The discussion here will focus on broader concerns of keeping the design focus on the required EPSC plans and SWPPP, and to offer some suggestions on design procedures that can be used design for surface protection.

2.3.1 Modeling Erosion

The most widely accepted model used to predict surface erosion is the Revised Universal Soil Loss Equation (RUSLE), and it is presented in Chapter 10 of the Design Division Drainage Manual. This model has been calibrated for agricultural uses throughout the U.S. and has been adopted by federal agencies as the model of choice for predicting erosion. It is used by EPA as the basis for a construction erosivity waver for activities that takes place in dry periods. However, it has not been effectively incorporated into the design procedures for temporary erosion prevention measures for construction sites.

Two methods can be used to estimate the relative acceptability of an erosion prevention method for inter-rill erosion on slopes. The first as described by Pitt and Clark (2002) uses maximum permissible shear stress as the key design parameter for slopes and channels. V.T. Chow's equation is used for estimating peak shear stress on a slope surface, and a form of Manning's equation is used to estimate sheet flow depth over a disturbed surface based on the estimated peak runoff rate found by the Rational Method.

Where slopes are concerned, Pitt and Clark use the following form of Manning to estimate sheet flow depth on hill slopes.

$$y = \left(\frac{qn}{1.49 s^{0.5}} \right)^{\frac{3}{5}}$$

Where;
y = the depth of sheet flow
q = the unit width flow rate (Q total flow rate in cfs over the slope width in ft)
n = the sheet flow roughness coefficient for the slope
s = the slope in ft/ft

Given the depth of flow the shear stress on the soil surface can be found using Chow's equation

$$\tau_o = \gamma y S$$

Where

γ = the specific weight of water (62.4lb/cf)

y = the depth of sheet flow (ft)

S = the slope in (ft/ft)

In a great majority of cases, the surface shear will exceed the maximum allowable shear stress for unprotected soil surfaces. Pitt proposes the following relationship to find the shear stress impacting the soil surface for a selected erosion prevention practice:

$$\tau_e = \tau_o (1 - C_f)\left(\frac{n_s}{n}\right)^2$$

Where:

τ_e = the effective shear stress on the soil under a BMP

τ_o = the maximum shear stress from sheet flow

C_f = the vegetal surface cover factor (bare soil $C_f = 0$)

n_s= the roughness coefficient of the underlying soil

n = the roughness coefficient for the unvegetated BMP

The values obtained from this equation can be compared against the maximum allowable shear stress for bare soil as one means of determining the acceptability of an erosion control practice for slopes.

Pitt (2002) also demonstrates a method to use RUSLE to test the relative acceptability of an erosion prevention material on slopes. RUSLE estimates the erosion rate in tons per acre per year based on the soil erosivity, regional rainfall characteristics, slope length factor, cover and practice factors. The acceptability of an erosion control method is determined by calculating the base erosion rate which sets the values of the cover and practice factors to one, and then calculating the maximum allowable value for a cover factor.

Because the interaction between the values of *C* the conservation cover factor and P the practice factor used in RUSLE are not well understood in relation to highway construction activities, only the *C* factor is used for testing the acceptability of a particular surface protection BMP. The TDOT Drainage Manual introduces RUSLE, and provides the tables and maps for determining the values for R, K, and LS. By setting the values of *C* and *P* to 1, the unprotected annual erosion rate can be estimated. The NRCS provides recommended tolerance (*T*) values that characterize the maximum allowable annual erosion for sustainable agriculture. The over all acceptability of a BMP is determined by comparing the estimated loss for a given BMP with the recommended tolerance value (*T*).

In most all cases, RUSLE tends to produce a very conservative value compared to the shear method. However, the equation is limited in that it does not predict the interaction of multiple BMPs and the cover practice (*C*) values for erosion prevention BMPs are not well developed for highway construction. The maximum permissible shear has similar weaknesses because of the difficulty of determining the maximum permissible shear stress of various soils, as well as reliable values for "Manning's n." Regardless of the relative weaknesses of each method, these provide best available means to document selection of slope protection materials and methods instead of using questionable rules of thumb.

2.3.2 Selecting Design Storm Parameters for Temporary Erosion Control Design

The current CGP offers little guidance beyond the recommendation that

> ...erosion prevention and sediment controls shall be designed to control the rainfall and runoff from a 2-year, 24-hour storm as a minimum. When clay and other fine particle

soils are present at the construction site chemical treatment may be used to minimize the amount of sediment being discharged.

In cases where a simple volume is concerned, as in the size of a sediment basin, the 2-year, 24-hour depth can be used. However, in cases where a peak discharge rate is needed, as in the case of designs for channel and slope surface protection, designs need to be based on storm durations and intensities equal to the drainage basins time of concentration. The depth value obtained from TP-40 for a 2-year, 24-hour storm or the 5-year, 24-hour storm for impaired or high quality waters, is sufficiently conservative for most all temporary erosion prevention and sediment control design.

However, when using the Rational Method to determine a peak discharge rate, it is recommended that the 24-hour depth be adjusted for a storm with duration equal to the drainage basin time of concentration. Then based on the depth of rainfall received, the intensity of rainfall can be derived. For example, the contributing drainage area to drain over an exposed construction site area located near Memphis has an area of 0.45 acres, a runoff coefficient of 0.30, and a concentration time of approximately .2 hours (12 min.). The TP-40, 2-year, 24-hour rainfall depth for Memphis is 4 in, find the intensity of rainfall and peak discharge rate as follows:

Note that the percent of the 24-hour rainfall depth for a Type II rainfall distribution is 0.25 of the 24-hour depth.

Therefore, the depth for a 12-minute storm is 0.25 x 4.0 or 1 inch.

The intensity (i) would be $\frac{60^{\frac{\min}{hr}}}{12^{\min}} \times 1^{in} = 5.0^{\frac{in}{hr}}$

The peak discharge would then be calculated as:

$$Q = CiA$$

$$Q = 0.30 \times 5^{\frac{in}{hr}} x 0.45^{ac}$$

$$Q = 0.68^{cfs}$$

The estimated discharge is small but these small discharges can produce significant erosion on disturbed, unprotected soils.

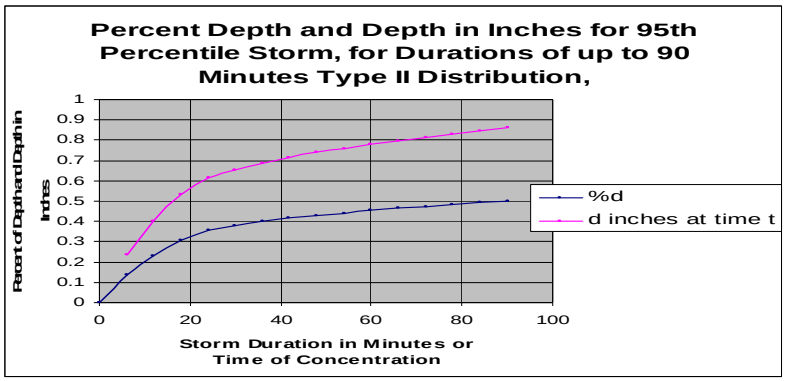

Figure 2-2: Percent of 24-Hour Rainfall Dept for Storms of Durations Up to 90 Min, NRCS Type II Rainfall Distribution

2.3.3 The 90th Percentile Storm as the Basis for Temporary EPSC Design

Another way of determining storm parameters being used for temporary EPSC design is the 90th or 95th percentile storm. That is using storm parameters that would capture 90% or 95% of the runoff from the disturbed area. As an example, the 90th percentile storm for the Nashville area is 1.6 in, and the 95th percentile storm is around 2.3 in where as the 2-year, 24-hour is 3.5 in., and the 5-year, 24 hour is approximately 4.5 in. This is a considerable difference and results in very different design.

The intent of the regulatory requirement is to provide sufficient protection for the most probable rainfall condition for adjacent waters and to provide a higher level of protection for high quality waters. However, simply using the 2 year and 5 year 24-hour depths fails to recognize the designs that result from using this parameter.

The depth of rainfall and return frequency are only two parameters needed for design of temporary EPSC measures. Rainfall intensity is a very important design consideration. When the national weather service publishes atlases of rainfall depths for a return frequency of 24 hours, it represents an average depth for all storms that occur in a 24-hour period. This does not recognize the fact that storms of short duration are of much greater intensity and can do more damage even thought they may not equal the average 24-hour depth. Where EPSC controls are concerned, the short, intense storms are usually of the greatest concern because drainage basins are typically small which allows rapid concentrations of runoff, yet the depths will be much less than the 24-hour total.

Because of the intensity issue, over design of EPSC measures using 24-hour depths will not necessarily give greater levels of protection. In fact in some situations it will likely result in less protection. For this reason, TDOT should further investigate other design standards. not adopt the 5-year, 24-hour depth as the primary design parameter, but rather look at possibly adopting a standard that would capture 90% or 95% of all rainfall events likely to occur during a construction period.

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3 Sediment and Erosion Control Materials and Methods

3.1 Testing of Sediment and Erosion Control Materials

This section addresses the broad area of testing erosion and sediment control materials, performance norms, and the development of specifications for various materials. Once again, the focus of this work will be on evaluation using function as the key determinate in testing and evaluation processes. We will first look at the kinds of testing that are being performed addressing American Society for Testing and Materials (ASTM), bench scale, and large scale testing programs and future directions that need to be considered. We will discuss the strengths as well as weaknesses in testing methods and suggest how current efforts can be used to maximize benefits and minimize costs.

A detailed section is provided on the current erosion and sediment control materials and technologies. The purpose of the section is to present the characteristics of the materials and their application. One particular goal in this discussion is to cover the full range of technologies and methods so traditional, cost effective technologies such as blown and crimped straw mulch, temporary seeding, etc are not overlooked in favor of more expensive manufactured materials. It is important to stress that most all materials currently on the market for temporary erosion prevention and sediment control have a place depending on the construction period, climatic factors, soils, vegetation, and the cultural and environmental sensitivity of the site.

3.1.1 Overview of Product Testing 15/A.2.a

Two types of testing are used to characterize erosion prevention and sediment control (EPSC) products: index testing and performance testing. Index testing can be used on many products to predict performance as in the case of concrete, or asphalt materials. However, where erosion control materials are concerned, specifically materials used to protect disturbed surfaces from inter-rill erosion or from bed scour in channels, and to foster the development of permanent vegetation, no suite of index tests has been developed that correlate with field performance. The Erosion Control Technology Council, which is principally a manufacturer's industry standards organization, has developed a series of "index properties" tests that adequately describes the physical properties of rolled erosion control materials. They have also led an effort in association with the American Association of State Highway and Transportation Officials' (AASHTO's) National Testing and Product Evaluation Program (NTPEP) to develop other so called bench scale tests for predicting performance. These same bench scale tests have also been presented to ASTM as working standards as predictors of erosion control performance. A full list of these in progress efforts can be found at the ASTM Website, but ASTM does not release copies of working standards. So far, efforts to correlate these index or "bench scale tests" to field performance have been inconclusive. This has been documented in two reports from research at Colorado State University by Robeson,

Thornton and Nelsen, 2004 and Lipscomb, Hudson, and Thornton, 2005, and by a parallel effort at Texas A&M University funded by TxDOT.

Several facilities conduct performance testing of erosion prevention and sediment control products. The best-known full-scale facilities include the laboratories at Texas A&M University operated by the Texas Transportation Institute, San Diego State University, Colorado State University, and the Erosion Lab, operated by American Excelsior at Rice Lake, WI. Each of these facilities has a different testing protocol but essentially test materials at full or near full-scale conditions. The full-scale tests adopted by ASTM are based on full scale outdoor protocols used at the American Excelsior, Rice Lake facility. However, no other laboratory uses this exact protocol.

The outdoor protocols have been criticized for their weaknesses in repeatability and measurement precision, because they are susceptible to the vagaries of weather and other climatic variables (Sutherland, et al. 1998). For these reasons, indoor protocols were independently developed for testing at the laboratories at San Diego State University, Colorado State University, and Texas A&M University. Each program uses large indoor facilities with tilting sediment beds and or flumes for testing.

The most significant problem with full-scale performance testing methods is cost, and lack of a standardized protocol that has been field calibrated. The Colorado State University facility is an indoor facility that has been used by many erosion control product manufacturers. They usually use a flume for testing. The facility at San Diego State University is an indoor facility and consists of a tilting sediment bed and rainfall simulators. The facility at Texas A&M University has a flume and tilting sediment beds for testing under a wide range of soil and flow conditions. The National Soil Erosion Research Laboratory is the oldest national research program dedicated to understanding soil erosion. This laboratory is responsible for the continued development of the Universal Soil Loss Equation and related soil loss modeling programs such as RUSLE-2 and the Water Erosion Prediction Program (WEPP). While this research is fundamental, it has little direct application to temporary erosion control in current highway practice.

The Texas Transportation Institute (TTI) facility currently conducts the TxDOT hosted, FHWA pooled fund project Number TPF-5 (015). This project is dedicated to producing research specifically oriented to the transportation industry and provides member states with performance data on a full range of erosion prevention and sediment control products including, rolled materials, hydraulically applied materials, channel liners, and non-manufactured materials such as sod, straw and hay mulches. The program is also focusing on the development of index tests that will predict material performance for a variety of characteristics including: moisture retention, longevity, and sediment reduction compared to bare soil, vegetation establishment, and shear resistance.

Clearly the direction in performance testing of EPSC materials whether the NTPEP, ASTM, FHWA pooled fund or ECTC is toward more economical small-scale tests that can be conducted in a laboratory setting. However, as noted earlier, none of the current index testing methods have demonstrated good correlation to field performance. Therefore, until the research and development efforts that are currently underway mature, full-scale testing is the most reliable means of determining EPSC performance.

3.1.1.1 Full-Scale Testing Methods

Currently, the country has four full-scale testing facilities: San Diego State University, Colorado State University, American Excelsior's Erosion Lab, and the TxDOT-TTI Facility at Texas A&M University. Of these facilities, the only one that has an active and ongoing indoor testing and research program aimed specifically at transportation applications is the facility at Texas A&M University. The American Excelsior facility has published an outdoor testing protocol that is the basis of the current ASTM standard but has no focused program on transportation applications. The San Diego State facility was developed and supported by Caltrans but no longer has an active research and testing program. Colorado State's facility does testing based on sponsor needs and does not use a standard protocol. For this reason, it is rarely possible to share data between the facilities to verify performance values.

TxDOT is currently sponsoring an FHWA pooled fund project No. TPF-5 (015). The purpose of this project is to:

- Provide timely testing data and quality assurance data to the member states; and
- Pursue an orderly program of research aimed at developing laboratory scale tests for EPSC materials that will predict field performance.

The program has tested over 130 different products for erosion prevention on slopes and in channel. These materials include all types of mulches, blankets, tackifiers, bonded fiber matrices, temporary and permanent flexible channel liners. The lab also maintains a quality assurance program that requires manufacturers whose materials have met the performance thresholds used by the testing program to submit product samples tri-annually for index screening. Alternatively, they may provide data from an independent laboratory, demonstrating that the product still has the type and quality of that which was originally tested.

After 10 years of outdoor testing using the same protocol, the outdoor protocol and accumulated data were evaluated first to address some criticisms of the procedures noted industry and by Sutherland, et al. 1989, and to determine what could be done to reduce costs and increase the precision of measurements. Because of this review, the testing protocol was revised in 2000. At that time, the outdoor protocol was dropped in favor of an indoor program. This change would increase the precision and repeatability of measurements, reduce costs and limit the influence caused by the vagaries of the weather. The results being obtained from the new protocol correlate well with the previous 10 years of outdoor testing.

The research program aimed at developing laboratory scale test to predict erosion prevention and sediment capture performance of materials is in only its third year of operation. The research program has focused on the identification of the physical material properties the may predict performance and to look at other small scale tests that have been proposed by industry to see if they correlate with the full scale performance data collected from over 15 years of material testing. To this point, funds for this program have been limited, and results from most of the tests have been inconclusive. This seems

to be borne out by the Colorado State University (CSU) study as well. Future directions in the research program will be determined by the pooled fund participants.

Where testing of EPSC technology and materials is concerned, it is important to remember that the pallet of EPSC tools is very broad. Most all of the current focus of testing programs is on what are called rolled erosion control products (RECPs) which include the broad groups of products called blankets and "Turf Reinforcing Mats" (TRMs, also referred to as flexible channel lining materials). Other materials that have also been tested in full-scale conditions include Bonded Fiber Matrices (BFMs), hydraulic mulches, natural materials such as hay, straw, sod and reinforced sod, and tackifiers including polymers. Most all of the testing done focuses on two key performance properties: sediment reduction and vegetation response. These two measures are almost universally accepted as the primary measures of performance for any erosion prevention material.

Sediment control products are not a significant part of most active testing facilities at this time. This is probably because sediment reduction is for the most part a passive system that uses materials that provide extended detention of sediment-laden runoff to settle out suspended materials. The only regularly manufactured materials that are used for sediment control are "silt fence," wattles, filter socks, and triangular silt barriers. While there is a wide variation in material, only limited testing has been done on performance. A recent body of work by Ellen Stevens, et al., 2004-2005, at Oklahoma State University demonstrates that installation is critical to reducing sediment using fabric barriers. They also show that the relative effectiveness requires installation on the contour. When not properly installed, performance varies considerably, with an average removal efficiency of around 50%. Again, this depends on the site, the soil, the fabric, installation, and relation to the contour of the land. Other tests have shown higher retention rates (see 3.2.4). Testing of sediment basin designs has also been conducted at Penn State and NC State (see 5.2.7).

ASTM has two index standards for silt fence materials: D6461-99 Standard Specification for Silt Fence Materials and D5141-96 (2004) Standard Test Method for Determining Filtering Efficiency and Flow Rate of a Geotextile for Silt Fence Application Using Site-Specific Soil. Sprague and Carpenter (2005) have proposed one new method for testing the performance of sediment retention devices, and a second method has been presented by Theisen and Spittle (2006). ASTM has a Working Standard, WK4030 New Standard Test Method for Determination of Sediment Retention Device Effectiveness, that is currently being considered and may be balloted this year. Until more research data is available on silt fence performance, the current ASTM standards are probably the most useful for specifying fabric silt fence fabrics.

Other standards are under review for EPSC materials, including one for Geotextile filter bags, the WK7555 Standard Test Method for Determining the Flow Rate of Suspended Solids from a Geotextile Bag. These may be useful when they are adopted.

3.1.1.2 Bench Scale Methods

This type of testing is widely used in industries where there is a wide range of material types and proprietary materials, such as in the chemical products or textiles industries.

Laboratory tests are developed and then calibrated to actual performance data. Once calibration is proved, the tests are then adopted as a means of predicting material performance. Many of these tests use apparatus that simulates environmental variables such as rainfall, solar radiation, wind, abrasion, structural fatigue, and the like.

Bench scale methods for testing erosion prevention products to this point have focused on sediment reduction, shear resistance and bed protection for channel liners, vegetation response, moisture retention, and longevity. Tests for sediment control have generally focused on issues of longevity and filtration.

Where erosion prevention materials are concerned only a few of the tests developed so far have demonstrated good correlation to field performance data. The vegetation response tests see, to adequately predict material performance with respect to germination response. Another variable that is linked to vegetation response is moisture retention. A small scale test has been developed that shows significant differentiation in material abilities to retain soil moisture but these results have yet to be calibrated to vegetation response.

A second test that has shown promise is the sediment yield test developed by Texas Research International/Erosion Control Technology Council (TRI/ECTC). In tests at Texas A&M University, the materials have performed in a range similar to full-scale tests. That is, if a material would meet the full-scale threshold for performance, it would generally pass or fail based on its performance when compared to other previously tested materials. However, the test substantially under predicts sediment losses in the range of field observations. Therefore, at this time it is not possible to calibrate the test to set meaningful performance thresholds. Since it seems to track the relative performance is promising, but additional work is needed to see if the results can be calibrated to correlate with field observations.

Longevity is a key consideration in selecting channel lining materials where shear stresses generated by design flows are greater than 2lb/sf. In these cases, a permanent soil reinforcing material is needed. Two types of tests have been proposed for determining long-term strength of TRM type products. The first method proposed measures CO2 generation for a 60 day period and compares the carbon lost to gas formation to the theoretical total carbon. The most promising of the longevity tests are those that use an environmental chamber with moisture, temperature and UV light exposure to simulate extended environmental exposure. These tests are common to the synthetic fibers industry. These tests do cause materials to loose strength over a period of 60 days but these results have not been fully calibrated to actual field conditions. To be useful more work must be done to calibrate the results to field observation. A recent study at Texas A&M University, Khanna, et al, 2006 conducted over a three-year period looking at the longevity of geosynthetics compared to organic materials documented the loss of tensile strength in a variety of channel lining materials but these results still need to be compared to environmental chamber data.

Two reports evaluating the “bench scale” tests proposed by the Erosion Control Technology Council and the National Technical Product Evaluation Program of AASHTO have been conducted by the Colorado State University Hydraulics Laboratory.

The first, Robeson et al, 2004 focused on the proposed test for channel protection from erosion due to shear. The second report was the Transportation Research Board, NCHRP Study, 20-07 (162), Lipscomb et al, 2005 was a more detailed study and focused on the channel shear test and the rainfall splash erosion test. The results of this study also showed that the results of these proposed tests were inconclusive in predicting material performance for shear resistance or hillslope protection.

The problem with efforts to develop small scale or "bench scale tests" is that efforts are focused on attempts to scale environmental conditions that are extremely variable; conditions of soil type, and physical properties of that soil, antecedent moisture, slope length, temperature, etc. all impact on the actual performance of a material. To this point, the work on small scale testing procedures suggests that no one has been able to successfully isolate the environmental characteristics that will allow the prediction of field performance. . An alternative that has been proposed as part of the FHWA pooled fund effort is to statistically analyze the data collected from years of indoor and outdoor testing to see if a combination of physical material properties will successfully predict performance. Early efforts by Li and McFalls, 1999 and 2002 did not show significant correlations. However, their efforts were very limited due to time and cost constraints. These efforts will be pursued over the next fiscal year as time and funds permit.

An additional avenue that also needs further exploration is the linking of the variables in the Revised Universal Soil Loss Equation (RUSLE) to physical material properties of erosion control materials and technologies. Some industry leaders have undertaken this work by developing proprietary design software for selecting their products. The technical theory behind these software programs is RUSLE. Some examples of this design software include: Propex Fabrics' (Formerly SI® Corporation), EC-Design®; North American Green's, Erosion Control Materials Design Software, ECMDS®; and American Excelsior's, Erosion Works®. Because of the years of research behind RUSLE and the fact that it has been demonstrated to do a good job of predicting average annual erosion, it makes sense to look closer at how RUSLE can be used for both design and product evaluation. The primary difficulty in using the equation currently is that there is only limited field calibrated data available for the values of ***C***, the conservation factor, and ***P,*** the practice factor, for products and methods of controlling hillslope erosion. If reliable tests could be developed to determine field verifiable values for ***C***, and interaction values for multiple technologies using ***P***, RUSLE could be the basis for design as well as part of a program for developing a qualified products list.

Efforts to develop and calibrate tests that will predict the performance of erosion prevention and sediment control materials will continue over the coming years. However, it is important to understand that none of the tests currently under review by ASTM and NTPEP have been demonstrated to predict performance. For this reason, there is no way to calibrate the test data in a way that would allow the setting of meaningful performance thresholds as a basis for accepting or rejecting products or providing usable information for design. The AASHTO, NTPEP program states in their published work plan that, while they have adopted the ECTC suite of bench scale tests:

> The values generated from the ECTC's Bench-Scale test protocols referred to in this plan are intended for use in conformance only. These values should not be used to design a

project or installation. The ECTC bench scale tests are currently index tests and do not reflect site and / or field conditions that these materials are typically subjected to.

3.1.1.3 Future Directions (Design parameters, i.e., Manning's "n", NRCS conservation factor (*C*), cover factor (*Cf*)

In the near future, NTPEP, ECTC, ASTM, and other university based research programs should be encouraged to pursue the development of smaller scale tests that will predict material performance. This effort is essential to reducing the cost of testing and to ensure that transportation agencies can meet water quality mandates.

As noted above efforts should also be encouraged to calibrate RUSLE and/or the Water Erosion Prediction Program (WEPP) to meet construction design needs. The Western Regional Coordinating Center Office of Surface Mining released a publication *Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands Toy and Foster, 1998,* this publication is one of the few studies accomplished that relates RUSLE specifically to construction sites. The RUSLE software has sense been revised and the validity of the interaction of cover (*C*) and practice (*P*) values remain unclear. However, the current version of the software package RUSLE2 does provide some means for adjusting interactions but little work has been done that relates specifically to highway practice and adjustments require both technical knowledge and experience to effectively use the programs capabilities. A project similar to Toy and Foster, 1998, aimed specifically at calibration of RUSLE2 for transportation practice may be of significant benefit at the national level.

The design and product selection software offered by manufacturers noted earlier ride on RUSLE theory. Because these tools are developed by manufacturers, they are proprietary and only guide the selection of their products. It is also not clear how the values for the equation are derived. For example, some applications ask the user for the soil K value. Others, more sophisticated applications, use lookup tables based on soil properties. In either case, the use of the program requires some knowledge of RUSLE properties. One direct benefit that being derived from these efforts are the data for P and C values that are being developed to support these programs. These efforts lead the way toward the kind of information that needs to be developed to support more informed design decisions.

To make RUSLE more useful highway related EPSC controls significant efforts need to be mounted in two areas:

1. Procedures need to be developed to establish the conservation cover factor (*C*), Manning's "*n*," and the surface cover factor (C_f) for surface protection materials i.e., blankets, TRMs, and BFMs.
2. Further research is needed to understand and predict the interaction of erosion control practices i.e., *C* and *P* to make RUSLE more useful in design.

Because RUSLE has been tested extensively and proven to provide good predictions of erosion rates, additional work to develop better application methods related specifically to highway construction sites could yield big benefits to the transportation industry in the future. These kinds of tools will become increasingly important as water quality standards mature and demands for better design tools increase.

3.2 Product Approval Procedures 15/A.2.a

The TDOT procedures section of the QPL list four types of "Erosion Control Blanket" (Type I, Type II, Type III, and Type IV). The material descriptions include 4 principle types of material, straw, curled wood fiber (excelsior), jute, and coconut fiber (coir). The specifications are so specific, with respect to index qualities, that many materials currently on the market that perform well may technically be disqualified based on composition alone. A second more critical consideration is that the product qualification does not take soil type into the application. Work in California, Forest et al, 2002, and Landphair et al, 2002 have demonstrated that materials perform differently depending on the soil type. The TTI research has shown that some materials perform satisfactorily on clay soils and do not perform well on sandy soils. This is believed to be related to material flexibility, soil contact and weight. However, more work is needed to understand the interactions of these variables. Regardless of the reasons for the difference in performance, the QPL variables of slope length and steepness are not necessarily sufficient measures of performance for these materials.

Section B of the current QPL, Alternatives to Blankets and Matting, is a means for other products to be approved on a case-by-case basis. While this gives the manufacturers an avenue to have their products on the QPL, it does not necessarily provide sufficient design guidance for product's application and relative cost effectiveness. At this time, the products in this category on the QPL are BFMs and an erosion control compost equivalent to Type I and Type II blankets.

3.2.1 Current TDOT Product Approval Procedures 19/A.2.a.(2)

The current product approval procedures for erosion control blankets are based on meeting specific physical properties with respect to various material types such as jute, excelsior, or straw. The assumption is that if a material meets the physical properties described that it will provide adequate performance for the slope length and steepness limits of each type.

For other non-rolled products, there is a requirement that they be proved in the field under conditions specified by TDOT. This method of approval is time consuming and can be expensive. Nor are the measures well described or likely to be of a precision that would be easily repeated or defended if challenged.

For approval as a channel liner current QPL procedures only required that the manufacturer of the material certifies that it meets shear stress limits when vegetated. The use of shear stress is the accepted measure of material strength under concentrated flow conditions; however, it does not take into account whether the material successfully works with the vegetation to prevent excessive bed erosion. Most of the current products marketed as channel liners do a reasonable job of limiting erosion once the vegetation is established but many of the products require at least 90 days to get any significant cover of vegetation. This is generally attributable to the density of the matrix and filler in the product.

The shear ranges in the current QPL standard are 2 lb/sf and less, 2 lb/sf to 5 lb/sf, 5 lb/sf to 8 lb/sf and greater than 8 lb/sf. This particular classification needs to be refined to

recognize that grass-lined channels are generally considered stable with out additional reinforcement up to 2lb/sf. Therefore, materials that are within this range of performance are considered temporary, biodegradable, products that can be used for channel protection while establishing permanent vegetation cover.

The problem is that many biodegradable materials can resist shear stresses greater than 2lb/sf when initially vegetated but will afford no long term reinforcing value. The current QPL classification methodology does not differentiate between long-term materials and biodegradable products to account for this. Most geosynthetics flexible channel lining materials, TRMs, have demonstrated long-term or permanent reinforcing properties while products made of vegetable fibers, straw, excelsior, jute, hemp and coir are only temporary. For this reason, it is suggested that the Type I category be used to include the temporary biodegradable products even though they may have an initial shear stress rating well in excess of 2lb/sf.

3.2.2 Recommendations for Accelerated Materials Approval 19/A.2.a.(2) and 15/A.2.a.(2)

Current TDOT procedures rely heavily on index testing methods for product approval. That is materials are approved based on their physical properties such as weight, tensile strength, flexibility, smolder resistance, etc. This sort of testing is very effective in predicting performance for a variety of materials such as aggregates, hydraulic cement, asphalt and the like. However, where EPSC materials are concerned, the variation in the raw materials is so broad as to render current methods of index testing of little value in assuring field performance. Not that index testing is of no value or may not be developed in a way that can be used for design and approval purposes. However, at this time index testing of EPSC materials is only useful for purposes of material quality control.

The FHWA pooled fund study sponsored by TxDOT is the only combined research and testing program that is funded by, directed by, and dedicated to the needs of transportation agencies. For this reason, we would suggest that TDOT consider the merits of the program and see if it might meet the information and testing needs of the department. The required annual contribution is considerably less than the cost of undertaking an independent research and testing effort and provides the department a voice in the research program as well as access to all testing and research data produced annually by the research and testing program, access to research staff and EPSC professionals.

3.3 Current Material Specifications and Performance Norms for Erosion Control Materials 15/A.2.a.(2) and 16/A.2.a.(2)

3.3.1 Introduction

The following section discusses the range of materials being used nationally by transportation agencies for the temporary prevention of erosion and capture of sediment on construction sites. The purpose of the discussion is to provide the background needed to explain the recommendations for changes and additions to the current TDOT specifications, evaluation procedures, and qualified products list. The rapid change in

material types and availability, and changes in regulatory environments have combined to require greater precision in design and specifying of temporary erosion prevention and sediment controls (EPSCs) on transportation construction sites. This is a problem for transportation agencies nationally and not unique to Tennessee.

3.3.2 QPL Programs for Other States

An assortment of state DOTs have established their own protocols and criteria for evaluating and approving new erosion control products. Summarized below are the protocols set forth by three of these states having well-organized protocols for the QPL selection process. These states include the Ohio Department of Transportation, the Wisconsin Department of Transportation, and the California Department of Transportation. Each of these agencies has established what criteria need to be included upon submittal of a product and the process that their internal department undergoes. The process of establishing QPL evaluation criteria and setting threshold limits for EPSC products is a complicated task and has been a significant challenge for other states.

3.3.2.1 The California Department of Transportation

The California Department of Transportation (Caltrans) issues an Erosion Control New Technology Report that identifies possible future products to be evaluated and field tested. The products are summarized based on design, specifications, applications, effectiveness, and cost. These products are identified through search committees who review available product descriptions, evaluations, and performance data available from vendors, manufacturers or developers. Products may also be submitted for review to the Caltrans New Product Coordinator.

The New Product Coordinator receives all requests for new product approval and coordinates the assessment with technical staff. The evaluation team also includes a Lead Corporate Program Manager who has the final responsibility of approving or rejecting new products, based on the findings and results from the technical staff. He is then responsible for notifying the New Product Coordinator of which products may be placed on the Approved or Qualified products list.

Once a product is submitted by the manufacturer for review, it is categorized as either a Type I or Type II product. Type I products are those that have not been previously evaluated, Type II products are those that may have been previously evaluated but have since been modified. The New Product Coordinator requires that a New Product Information Form and A Material Safety Data Sheet be submitted at a minimum, also requested is available product literature, material specifications, independent product testing results, any documented use by other agencies, and engineering designs and calculations. Caltrans strongly encourages independent testing of products submitted and documentation of the products compliance with state specifications and standards. The product is then evaluated based on: Caltrans potential need for the product, the competitive cost of the product, and whether approval will create a sole-source problem or increase the competitive market.

For the product to meet final approval it must be approved by the technical committee, Corporate Program Manager, and the New Product Coordinator; it must meet the safety

and health standards, and must comply with the environmental rules and regulations. If no apparent need is recognized and the product is not approved, the manufacturer has the right to appeal and meet with the technical committee and New Product Coordinator. Decisions made in this meeting are final.

3.3.2.2 The Ohio Department of Transportation

The Ohio Department of Transportation (ODOT) has had a protocol for evaluating erosion and sediment control products in place for the past ten years; it was last revised in May 2006. In order for a product to be approved for evaluation, it must undergo both laboratory and field testing. It is the manufacturer's responsibility to work with a contractor willing to test the new product on-site. Field tests and evaluations are then performed by the contractor. Once tests are completed, the contractor may submit the product to ODOT. The contractor assumes all responsibility for on-site testing so if the product fails it must be replaced with an accepted substitute. When submitting a product to ODOT the following items must be included: the intended use must be stated, the manner in which it will either replace an already existing product and/or achieve the NPDES requirements, and documentation and performance evaluations from both laboratory testing and field testing on a weekly basis for at least the past three months. The department will then assess the product and determine whether it meets the stated erosion control requirements. ODOT imposes no fee for submittal of a new product for evaluation.

3.3.2.3 The Texas Department of Transportation

The Texas Department of Transportation (TxDOT) develops its EPSC Approved Products List (APL) based on a continuing testing program it operates in under a contract with TTI. This program has developed the original outdoor testing protocol, which has been the basis for the development for other similar outdoor testing protocols such as the one adopted by ASTM. Vendors that wish to have their product added to the approved product list are required to submit application to TTI for testing. Products are tested on a first come first serve basis. There is a fee for the testing that varies depending on the type of product, mulch, blanket or channel lining material. Material performance is based on two parameters, vegetation response and sediment loss. The thresholds used for all slope and channel products are as shown in Table 3-1: TxDOT Thresholds for Vegetation and Sediment Loss and Table 3-2: TxDOT Thresholds for Shear Stress on Flexible Channel Liners.

Table 3-1: TxDOT Thresholds for Vegetation and Sediment Loss

Slope	Soil	Vegetation Cover Threshold	Sediment Loss Threshold lb/100sf (t/ac/event)
2:1	Non-cohesive	50%> than control	632[1] (137)
2:1	Cohesive	50%> than control	7.9 (2)
2:1	Bare soil reference non-cohesive	N/A	3,885 lb/100sf (846)
	Bare soil reference cohesive	N/A	297 lb/100sf (65)
3:1	Non-cohesive	50%> than control	284[2] (62)
3:1	Cohesive	50%> than control	7.9 (2)
3:1	Bare soil reference non-cohesive	N/A	1,710 lb/100sf (372)
3:1	Bare soil reference cohesive	N/A	267 lb/100sf (58)

[1] This threshold is currently being reconsidered and may be raised. Several products limit loss to less 400 lb/100 sf which is significantly better

Table 3-2: TxDOT Thresholds for Shear Stress on Flexible Channel Liners

Shear Stress (lb/sf)	Maximum Allowable Sediment Loss lb/100sf[1] (t/ac) Cohesive soils
2	350 (76)
4	500 (109)
6	620 (135)
7	800 (174)
10	1180 (257)
12	1200 (261)

[1] Volume loss is based on the average soil loss which is the calculated volume of soil lost from 3 flume trays for three events each

Other EPSC measures approved for use are introduced by special specification. If the materials and methods are successful, they may be added to the standard specifications at the next revision.

3.3.2.4 The Wisconsin Department of Transportation

The Wisconsin Department of Transportation (WisDOT) re-evaluates and compiles its erosion control Product Acceptability Lists (PAL) for erosion mats, soil stabilizers, tackifiers, inlet protection, and temporary ditch checks annually. For a product to be submitted for evaluation, the manufacturer or distributor must include:

- a representative product sample of approximately 10 ft^2
- product specifications and any associated literature
- field performance data and laboratory data

- any other state agencies that have tested the product and their results
- a completed Product Preliminary Information Sheet provided by WisDOT Technology Advancement Unit; and
- a private label identification of the product identifying the source and material used.

Laboratory testing must be performed by a state approved laboratory. The current list of approved labs is available at http://www.dot.state.wi.us/business/engrserv/lab-current-listing.htm.

Erosion control mats have designated specifications, which must be met in order for the product to be placed on the Product Approval List (PAL). These specifications include requirements to meet shear stress, slope erosion protection, and vegetative enhancement standards. For shear stress analysis, results from an approved lab using ASTM D6460-99 will be accepted, where failure is defined by the loss of ½ inch of soil in channel. For the evaluation of slope erosion protection tests must be performed using ASTM D64545-99, where the soil loss must not exceed a cover management (C) factor of 0.20. Finally, for vegetative enhancement, erosion mats must allow for a density of 70% in sandy soils, and 80% in clay soils. Vegetation results will be evaluated after the first year of installation.

Upon submittal, the manufacturer or distributor is also required to include installation instructions for the following possible locations: slopes, channels, shorelines, high wind locations, and areas adjacent to traffic lanes. If the product is approved by WisDOT, it must be insured that the final product is of the same material and manufacturing specifications than that submitted for evaluation. Once a product is placed in the PAL, it is subject to random sampling by WisDOT where the original approved sample will be compared to a representative sample.

3.3.2.5 Technology Acceptance and Reciprocity Partnership

Several states use the TARP program to share product data in assisting them in the evaluation of products for the QPL. These states include California, Illinois, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and Virginia. The Technology Acceptance and Reciprocity Partnership (TARP) provides a guideline to product evaluation and performance testing with the Protocol for Storm Water Best Management Practice Demonstrations. This protocol establishes a uniform method for demonstrating storm water technologies and develops quality assurance plans to certify and verify product performance claims. It is intended to eliminate duplicative testing and demonstrate the effectiveness of the product. At a minimum, the products submitted must be environmentally beneficial, commercially available, field-tested, and quality controlled.

Upon submittal of a product, the scientific and engineering principles, design specifications, operating conditions, maintenance requirements, secondary impacts, and safety concerns must be included with the technology specifications. A performance claim is also submitted for review that states the products expected capabilities to remove

contaminants and control runoff. To validate the product, storm water data must be collected based on standardized test methods and procedures such as those specified by ASTM, or ASCE for example. Testing and sampling analysis must be performed by a certified or accredited laboratory. The protocol further identifies storm events to sample, guidelines on determining a representative data set, and appropriate sampling methods and locations on the test site. Test parameters must also be selected depending on the product and the performance claim; however, it is recommended that at a minimum, total suspended solids (TSS), and suspended sediment concentration (SSC) be included to determine the solids removal efficiency of the product.

Products submitted and tested based on the TARP protocol for storm water treatment technologies are listed at the "Storm water Technologies Clearinghouse," a free searchable database developed by the University of Massachusetts. This database is readily accessible at www.mastep.net. The evaluated products are displayed with their performance data and associated technical information. The database indicates whether the product met the minimum TARP requirements or whether further study is being conducted. However, currently, no products evaluated have met the specified approved requirements.

State government agencies can join TARP by agreeing to participate in one of the available levels, for example the Storm Water Technology Protocol. The agency must agree to participate in the review and product evaluation process of the submitted reports, and will be able to actively participate in the revision of the TARP program. The third revision of the program is currently underway. There is no application fee or membership charge to participate in TARP.

3.3.3 Testing and Performance Related to Material Type and Function

3.3.3.1 Rolled Erosion Control Materials

Rolled erosion control materials include the full spectrum of materials that are often called erosion control blankets or erosion mats. To distinguish these materials from other hillslope protection materials, the industry has adopted the term "Rolled Erosion Control Products" or RECPs. These materials are provided in rolled sheets or mats of varying widths and lengths. The materials used to manufacture rolled products are so different it is not possible to develop a single general specification that will generically embrace all of the products. Therefore, transportation agencies and the industry have developed classification systems that group the materials by their material properties, longevity, and performance properties related to soils, slope steepness and length or other physical index properties. The Erosion Control Technology Council (ECTC), which is an industry council, divides rolled materials into five (5) Types. Each Type is divided into subtypes such as 1.A, 1.B, etc. These denote different performance capabilities within a particular type. Types 1 through Type 4 are considered short-term biodegradable products while Type 5 products are considered permanent materials. This breakdown does a reasonable job of classifying the broad differences in rolled products; however, it only differentiates material performance by slope steepness. Netting is a feature used to differentiate some rolled products in the ECTC specification. Whether a material has a double or single net, does not seem to impact sediment reduction performance, and therefore does not seem to

be a critical characteristic in specifying materials for temporary surface erosion control. In fact heavier stiffer materials tend to be somewhat less effective that looser more flexible materials. Field experience suggests that the primary benefit of the heavier double net materials, regardless of the fiberfill is that they are less susceptible to damage during handling.

ECTC's specification does not consider either slope length or soil type. As noted previously, full scale testing has shown that soil type does impact material performance on slopes. For this reason, the current ECTC classification still lacks guidance for appropriate application. The complete current ECTC standard specification and classification for temporary and permanent rolled erosion control products is provided in Appendix B.

The real measure of a product's erosion prevention performance has little to do with the netting, the fill materials or whether it is woven or non-woven. It is how well it holds the soil surface and promotes the establishment of permanent vegetation cover. The TxDOT sponsored program is the only program that has published performance thresholds for sediment reduction and vegetation cover as shown in Table 3-1: TxDOT Thresholds for Vegetation and Sediment Loss and Table 3-2: TxDOT Thresholds for Shear Stress on Flexible Channel Liners. These thresholds have been in place since 1991 and many of the materials tested since that time have performance numbers much better than the current thresholds, particularly on steep slopes and non-cohesive soils. TxDOT is considering raising the performance thresholds for all of the Class I erosion control materials, which includes all the temporary erosion, control blankets but no action has been taken as of yet.

It can be seen that soil type together with slope does have a significant impact on the volume of sediment produced in an average rainfall event particularly in non-cohesive soils. Overall, soil characteristics seem to have a greater impact on sediment loss as steepness increases. This is why it is essential to include soil as a variable when developing criteria for the QPL and other design guidance.

For temporary and permanent flexible channel lining materials, tests have only been run on cohesive and loamy soils. The tests at TTI are run 90 days after seeding, so vegetation anchors the channel liner in place. The thresholds for sediment loss adopted by TxDOT are based on the shear stress categories shown in the Appendix.

It is important to note that, for all surface protection materials, there may still be a significant sediment loss, particularly for non-cohesive soils on steep slopes. This underscores the need to use multiple measures to obtain effective erosion prevention and sediment control during construction.

All of the published thresholds and performance numbers are from full-scale testing protocols. As noted in earlier discussions the small scale tests that have been put forward by ECTC and NTPEP for shear stress in channel liners and for sediment loss of RECPs have not been successful in predicting full scale performance of materials, Lipscomb et al, 2005. Therefore, without further research and development it is not possible to develop any meaningful performance predicting thresholds using these methods.

3.3.3.2 Mulches, Bonded Fiber Matrices, and Compost

Some non-rolled products are effective in preventing erosion and fostering the establishment of permanent vegetation. Bonded Fiber Matrix products and specially formulated compost materials have been demonstrated to perform as well as rolled products in certain conditions. These materials include:

- Straw and hay mulch
- Bonded Fiber Matrices (BFMs)
- Erosion control composts

Cellulose fiber mulches and paper based mulch products also have some application in fostering the establishment of permanent vegetation but offer little erosion protection on moderate to steep slopes.

Cellulose Fiber Mulches: are applied hydraulically and are used to help maintain soil moisture and to foster seed germination. Unless a tackifier is used with the mulch material, cellulose fiber mulches provide little or no erosion control. In general, these mulch materials should not be used on moderate to steep slopes unless some type of soil binder and/or tackifier is included in the application.

Paper Based Mulches: These materials are made principally of recycled paper and are marketed as hydraulic mulches. In testing, these products have not performed as well as the cellulose fiber mulches, and they are not recommended for highway construction applications.

Straw and hay mulch: Straw and hay have been used for centuries as an aid in reducing erosion and establishing vegetation cover. In a mature stand of vegetation the natural crop residue or "thatch" that builds up at the surface works with the live vegetation to prevent soil erosion. Hay and straw are crop residue products that are a natural form of erosion control when left in place. Hay and straw mulch materials are still in use today because they work. Traditionally hay and straw were held in place by crimping or tacked with an asphalt emulsion. However, asphalt emulsions are considered environmentally unfriendly so vegetable based tackifiers have become the norm.[2] Straw is a stiffer, longer-lived material than hay and can be more easily crimped, while hay is more flexible and shorter lived but tends to provide better initial sediment reduction.

Testing of crimped straw mulch shows that it is as effective as any erosion control blanket or BFM on non-cohesive soils. However, it compares less favorably on cohesive soils.

Bonded Fiber Matrices: BFMs are a relatively new product composed of proprietary mixes of cellulose fibers and tackifiers that are applied hydraulically. These materials must not be confused with hydraulic mulches or mulch with tackifier. The ingredients must be carefully blended and applied at the manufacturer's prescribed rate to achieve the desired performance. BFMs have a limited service life of about one growing season but

[2] In the literature the primary objection to asphalt emulsions has more to do with volatile air pollutants than any danger to water.

are very useful in reducing erosion on steep slopes where equipment access is very limited.

Erosion control composts: Composts, composed principally of yard waste, have demonstrated good ability to reduce sediment loss on bare soils when applied at depths of three to four inches. Tests at lower rates have not been successful in preventing erosion. Their added nutrients and moisture holding characteristics are also of some benefit in encouraging more vigorous stands of vegetation. Other types of compost such as cow or chicken manure or biosolids, while generally successful are not recommended near high quality or impaired water bodies due to the soluble phosphorus content.

3.3.3.3 Silt Fence and Filter fabrics

Most transportation agencies use the ASTM standards or standards developed by the Geosynthetics Research Institute (GRI) of Drexel University for silt fence. For the most part these standards are not performance based, although one of the GRI tests is for long term flow through fabric. Recent performance testing of silt fence has been done at Oklahoma State University by Stevens, Barfield, et al (2004), the University of Texas, Austin, Barrett et al, 1998 and at Pullman WA, . P.R Robichaud et al 2000 found sediment retention of greater than 90% when placed parallel to the contour. Additional data recently generated in a flume at North Carolina State University confirms the retention sediment introduced to the flow is about 90% (McLaughlin, unpublished data). However, Stevens et al, (2004) demonstrates that these numbers can be misleading because the actual performance of any silt fence is dependent on a wide range of variables including: the openness of the fabric, the type of soil, and the installation.

In general, silt fence is a cost effective means of providing protection against offsite discharge of sediments when properly installed parallel to the contour, and in conditions where flows will be less than 0.5 cfs per 100 lf of material

3.3.3.4 Wattles, Filter Socks, and Triangular Silt Barriers

These are tubes or long rolls of material that have many uses in temporary erosion control. Three different groups of materials are described variously as wattles, filters socks, and dikes.

Wattles: By definition a wattle is a type of structure made of poles woven with twigs and branches. The term was first applied to erosion control by Europeans such as Arthur von Kruedener (1951) and Hugo Schiechtl (1952) who developed biotechnical soil stabilization techniques. In this venue wattle means a bundle or roll of live branches laid in a shallow trench parallel to the contour. The U.S. erosion control industry has adopted the term wattle to describe rolls of organic fibers such as straw, excelsior, or coir held together by synthetic netting.

Kelsey and Johnson, 2006, demonstrated that wattles are very effective in interrupting sediment laden surface flows and reducing sediment loss. They are particularly effective in improving the performance of blankets and other surface coverings. Kelsey and Johnson also suggest that the greater the density of the wattle the more effective it will be in maintaining good surface contact. Theisen and Spittle have proposed a method for

evaluating the performance of wattles and tubes. Their work tends to support Kelsey's finding that the more dense materials will perform best.

Filter Socks: Filter socks are synthetic fiber tubes that can be filled with some type of filtration media. The most popular material is compost, or a mix of compost and wood chips. To be effective the compost needs to include long fibrous material to hold the fine materials in the tube. In general compost from biosolids, chicken mortality, or cow manure must be mixed with yard waste materials or decomposed wood chips to be effective. Some proprietary filler mixes are being marketed for this purpose, and some specifications for erosion control compost and compost filter fillers have been recommended. An example compost specification can be found at (ftp://ftp.dot.state.tx.us/pub/txdotnfo/cmd/cserve/specs/2004/standard/s161.pdf).

Triangular silt barriers: These are materials made of plastic or foam, which may be covered with a geosynthetics fabric used to reduce velocities and trap sediment. The most common application of these materials is as a cross ditch check. They can also be used for perimeter protection, diversions and as inlet protection. All of the materials are proprietary, but they have been employed in venues with very good success.

3.3.4 Recommendations for TDOT QPL Evaluation Program:

The proposed protocol is for the review of new EPSC products by the TDOT Materials and Tests office. This covers erosion control materials, flow controls, and sediment control devices and requires the submittal of the product by the manufacturer, manufacturer's representative, or the contractor to TDOT for an initial review. The initial reviews would be conducted by a new TDOT research committee, within the Materials and Tests group to actively identify new EPSC materials and methods emerging on the market.

The required submittal must include the following items:

- Product Evaluation Form;
- The submitter is to specifically identify what type of product, already approved in the standard drawings or within the QPL, is being improved or replaced
- Product sample;
- Manufacturer's specifications;
- Material Safety Data Sheet (MSDS);
- Product literature;
- Results, including description of protocols and any deviations from standardized protocols from independent product testing;
- Any documented use by other agencies, and
- Installation instructions.

Upon submittal, the manufacturer or distributor is also required to include their regularly published installation instructions. If the product is approved by TDOT, it must be certified that any product furnished to the department are of the same material and manufacturing specifications as those submitted for evaluation. If the product is marketed under more than one name or if the name of the product is changed it is the responsibility to notify TDOT of that change and provide certification is the same as the product originally evaluated. If there is any other change in the materials formulation, composition, or manufacturer that product must be submitted for reevaluation even if it is said to be an improvement and marketed under the same name.

As stated earlier, the submitter of the product for evaluation is to specifically identify what type of product, already approved in the standard drawings or within the QPL, is being improved or replaced. Specific categories for submission be classified

- Surface Erosion Controls
- Flexible channel liner
- Sediment Controls
- Flow controls

Further sub-categories under these four broader headings will be established by TDOT Testing and Materials staff and consultants working together in the implementation phase of the SSWMP.

A flow chart of the proposed QPL review program is given in Figure 3-1: Approval Process Flowchart for EPSC Products.

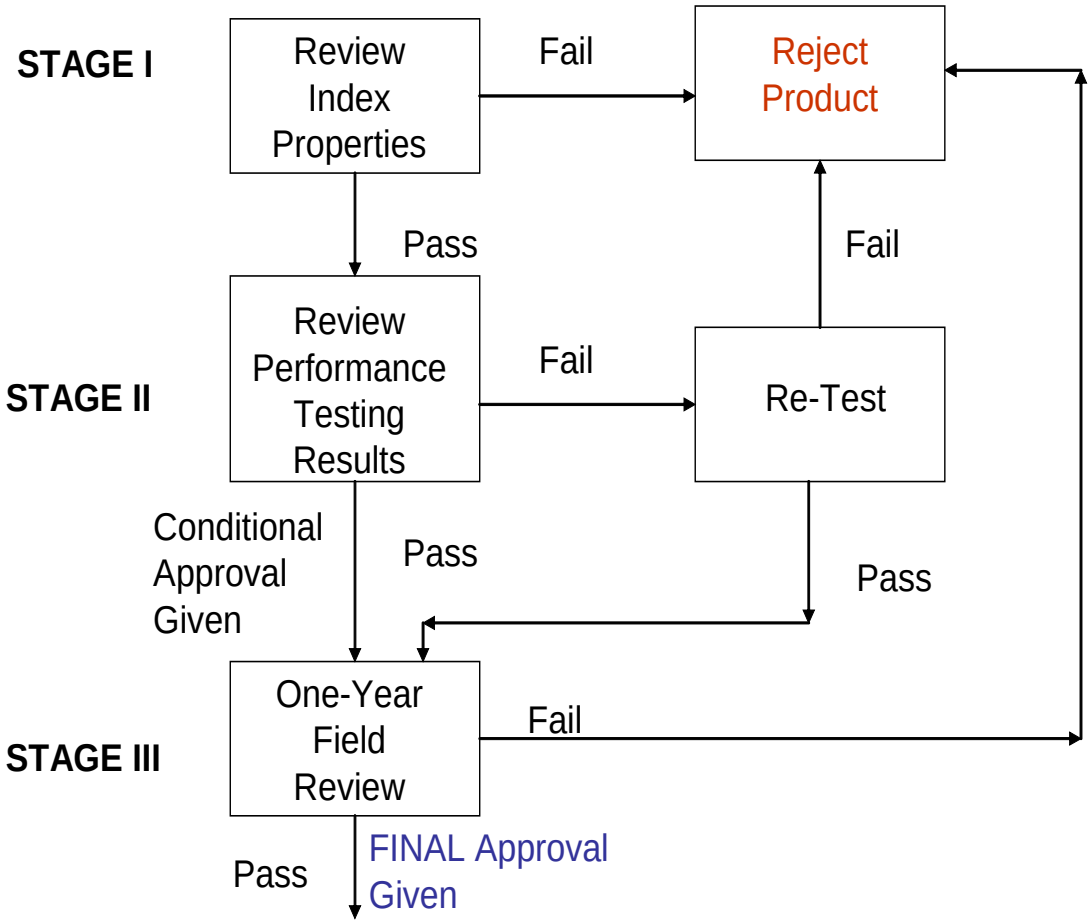


Figure 3-1: Approval Process Flowchart for EPSC Products

3.3.4.1 Stage I

Once all of the required items are submitted, the QPL review process will commence. The first stage of the review process involves the review of the list of index properties and their values. Specific properties will be dependent on the type of product. This is called "Stage I." The manufacturer is responsible for submitting index test data appropriate to the product type above, from a certified laboratory, for quality control purposes. Index testing data are considered in Stage I only. Initial thresholds are given for mats and blankets based on ECTC published criteria given in Table 4 and 5.

In addition, new blanket and TRM products must have an ECTC Test Method #4 Determination of Rolled Erosion Control Product (RECP) Enhancement of Seed Germination and Plant Growth, included in the appendix materials, with a result of a minimum 150%, over the control of a bare soil surface.

The manufacturer shall submit 3-year National Transportation Product Evaluation Program (NTPEP) data for the Department's review. Data will be reviewed for full

compliance with TDOT Specifications and AASHTO M 268 (ASTM D 4956). Product must be in full compliance at the beginning and end of the three year period.

The manufacturer must certify that the materials to be supplied are formulated the same as when tested by NTPEP and will conform to the requirements of this specification. New erosion control products that would be considered equal to or substitutes for other TDOT-approved surface covers such as mulches and soil binders must present index data that meets the specifications for the items already approved and established in the QPL. Other threshold values for the index properties for erosion control products will be established by TDOT Testing and Materials staff and consultants working together in the implementation phase of the SSWMP.

Sediment control products that would be considered equal to or substitutes for materials established on the QPL must meet the current approved TDOT standards. For example, a new item that is attempting to compete with standard silt fence must meet the index requirements for silt fence already approved and established in the QPL. Threshold values for the index properties for sediment control products will be established by TDOT Testing and Materials staff and consultants working together in the implementation phase of the SSWMP.

If a new erosion or sediment control product is seeking approval where no TDOT index properties or test thresholds have been established due to a lack of research information, the product would immediately move to comparative performance testing as described in Stage II.

The vendor/manufacturer must also submit verification that the new product will perform its intended EPSC function for storm events up to and including the 5-year, 24-hour storm events, as documented for each region of the state of Tennessee.

The Stage I program needs to be flexible, with annual re-evaluations of threshold values. As research provides new data, the Stage I thresholds should be revised to incorporate new information to assist the department in evaluating new products. Part of the implementation phase of the SSWMP must involve on-going assistance from consultants to the Division to help further establish minimum index parameters and threshold values for both erosion control materials and for sediment control devices.

If the new product submittal data meets all of the threshold standards, the new product will move to the Stage II evaluation.

3.3.4.2 Stage II

The Stage II review requires the manufacturer to provide full-scale third-party performance testing for the new products submitted for approval. This requires the testing of the product include protocols that include specific soil characteristics of Tennessee and cover conditions/situations that are not accounted for from index tests. Stage II is a verification step to validate product performance. It is the vendor's or manufacturer's responsibility to prove verification of product capabilities and performance.
As part of the Stage II process, TDOT Division of Materials and Tests would generate a list of approved independent labs that would perform the testing for the products, as part of the SSWMP implementation phase. The Division would regularly evaluate and update

the approved list. Manufacturers would be required to pay all expenses associated with the third-party testing of the manufacturer's product. The performance testing would be carried out using the specific soil types encountered in Tennessee. The protocols to be used for the tests would be initially as specified by the protocols given in the TARP program. However, alternate protocols can be submitted to the Division for approval. The current testing protocols for the TxDOT program and the ECTC programs are included in the appendix materials. Protocols will be regularly evaluated and updated based on the progress of the erosion and sediment-control industry towards more standardized methods of performance testing. This stage of the program must be flexible to keep up with industry changes.

The focus of the Stage II testing is to compare the new product performance with a "control" product. The "control" product would be one that is already approved by TDOT for a specific EPSC function, e.g., surface protection, channel liner, sediment capture and/or flow control. The new product proposed for evaluation must perform comparable or better than the current TDOT-approved products the vendor/manufacturer has specifically noted in the submittal documentation. The tests to be used will be based on the category of the product being evaluated. Part of the implementation phase of the SSWMP will involve the establishment establish of minimum parameters that must be included in full-scale testing for all categories of erosion control materials and for sediment control devices. For example, for sediment control devices, two parameters to use would be filter efficiency and flow-through hydraulic capacity. Both the "control" product and the new product would undergo the same full-scale testing and the results from the designated test parameters would be statistically compared. If the new product is statistically equivalent to or better than the "control," the product will qualify for Stage III evaluation.

Stage II performance data could also come from the TARP program (recommended for TDOT and involves no costs to belong) and/or the TTI pooled-fund program, if

- The new product has already undergone testing under one or more of these programs; and
- The results clearly demonstrate that the new product performs comparable to the TDOT-approved material serving the specific EPSC function.

It is recommended that TDOT consider participation in the FHWA Erosion Pooled Fund Study Number: TPF-5 (015) and the TARP program for access to current full-scale testing research data from other states. The cost to TDOT participation in the pooled fund project is approximately $10,000 annually.

The Stage II testing could eventually be replaced by bench-scale tests if future research establishes bench scale protocols with good correlation to field performance.

3.3.4.3 Stage III

If the performance stage (Stage II) demonstrates the new product is comparable or better than the "control," then the new product will be "conditionally approved" and will move to the field application stage (Stage III). It is the responsibility of the vendor or manufacturer to identify contractors having active projects across the state and willing to

use the product for field application purposes. The conditionally approved product must be installed on at least one or more active projects. Installation of the conditionally approved product in several different TDOT regions is encouraged to enhance the quality of the evaluation. Field applications will be reviewed by TDOT Division of Testing and Materials personnel, TDOT project managers, the designated TDOT EPSC specialist, personnel from each of the 40 construction offices, EPSC Inspectors, and Environmental QA/QC Assessors for one year. Stage III will also require the development of the EPSC New Product Review Committee. The committee will have three representatives from of the following areas:

- The EPSC specialist from the Construction Division Office the new product is being implemented;
- The project engineer where the new product is being implemented;
- A representative from TDOT Testing and Materials

This committee would meet three times during the Stage III evaluation of a new EPSC product: 1) at the commencement of the field review (initial installation of the product), 2) 6 months after the installation of the new product, and 3) at the one-year anniversary of the installation of the new product. The committee would be the clearinghouse for information gathered during weekly EPSC inspections, QA/QCs, and other field reviews of the new product in the field. The new product must be functioning on-site on one or more TDOT projects for a total cumulative time of one full calendar year. If after one year, there are no significant issues with the performance of the product, the product would be designated as "fully approved." If there are major concerns from field personnel or members of the EPSC New Product Review Committee, the product would be rejected.

The Department would reserve the right to reject any product, which does not demonstrate satisfactory performance in any of the above stages of evaluation. The Department also would reserve the right to remove any product from the Qualified Products List that does not perform satisfactorily under full-scale field conditions, at any time beyond the one-year field application stage.

If the product is not approved, the vendor or manufacturer would have the right to appeal and meet with the Division of Materials and Tests. Decisions made in this meeting would be final.

Products that are currently approved on the QPL will be required to meet all of the requirements under the new evaluation program. A one-year grace period will be given to the vendor or manufacturer to meet the new requirements.

3.3.4.4 Division Training for QPL Program

Additional staff training is recommended to improve skills in interpreting testing and materials data for both erosion control and sediment control materials and methods. The Materials and Testing staff must be involved in the SSWMP-proposed EPSC Training program for TDOT Environmental, Construction, and Design Division staff.

3.4 Seeding and Seed

3.4.1 Seed Mixes for Tennessee

TDOT's current seeding practice is built around one cool season forage grass Kentucky 31 Fescue (*Lolium arundinaceum)* and one warm season perennial Bermudagrass (*Cynodon dactylon*), with the remaining species being annual forbs, herbs, grasses and annual small grains. The means of specifying seed mixes is vague and the specifications are so general as to allow a great deal of variation in seed application and quality. Most states have or are developing new seed mixes for roadside planting that are based around a mix of available native species, nurse grasses and adapted species that are considered non-invasive. Some of this recent emphasis on review of seed mixes can be attributed to a national focus on using native species on the roadside and response to Executive Order 13112, February 3, 1999, Invasive Species. Because of this executive order, there have been several publications and papers that that list any non-native plant as an invasive species. This can be very confusing and must be carefully evaluated. For example, there is an FHWA website (http://www.fhwa.dot.gov/modiv/invasive.htm) that implies that both tall fescue and bermudagrass are invasive species. While it is true that both of these grasses have been introduced from outside the U.S., and they are listed by some states and agencies as invasives, they are not considered invasive in Tennessee or the surrounding states. In transportation practice these grasses a considered adapted species in that they will in the right microclimatic conditions, colonize the roadside and form stabile plant communities mixed with other native plant species that volunteer from natural seed sources.

While the adapted species should continue to be the core of the permanent stabilization seed mixes there are a number of native and adapted species listed in Table 3-3 could be useful in roadside seed mixes in Tennessee. However, in studying available distribution maps it is clear that these species are not uniformly distributed across the state and must be carefully matched to the soils and climatic conditions of the state.

Tennessee is in an ecotone, that is, an ecological transition zone between areas where cool season and warm season grass persist. The southern and western areas of the state tend to be more suited to the warm season grasses while the northern and eastern areas have climates that will support cool season grasses. The map of physiographic regions of Tennessee (Figure 3-2 and Figure 3-3) clearly illustrates the need for more consideration of current planting practices and careful evaluation of alternative seed mixes.

Table 3-3: Native and Adapted Grasses with Potential for Roadside Use in Tennessee

Common Name	Scientific Name	Native (N) or Adapted (A)
Permanent or Persisting Grasses		
Little Bluestem	Andropogon scoparius	N
Canada Wild Rye	Elymus canadensis	N
Bermudagrass	Cynodon dactylon	A
Indiangrass	Sorghastrum nutans,	N
Switchgrass	Panicum virgatum	N
Broomsedge	Andropogon virginicus,	N
Kentucky Bluegrass	Poa pratensis var.	A
Side Oats Grama	Bouteloua curtipendul	N
Bahaiagrass	Paspalum notatum	A
Dallisgrass	Paspalum dilatatum	A
Easter Gammagrass	Tripsacum dactyloides	N
Sand Lovegrass	Eragrostis trichodes	N
Nurse Grasses or Temporary Cover Crops		
Italian Ryegrass	Lolium multiflorum	A
Summer Oats	Avena spp.	A
Balboa Ryegrass	Lolium spp.	A
Italian Ryegrass	Lolium perenne	A
Foxtail Millet	Seta riaitalica	A
Starr Millet	Pennisetum spp.	A
Western Wheatgrass	Agropyron smithii	A
Wheat (Red, Winter)	Triticum spp.	A

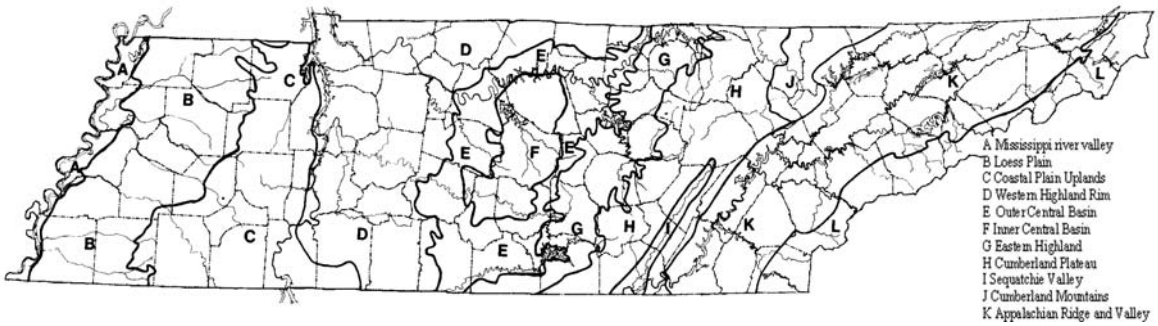
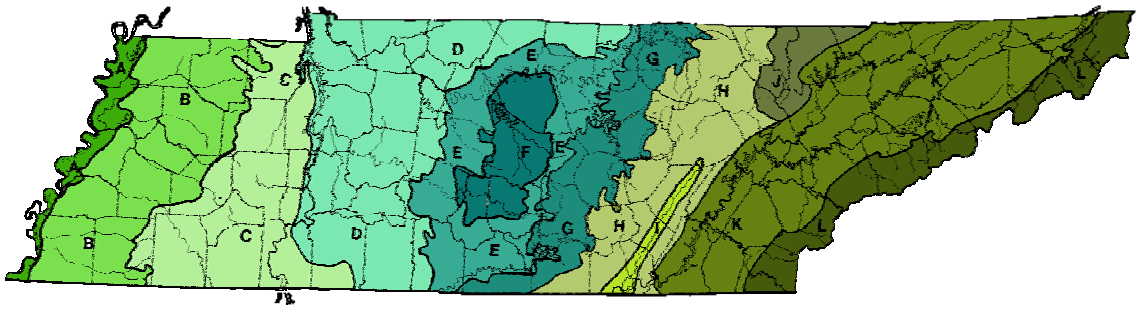


Figure 3-2: Physiographic Regions of Tennessee



A. Mississippi River Valley, B. Loess Plain, C. Coastal Plain Upland, D. Western Highland Rim, E Outer Central Basin F. Central Basin, G. Eastern Highland H Cumberland Plateau I. Sequatchie Valley, J. Cumberland Mountains, K. Appalachian Ridge and Valley.

Figure 3-3: Grouping of Physiographic Regions of Tennessee for Roadside Planting

Because of these varied conditions, it would be imprudent to make any firm recommendation about specific seed mixes. It can be said with some certainty that the current practices are questionable from cultural and maintenance point of view, and that to develop more compatible and sustainable seeding mixes will require a significant research effort on the part of TDOT.

3.4.2 Use of Native Seed in Roadside Applications

The FHWA and other organizations currently encourage the use of native plant species on the roadsides. While this movement is well intentioned, significant problems can occur when it comes to roadside conditions if the use of natives is generalized to the entire roadside. First, it is important to understand that the roadside is a part of the highway structure, it is steeply sloped to drain, the soils are compacted to protect the road base and support wheel loads and all of these conditions are inhospitable to many native plant species.

In ecological terms, most native grass communities would be classified as late successional communities or climax communities. Where as the recently completed highway roadside, even when properly topsoiled and planted, would be an early successional community. This means that the species initially planted on the highway need to be selected to foster the development of a sustainable plant community that will gradually succeed to a more stable community of climax native species.

Most of the national research on grass establishment has been conducted for growing livestock forage or ornamental turf grasses for lawns and golf courses. Therefore, the research focus is on cultivation of the grasses for food value or aesthetic concerns. However, where the highway is concerned the primary objective is a stable plant community that provides erosion control and protection for the highway. Only limited and regionally focused research has been conducted to determine how stable roadside grass communities evolve. A brief look at the Tennessee Agricultural Extension literature suggests that the current TDOT seeding mixes were developed from forage seeding

recommendations. As noted, the roadside is a significantly different environment than a pasture in terms of both environment and management.

This problem has long been recognized in Texas where there is a significant body of research conducted to develop seed mixes for every district in the state. With the national focus on using natives and the pressure to develop mixes that will hasten the revegetation process TxDOT has several new projects under way to address these issues. These studies are looking at native grass mixes and standard seeding mixes on different soil types with field verification plots.

Figure 3-4: TxDOT Roadside Seeding Research, (Left) mixes on 8 regional soil types, (Right) Field verification plots

Companion studies underway include mowing practices, and seeding rates. These studies will require between 3-7 years to complete, and results will not easily translate outside the south central part of the county. Another study conducted in the early 90's by Landphair et al, TxDOT for FHWA (0-1504) clearly demonstrates the successional process on the roadside, showed that roadside plots when left unmowed for 5 years after planting tended to be rapidly overtaken by taller native species while mowed plots tended to be invaded by weedy materials.

Two broad concerns with the current TDOT seeding mixes are:

1. Little consideration exists for the differences in regional climatic and soil conditions across the state that tends to warmer season grasses.
2. No native or adapted forbs or grasses are included in the seed mix to foster the development of a more diverse herbaceous roadside community.

While some anecdotal publications suggest the value of establishing native grass communities on rights-of-way, there are no systematic studies that document the planting and development of diverse grass communities in roadside conditions. For this reason, TDOT is encouraged to work with their university-based research communities to develop studies, similar to those being conducted by TxDOT that will address appropriate

seed mixes for revegetation of roadsides, along with cultural practices that will assist in sustainable roadsides.

Until these studies can be completed, suggested interim seed mixes have been proposed to better recognize the various differences in soils climatic conditions of the state. The seed mixes were developed by carefully reviewing the species mixes and applications in all the surrounding states including Georgia, Alabama, Mississippi, Arkansas, Missouri Kentucky and Virginia, and by looking closely at the physiographic regions of Tennessee. In addition, extension specialists with the University of Tennessee system were consulted to be sure that the recommendations were reasonable. In general the most significant change is toward the use of more warm season grasses, which seems justified when looking at neighboring states.

Seed mixes are to be planted by region and in the appropriate season. The state is divided into three Regions I –III. These are shown on the map in Figure 3-4. Region I includes the Mississippi River Valley, Loess Plain and the Coastal Plain Upland. Region II is the Western Highland Rim, the Outer Central Basin, Central Basin and the Eastern Highlands. Region III is the Cumberland Plateau, Sequatchie Valley, Cumberland Mountains and the Appalachian Ridge and Valley.

Table 3-4: Recommended Interim Seed Mixes for TDOT

Region	Zone	Best	Marginal	Mix (lb/acre PLS)
1	Poorly drained soils	Feb – Mar 20 Sept 1 – Sept 30	Feb 15 – Apr 30 Sept 1 – Oct 31	Pensacoal bahiagrass (80) (Bermudagrass hulled) (30) Sericea lespedeza (20) Kobe lespedeza (10)
1	Well drained soils	Apr 1 – July 15		Pensacola bahiagrass (50) Bermudagrass (hulled) (15) Sericea lespedeza (30) Foxtail millet (15)
1	Grass Channels	Apr 1 – July 15		Bermudagrass (40)
1	Temporary Seeding Summer	June 1 – Oct 15		German Millet (30) Sudangrass (40)
1	Temporary Seeding Fall	Oct 15 – May 31		Annual Ryegrass (40) Foxtail millet (30)
2	Slopes and Poor/Shallow Soils	Aug 25 – Sept 15 Feb 15 – Mar 21**	Aug 20 – Oct 25 Feb 1 – Apr 15	Pensacola bahiagrass (100) (Bermudagrass hulled) (40) Korean lespedeza (30) Kobe lespedeza (10)
2	Moderate slopes soil >6in depth	Aug 25 – Sept 15 Feb 15 – Mar 21	Aug 25 – Oct 25 Feb 1 – Apr 15	Pensacola bahiagrass (80) (Bermudagrass hulled) (30) Korean lespedeza (20) Kobe lespedeza (10)
2	Roadside Channels and Ditches	Aug 15 – Oct 15	Feb 15 – Apr 15	KY 31 Fescue (150) Bermudagrass (hulled) (20)

Region	Zone	Best	Marginal	Mix (lb/acre PLS)
2	Temporary Seeding Summer	May 1 – Sept 15	April 15 – Oct 1	German Millet (30) Sudangrass (40)
2	Temporary Seeding Winter	Oct 31 – Feb 15	Oct 15 – Mar 1	Annual Ryegrass (40) Foxtail millet (30)
3	Mountains Steep Slopes >2,500ft	July 25 – Aug 15 Mar 20 – Aug 20	July 15 – Aug 30 Mar 5 – May-15	KY 31 Fescue (100) Sericea Lespedeza (20) Korean lespedeza (10) Redtop (5)
3	Mountains Steep Slopes <2,500ft	Aug 15 – Sept 1 Mar 1 – Apr 1	July 25 – Sept 15 Mar 1 – May 10	
3	Shallow Soils >2,500ft	July 25 – Aug 15 Mar 20 – Apr 20	July 15 – Aug 30 Mar 5 – May 15	KY 31 Fescue (40) Korean lespedeza (10) Redtop (10) Crown vetch (10)
3	Shallow Soils <2,500ft	Aug 15 – Sept 1 Mar 1 – Apr 1	July 25 – Sept 15 Mar 1 – May 10	
3	Soil >6in moderate slopes >2,500ft	July 25 – Aug 15 Mar 1 – Apr 1	July 15 – Aug 30 Mar 5 – May 15	KY 31 Fescue (60) Sericea lespedeza (15) Korean lespedeza (15)
3	Soil >6in moderate slopes <2,500ft	Aug 15 – Sept 1 Mar 1 – Apr 1*	July 25 – Sept 15 Mar 1 – May 10	
3	Roadside Channels >2,500ft	July 25 – Aug 15 Mar 1 – Apr 1	July 15 – Aug 30 Mar 5 – May 15	KY 31 Fescue (150) Italian ryegrass (35) Smooth bromegrass (20)
3	Roadside Channels <2,500ft	Aug 15 – Sept 1 Mar 1 – Apr 1	July 25 – Sept 15 Mar 1 – May 10	
3	Temporary Seeding Summer	May 1 – Sept 15	April 15 – Oct 1	German Millet (30) Sudangrass (40)
2	Temporary Seeding Winter	Oct 31 – Feb 15	Oct 15 – Mar 1	Annual Ryegrass (40) Foxtail millet (30)

3.5 Recommended Materials Testing Procedures for Tennessee

As noted in an earlier section the EPSC materials palette needs to be expanded to embrace the full range of available materials and technologies. The testing program can then be built around the adopted nomenclature. The only bench scale testing protocols currently available are the ECTC index tests for material properties and three bench scale tests for splash, shear, and germination. The three index tests that were proposed to predict performance have not been successfully correlated to field performance and therefore should only be used as part of an index-testing program to maintain quality

control. That is, used as a method to verify the quality and type of material, not the predicted performance.

Table 3-5: ECTC Index Tests for Degradable and Non-degradable RECPs

Test Method	ECTC Manual Section
Thickness	9
Resiliency	10
Density	11*
Mass Per Unit Area	12
Porosity	13
Open Volume Per Unit Area	14
Stiffness	17
Light Penetration	18
Tensile Properties	20
Compression Behavior	21

*Used for non-degradable materials only

Several testing facilities have been described in earlier sections. The only continuing program that has a standard performance testing protocol used for all materials and that demonstrates field performance is the TxDOT sponsored program managed by the Texas Transportation Institute (TTI) and the TxDOT sponsored pooled fund project, FHWA Erosion Pooled Fund Study Number: TPF-5 (015). The continuing research testing program provides participants in the pooled fund data on the performance of new products and a voice in the ongoing research program. Other facilities do not have continuing testing programs with a standing protocol used for all erosion products (RECPs, mulches, BFMs, TRMs). One of the key objectives of this program is to develop laboratory scale protocols that will adequately predict field performance of all erosion control technologies for use in determining cost effective applications and design. This is a significant weakness in the industry-sponsored programs, which ignore many useful technologies such as mulches, and other soil stabilizing materials. The current testing protocols for the TxDOT program and the ECTC programs are included in the appendix materials.

TDOT is strongly encouraged to consider participation in the TxDOT sponsored pooled fund. By participating, they will have a voice in the research and benefit from the annual meetings for exchange of information and review of the program. The annual minimum for program participation is considerably less than developing and maintaining an independent research effort.

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4 Recommended Sediment and Erosion Control Technology for Tennessee 17/A.2.a (2)

This section presents specific recommendations for EPSC measures recommended for use by TDOT. The first section addresses what selected departments are doing nationally. Then it will draw on the previous discussion in this report and make specific recommendations for temporary EPSC technologies, materials and methods for TDOT. In the Recommendations section, three properties of EPSC measures will be emphasized: functional properties, areas of application, and relative cost.

4.1 Summary of Current National Practice: Materials and Methods for Erosion and Sediment Control for Construction Sites 17/A.2.a (2)

The standard construction specifications of 16 states were reviewed along with the industry standard for rolled erosion control products. In addition to the specifications 17 state erosion and sediment control manuals plus manuals and guidance documents produced by the EPA, U.S. Forest Service and the Office of Surface Mining. These documents provided a good overview of what materials and practices are being used nationally to affect erosion prevention and sediment control on construction sites and other major land disturbances. While there are some differences in the specific practices and materials overall the practices can be fairly characterized as very similar and include the full range of materials and technologies. For this reason, a discussion of individual states would serve no useful purpose. The following section is characterization of current national practice. A list of the state standard specifications and manuals reviewed is provided in the reference section.

4.1.1 Materials for Temporary Erosion Prevention on Construction Sites

Erosion prevention materials can be divided into several generic categories. Within each category, the properties of the materials themselves vary widely. The materials and methods used to prevent erosion on construction sites can be placed in four groups: soil binders, mulches, blankets and flexible channel liners, and vegetation. Materials in all of these groups are employed by transportation agencies across the country and around the world.

Soil Binders (tackifiers): This group includes a wide range of chemical materials, also called tackifiers used to bind soil particles together and prevent them from being suspended and transported down slope. Soil binders include: asphalt emulsions, polymers, vegetable base materials like Guar or Psyllium, and cementitious-based material. Chemical soil binders have been shown to be very effective in reducing sediment from construction sites for short periods, generally about three months. Some of the acrylic copolymers do offer greater longevity but some potential environmental hazards must be taken into account when using these compounds. However, when used as recommended by the manufacturers, they are very effective materials. Table 4-1 is a

guide to the application of chemical soil binders for erosion prevention on construction sites.

Mulches: Mulches are the oldest and still one of the most cost effective of all the erosion prevention materials available. To ensure effectiveness mulches must be used in the right situation and applied at an appropriate rate. A broad range of materials can be used for erosion control mulch. These include: straw, hay, composts, and processed wood cellulose fiber.

In transportation practice, hay and straw are usually applied with equipment that blows the straw or hay on the surface and then the material is anchored by crimping or with a tackifier to keep the material in place. When hydraulically applied mulches are used, cellulose fiber materials are preferred to the recycled paper products. Wood cellulose fiber mulches are applied hydraulically to help maintain moisture and temperature conditions that will foster good germination and vegetation establishment. Hydraulic mulches provide little erosion prevention on steep to moderate slopes and only moderate erosion prevention on shallow slopes unless used with some type of soil binder or tacking agent.

Table 4-1: Types and Applicability of Soil Binders

Type	Class	Flow	Maximum Slope H:V[1]	Soil Classification[2]	Surface Area	Atmospheric conditions	Accessibility	Drains to 303(d) listed water body	Duration of Need[3]
Guar	Short Lived Plant-Based Materials	Sheet Flow	2:1	GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt	Materials are effective on areas of one acre and greater	Hydraulically applied soil stabilizers cannon be applied during a storm event or freezing conditions. Avoid application in high winds and overspray.	The disturbed area must be accessible to equipment	All products are potential non-visible pollutants. There is a pollution hazard if a breach in perimeter protection occurs or if there is a BMP malfunction allowing a discharge to the water body.	Less than 3 months
Starch				GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Less than 3 months
Psyllium				GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Between 3 and 12 months
Pitch and Rosin Emulsion	Long-Lived Plant-Based Material			GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Between 3 and 12 months
Liquid polymers of Methacrylateas and Acrylamides	Polymeric Emulsion Blends			GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Less than 3 months
Copolymers of Sodium Acrylates & Acrylamides				GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Less than 3 months
Poly-Acrylamides & Copolymer of Acrylamides				GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Between 3 and 12 months
Hydro-Colloid Polymers				GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Between 3 and 12 months
Acrylic Copolymers & Polymers				GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Greater than 12 Months
Gypsum	Cementitious-based Binders			GM[4], GC[4], SW, SP, SM, SC, ML, CL OL, MH[5], CH[5], OH[5], Pt					Between 3 and 12 months

[1] Conservative maximum slope inclination recommended by Caltrans for product applicability, manufacturer may recommend greater slope
[2] Unified Soil Classification System
[3] Data from Caltrans, USR Greiner Woodward Clyde, Soil Stabilization for Temporary Slopes, 1999
[4] Use of soil binder in soils with gravel content is less effective as gravel content increases
[5] Soil with high moisture content may compromise the soil binder's effectiveness and curing time. Soil binders are not recommended for these soils
Source: California Department of Transportation: Guidance for Temporary Soil Stabilization

Table 4-2 summarizes the types and applications of mulches for erosion control.

Table 4-2: Types and Applications of Mulches for Erosion Control

Type	Base Material	Flow	Max Slope H:V1	Soil Type	Area of Coverage	Accessibility	Drains to 303(d) listed water body	Longevity
Cellulose Fiber[1]	Wood	Sheet Flow	10:1	Sand/Clay	0.5ac>	All slopes must be accessible to equipment for placement of mulch and tacking or crimping.	Little hazard to waters if applied properly	1-3 months
Hay[2,3]	Grass		2:1	Sand	0.5ac>			3-4 months
Straw[2,3]	Small Grains		2:1	Sand	0,5ac>			6-10 months
Compost[3]	Yard Waste		2:1	Sand/Clay	0.5ac -10ac		Compost should be used advisedly near high quality and Impaired Waters	6-10 months
	Manure		6:1		0.5ac -10ac			1-3 months
	Bio-Solids		6:1`		0.5ac -10ac			1-3 months

[1] These mulches are applied hydraulically and do not provide erosion control on slopes steeper than 10:1 (h:v)
[2] Hay and straw are most effective on sandy soils. Application rates of 2t/acare sufficient on slopes up to 3:1 on slopes greater than 3:1 the rates should be increased to 3-4t/ac depending on the soil.
[3] Hay and straw do not give good performance on clay soils (TTI unpublished study, 2006) blankets or BFMs are more effective.
[4] Yard waste compost or compost composed of 50% wood chips mixed with mature compost of bio-solids or manure.

Compost materials are being marketed as erosion control materials but to be effective compost must be an appropriate type and applied at a rate sufficient to protect the surface and hold the slope. Composts composed of manure or biosolids do not function well for erosion control because they are composed of fine material that will not bond together well. Erosion control composts generally have a considerable amount of yard waste material, which has long fibers and tends to form surface mat. Erosion compost is best applied to large areas with manure spreaders.

Erosion Control Blankets (Mats or RECPs) and Flexible Channel Liner (TRMs) s:
Erosion control blankets were also referred to as mats, or rolled erosion control products or RECPs. Flexible channel lining materials are also called Turf Reinforcing Mats or TRMs. All of these products are made of many different materials. The most common materials used in blankets for roadside applications are: synthetic fibers, straw, curled wood fiber (excelsior), coconut hull fiber (coir), jute, and hemp. The product may be either woven as in the case of jute and hemp or non-woven as in straw, excelsior based materials. Blankets are furnished in rolls of varying lengths up to about 100 ft and widths

to 10 ft. The materials are spread over a prepared surface and held in place with some type of staple or pin.

Blankets have their greatest application on steep slopes where loose mulches, or hydraulically applied mulches are not able to protect the seedbed from erosion before vegetation becomes established.

Table 4-3 summarizes the types and application of erosion control blankets and flexible channel liners.

Vegetation: Vegetation used for erosion control was described in most cases as either permanent or temporary vegetation. Sometimes temporary erosion vegetation was referred to as a cover crop. In general, vegetation is the least expensive and one of the most effective means of preventing erosion on a construction site. The primary disadvantage of vegetation is that it takes time to establish and reach its full erosion prevention capability and it can be easily damaged by construction traffic.

Vegetation is the primary permanent erosion control material for all but the most unusual and demanding situations. Exceptions include situations like permanently shaded areas under bridge abutments, roadside channels, and drainage structures with flows generating shear stresses greater than 2lb/sf, and unstable slopes that require mechanical or biotechnical stabilization. In all other cases, vegetation is the desired permanent erosion control along the roadside.

All the other erosion control technologies are temporary measures designed to hold the seedbed (soil), in place until the vegetation is sufficiently established to provide the necessary protection.

Depending on the regional climatic conditions, soils, rainfall amounts, and frequency vegetation cover can usually be established in a matter of a few weeks to a few months. This assumes the use of seed mixes that include rapidly germinating species (nurse grasses and small grains) that provide the initial seed bed protection and erosion control and protect the slower growing permanent species, which may require a few months to establish. Poor weather conditions, lack of rainfall, cold or freezing weather, or abuse can slow the establishment process.

Table 4-3: Types and Application of Erosion Control Blankets and Flexible Channel Lining Materials

Type	Base Material	Flow	Max Slope H:V[1]	Soil Type[2]	Area of Coverage[3]	Accessibility	Drains to 303(d) listed water body[6]	Longevity[7]
Biodegradable[4]	Woven Jute Mesh	Sheet & Concentrated Flows	3:1	Sand/Clay	0.5ac -5ac	Slopes must be accessible to equipment and crews to install the materials. Considerable hand labor may be required on steep slopes.	These materials have superior temporary erosion prevention performance when compared to most other materials and are when properly installed provide optimum protection near high quality and 303(d) listed waters.	18-24 months
	Curled Wood Fiber (Excelsior)		2:1	Sand/Clay	0.5ac - 5ac			12-24 months
	Straw Blanket		2:1	Sand/Clay	0.5ac - 5ac			6-12 months
	Coconut Fiber (coir non-woven)		2:1	Sand/Clay	0.5ac - 5ac			24-36 months
	Coconut Fiber (coir woven)		2:1	Sand/Clay	0.5ac - 5ac			24-36 months
	Plastic mesh woven (UV degradable)		2:1	Sand/Clay	0.5ac - 5ac			12-18 months
Non-biodegradable[5, 7] (Flexible Channel Liners)	Plastic mesh woven (UV Resistant)	Concentrated Flow	2:1	Sand/Clay	0.5ac - 5ac			>10 years
	Plastic Netting, non-woven (UV Resistant)		2:1	Sand/Clay	0.5ac - 5ac			>10 years
	Synthetic Matrix with Synthetic Fibers		2:1	Sand/Clay	0.5ac - 5ac			>10 years
	Bonded Synthetic Fibers (non-woven)		2:1	Sand/Clay	0.5ac - 5ac			>10 years
	Synthetic Matrix with Biodegradable Fibers		2:1	Sand/Clay	0.5ac - 5ac			>10 years

[1] Materials will vary in their performance by type and manufacturer. Manufacturer's data and test data should be consulted for soil type and performance limits
[2] Performance will vary depending on the actual properties of the material. Manufactures literature and laboratory test data should be consulted for each material
[3] Rolled are expensive compared to other erosion prevention technologies. Other less expensive methods should be considered for large areas.
[4] Many of the heavier biodegradable blankets, particularly the coir materials, are suited as temporary channel liners where designed shear stresses are 2lb/sf or less.
[5] The non-biodegradable materials are generally considered permanent Turf Reinforcing Mats (TRMs) and are specifically of concentrated flow applications with shear stresses greater than 2lb/sf. Manufacturer's literature and testing data should be consulted for specific performance properties.
[6] Comparisons based on comparison of over 130 material test records from the TxDOT/TTI testing program at Texas A&M University, College Station, TX.
[7] Longevity based on test data and recently completed study at the TxDOT/TTI, College Station, TX. Paper submitted to American Society of Agricultural and Biological Engineers, 2006. Materials removed from the ground after 10 years have maintained more than 50% of their initial tensile strength. Since the initial strength of these products is about 50 lb/ sf, the retained strength is still sufficient to be considered a permanent material.

4.1.2 Materials for Sediment Control

Sediment controls are methods and technologies used to trap water and allow sediment to settle from suspension. For the most part, sediment control BMPs rely on passive, extended detention of storm water, or filtration. In difficult cases, flocculants may be used to help precipitate fine or charged materials from suspension. Only temporary materials and methods are considered here. In general, sediment controls are divided into two groups: structural and non-structural. Structural controls include: sediment traps, sediment basins, construction entrances, and filtering devices such as filter bags and catch basin filter assemblies. Non-structural controls include street sweeping, watering for dust control, etc.

For the most part, transportation agencies nationally rely on structural controls using non-structural controls as needed. The most popular and useful of these sediment management tools are shown in Table 4-4. Sediment removal for many of the listed devices is as low as 35% to as high as 85%. The difference in performance can be attributed to a number of variables including: physical material properties, soil particle size distribution, particle charge, soil pH, proper installation, and maintenance. In most situations proper installation and maintenance of sediment control BMPs will reduce the sediment loss to acceptable levels if adequate upstream erosion prevention controls are in place, but there is no way to accurately predict actual field performance.

4.1.3 Flow Controls

Flow control is an essential part of an effective erosion control strategy for a construction site. The basic principle is to divert the clean water away from the disturbed areas of the construction site to minimize the transport capacity of the runoff. Flow controls include interceptor ditches or swales that collect runoff from areas that drain onto disturbed portions of the site and convey it to a suitable discharge point in pipes or improved channels. The design of these temporary structures is based on basic open channel hydraulics

Table 4-4: Types and Application of Temporary Sediment Control BMPs for Construction

Type	Application(s)	Area of Coverage	Flow Type	Accessibility	Longevity[6]
Silt fence[1]	Perimeter protection off site discharges	<0.5 ac	Sheet	All sediment control devices must be accessible to equipment to maintain the structures.	12 mo-36 mo
Reinforced Silt Fence	Online sediment trap	0.5 ac -1.0 ac	Shallow Concentrated		12 mo – 36 mo
Soil windrow[2]	Perimeter protection off site discharges	<0.5 ac	Sheet		12 mo-18 mo
Filter Sock	Perimeter, online trap, inlet protection	<0.5 ac	Shallow Concentrated		24 mo-36 mo
Erosion Wattle	Perimeter, online trap, inlet protection	<0.5 ac	Shallow Concentrated		12 mo -36 mo
Rock Check	Online trap, inlet protection	0.5 ac- 2 ac	Concentrated		Indefinite
Excavated Silt trap	Online or offline traps	0.5 ac -10 ac	Shallow Concentrated		Indefinite
Sediment Basin[3]	Online or offline catchment	>10 ac	Concentrated		Indefinite
Sediment bag	Online or offline filter		Pumped		12 mo-24 mo
Catch basin filter	Inlet protection	0.5 ac– 2 ac	Shallow Concentrated		12 mo -24 mo
Catch basin insert[4]	Inlet protection	0.25 ac-0.5 ac	Shallow Concentrated		12 mo-24 mo
Vegetation filter strips[5]	Perimeter protection offsite discharges	0.25 ac-0.5 ac	Sheet flow		Indefinite
Rock Construction Entrance	Tracking prevention	N/A	N/A		1-2 rainfall events
Timber/Cattle Guard Entrance	Tracking prevention	N/A	N/A		Indefinite

[1] Where possible, silt fence should be installed with slicing technology to minimize undermining. The optimum performance is achieved when silt fence is set parallel to the contour. When silt fence has to be set at an angle to the contour velocity checks should be provided and the fence must be tied back to the slope in hook to prevent sediment loss.

[2] Windrows are effective in preventing offsite discharges when sufficient ROW is available. Temporary seeding is recommended if the windrow is to be in place for more than a few days.

[3] Sediment basins are earthen structures that must be designed by a professional engineer. They should have an emergency bypass spillway and a staged outlet to handle discharges from multiple storms.

[4] Catch basin inserts are not recommended for most construction activities because of the frequent maintenance that will be required. Inserts have their greatest application in maintenance yards and other permanent facilities.

[5] Vegetation filter strips can be effective if used in conjunction with other sediment controls such as small windrows or silt fence. They should never be relied upon as a primary sediment management tool for construction sites because they can be completely inundated by sediment from heavy events that can kill the vegetation or greatly minimize its effectiveness.

6 Actual life will depend on exposure, climatic conditions and maintenance.

4.2 Recommended Temporary Erosion and Sediment Control Materials and Practices for TDOT Construction Projects 17/A.2.a.(2)

This section gives specific recommendations for TDOT practice. Three areas are emphasized in the recommendations functional properties, areas of application, and relative cost. The purpose of this section is to ratify applicability of the technologies discussed in the previous section to TDOT needs.

4.2.1 Recommended Temporary Erosion Prevention Materials

There is no single best temporary erosion control method or material. Proper selection requires knowledge of temporary erosion control materials, the construction period, the site conditions as well as the soil and regional climatic characteristics. All of these factors need to be taken into account when selecting a material or method. Tables 4-1 through 4-3 list the erosion prevention materials that are recommended for use by TDOT. As noted in the preceding section these materials are in general use nationally and they all have some a role in temporary EPSC for construction sites. Each table lists some key considerations for performance and application. Design decisions and final material selection should be done in accordance with the TDOT Design Division's Drainage Manual, Chapter 10. Additional numeric methods have been suggested in Section 2 of this report for inclusion in Chapter 10 as the basis for selecting appropriate surface protection erosion materials. Other recommendations have been made for changes to the materials definitions, materials specifications, and QPL to accommodate these recommendations.

4.2.2 Recommended Temporary Sediment Controls Materials and Methods

Table 4-4 provides a list of materials and methods that are recommended for use by TDOT to affect sediment controls on construction sites. These technologies and materials are in common use nationally and will provide good performance when designed in accordance with the recommendations of the TDOT Design Division Drainage Manual Chapter 10 and when properly installed and maintained.

4.2.3 Maintenance and Longevity

The information given in Tables 4-1 through 4-4 lists the relative longevity that can be expected of the individual materials. The actual performance of any biodegradable material depends on exposure to sunlight, humidity, and temperature. In cool dry conditions, materials will perform at the high end of the longevity range given. In hot humid conditions and direct sunlight, materials will perform at the low end of the longevity range.

Maintenance of erosion prevention and sediment controls is essential to longevity and performance. Materials used for slope protection such as BFMs, Blankets, and mulches must be protected from all types of traffic. If the material is damaged, exposing the seed bed repairs need to be completed before the next significant rainfall event or more damage may occur and sediment losses can be sufficient to over load the down stream sediment controls.

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5 Maintenance of Storm Water Quality Management Practices (21/A.2.a (2))

Maintenance is the key to long term success of storm water BMPs on a construction site, and this section addresses the short and long term maintenance of storm water quality controls. Issues of installation, longevity, cost, as well as short- and long-term maintenance are addressed.

The day to day demands of a construction site will require that some storm water management practices be removed and replaced, damaged structures repaired and that temporary stabilization be installed and maintained when construction is temporarily suspended due to season or construction phasing. This section discusses specific maintenance activities that are essential to successful construction site storm water management.

5.1 Using the inspection process

The inspection process required by the Construction General Permit is the primary tool to ensure that TDOT projects are in regulatory compliance and that adjacent waters are adequately protected. The inspection process must be approached as a quality assurance tool rather than a paperwork task.

The CGP requires inspections be performed twice weekly 72 hours apart. These formal inspections should be performed carefully to verify that all controls are in place and working properly. Inspectors must not only identify failures but any potential for sediment discharges. The inspector may also recommend actions that might be taken by the contractor to prevent a discharge. However, it is ultimately the responsibility of the contractor for implementing maintenance and corrective actions. In addition to the basic EPSC measures, issues related to housekeeping, waste management, and material storage and handling must be checked. It is vital that inspectors are aware that, while soil is the primary pollutant from a construction site, many other materials on the site can pollute adjacent water bodies if not properly managed.

5.2 Maintenance Actions by BMP Type

This section provides a brief summary of the types of maintenance and repair activities necessary to keep temporary sediment and erosion controls in good working order. It emphasizes the field aspects of management rather than considerations of design. The Manual for Management of Storm Water Discharges Associated with Construction Activities provides even more detailed information about maintenance of specific BMPs as well as trouble shooting and recommended corrective actions. Blankets and flexible channel lining materials:

5.2.1 Blankets and flexible channel lining materials:

These materials should be checked regularly for fabric damage and any significant erosion that may be taking place under the blanket. An indicator of this sort of problem is

the presence of sediment deposits covering the fabric at the toe of the slope. When these signs occur the inspector should check for the development of rills. If rills are present, the material should be rolled back, the rills filled, and the materials replaced. Reseeding should be done as needed. Under cutting of blankets is most common on non-cohesive soils. The Construction Manual provides some suggestions for minimizing rill formation in non-cohesive soils. In channels, vegetation is critical to the success of a liner. Until vegetation is visible coming through the channel lining it is important to check the staples and be sure they are holding the material in contact with the channel bed. If they have work loose they should be replaced and additional staples added. Removal blankets and repair of rills is not recommended in channels because it is difficult to get the backfill material to bond in the channel and it will simply increase the downstream sediment load. Channel repairs should only be made if there is significant scour and loss of the lining material by an anomalous event.

5.2.2 Silt Fence, silt fence with wire backing, enhanced silt fence

Silt fence should have sediment removed when it reaches approximately 1/2 the height of the exposed fabric. Fabric checks in swales should be checked to be sure that the ends of the material are extended far enough up the bank to prevent flow around the ends. If there is any evidence of flow around the ends or of undermining at the base repairs should be undertaken prior the next rainfall event.

Silt fence is effective if it is placed on the contour. If it is not perfectly aligned with the contour undermining will occur at the base of the fence do to concentrated flows. When these conditions are observed corrections are needed to ensure proper function. The Construction Manual suggests how these problems can be corrected.

5.2.3 Mulches:

Mulches mimic the natural thatch cover that results from mowed grains or grasses. To be effective the mulch must form a uniform cover of the surface and the mulch material must be in intimate contact with the soil surface. The maintenance of mulch covers requires inspection for damage or loss of surface cover. If bare places are found reapplication of the seed and mulch material that has been lost or damaged is required. Repairs should be affected before the next rainfall event or more damage is likely to occur. Significant damage may require replacement of soil recompaction, replacement of topsoil and seeding. It is important to include sufficient quantities in the bid documents to handle repairs caused by unpredictable events.

5.2.4 Other in-channel silt traps:

For other in channel sediment traps, cleaning at 50% of the designed capacity is the norm. In rare occasions, rock checks can be damaged by unexpected flow events. After major events, trash and debris trapped in the rock should be removed since subsequent flows may begin to dislodge rock from the top of the check.

5.2.5 Vegetated barriers:

If vegetation buffer strips are used between construction sites and high quality waters, they should be checked after each significant event to be sure the sediment captured does not completely cover the strip. If there is significant sediment buildup, it should be removed. If removal is by washing, care must be exercised to ensure that the sediment removed does not enter the adjacent water body.

5.2.6 Inlet protection:

Inlet protection devices are devices that experience frequent failures if not carefully maintained. Since inlets are points of concentrated flow the loads and generated by sediments and water on the fabric, or check material can be very high. In most cases, fabrics do not filter after one or two significant events and water will build up to the top of the structure. For this reason it is imperative that these structures be cleaned and checked regularly. In most cases, these structures are the last barrier between the construction site and the adjacent water body or property.

5.2.7 Construction entrances and exits*:*

The purpose of these controls is to prevent tracking of sediments onto adjacent pavements. Coarse rock is usually the favored means of achieving this control. However, they are seldom effective for more than one or two rainfall events. The wet soil and heavy wheel loads usually presses the rock into the upper soil layer and then there is no protection in the next event. The fact that the construction proceeds along a corridor further complicates location of these structures. If exits are only needed for a brief period adding additional rock after an event may be sufficient. However, if an exit is to be used over an extended period such as the entrance to a storage yard or staging area, then a more positive long-term structure of steel plates, timbers, or pipe provides more cost effective control with less maintenance required. In critical areas, wash stations may be necessary. These are either manual, generally where a high-pressure washer is used to clean the wheels, or automatic, in which the wheels are mechanically rotated and washed.

5.2.8 Disposal of sediment removed:

Sediment removed from traps, basins, and other structures is not a hazardous material and can be disposed of onsite. However, sediments are principally silt size particles with some fine sands and clays. These materials can be easily mobilized and redeposited if left on the surface. Collected sediments should be placed in pits or spread over the surface and immediately seeded to prevent remobilization.

5.2.9 Temporary vegetation:

Temporary vegetation materials are selected for rapid germination and short period of persistence. The object of these cover crops is to hold the soil in place until the conditions are favorable for planting permanent vegetation or construction activities resume. Little maintenance is required unless there is damage or poor coverage of an area. Reseeding is called for in these cases. The value of a cover crop or temporary vegetation cover can be

extended by mowing and then crimping the dead material. Permanent seeding can then be planted through the dead material with a no-till drill.

5.2.10 Permanent vegetation:

Plant species used as permanent roadside vegetation are selected for their tolerance of drought and adverse microclimatic conditions. When properly selected the initial planting should establish a sustainable plant community that will gradually change and become dominated by native and adapted species. The single most important maintenance tool on the roadside is mowing. Most native grasses are tall bunch grasses that will not tolerate frequent low (<6in) mowing. Low mower heights will result in roadsides dominated by low growing weedy grasses and other adapted undesirable plants. Good stands of native and adapted grasses mowed at the proper height will help prevent the invasion of woody species, which eventually constitute a safety hazard.

5.2.11 Storage Yards and Staging Areas

These facilities have significant potential for discharging pollutants other than soil. It is essential that staging areas, materials storage areas, batching plants, and equipment maintenance areas be maintained properly to prevent spills or releases of other types of pollutants. Storage tanks for chemicals and petroleum products must have perimeter containment. Sanitary facilities should be protected and anchored to prevent overturning or vandalism. Temporary sheds or containers must be provided to store materials like chemical fertilizers, paint, hydraulic cement and other pozzolans, curing compounds, etc. Waste bins must be provided to collect solid waste. Bulk materials and wastes that that can be stockpiled must have perimeter containment to ensure that they do not discharge any pollutants to storm water leaving the site.

Good housekeeping is critical to keeping a construction site in compliance with storm water quality regulations as well as maintaining a good public image.

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6 Assessment of Water Quality Monitoring Protocols for Construction Sites

The objectives of this section of the report include an assessment of water quality monitoring protocols currently used to assess EPSC performance and development of a methodology and water quality standards for the use of polymers for sediment control.

6.1 Construction Sites Monitoring Current Practice (A.1.j)

The objective of this section is to provide an evaluation of the water quality monitoring protocols currently being used to assess the effectiveness of various EPSC practices. Specific tasks include:

- Review the research and monitoring plans associated with the current contract between the State and the United States Geological Survey
- Recommend specific erosion prevention or sediment control installations or combinations to be tested in conjunction with the USGS monitoring or research
- Review the literature and the experience of other states and local governments in the use of water quality monitoring protocols and make recommendations as appropriate
- Review the turbidity and total suspended solids standards and test methods and other applicable protocols used by other states and local governments
- Evaluate options and methods of visual evaluation of sediment deposits as a substitute for quantitative sampling.

6.1.1 USGS Research and Monitoring Effort

6.1.1.1 Current Program

The objectives of the current stream-monitoring program are to:

1. Determine if in-place EPSC measures are adequate to prevent sedimentation and damage to area streams;
2. Provide a trigger mechanism for the reevaluation of in-place EPSC measures at the site if turbidity or suspended-sediment evaluation thresholds are exceeded; and
3. Provide research data and information to be used in the development of the Statewide Storm Water Management Plan.

Four types of stations are being monitored: suspended-sediment stations (immediately below the last EPSC measure), turbidity stations (in streams, near the upstream and downstream edges of the right-of-way), rainfall stations (along the right-of way), and continuous monitoring stations (downstream of the right-of-way). Together, these types of stations meet the requirements of the amended consent order and agreement for

rainfall, suspended-sediment, and turbidity monitoring, and support the research objectives outlined in the amended order and agreement.

Suspended-sediment samples are collected at representative outfalls (just below current EPSC structures). Single-stage samplers are the primary method used to collect samples at the outfalls. These samplers take one sample of runoff as the water rises past a selected level. Multiple single-stage samplers are used to collect samples throughout the rising limb of hydrographs.

Multiple-bottle automatic samplers are used to collect samples throughout the period of storm runoff (including the falling limb of the hydrograph). Two automatic samplers will be shifted among outfall sites to characterize typical temporal variability of sediment characteristics, testing the hypothesis that the earliest storm runoff carries the highest concentration of sediment.

Suspended-sediment monitoring at outfalls is supplemented by collecting suspended sediment at the six continuous monitoring stations downstream of the right-of-way. The basins for these sites include nearly the entire highway project. Multiple-bottle automatic samplers at these sites are activated by changes in water level. The frequently collected suspended-sediment data and the continuous discharge data at these sites are used to calculate suspended sediment loads before, during, and after additional construction.

Turbidity is monitored in-stream at selected streams along or near the right-of-way. Single stage samplers are the primary method used to collect samples in streams. Four continuous water-quality monitors are/will be shifted among the stream sites to characterize the temporal variability of turbidity in streams. Two multiple-bottle automatic samplers (in addition to the two used for sediment monitoring) will be used at the same sites as two of the continuous water-quality monitors to evaluate the single-stage samplers and the continuous water-quality monitors. Turbidity monitoring in streams along the right-of-way is supplemented by monitoring turbidity at the continuous data stations downstream of the right-of-way. The basins for these sites include nearly all the highway project, and turbidity is continuously monitored at all of these sites. When possible, turbidity is monitored in streams at sites immediately upstream and downstream of the right-of-way.

Monitoring stations are also located downstream from the project at a scale that allows nearly all the flow from the site to be sampled in a few stream reaches. Unlike the upstream turbidity sampling, turbidity is monitored throughout storm hydrographs. Unlike the upstream sediment sampling locations, at which only a few samples are collected through the hydrograph, and only at a representative set of locations, a sediment-concentration pattern throughout the hydrograph is defined. The measurement of discharge will differentiate brief, small events from larger floods. With the smaller number of this type of station, obtaining data in near real time is possible, allowing a prompt response.

6.1.1.2 Future Research Program

There are a number of objectives of the USGS program in addition to the assessment of the effectiveness of EPSC measures. These include the usefulness of turbidity and/or TSS, and the effects of road construction on water quality (physical/chemical), fish, and

benthic invertebrates. Potentially this additional research on 840 and other sites across Tennessee will result in the development of a scientifically based assessment of what discharge quality must be maintained at construction sites to prevent degradation to downstream resources. This would be a substantial improvement over the 25 NTU, 40 mg/L TSS standards currently in place, which have little empirical basis.

6.1.1.3 Program Assessment

The current program is generally sufficient to document the cumulative effectiveness of the installed EPSC measures and trigger additional work when in-stream water quality thresholds are exceeded. However, it is not designed or operated in a way to establish the effectiveness of individual practices and some technical limitations in the program result from the choice of equipment. These choices were dictated to some extent by the requirements of the Consent Decree, which required sampling across a large number of outfalls.

Much of the water quality sampling is accomplished with the use of single stage samplers. These samplers collect a sample when the water rises to a preset level and are appropriate for one of the project goals, which was to establish maximum turbidity values and suspended sediment values. These are relatively inexpensive samplers, but have one major drawback – samples can only be collected during the initial part of the storm when the water level is rising. This means that the entire storm cannot be sampled and, consequently, data cannot be used to estimate the total amount of sediment leaving the site or being conveyed downstream. Although mobile automatic samplers are shifted among the sites to provide a more complete assessment of the amount of sediment leaving the site, the amount of data collected from any one site is very limited. Consequently, the best and most comprehensive data would be provided by installing automatic samplers at all monitoring sites, even if the logistics or expense requires that the total number of sites be reduced. However, one constraint to the use of automatic samplers is that accurate flow measurements must be made at the sampling point and this is not feasible at all the sites.

The suspended sediment-monitoring program could also be improved by installing samplers and flow meters upstream of the roadway. This would provide a better assessment of the total increase in sediment resulting from the highway construction activities. One difficulty of implementing this strategy is that the streams in question are small, difficult to access, and poorly suited to flume installation, so that results would likely be quite imprecise. At this time, turbidity measurements are taken upstream and downstream of the construction project and this provides at least an indication of the magnitude of the change; however, the correlation between TSS and turbidity is not always that good.

The turbidity measurements collected at the continuous monitoring sites is slightly limited by the range of the instruments. There are occasional times, even in undisturbed drainages, when the turbidity exceeds the range of the instrument. However, the cost to install a second probe to measure just the highest turbidities is probably not justified since automatic samplers are also present at the sites.

Although not required under the Consent Decree, another potential objective of this monitoring program is to establish the effectiveness of individual EPSC practices based

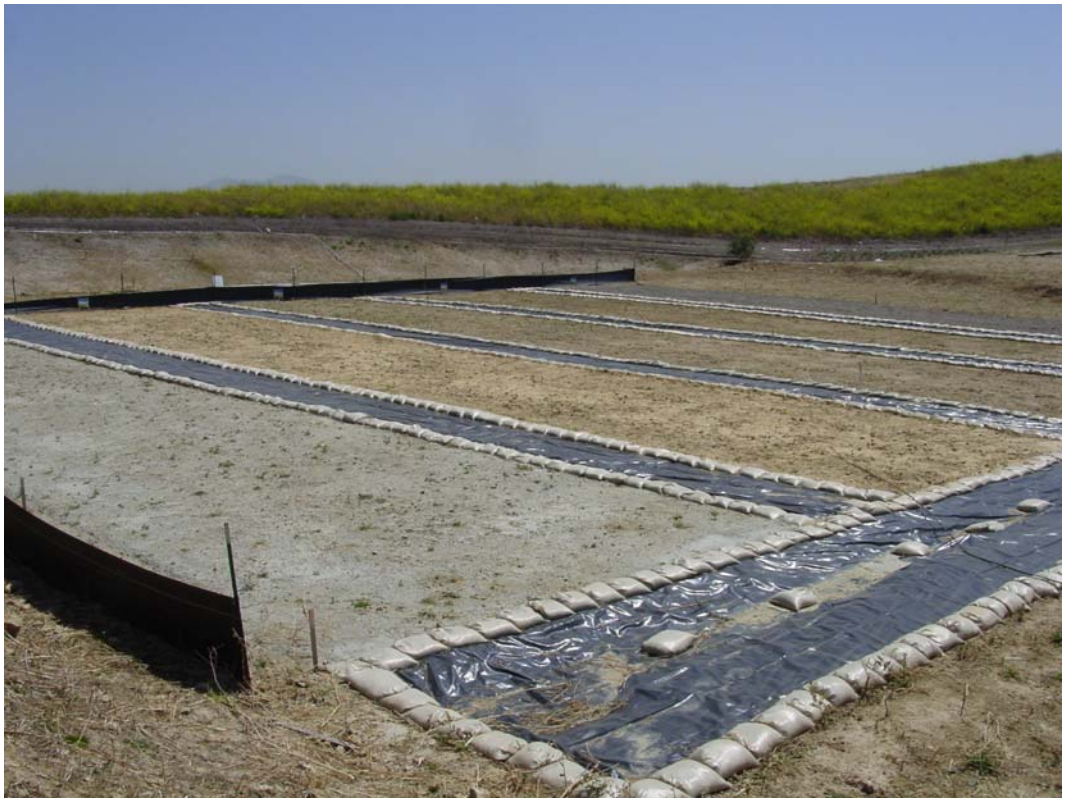
on monitoring at eight sites across Tennessee. Meaningful evaluation of individual sediment-control structures (silt fences, settling basins, etc.) requires a high level of control of such relevant factors as basin size, slope, and rainfall duration, timing, and intensity. Such control is difficult to achieve at working construction sites. The catchments monitored by the USGS commonly contain multiple EPSC measures, so suspended-sediment measurements at the outlets of such systems integrate the net effect of the system as a whole, rather than the effects of its component parts. Consequently, the existing monitoring by the USGS is more appropriate for evaluating the overall effectiveness of the EPSC program than individual practices.

Evaluation of individual EPSC practices is best accomplished on dedicated test plots or in controlled testing situations. Monitoring of outdoor test plots in an area with little construction activity provides an opportunity to observe and measure the performance of individual products over an extended period. An example of this type of monitoring is shown in Figure 6-1, which is a photograph of test plots in Orange County, California where a number of hydraulic mulches and polymers are being evaluated to develop a recommended product list. This type of testing can be used to establish the relative performance of products when they are all tested at the same time, but variation in rainfall intensity and depth limit the ability to compare products evaluated during different test cycles. USGS or a local university in Tennessee could perform this type of outdoor testing for TDOT; however, the experimental protocol would need to be much different from that now in place, which is designed to assess the overall performance of the program.

To overcome the limitations of field-testing, the major EPSC testing facilities now evaluate products in dedicated indoor facilities where climatic variables, soil, slope, and other factors can be controlled. The two major test facilities are located at the Texas Transportation Institute (http://tti.tamu.edu/enviro_mgmt/facilities/hec) and San Diego State University (http://erosionlab.sdsu.edu).

These two facilities use a very similar approach for testing individual EPSC products at various slopes and with different soil types. Both facilities employ a tilting bed where the product is installed and an overhead rainfall simulator is positioned over the bed. The rainfall simulation device selected for the SDSU Soil Erosion Laboratory is the Norton Ladder Rainfall Simulator, which was developed at the USDA-ARS National Soil Erosion Research Laboratory by Dr. Darrell Norton. This apparatus has been used worldwide, is reasonably inexpensive, and is easily transported and operated. The Norton simulator is reliable and is documented as giving reproducible results. For testing in the indoor laboratory, multiple simulators are installed in parallel above the soil test bed to uniformly apply precipitation over the entire test plot area.

Figure 6-1: Individual EPSC Test Plots



The data produced by indoor testing facilities can be statistically analyzed and can be used to develop approved product lists. TxDOT uses the data provided by the Texas Transportation Institute to maintain discrete minimum performance standards for each classification of product evaluated at the TxDOT/TTI Hydraulics and Erosion Control Laboratory. In order for a product to be placed on TxDOT's Approved Product List, the product must meet (or exceed) all adopted minimum performance standards for that application. Failure to meet any of the adopted minimum performance standards will automatically reject the product from being placed on the list. Each of the products can be tested at 2:1 or 3:1 slopes with either sandy or clayey soils and each test consists of three repetitions of three, 10-minute storms in the range of 4 to 7 in/hr. A picture of the TTI test configuration is shown in Figure 6-2.

Recommendations

The USGS monitoring program at existing and future sites should be refocused on determining the amount of impact that TDOT construction activities have on the receiving waters, rather than the performance of individual EPSC measures. This means that sampling should focus on an upstream/downstream comparison of water quality using either automatic samplers or real time turbidity meters with the appropriate range and not the sampling of individual outfalls. This may not be feasible in all situations however. Difficulties commonly occur when the upstream watershed is large in comparison to the construction project, which substantially dilutes the discharge from the construction site. In addition, when highways are constructed near ridge lines there may be little or no baseflow upstream to monitor.

Figure 6-2: TTI EPSC Testing Facility

Where feasible, the upstream/downstream methodology will reduce the total number of monitoring sites and allow better equipment to be used at the selected sites, while still indicating whether the construction activities are impacting water quality. Where sampling indicates substantial increases in sediment or turbidity, visual observation can be conducted in the watersheds of the individual outfalls to identify failed or inappropriate EPSC measures. In addition, geomorphology studies can also help assess changes due to construction and associated EPSC measures.

Existing data collected at the current monitoring sites should be analyzed to determine the appropriate storm size that triggers in-stream monitoring. Past experience indicates that smaller events do not produce sufficient runoff for sampling; consequently, it may be appropriate to target the largest events (>1 inch of rainfall in 3 hours) to reduce the number of false starts and since it is those types of events that mobilize the most sediment. An alternative approach would be to trigger the automatic samplers based on a

predetermined rise in water level or turbidity and the perennial gages. This has the advantage of only sampling those events with significant runoff.

6.1.2 Recommendations for EPSC Testing

Testing of individual EPSC measures by TDOT is only one of several ways that new products can be added to the QPL. Ongoing testing by TTI and others provides the information necessary to evaluate new products. This information is available on the internet or TDOT could participate directly through the pooled fund portion of the study. Using the information developed by existing testing programs will provide a cost effective means for TDOT to evaluate erosion control products based on performance testing, and access to current research developments relative to future developments of reliable bench-scale testing protocols. For this reason we would suggest that TDOT consider the merits of the program and see if it might meet the information and testing needs for erosion control products of the department.

A more important need for TDOT is to develop demonstration and training facilities to ensure that approved measures are correctly selected and installed. These facilities may incorporate a research component; however, the primary objective would be to give staff the opportunity to see various measures correctly installed in the field.

6.1.3 Water Quality Monitoring Protocols of other Jurisdictions

Water quality monitoring of construction site runoff is extremely rare in the U.S. for a number of reasons. These include the difficulties of specifying appropriate protocols and the lack of discharge standards in most jurisdictions. The protocols of selected states where sampling is required are described below.

6.1.3.1 Georgia

Georgia requires the monitoring of storm water discharges from construction sites to determine turbidity. Georgia sampling requirements include:

(1). A USGS topographic map, a topographic map or a drawing (referred to as a topographic map) that is a scale equal to or more detailed than a 1:24000 map showing the location of the site or the common development;

> (a) The location of all perennial and intermittent streams and other water bodies as shown on a USGS topographic map, and all other perennial and intermittent streams and other water bodies located during mandatory field verification, into which the storm water is discharged and
>
> (b) The receiving water and/or outfall sampling locations. When the permittee has chosen to use a USGS topographic map and the receiving water(s) is not shown on the USGS topographic map, the location of the receiving water(s) must be hand-drawn on the USGS topographic map from where the storm water(s) enters the receiving water(s), to the point where the receiving water(s) combines with the first blue line stream shown on the USGS topographic map;

(2). The analytical method used to collect and analyze the samples including quality control/quality assurance procedures. This narrative must include precise sampling methodology for each sampling location.

(3). When the permittee has determined that some or all outfalls will be monitored, a rationale must be included for the NTU limit(s) selected from Table 6-1. This rationale must include the size of the facility or common development, the calculation of the size of the surface water drainage area, and the type of receiving water(s) (i.e., trout stream or supporting warm water fisheries).

(4). If any additional information is necessary to be part of the Plan, the State will provide written notice to the permittee of the information necessary and the time line for submittal.

Table 6-1: Nephelometric Turbidity Unit (NTU) Tables for Georgia

Cold Water (Trout Stream)

		Surface Water Drainage Area, square miles							
		0-4.99	5-9.99	10-24.99	25-49.99	50-99.99	100-249.99	250-499.99	500+
Site Size, acres	1.00-10	25	50	75	150	300	500	500	500
	10.01-25	25	25	50	75	150	200	500	500
	25.01-50	25	25	25	50	75	100	300	500
	50.01-100	20	25	25	35	59	75	150	300
	100.01 +	20	20	25	25	25	50	60	100

Warm Water (Supporting Warm Water Fisheries)

		Surface Water Drainage Area, square miles							
		0-4.99	5-9.99	10-24.99	25-49.99	50-99.99	100-249.99	250-499.99	500+
Site Size, acres	1.00-10	75	150	200	400	750	750	750	750
	10.01-25	50	100	100	200	300	500	750	750
	25.01-50	50	50	100	100	200	300	750	750
	50.01-100	50	50	50	100	100	150	300	600
	100.01 +	50	50	50	50	50	100	200	100

6.1.3.2 Sample Type

All sampling can be collected by "grab samples" and the analysis of these samples must be conducted in accordance with methodology and test procedures established by 40 CFR Part 136 (unless other test procedures have been approved).

(1) Sample containers should be labeled before collecting the samples.

(2) Samples should be well mixed before transferring to a secondary container.

(3) Large mouth, clean and rinsed glass or plastic jars should be used for collecting samples. The jars should be cleaned thoroughly to avoid contamination.

(4) Manual, automatic or rising stage sampling may be used. Samples required by this permit should be analyzed immediately, but in no case later than 48 hours after collection. However, samples from automatic samplers must be collected no later than the next business day after their accumulation, unless flow through automated analysis is used. Dilution of samples is not required. Samples may be analyzed using a direct reading, properly calibrated turbidimeter. Samples are not required to be cooled.

(5) Sampling and analysis of the receiving water(s) or outfalls beyond the minimum frequency stated in this permit must be reported to EPD as specified in Part IV.B.

6.1.3.3 Sampling Points

(1) For construction activities, the primary permittee must sample all receiving water(s), or all outfall(s), or a combination of receiving water(s) and outfall(s). Samples taken for the purpose of compliance with this permit shall be representative of the monitored activity and representative of the water quality of the receiving water(s) and/or the storm water outfalls using the following minimum guidelines:

(a) The upstream sample for each receiving water(s) must be taken immediately upstream of the confluence of the first storm water discharge from the permitted activity (i.e., the discharge farthest upstream at the site) but downstream of any other storm water discharges not associated with the permitted activity. Where appropriate, several upstream samples from across the receiving water(s) may need to be taken and the arithmetic average of the turbidity of these samples used for the upstream turbidity value.

(b) The downstream sample for each receiving water(s) must be taken downstream of the confluence of the last storm water discharge from the permitted activity (i.e., the discharge farthest downstream at the site) but upstream of any other storm water discharge not associated with the permitted activity. Where appropriate, several downstream samples from across the receiving water(s) may need to be taken and the arithmetic average of the turbidity of these samples used for the downstream turbidity value.

(c) Ideally the samples should be taken from the horizontal and vertical center of the receiving water(s) or the storm water outfall channel(s).

(d) Care should be taken to avoid stirring the bottom sediments in the receiving water(s) or in the outfall storm water channel.

(e) The sampling container should be held so the opening faces upstream.

(f) The samples should be kept free from floating debris.

(g) Permittees do not have to sample sheet flow that flows onto undisturbed natural areas or areas stabilized by the project. For purposes of this section, stabilized shall mean, for unpaved areas and areas not covered by permanent structures, 100% of the soil surface is uniformly covered in permanent vegetation with a density of 70% or greater, or equivalent permanent stabilization measures (such as the use of rip rap, gabions, permanent mulches or geotextiles) have been used. Permanent vegetation shall consist of: planted trees, shrubs, perennial vines; a crop of perennial vegetation appropriate for the time of year and region; or a

crop of annual vegetation and a seeding of target crop perennials appropriate for the region. Final stabilization applies to each phase of construction.

(h) All sampling pursuant to this permit must be done in such a way (including generally accepted sampling methods, locations, timing, and frequency) as to accurately reflect whether storm water runoff from the facility/site is in compliance with the standard set forth in Parts III.C.3. or III.C.4., whichever is applicable.

6.1.3.4 Sampling Frequency

(1) The primary permittee must sample at least once for each rainfall event described below. For a qualifying event, samples must be taken within 45 minutes of:

(a) the accumulation of the minimum amount of rainfall for the qualifying event, if the storm water discharge to a monitored receiving water or from a monitored outfall has begun at or before the accumulation, or

(b) the beginning of any storm water discharge to a monitored receiving water or from a monitored outfall, if the discharge begins after the accumulation of the minimum amount of rainfall for the qualifying event.

(2) However, where manual and automatic sampling are impossible (as defined in this permit), or are beyond the permittee's control, the permittee shall take samples as soon as possible, but in no case more than twelve (12) hours after the beginning of the storm water discharge.

(3) Sampling by the permittee shall occur for the following events:

(a) For each area of the site that discharges to a receiving stream, the first rain event that reaches or exceeds 0.5 inch and allows for monitoring during normal business hours* (Monday thru Friday, 8:00 AM to 5:00 PM and Saturday 8:00 AM to 5:00 PM when construction activity is being conducted by the Primary permittee) that occurs after all clearing and grubbing operations have been completed in the drainage area of the location selected as the sampling location;

(b) In addition to (a) above, for each area of the site that discharges to a receiving stream, the first rain event that reaches or exceeds 0.5 inch and allows for monitoring during normal business hours* and that occurs

- either 90 days after the first sampling event or
- after all mass grading operations have been completed in the drainage area of the location selected as the sampling location, whichever comes first;

(c) At the time of sampling performed pursuant to (a) and (b) above, if BMPs are found to be properly designed, installed and maintained, no further action is required. If BMPs in any area of the site that discharges to a receiving stream are not properly designed, installed and maintained, corrective action shall be defined and implemented within 2 business days, and turbidity samples shall be taken from discharges from that area of the site

- for each subsequent rain event that reaches or exceeds 0.5 inch during normal business hours* until the selected turbidity standard is attained, or
- until post-storm event inspections determine that BMPs are properly designed, installed and maintained; and

(d) Existing construction activities, i.e., those that are occurring on or before the effective date of this permit, that have met the sampling required by (a.) above shall sample in accordance with (b.). Those existing construction activities that have met the sampling required by (b.) above shall not be required to conduct additional sampling other than as required by (c.) above.

The current sampling frequency (2 times/year) is the result of negotiations between regulators, environmentalists, and developers. Sampling was initially required by the Georgia EPD in response to environmental lawsuits and was not desired by the regulatory agency. An older version of the permit required more frequent sampling; however, the net effect was that huge amounts of sampling data accumulated on the desks of over worked regulators and were never looked at or used for enforcement purposes. Recognizing that the older program was not achieving the desired results, the sampling frequency was reduced and the number of inspections increased with the hope of improving sediment retention on job sites.

6.1.3.5 California

Requirements for sampling of construction site runoff in California were adopted in 2004 and include sampling provisions for non-visible pollutants and sediment (SWRCB, 2004). Although sampling and analysis are required at many construction sites, they are not required at all construction sites.

Non-Visible Pollutants

The monitoring requirements in the California CGP require sampling and analysis for pollutants that are not visually detectable in storm water discharges, which are or should be known to occur on the construction site, and which could cause or contribute to an exceedance of water quality objectives. As is explained below, the situations where non-visible pollutants may occur in runoff from a construction site are limited. Where such non-visible pollutants are known or should be known to be present and have the potential to contact runoff and to contribute to an exceedance of a water quality objective, sampling and analysis are required.

For pollutants that are visible in runoff, the CGP requires the discharger to perform visual monitoring of the site and does not require sampling and analysis. The sampling and analysis requirements only apply to pollutants that do not leave a visible trace or are not associated with a visible tracer. Examples of such potential non-visible pollutants include increased pH, pesticides, and nutrients such as nitrogen or phosphorus. The presence or use of a material on the construction site does not always mean that dischargers must sample for it in runoff. The CGP requires sampling and analysis when non-visible pollutants could “cause or contribute to an exceedance of water quality objectives in the receiving water.”

Examples of where sampling for non-visible pollutants is required include:

- Where construction materials and compounds are stored or applied so they may come in contact with storm water runoff.
- For construction projects that use soil amendments or soil treatments that can come in contact with storm water runoff. (If there are independent test data available that demonstrate that the soil amendments cannot result in concentration levels in storm water discharges that will cause or contribute to exceedance of applicable water quality standards, sampling and analysis may not be required.)
- When a leak or spill occurs that is not fully contained and cleaned before a storm event.
- When a leak or spill occurs, during a storm event, and it cannot immediately be isolated and/or cleaned-up, and the possibility of an off-site discharge exists.
- When, during regular inspections, it is discovered that cover and containment BMPs have been compromised and storm water comes in contact with materials resulting in runoff discharging into a storm drain system or water body.
- When material storage BMPs have been compromised, breached, or have failed.

The most effective way to avoid the sampling and analysis requirements, and to ensure permit compliance, is to avoid the exposure of construction materials to precipitation and storm water runoff. Materials that are not exposed do not have the potential to enter storm water runoff, and therefore do not need to be sampled for in runoff. Preventing contact between storm water and construction materials is one of the most important BMPs at any construction site. Manage any potential pollutants on the site in such a way that the exposure of the pollutant to rainfall or storm water is minimized or eliminated.

If a determination is made that sampling is needed, storm water runoff samples must be collected regardless of the time of year, status of the construction site, or day of the week. Samples must be collected during the first two hours of runoff (during daylight hours). Storm water inspections and sample collections are required even during non-working days (including weekends and holidays).

Samples must be collected at all discharge locations that drain the areas from which the pollutants may have entered the runoff and at locations that have not come in contact with the pollutants (reference sampling). This allows a comparison of reference samples with the sample(s) collected from storm water suspected of containing construction-related pollutants. The collection of this sample is important in the interpretation of the potentially contaminated sample because it provides information on the characteristics of the storm water without the exposure.

Sediment-Impaired Water bodies

The California CGP requires sampling and analysis for sediment/silt or turbidity when the construction site runoff discharges directly into a water body that is impaired by sedimentation/siltation, sediment, or turbidity (that is, the water body is on the 303(d) list for one or more of these pollutants.) A key point is that the discharge of storm water runoff must directly enter the impaired water body or impaired segment of a water body. Construction site runoff that flows through a tributary or storm drainage system and is

commingled with other sources of flow, is not considered a direct discharge even if the flow eventually enters an impaired water body.

The California CGP requires that the SWPPP identify a strategy for conducting the sampling and analysis, including the frequency at which sampling will be conducted. The SWPPP must also describe the:

- Location(s) of direct discharges from construction activities to a water body listed on the 303(d) list for sedimentation/siltation, sediment and/or turbidity;
- Designated sampling location(s) in the listed water body representing the prevailing conditions up-stream of the discharge;
- Designated sampling location(s) in the listed water body representing the prevailing conditions down-stream of the discharge; and
- Sampling design which describes the sampling devices used; the sample size; the number of samples to be taken at each location, the laboratory protocol employed; and, if applicable, the statistical test used to determine if the upstream/downstream samples differ to a statistically significant degree.

Requirements on when to sample include:

- Dischargers must collect samples during the first two hours of discharge (runoff) from storm events which result in a direct discharge to any 303(d) listed water body, but samples need only be collected during daylight hours (sunrise to sunset).
- Dischargers must collect samples regardless of the time of year, status of the construction site, or day of the week. Samples should be taken during the first two hours of a storm event.
- Storm water inspections and sample collections are required even during non-working days (including weekends and holidays). Samples must be taken from the same storm event for comparison, concentrations are not comparable across storm events.
- Dischargers do not need to perform upstream/downstream sample collection for more than four (4) rain events per month.

If the water body is listed as impaired for sedimentation or siltation, samples must be analyzed for Settleable Solids (mL/L) and Total Suspended Solids (mg/L) according to U.S. EPA 160.2 and U.S. EPA 160.5, respectively. Samples may be analyzed for suspended sediment concentration (SSC) according to ASTM D3977-97 instead of or in addition to Total Suspended Solids and Settleable Solids. If the water body is listed as impaired for turbidity, samples must be analyzed for turbidity per U.S. EPA 180.1 or analyzed in the field using a correctly calibrated turbidity meter.

In-stream sampling is required, both upstream and downstream of the discharge. The CGP does not require that the effluent be sampled. However, effluent sampling is recommended. Both upstream and downstream samples should be taken within the actual flow of the water body.

Samples of the 303(d) listed water body must be collected at the following locations:

- Upstream of the construction site discharge in a location representative of the sediment load present in the water body before it is impacted by discharge from the construction site.
- At a point immediately downstream of the last point of discharge from the construction site.

Additionally, for the purpose of interpreting the results of the samples collected from the 303(d) listed water body, collect and analyze samples of the actual discharge from the construction site (effluent sample) before it being commingled in the receiving water. This sample can be used to verify whether the source of the sediment in-stream is emanating from the construction discharge. Remember that samples should only be collected from safely accessible locations.

In general, sample away from the bank in or near the main current. Avoid collecting samples directly from ponded, sluggish, or stagnant water. Be careful when collecting water upstream or downstream of confluences or point sources to minimize problems caused by backwater effects or poorly mixed flows. Note that samples collected directly downstream from a bridge can be contaminated from the bridge structure or runoff from the road surface. Choose the upstream location in water that appears to represent the nature of the flow in the stream. Downstream samples should represent the receiving water mixed with flow from the construction site. For instance if the flow from the site can be observed by either a color or a flow difference, collect the downstream sample from within the affected water.

The sampling requirements in California do not reflect the original intent of the State Water Resources Control Board. Instead, the Board was sued by environmental groups and adoption of the current standards was the result. In practice, little monitoring is done for non-visible pollutants. Most contractors assert that the subject materials are not exposed to storm water, so no sampling is required. Sampling for sediment is restricted to sites discharging directly to water bodies on the 303(d) list for sediment impairment. It turns out that there is not that many direct discharges to these water bodies, since runoff from most sites is commingled with other storm water runoff before entering the receiving water. Consequently, the level of monitoring has been well below that envisioned by environmental groups when the legal settlement was reached. California is currently revising the permit terms and a new permit is expected later this year that may substantially change the current monitoring requirements.

6.1.3.6 Washington State

Washington State is currently developing a draft permit that will require monitoring; however, the final version is not yet available. They are also preparing a manual, *How to Do Storm Water Monitoring: A Guide for Construction Sites,* which will provide information on appropriate protocols. Since the sampling program in Washington is so new, there is not sufficient experience to assess its effectiveness.

Construction sites discharging to water bodies with TMDLs or on the 303(d) list for turbidity, fine sediment, high pH, phosphorus, or other applicable water quality parameters are required to verify, through sampling and analysis, that discharges are not

causing or contributing to violations of water quality standards. The draft permit also clearly states that storm water discharges must comply with water quality standards and provides for the presumption that discharges are in compliance with water quality standards if permittees are in compliance with permit conditions, unless site specific information shows otherwise. The Department of Ecology proposes a weekly sampling regime for these sites when storm water is discharged from the site.

The Washington Department of Ecology is also concerned with pH at construction sites because these sites typically use or have alkaline materials (e.g., concrete, cement, mortar, etc.). When fresh alkaline materials are exposed to storm water runoff, they can quickly raise the pH of the storm water. Several factors play a role in the impact of high pH on surface water quality, such as size of the receiving water and its availability to buffer high pH, quantity of fresh concrete pours (i.e., surface area of exposed concrete), volume of discharge, time of day, exposure to rain, etc. Ecology believes that use of a matrix of parameters to define a trigger for sampling is unworkable. Therefore, Ecology is proposing simple pH sampling triggers that were designed from best professional judgment and data provided by the Washington State Department of Transportation. These triggers are:

1. Greater than 1000 cubic yards poured concrete;
2. Greater than 1000 cubic yards recycled concrete; and
3. The use of soil amendments (engineered soils) such as Portland cement treated base, cement kiln dust, fly ash, etc.

All of these activities, if exposed to rainwater, have the potential to significantly alter the pH in runoff, and potentially in the receiving water. When one of the triggers listed above occurs, the operator must sample for pH, at a frequency of at least weekly at the location where runoff from the affected area is collected (typically a sediment pond, or other impounded body of water onsite) before discharge from the site. The permittee will be required to neutralize the pH if it is over 8.5 standard units, prior to discharging such waters. The first sample should be collected after the first rainfall interacts with the recently applied alkaline material, because that is when pH will be the highest and therefore has the greatest potential to adversely impact the receiving water.

6.1.4 Standards and Test Methods for Sediment and Turbidity

6.1.4.1 Standards for Sediment and Turbidity

One of the initial problems is that the vast majority of states have not adopted numerical standards for discharges from construction sites. A summary of the requirements of the various states is presented in Table 6-2. Part of the reason for the lack of standards is that water quality standards for sediment are generally narrative rather than numerical. In addition, provisions of the Clean Water Act require a technology based standard rather than effluent limits. These provisions require controls of pollutant discharges that use best available technology economically achievable (BAT) and best conventional pollutant control technology (BCT) to reduce pollutants.

The U.S. EPA has considered permit options that would contain numerical requirements for the removal of specific pollutants from construction site runoff. EPA initially

considered targeting a variety of pollutants including sediment, TSS, turbidity, nutrients, metals and other priority pollutants; however, little data are available supporting the feasibility of controlling pollutants other than sediment (or associated indicator parameters such as TSS, turbidity, total suspended sediment, or settleable solids). This option could be expressed either as a percent removal through sediment controls (such as sediment basins or traps) or as a total site reduction (incorporating consideration of sheet flow and diffuse runoff in addition to discrete conveyances). In addition to establishing numerical requirements for the control of sediment, EPA preliminarily considered establishing requirements for removing fine-grained and slowly- or non-settleable particles contained in construction-site runoff (such as turbidity). This option would likely have relied primarily on chemical treatment of soils or construction site runoff using polymers or coagulants such as alum to prevent the non-settleable fractions of solids from being transported off-site (EPA, 2002).

EPA also considered the inclusion of monitoring requirements for evaluating the effectiveness of erosion and sediment controls. Monitoring of storm water discharges from construction sites could be used to evaluate the effectiveness of individual sediment controls (such as sediment basins), or monitoring the receiving water above and below construction sites. Monitoring requirements could be incorporated with any of the previously discussed regulatory options considered (EPA, 2002).

In the end, EPA wanted local decision-makers to have maximum flexibility to develop control strategies that are tailored to the discharges of storm water runoff from construction sites under their jurisdiction. Further, EPA considered the costs of the proposed regulatory options to be very high, and these options would provide only marginal environmental improvements over regulations already in place. The most stringent of the regulatory options would have reduced sediment loadings from construction sites by only about one percent more than the existing regulations. For these reasons, EPA has decided that effluent guidelines are not appropriate at this time.

6.1.4.2 Washington

Table 6-2 indicates that the State of Washington does not have discharge standards for construction sites; however, a draft permit being developed does include them. Numeric effluent limitations will apply to sites in Washington State that discharge to water bodies that are impaired for the following parameters:

- Suspended sediment (turbidity, fine sediment, total suspended solids, and sedimentation);
- High pH;
- Phosphorus; and/or
- Other applicable parameters identified by Ecology.

For these sites, the permittee is assigned a numeric effluent limitation that is equal to the applicable water quality standard at the point of discharge. For all suspended sediment parameters (turbidity, fine sediment, etc.), Washington has determined that turbidity is the appropriate surrogate parameter. The draft permit contains a turbidity benchmark value of 25 NTU and a surrogate transparency benchmark of 32 cm.

6.1.4.3 Georgia

As mentioned previously, Georgia has adopted turbidity standards for construction site runoff. Georgia law limits the increase in turbidity to 25 NTU in the receiving water. This can be demonstrated using upstream/downstream monitoring. Georgia also provides another option for sampling individual outfalls and with the concentrations based on the type of receiving water and the size of the construction project. These standards are shown in Table 6-1. In practice, enforcement actions by regulators in Georgia are complaint driven. Their experience is that a field inspection triggered by downstream complaints easily identifies failed or inappropriate controls without the need for water quality monitoring.

Table 6-2: Construction Requirements of Other States (U.S. EPA, 2002)

Geographic Area Name	Disturbed Area Limit for Permet Coverage (feet^2)	Numeric Standard or Pollutant Reduction Requirement	Minimum Depth of Runoff or Storm Return Frequency to Treat for Water Quality Management (per acre)	Maximum Allowed Denuded Acreage or Soil Stablilization Requirement	Visual Inspection Frequency	Notes
Clean Water Act NPDES Storm Water program for Phase I and Phase II MS4s	43,560				After 0.5 inch rainfall and every 14 days	Phase II compliance date is March 10, 2003.
CZARA	5,000					Must prepare and implement an approved erosion and sediment control plan or similar document that contains erosion and sediment control provisions.
Alabama	217,800	Turbidity < 50 NTU				
Alaska (AK)	217,800	TSS > 20 microns	2 year / 6 hour		After 0.5 inch rainfall and every 7 days	Inspector must be qualified personnel provided by the discharger.
Arizona	217,800					
Arkansas	217,800		10year / 24hour		Every 7 days	Developers must submit erosion and sediment control plan and storm water pollution prevention plan before filing a notice of intent. Sites 10 acres or more need temporary or permanent sediment basin. Sites less than 10 acres need sediment traps and silt fences.
California (CA)	217,800		2 year / 24 hour		After 0.5 inch rainfall	Inspections will be performed before anticipated storm events, during extended storm events, and after storm events, and once each 24-hour period during extended storm events to identify BMP effectiveness and implement repairs or design changes as soon as feasible depending on field conditions. Discharger is also responsible for inspecting and cleaning all public and private roads for sediment. Construction activities that fall under the jurisdiction of the California Department of Transportation (CALTRANS) have separate permit and regulations.
Colorado (CO)	217,800				Any precipitation or snowmelt event that causes erosion and every 14 days	Storm water management plan must be submitted to state for a 10 day review, as well as be retained on site.
Connecticut	217,800	80% TSS reduction				
Delaware	5,000	80% TSS reduction	0.5 inch			
Florida , DEP, Northern District (only applies in NW Florida)	217,800	80% TSS reduction	0.5 inch*			*>100 acres, 1 inch rainfall, <100 acres, 0.5 inch rainfall.
Florida, South Florida Water Management District (General, Standard General, Noticed General and Individual Permits)	435,600		1 inch			
Florida, Southwest Florida Water Management District	217,800		0.5 inch			
Florida, St. Johns River Water Management District	217,800	Turbidity <29 NTU				
Florida, Suwannee River Water Management District	43,560	80% TSS reduction	1 inch			
Georgia	47,916	Turbidity < 10-25 NTU*	25 year / 24 hour			*<25 nephelometric turbidity units for waters supporting warm water fisheries, or <10 nephelometric turbidity units for waters classified as trout waters.

Geographic Area Name	Disturbed Area Limit for Permet Coverage (feet^2)	Numeric Standard or Pollutant Reduction Requirement	Minimum Depth of Runoff or Storm Return Frequency to Treat for Water Quality Management (per acre)	Maximum Allowed Denuded Acreage or Soil Stablilization Requirement	Visual Inspection Frequency	Notes
Hawaii (HI)	217,800				After 0.5 inch rainfall and every 7 days during dry season, every day during rainy season	Construction shall be phased for large projects; one phase must be stabilized before another can begin. 50 days maximum from destruction of pre-construction conditions to temporary stabilization.
Idaho (ID)	217,800				After 0.5 inch rainfall and every 14 days	
Illinois	217,800		3,600 cubic feet per acre		Every 7 days	
Indiana	217,800				Every 7 calendar days and within 24 hours of 0.5 inch of precipitation	
Iowa	217,800	80% TSS reduction			Every 7 days	
Kansas	217,800				At least once per week	
Kentucky	217,800	Goal of 80 % TSS reduction (compared to pre-construction conditions)				
Louisiana	217,800					
Maine	217,800	40-80% TSS reduction	2 year			
Maryland	5,000	80% TSS reduction*	2 year / 24 hour			*Based on the average annual TSS loading from all storms less than or equal to the 2 year/24 hour storm.
Massachusetts	217,800	80% TSS reduction	2 year / 24 hour			
Michigan	43,560		3,600 cubic feet per acre		Encourage weekly inspections	Sites >10 acres require onsite temporary basin.
Minnesota	217,800		0.5 inch		1 time every 7 days or within 24 hours after a significant rain event which results in runoff leaving a construction site.	
Mississippi	217,800					
Missouri	217,800	Settleable Solids < 0.5 -2.5 mL/L/hour*			Periodic	*2.5 mL/L/hour for normal land disturbance, 0.5 mL/L/hour for land disturbance within sensitive areas.

Geographic Area Name	Disturbed Area Limit for Permet Coverage (feet^2)	Numeric Standard or Pollutant Reduction Requirement	Minimum Depth of Runoff or Storm Return Frequency to Treat for Water Quality Management (per acre)	Maximum Allowed Denuded Acreage or Soil Stablilization Requirement	Visual Inspection Frequency	Notes
Montana (MT)	217,800		2 year / 24 hour		After 0.5 inch rainfall and every 7 days	Dischargers must submit with the state application form a stormwater erosion control plan (SWECP) that resembles EPA's construction site SWPPP. Permit coverage begins only when Montana DEQ reviews and approves SWECP. Must also inspect everyday during prolonged precipitation or snowmelt periods. A registered PE must prepare the ESC plan if site is greater than 20 acres. Also regulate down to 1 acre if construction site within 100 feet of a surface water body. Montana has a sediment and erosion control guidance manual that lists standard use BMPs. If other BMPs are used, they need to be submitted with ESC plan to the state for approval. For slopes steeper than 3:1 and greater than 5 vertical feet, surface roughening is required. Filter fences should be used on drainage areas >1acre; sediment traps should only be used on drainage areas > 3 acres; and temporary sediment ponds should only be used on drainage areas > 10 acres.
NC	43,560	Y		20 acres total disturbance at any given time for areas discharging to high quality waters	Every 7 days	
Nebraska	217,800				Once a month.	
Nevada	217,800					
New Hampshire	100,000					
New Jersey	5,000					
New Mexico	217,800				Y	
New York	217,800		0.5 inch			
North Dakota	217,800				Y	
Ohio	217,800					
Oklahoma	217,800		3,600 cubic feet per acre		Y	A vegetated buffer zone of at least 100 ft must be retained or successfully established between the area disturbed during construction and all perennial or intermittent streams on or adjacent to the construction site. A vegetated buffer zone at least 50 ft wide must be retained or established between the area disturbed during construction and all ephemeral streams or drainages. Treatment volume is the lesser of 3,600 or the runoff volume of a 2 year 24 hour storm.
Oregon (OR)	217,800				Every 7 days, and daily during periods of stormwater runoff and snowmelt runoff; only every 14 days during periods of 7 days or more of non-construction activity.	If site is >20 acres, erosion and sediment control plan must be prepared by a Professional Engineer, or Registered Landscape Architect, or Certified Professional in Erosion and Sediment Control, and plan must be submitted 90 days before construction begins. All permittees must submit an Oregon Land Use Compatibility Statement if they do not already have one on file with Oregon DEQ.
Pennsylvania	217,800		5 year		Y	Basins should drain no quicker than 4 days and no longer than 7 days.

Geographic Area Name	Disturbed Area Limit for Permet Coverage (feet^2)	Numeric Standard or Pollutant Reduction Requirement	Minimum Depth of Runoff or Storm Return Frequency to Treat for Water Quality Management (per acre)	Maximum Allowed Denuded Acreage or Soil Stablilization Requirement	Visual Inspection Frequency	Notes
Rhode Island	217,800	80-90% TSS reduction	10 year			
South Carolina	>87,120	80% TSS reduction	3,600 cu ft / ac		Y	Trapping efficiency is a performance based requirement for any BMPs. The major requirements for storm water control plans are: application, location map, type and location of BMP's, construction sequencing, location of disturbed areas, property line & waters of the state, standard notes, grassing specifications. The minimum required volume for water quality management is 3600 cubic feet for a disturbed area of more than 10 acres. If there is not a sediment basin of 3600 cubic feet and the drainage area is less than 10 acres, then sediment traps, silt fences, or equivalent measures are needed for sideslope and downslope boundaries for the construction area. However, the first 0.5 inch rainfall runoff in a 24-hr period is applicable to the coastal counties only.
South Dakota	217,800		5 year			
Tennessee	217,800				Y	The permittee shall maintain records of checks and repairs.
Texas	217,800		3,600 cubic feet per acre			
Utah (UT)	217,800		24 hour OR 1 inch storm event		Once every 14 days, before anticipated storm events expected to cause significant runoff, and within 24 hours of the end of a storm that is 0.5 inch or greater.	Where sites have been finally or temporarily stabilized, or when runoff is unlikely due to winter conditions, or during seasonal arid periods in arid areas and semi-arid areas inspections shall be conducted at least once every 30 days. 10yr, 24hr storm event for water quality is for 10 acres or greater. For areas less than 10 acres, or where calculations for volume of runoff for disturbed acres is not performed, a sediment basin providing 3600 cubic feet of storage per acre drained or equivalent control measures shall be provided. 1) Where the initiation of stabilization measures by the 14th day after construction activity temporary or permanently cease is preclude by snow cover or frozen ground conditions, stabilization measures shall be initiated as soon as possible. 2) In arid areas , semi-arid areas, and areas experiencing droughts where the initiation stabilization measures by the 14th day after construction activity has temporarily or permanently ceased is precluded by seasonal arid conditions, stabilization measures shall be initiated as soon as practicable.
Vermont	217,800					
Virginia	217,800		3,600 cubic feet per acre		Y	Sediment basins required for sites of 10 acres or more (except those with final stabilization); for sites <10 acres, same units required but only for sideslope and downslope boundaries of construction sites.
Washington (WA), Large Parcel	>43,560		24 hour / 6 month	2 days between October 1 and April 30 (i.e., the wet season); 7 days between May 1 to September 30 (dry season)		

6.1.4.4 Test Methods for Sediment and Turbidity

Two main test methods are available for determining the concentrations of suspended solids in water. These are Total Suspended Solids (TSS), which is described in EPA 160.2 and Standard Methods 2540D, and Suspended Sediment Concentration (SSC), which is described in ASTM D 3977-97. These two measures are performed in much the same way and often the terms SSC and TSS are used interchangeably. In both cases, a known volume of the sample is passed through a standard filter paper. This filter is dried at 105˚C, brought to room temperature in a desiccator, and weighed both before and after the sample is filtered. The difference in the weight of the two measurements is the mass of sediment captured on the filter.

The difference in the two measurements is in how the sample to be measured is obtained. In the TSS method, a sub-sample is taken from the suspension with a pipette and then is dispensed onto filter paper to measure the sediment. For SSC, the whole sample is poured onto the filter paper to catch the sediment. The SSC technique is considered by many to be the preferred method for runoff samples because it can be difficult to get a representative sample into a pipette, especially where the solids include a substantial, sand sized fraction (Gray, 2000). These sand particles settle rapidly to the bottom of the container, so it is difficult for them to be pulled up by the pipette.

SSC measurements have been shown to provide a more accurate assessment of the total amount of solids present in natural waters containing a significant amount of larger material. This methodology is used almost exclusively by the USGS for analyzing sediment in water. A drawback is that few commercial laboratories provide this type of analysis or will charge extra to first document a protocol. Consequently, samples collected and analyzed by the USGS should be analyzed using the SSC protocol. When analyses are done by a different lab, TSS is the easier protocol to specify, but one needs to be aware that the two values are not comparable.

Since TSS measurements do not indicate the mass of sediment that can be removed in sedimentation basins, settleable solids have been used (in California) to supplement the data from TSS measurements. This procedure is a direct measurement of the fraction of material that can be removed without the addition of chemical flocculants. The test is conducted using an Imhoff cone. One liter of well mixed sample is placed in the cone and allowed to settle for 45 minutes, gently agitating, and then settling for an additional 15 minutes. The results are commonly reported as mL/L.

Turbidity is a measure of the clarity of water. In general, the more material that is suspended in water, the greater is the water's turbidity and the lower its clarity. Suspended material can be particles of clay, silt, sand, algae, plankton, micro-organisms and other substances. Turbidity affects how far light can penetrate into the water. It is not related to water color: tannin-rich waters that flow through peaty areas are highly colored but are usually clear, with very low turbidity. Measures of turbidity are not direct measures of the concentration, type or size of particles present, though turbidity is often used as an indicator of the total amount of material suspended in the water.

Turbidity was for many years a primary consideration in drinking water treatment; consequently most methods and instruments are designed to have greatest accuracy in

relatively clean water, rather than storm water runoff from construction sites. The most common turbidity meters used to analyze relatively clean water are nephelometric and the results are reported as nephelometric turbidity units (NTU). Nephelometers are relatively unaffected by small differences in design parameters and therefore are specified as the standard instrument for measurement of low turbidities. These instruments measure scattered light with detectors located at 90 degrees to the incident beam. Unfortunately, the amount of suspended sediment in very dirty water obstructs the light beam so greatly that little light is scattered resulting in a very low reading.

There are now instruments from a variety of manufacturers (Orion and Hach, for instance) that attempt to overcome the light blocking associated with very turbid waters as well as the effects of differences in particle size, composition and geometry. The instruments may use multiple light sources and detectors oriented at various angles to the incident light beams. Because of the differences in design the measured turbidity from a given sample may not be exactly the same. Consequently, it is recommended that when measurements are made of individual samples, all measurements be obtained from a single model of turbidity meter and that the meter have an operating range that extends to at least 10,000 NTU.

The type of monitoring specified is a function of the ultimate objective of the monitoring program. If the monitoring is done solely to determine whether a construction project is impacting surface water quality, then turbidity tests of grab or stage samples would be the primary choice. Turbidity measurements can be conducted in real time, so there is no waiting on the results of laboratory analyses. In addition, the turbidity measurements have an extremely low cost, so measurements can be made in many locations without a substantial economic burden on the discharger.

If the objective of the monitoring program is to quantify the mass of sediment discharged from a site, then the parameter choice would be either the SSC or TSS methodology. These tests conducted on flow-weighted composite samples can give a reasonably accurate estimate of the total mass and volume of sediment discharged from a site. This information might be useful for determining loss of storage in reservoirs for instance.

6.1.5 Visual Evaluation of Sediment Deposits

Visual evaluation of sediment deposits is a much more common tool for identifying inadequate EPSC measures than sampling and laboratory testing of discharges. These deposits are easily recognizable because of their generally fine-grained character, the lack of vegetation, and their unconsolidated nature. The presence of deposits of this type usually triggers requirements by regulatory agencies to immediately remove this material. Once the source area is stabilized, these unconsolidated deposits will be quickly conveyed downstream during subsequent events. Consequently, any remedial action must be performed immediately.

Visual observation is not a satisfactory way to quantify the relative performance of different types of EPSC measures. It is difficult to determine the volume of sediment in these deposits and substantial amounts of the finer particles will have been conveyed so far downstream and dispersed that they are no longer in close association with the

construction activities. Therefore, any program that has a goal of determining absolute amounts of sediment washed off construction sites or quantitative evaluation of EPSC measures should rely on water quality sampling of the entire event.

6.2 Use of Flocculants and Polymers (A.1.k)

6.2.1 Recommendations on the use of Polymers

We recommend that anionic PAMs be considered as approved best management practices (BMPs) for construction sites for erosion control and turbidity reduction. Application rates should be verified through the vendor or supplier and strictly followed. The following factors should be considered when determining the use of polymers on a construction project:

1. **The site is the watershed of an Outstanding Resource Water or High Quality Water.**
2. **The site drains to an environmentally sensitive area, such as critical habitat.**
3. **Site characteristics such as slope, soil type, and proximity to water, which might lead to excessive erosion and discharge of turbid storm water.**

Each project must be evaluated for its responsiveness to polymer applications.

The following sections describe sampling protocols, toxicity, applications, and research on the use of polymers.

6.2.2 Recommended Sampling Protocol

Polymer sampling depends on the polymer type used; however, the calculation of polymer concentration is more cost effective and potentially more reliable than sample collection when testing for anionic polymers. Sampling methods are described below.

6.2.2.1 Identification of Types of Polymers/Flocculants

Many polymer types are currently on the market with varying ranges of toxicity. Polymers available include:

<u>Chitosan</u>

Chitosan is a refined, chemically modified form of chitin, the structural material found in the shells of crustaceans. It is typically manufactured from waste shells of crab, shrimp and lobster. It is then processed to remove the calcium and protein and made in a dry, flaky product or a liquid. Recommended storm water treatment includes adding 0.5 to 1 mg/L of chitosan in the storm water before treatment ponds or pumping the storm water through a pipe that has chitosan packed in a multi-chambered sock.

<u>Aluminum-chloride polymers</u>

Polyaluminum chloride can be used for storm water treatment; however, a coagulation and flocculation step is required and it cannot be directly spread on the ground.

Polyacrylamide (PAM)

PAM is a term used for long chain organic polymers that can be used as a flocculating agent. PAMs are classified according to their molecular weight (high to low) and ionic charge (anionic, nonionic and cationic) and are available in solid, granular, liquid or emulsions. The most commonly used PAM in soil conservation is an anionic polymer with a high molecular weight of 12 to 20 million g/mol.

Anionic PAM

Anionic PAM has very low toxicity to humans, aquatic organisms, or plants. These PAMs can be used for both erosion and turbidity reduction with very little concern for impacts on aquatic systems.

Cationic Polymers

Cationic PAM has an advantage in that it can react directly with the negatively charged suspended clays and silts, while the anionic PAMs require a bridging cation. The flocculation obtained may be more complete and rapid with the cationics, as well. However, they are more toxic to aquatic organisms and, as a result, are discouraged or banned from use in many locations. Published studies indicate that their toxicity is greatly reduced in the presence of normal amounts of suspended materials (sediment, organic matter).

6.2.2.2 Sampling Criteria

Determining the concentration of PAM or chitosan in storm water is difficult and expensive. Dissolved organic matter and salts, which are present in most surface water samples cause interferences in the majority of available PAM determination methods. Analytical techniques for determination of PAM content in natural soils still needs to be developed.

Sampling Criteria and Frequency

Due to the difficulty of chemical analysis for polymers, and since typical application rates are significantly less than toxic concentrations, direct sampling for polymer is typically not performed except for research purposes. A more practical determination of polymer concentration is to estimate runoff concentrations by calculating applied amounts and subtracting the percentage of polymer that adheres to the soil. However, when PAM dissolved in irrigation water was introduced to furrows, very little (<1%) remained at the end of the field (Lentz et al. 2002). Other studies have shown that PAM does not desorb from soil unless subjected to high shear (Nadler et al. 1992; Lee and Fuller 1985). This suggests that PAM applied to soil or bound to suspended sediment will not be found in significant concentrations in runoff water, and most likely will not be detectable.

Sampling Methods

The use of polyethylene containers for toxicity samples has been shown to reduce toxicity when cationic polymers are present. The charged surface of plastic containers reduced the toxicity. Polycarbonate has been identified as an alternative to polyethylene

because it is less reactive to organics. If samples are taken for polymer concentration, they should be collected on ice in polycarbonate containers.

Analytical Methods

Where PAM is being metered in known amounts into known flows, such as in a pumping operation, calculation based on the dosing is the simplest approach to estimating concentrations. The methods for analyzing for PAM in water are difficult due to the very large size of the molecules, which prevents typical methods for organic chemicals such as various types of chromatography (liquid, gas, etc.). The 11 methods developed to date were reviewed by Lu and Wu (2003), and are indicated below.

Chemical properties of amide groups. This method includes fluorescence spectrometry, amide hydrolysis with ammonia detection and N-bromination method. These methods are subject to interference from dissolved soil organic matter containing amide groups or nitrogen-containing species in the solution, however, corrections are possible. The N-bromination method determines the total concentration of amide groups from PAM and dissolved organic matter by spectrophotometry. The dissolved organic matter is then determined by spectrophotometry at a different wavelength. The actual PAM concentration is then calculated from the difference. This method works only if the background dissolved organic matter comes from a similar source. Often the organic matter in samples is much higher than PAM, creating problems in quantifying PAM.

Physical properties of the large molecular size. This method includes viscosity measurement, flocculation-based method, and size exclusion chromatography. The reproducibility of viscosity measurement and flocculation-based method is dependent on salt and temperature conditions. The flocculation-based method determines the quantity of PAM in the material by measuring the settling speed of flocs formed in clay minerals. Dissolved organic matter and salts that greatly affect the flocculation process makes this procedure unsuitable in most surface waters. Size exclusion chromatography can be difficult if breakdown of PAM molecules occurs because of interaction with soil particles.

Chemical properties of amide groups and on physical properties of large molecular size. This method includes colloid titration, turbidimetric method, and polarography. These methods are vulnerable to interference from salts, pH, temperature and organic matter.

Total organic carbon and radioactive labeling. Total organic carbon analyzes all organic matter in water, not only the polymer. This causes it to be a poor method if any waters containing organic matter which will include most surface waters. Radioactive labeling is only effective for PAM tagged with a radioactive isotope, which limits its use and increases cost.

Chitosan Concentration. A colorimetric method for the determination of the presence of chitosan higher than 0.1 mg/L has been developed by the manufacturer. This method does not quantify chitosan; however, it does detect its presence grater than 0.1 mg/L. This concentration is the limit employed by the State of Washington due to this quantification technique.

The method involves adding iodine to the test sample that after adjusting the pH to 8. The sample is filtered through a glass fiber filter and allowed to dry. One drop of iodine is placed on the filter. The color of the iodine will change from the original yellow-rust color to a deep blue-black color indicating the presence of a polysaccharide. Interferences include polysaccharides other than chitosan and accumulation of dirt particles on the glass fiber filter. The method has been difficult to reproduce.

6.2.2.3 Allowable Concentrations

The concentrations that can be present in the discharge are polymer dependent. Toxicity reports should be reviewed so application rates do not approach levels toxic to aquatic organisms. The allowable discharge concentrations on the products currently used by TDOT on the SR-840 project are supplied by Applied Polymers Systems Inc. presented below. Also presented are chitosan and polyaluminum chloride toxicity information. The concentrations presented are ecologically safe (based pm fathead minnow and *Daphnia magna* tests), and full toxicity reports and concentrations can be obtained by the manufacturer. Two approaches to regulating the concentration involve using either the LC_{50} or the chronic toxicity.

The LC_{50} is a measure of the concentration at which 50% of the test organisms die after 48 hours of exposure. The chronic toxicity is a measure of the concentration above which might have non-toxic impacts on the organisms, such as poor reproduction or growth compared to the control. Chronic tests were conducted on the Applied Polymer Systems products include 7-day fathead minnow and *Ceriodaphnia dubia* (required for registration in North Carolina). Minnow effects are measured by weight gain and *Ceriodaphnia* effects by reproduction, usually 2-3 broods in the 7 day period. The following are numbers developed for the products used on 840.

<u>Dry Polymers</u>

705 Silt Stop

LC 50/Fathead minnow/96h >1,000 mg/L

LC 50/*Daphnia magna*/48h/>420 mg/L

IC 50/Fathead minnow (7 day): 358 mg/L (survival) and 94 mg/L (growth).

IC 50/*Ceriodaphnia dubia* (7 day): 27.7 mg/L (reproduction)

No bioaccumulation is expected.

<u>740 Silt Stop</u>

LC 50/Fathead minnow/96h>1,000 mg/L

LC 50/*Daphnia magna*/48h/>420 mg/L

Samples did not exhibit 50% or greater mortality for connections of 420 mg/L, there for an LC 50 was not calculable.

IC 50/*Ceriodaphnia dubia* (7 day): 5.2 mg/L (reproduction)

<u>640 Silt Stop (M Emulson)</u>

LC 50/Fathead minnow/96h>1,000 mg/L

LC 50/48h/ *Chaetogrammus marinus*/15 mg/L (MSDS)

LC 50/*Daphnia magna*: 4.4 mg/L

Floc Logs

APS 703D Floc Log

LC 50/Fathead minnow/96h>1,000 mg/L

LC 50/48h/*Chaetogrammus marinus*/383 mg/L (MSDS)

APS 706B Floc Log

LC 50/*Daphnia magna*/48hr/>420 mg/L

LC 50/Rainbow trout/420 mg/L

NOAEC (No Observed Acute Effect Concentration) 420 mg/L

APS 730 B

LC 50/Fathead minnows/96h>1,000 mg/L

LC 50/*Daphnia magna*/48h/>420 mg/L

Polyaluminum Chloride (15 – 40% WT/WT)

LC 50/*Daphnia magna*/48hr/1,698 mg/L

LC 50/Rainbow trout/96 hr/1,768 mg/L

LC 50/Fathead minnow/96 hr/1074 mg/L (NOEC: 20 mg/L)

LC 50/*Ceriodaphnia Dubia*/48 hr/1,106 mg/L (NOEC: 625 mg/L)

Chitosan

LC 50/Fathead minnow/1,108 mg/L

LC 50/Rainbow trout/155 mg/L

LC 50/Daphnia Pulex/48hr/417 mg/L

6.2.2.4 Identification of Allowable Concentrations and Rationale

The most sensitive tests conducted are the 7-day chronic tests, but this type of exposure would only be expected during a pumping operation in which the discharge occurred over many days or weeks. The 48-96 hour LC_{50} values are much more representative of exposures which occur when PAM or other materials are used for erosion reduction or for passive treatment of runoff.

6.2.2.5 Rationale for Concentrations

The use of PAM for reducing erosion should be based on efficacy and costs, and not on potential impacts on aquatic organisms. It is highly unlikely that PAM used at recommended rates of 20-40 lb/ac. will be detectable in receiving waters. The potential for free acrylamide, present in minute quantities (<0.02 lb/ac. or 4 g/ha), to be detectable

in runoff where PAM is applied is very low due to the low quantities and since it degrades rapidly (hours) in natural environments.

Passive dosing of runoff from disturbed areas, generally involving directing the flow over solid forms of flocculants, has some limited potential for releases of product in excess of the optimal dose for flocculation. For instance, if too many PAM blocks are present during an event, more PAM may be released than was determined to be the optimum concentrations. PAM release curves should be developed for these types of systems to determine the potential for this to occur. However, it is unlikely that concentrations from these applications will approach the LC_{50} concentrations for the test species. The blocks would have to be placed in an optimal location for PAM release and the runoff would have to have very little suspended material for this to occur, neither of which are likely on construction sites.

Active dosing of pumped water should be relatively simple to control and the concentrations maintained well below the chronic toxicity values for long-term pumping and the acute toxicity values for short-term pumping.

6.2.3 Background and Use Recommendation

The importance of controlling erosion is well established. Sediment losses from disturbed areas on construction sites can exceed 100 tons per acre per year, resulting in a high potential for the failure of sediment control devices and releases into receiving waters. Ground covers usually reduce erosion rates by 90% or more, especially once vegetation is established temporarily or permanently. Rates of 99% control with some ground covers have also been reported. In addition to a wide variety of physical barriers to erosion (straw, mulch, mats, etc.), a number chemicals have been used to either directly replace ground covers or to improve their performance. The most prominent of these have been gypsum and polyacrylamide (PAM).

Conventional sediment control methods may collect 60% or more of the sediment delivered, but even the most effective devices discharge turbid water in most cases. This turbidity can result in significant impacts on receiving waters and is often the source of complaints. Chemical treatment is usually required to settle these materials, and several systems have been or are being tested to apply this technology to construction sites.

6.2.3.1 Current Use of Polymers and Flocculants in TDOT Storm Water Program

The majority of polymer use within TDOT has been on the SR-840 construction project. The polymers used included three different types of Floc Logs (APS 703D, APS 706B, and APS 730B) and three different types of polymers (Silt Stop 640 emulsion, Silt Stop 705 powder, and Silt Stop 740 powder) all supplied by Applied Polymers Systems Inc.

6.2.3.2 Current Polymer Application

Floc Logs are blocks containing PAM and undisclosed materials that are placed in receiving streams. They have been placed before or in drop inlets so the flocculated solids will adhere to the downstream rock checks or other sediment control device. The granular PAM has been used on bare soils before rip-rap channels. The purpose of this

PAM addition was to cause the small sediment particles to form larger flocs, which would be trapped by the rip-rap.

Construction personnel have experimented with PAM application such as applying a layer of polymer between two rows of silt fences. This experimentation of application techniques is not recommended due to the potential of adding an excessive amount of PAM, which can decrease effectiveness, increase cost and cause potential toxicity.

The following are instructions developed for using PAM on the SR-840 project:

- Ensure Polyacrylamide (PAM) emulsions and powders are of the **anionic type only** and meet the following requirements:
    - Meets the EPA and FDA acrylamide monomer limits of equal to or greater than 0.05% acrylamide monomer.
    - Has a density of 10% to 55% by weight and a molecular weight of 16 to 24 Mg/mole.
    - Mixture is non-combustible.
    - Contains only manufacturer-recommended additives.
- PAM shall be mixed and/or applied in accordance with all Occupational Safety and Health Administration (OSHA) Material Safety Data Sheet (MSDS) requirements and the manufacturer's recommendations for the specified use conforming to all federal, state and local laws, rules and regulations.
- All vendors and suppliers of PAM, PAM mix or blends shall present or supply a written toxicity report which verifies that the PAM, PAM mix or blend exhibits acceptable toxicity parameters which meet or exceed the EPA requirements for the state and federal water quality standards. Whole effluent testing does not meet this requirement as primary reactions have occurred and toxic potentials have been reduced.
- Cationic forms of PAM are not allowed for use under this guideline due to their high levels of toxicity to aquatic organisms. Emulsions shall never be applied directly to storm water runoff or riparian waters due to surfactant toxicity. Contractor must seek the approval of the EPSC Design Engineer and TDOT if Chitosan is proposed for use on this project.
- All vendors and suppliers of PAM, PAM mix or blends shall supply written "site specific" testing results demonstrating that a performance of 95% or greater reduction of NTU or TSS from storm water discharges.
- Emulsion batches shall be mixed following recommendations of a testing laboratory that determines the proper product and rate to meet site requirements. Application method shall insure uniform coverage to the target area**. (Emulsions shall never be applied directly to storm water runoff or riparian waters).**
- Dry form (powder) may be applied by hand spreader or a mechanical spreader. Mixing with dry silica sand will aid in spreading. Pre-mixing of dry form PAM

into fertilizer, seed or other soil amendments is allowed when specified in the design plan. Application method shall ensure uniform coverage to the target area.

- Block or Log forms shall be applied following site testing results to ensure proper placement and performance and shall meet or exceed state and federal water quality requirements. Place anionic gel logs at the inlet to ponds and traps on-site, or other locations where flow and mixing are optimal. Post-treatment settling or filtration is required. The number of logs to use will be determined by the EPSC Design Engineer and/or EPSC Inspector.

6.2.4 PAM Uses and Applications

The two uses of PAM directly related to water quality are for enhanced erosion control and for turbidity reduction. PAM has been proven effective in both areas, but it is important that the applications adhere to certain principles to be effective.

Erosion Control:

Physical ground covers should be used and PAM added to improve performance.

While PAM has been shown to reduce bare soil erosion on slopes, mulches or blankets are much more effective. An application of PAM can significantly reduce erosion during the vegetation establishment phase even with a mulch or blanket.

PAM should be applied at 20 lb/ac on most slopes, higher rates above 3:1 slopes.

Application rates lower than 20 lb/ac have not been effective except on very low slopes (<10%), which are uncommon on highway projects. Rates as high as 80 lb/ac have been used on steeper slopes on bare soil, but 30-40 lb/ac is sufficient where mulch has been applied.

PAM should be applied as a solution rather than in dry powder form. The primary reason is that solutions are better distributed on the soil surface and have better contact with the soil. Applied PAM granules have to dissolve in soil water first before they can begin to react with the soil and bind particles together. PAM does not dissolve easily, so erosion may occur before the reaction occurs. Studies have shown that solutions are more effective.

Turbidity Reduction:

Sediment reduction should be achieved first, then turbidity reduction with PAM. Traditional sediment control methods generally involve a settling process to remove the heaviest sediment.

PAM should be introduced where high mixing and turbulence occur before settling. Contact between the particles and PAM molecules is important to create the flocs. The longer the mixing time the better.

A settling basin or similar feature is needed after PAM dosing and mixing. Once the reaction has taken place, the flocs need a place to settle before discharge of storm water. PAM should never be introduced just before discharge.

PAM is more reactive when it is dissolved in water before applications. PAM molecules have to "unfold and extend" first when dissolving before they are fully reactive. Where possible, solutions should be used to reduce turbidity. However, this can be impractical in most situations, except where turbid water is being pumped.

PAM blocks should be placed where they are kept moist and free from sediment. Dry PAM blocks tend not to release PAM until they are rewetted by storm flows, and this can take hours to take place. In addition, moist PAM blocks are sticky and tend to hold sediment and debris, which is in storm flows. Once coated, the blocks will not release much PAM. Storm drains and riser barrels are excellent locations as long as they are protected by gravel collars or similar inlet protection. Use in ditches leading to sediment traps and basins is not recommended due to high sediment loads. Basins with a first bay (forebay) fitted with a surface outflow to a second bay may provide an opportunity to place the PAM blocks in between the bays.

PAM powder can be spread where storm water flows but will have reduced effectiveness if it has high sediment loads. PAM granules will stick to many wet surfaces, particularly natural fibers, and will release PAM into passing flows if the velocity is sufficient. However, like the PAM blocks, if the surface becomes coated with sediment very little PAM will be released. PAM powder will have to be reapplied frequently, usually after each storm, for continued treatment.

Perform soil and water testing. These tests will typically be performed PAM suppliers or manufacturers before a particular product is recommended. Differences in soil type, pH and storm water flow will change the type and concentration of polymer required. It is important that staff be aware that changes in soil properties can occur over the length of a project and with the depth of excavation. Fill material may also have very different properties from native soil. There may be a number of different PAM types needed on an individual project.

6.2.5 Sampling Protocols

No direct polymer sampling by TDOT was identified. The polymer manufacturer for the polymer supplied at the SR-840 project Applied Polymer System, Inc., calculated potential effluent discharge concentrations using suggested applied concentrations and potential rainfall to assure the effluent concentrations did not reach toxic concentrations. However, this calculation involves many assumptions and may be significantly in error. Section 5.2.1 discusses potential analytical techniques.

6.2.6 Discharge Concentrations

Discharge concentrations in construction site runoff from TDOT construction projects have not been measured. Concentrations can, however, be estimated based on polymer amount applied to the site. As discussed previously, it is very difficult to determine how much free PAM is present in discharges due to the low concentrations and difficult analytical procedures.

6.2.7 Literature Review

6.2.7.1 Published Studies

Polyacrylamide applied to soil directly or in irrigation water can reduce erosion by stabilizing soil aggregates and preventing surface sealing (Shainberg et al. 1990). Its use increased from 9,000 ha (22,200 ac) in 1995 to over 450,000 ha (1,100,000 ac) in 1998 for erosion prevention during furrow irrigation in the U.S. (Orts et al. 1999). The use of PAM is considered a best management practice by the Natural Resources Conservation Service (NRCS), and is included in the NRCS' National Handbook of Conservation Practices (NRCS 2001). A review of PAM studies found that PAM stabilizes existing soil aggregates and prevents the detachment of soil particles (Seybold 1994). Rates of PAM as low as 1.12 kg/ha (1 lb/ac) dissolved in furrow irrigation water were efficient in reducing sediment, phosphorus, and nitrogen losses by 85- 99% (Lentz et al. 2002). Bjorneberg et al. (2000) applied PAM with sprinkler irrigation to the soil surface on a 2.4% slope with and without a straw mulch residue. The application of PAM with straw mulch was more effective at reducing runoff, erosion and phosphorus loss than either PAM or straw mulch alone. Shainberg et al. (1990) found that polyacrylamide applied at rates of 20 and 40 kg/ha (18 and 36 lb/ac) on a 5% slope increased infiltration rate by three times.

The longevity of PAM benefits in reducing runoff and erosion from the time of application is an important management question. Flanagan et al. (1997a,b) applied PAM at 20 kg/ha on 6% to 9% slopes resulting in significant reduction in runoff and sediment loss for the initial rainfall simulation. However, runoff and sediment reductions did not occur during the second (subsequent) rainfall simulation on the wet soil (Flanagan et al., 1997 a, b). Studies of PAM applied at higher rates (60 – 80 kg/ha) have shown continued reductions over many artificial or natural rainfall events (Peterson et al. 2002; Flanagan et al. 2002a,b).

Testing of PAM for erosion control on construction sites suggests that application rates will need to be higher compared to the rates found to be successful in furrow irrigation. Polyacrylamide solutions applied to bare soil at rates up to 6.7 kg/ha and applied as dry powder at 20 kg/ha did not reduce runoff volume or sediment loss on a 5% slope compared to bare soil alone, but straw alone did (Soupir et al. 2004). On 20-50% slopes, a straw mulch and seed combination reduced average runoff turbidity by 61% yet additions of up to 11 kg/ha PAM did not significantly reduce runoff turbidity (McLaughlin et al. 2002; Hayes et al. 2005). Substantially higher PAM rates have been shown to be effective; however, Roa-Espinosa (1999) found a treatment of 22.5 kg/ha PAM and mulch applied to dry soil (10% slope) decreased the sediment loss an average of 93% compared to the bare soil control. Flanagan et al. (2003) summarized a series of experiments on PAM applied at 20-80 kg/ha on slopes up to 45%. Polyacrylamide was found to significantly reduce runoff volume and sediment yield at application rates of 20 kg/ha on gentler slopes (6-9%) and 80 kg/ha on steep slopes (32-45%). Zhang et al. (1998) found that 20 kg PAM/ha PAM on a 6% slope reduced runoff volume by 44% and soil loss by 19% over a five month period. McLaughlin and Brown (2006) found that 19 kg PAM/ha reduced turbidity and sediment losses in some cases for slopes up to 20%, but

the results were not consistent among ground cover treatments. They also found some advantage in grass growth when PAM was applied.

6.2.8 State Agency Storm Water Programs

California Department of Transportation conducted jar testing to evaluate the ability of different coagulants to improve storm water quality at a wide range of water quality parameters and temperatures. The removal of solids (TSS and turbidity) was the main basis for deciding if a coagulant was effective. Chemicals tested included aluminum sulfate, ferric chloride, four polyaluminum chloride compounds, one polyaluminum hydroxchloride compound, one polyaluminum hydroxchloride polymer blend, one anionic polyacrylamide, one cationic polyacrylamide, and one polyaluminum hydroxychlorosulfate.

The most promising compounds were the two metallic salts (aluminum sulfate and ferric chloride), three polyaluminum coagulants and an anionic polyacrylamide. Further testing demonstrated a polyaluminum chloride compound performed the best at 100 mg/L. The concentration for the anionic polyacrylamide (PAM) was only 3.5 mg/L due to toxicity and did not perform as well at that concentration. An anionic PAM with a lower toxicity was not analyzed.

Michigan specifies the identification of on-site soil characteristics is essential to determine the correct product for application. Michigan has identified the following forms of PAMs that are potentially toxic to the aquatic environment and not suitable for use in the state:

- Non-food grade PAMs - These PAM may contain residual monomer acrylamides that may be toxic to the environment.
- Cationic PAMs.
- Emulsion-based PAMs or polymer that are pre-mixed in something other than water; these emulsions may be toxic.

Washington tested direct application of PAM on two construction sites. The PAM was spread dry using a held fertilizer spreader at a rate of 3 lb/ac, a level determined to be non-toxic. The PAM worked to reduce erosion for up to six weeks with suspended solids concentrations reduced 67% to 84% and turbidity 67% to 76%.

Idaho: PAM was applied in granular and liquid forms within an entire watershed for a two-week period to soils in the Conway Gulch in Idaho. It was concluded that PAM should be applied in solution or with an automatic applicator. The PAM was very effective in reducing erosion and did not negatively impact water quality at rates less than what is recommended by the Agriculture Research Service. The amount of PAM needed for adequate erosion control was variable. The amount required had to be adjusted throughout the study. Different products seem to have greater effects on erosion than others.

Virginia conducted a study that found anionic PAM application could reduce runoff sediment by up to 70%. Virginia has imposed the restrictions on the type of polymer that can be used. A summary of those restrictions are as follows:

- PAM must be anionic with a charge density of 8% to 35% by weight
- Ultra high molecular weight of 6 to 24 mg/mole
- Water-soluble, linear or non-crosslinked
- Highest grade (potable drinking water grad)
- Non-combustible
- Does not change pH
- Expiration date included
- Must be accompanied by MSDS and toxicity information
- Must be accompanied by manufactures written instructions to ensure proper use

Alabama produced a guide sheet for the use of anionic polyacrylamide. A summary of those restrictions are as follows:

- The acrylamide should meet monomer limits of < 0.05%
- The PAM should have a charge density of 10 to 55% by weight
- The molecular weight should be 6 to 24 mg/mole.
- PAM application rates should be adjusted based on soil properties, slope, and type irrigation system used.

PAM should be used in combination with other conservation and MBPs.

North Carolina: The DOT has used Floc Logs in numerous locations but no formal study was done to determine results. Most of the work on PAM has been done through North Carolina State University, either at their test facility or locations around the state. The solid PAM blocks have been proven to work under specific conditions as listed in 3.1.2.

The Department of Environment and Natural Resources – Division of Water Quality has established a protocol for determining acceptability of PAMs for turbidity control based on a 7-day chronic exposure using *Ceriodaphnia dubia* (water flea). Companies can submit the test data and the state will list the products with acceptable concentrations on a web site (http://h2o.enr.state.nc.us/ws/documents/pams_list.pdf). As of this writing four granular products from Applied Polymer Systems are listed, although several PAM blocks will likely be listed soon (the manufacturer had to establish anticipated concentrations first).

Georgia: The GA DOT has established a list of acceptable PAMs, which includes four manufacturers and essentially all of their products used for construction sites.

6.2.9 References

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7 Assessment of Current ROW Practice A.2.a (3), A.2.a (4)

7.1 Assess storm water related practices related to ROW

The Right-of-Way Procedures Manual and the TDOT Roadway Design Guidelines were reviewed for information regarding storm water related activities during the ROW process.

The **Right-of-Way Procedures Manual** has been prepared to assist the ROW Division employees, other TDOT personnel, and state government personnel as well as clientele not in state government on matters related to right-of-way. The initial focus was on land disturbance activities that take place before the project is let to construction. The Procedures Manual does not refer to timber removal, topsoil removal, grading or any other type of disturbance activity that could be negotiated by the property owner. TDOT ROW personnel indicate that the unwritten policy is that the removal of trees, stripping of topsoil, grading, etc. are discouraged and for the most part not allowed or negotiated with the property owner. Once property owners find out that the value of these items will be deducted from the formal offer, they rarely push the issue. Once the sale is final, the property owners no longer have rights to the land unless specifically described in the closing documents.

The removal of improvements (e.g., buildings) on a tract of land can take place in one of the following methods:

1. The owner retains the improvement and is responsible for removal.
2. The state retains the improvement and has it removed by an independent contractor through sealed bids or public auction.
3. The improvements are removed by the construction contractor once construction begins.

Methods 1 and 2 require the owner or successful bidder to provide a surety bond or deposit that is refunded once the improvement has been removed per the standard agreements. The standard agreements contain clauses with time limits that require the improvement to be fully removed including all debris resulting from said removal. If the improvements are removed by the contractor during construction, then this disturbance is treated the same as any other land disturbance activity by the contractor.

If the ROW department finds out that improvements have been removed, timber has been cut or grading has taken place without permission they turn the issue over to the State Attorney General to investigate the activities for prosecution of trespassing and theft.

The Procedures Manual does discuss the removal of Underground Storage Tanks (UST) and remediation or cleanup of contaminated parcels. This process is coordinated with TDEC and/or federal officials. The ROW Division has dedicated personnel that are

responsible for dealing with removal and cleanup of USTs. This process has been in place for several years and is working to address removal of UST's.

The TDOT **Roadway Design Guidelines** are documents that establish uniform guidance and procedures for roadway design activities within TDOT. The guidelines provide guidance for designers through the development of preliminary, right-of-way and construction documents for TDOT roadway projects.

These guidelines pertain to storm water issues by providing guidance for the designer in the development of drainage plans, erosion prevention and sediment control plans, coordination with ecology and environmental permits, right-of-way requirements, and earthwork as well as the many other requirements of construction documents.

7.2 Recommendations for improvements to current ROW guidelines

Suggestions for improvements to the **Right-of-Way Procedures Manual** include:

- Develop a written policy that timber removal, grading or other land disturbance activities by anyone other than TDOT or their representatives are not allowed once the sale is final. If disturbances such as these are necessary then the property owner must complete this activity before the sale and return the ground to stable conditions before the sale can take place.
- For removal of improvements by the original property owner or independent contractor, add wording such as the following to the standard agreements:

  > Once the removal of improvement including all debris has been completed, the responsible party shall seed, fertilize and mulch the disturbed ground to establish groundcover. This shall be accomplished in accordance with TDOT Standard Specifications for Road and Bridge Construction. Once groundcover (i.e., grass) has been reestablished, the performance bond or deposit will be released.

- If improvements that are to be removed are located immediately adjacent to a spring, stream, wetland, or other waters of the state the ROW personnel must contact the Regional Environmental Coordinator for guidance on additional measures that should be used to protect the waters of the state during removal.
- During initial field visits or assessments of proposed ROW, TDOT personnel should look for areas that are denuded, unstable and/or highly eroded. This does not include areas within stream banks that are naturally occurring or agricultural fields. This primarily pertains to areas that have been disturbed by mechanical means and not restabilized. An example would be grubbing of land after it has been clear-cut. Training of ROW staff will be required to help them understand what they should be looking for in the field. If areas such as these are observed the TDOT Regional Environmental Coordinator should be contacted for guidance. If an unstable piece of ground is contributing to pollution of a stream, and the state of Tennessee purchases that land, then the state becomes responsible for stabilizing the area and stopping the pollution to waters of the state. The Environmental Coordinator should be responsible for working with the ROW staff to develop a plan for stabilizing the parcel of land once it has been

purchased by TDOT. The regional staff should be responsible for ensuring that the plan is implemented after purchase.

- Either when the final offer is accepted or at closing consider developing a separate document for the property owner to sign that emphasizes the fact that once the sale is complete, the property owner no longer has any right to the land except as stated in the final signed agreement. Unless specially addressed in the closing documents the property owner is restricted from accessing the ROW to remove vegetation, improvements or other land disturbing activities. These actions would be considered trespassing and/or theft of property.

Suggestions for improvements to the **TDOT Roadway Design Guidelines** include:

- The flow (Q), water surface elevation and velocity for 2-year and 5-year storms are routinely required during the EPSC design and are useful in the field during construction. Consider adding this information to the drainage data contained on the profiles and culvert cross sections of the plans.
- Add emphasis on balancing the earthwork during design for the project. This will not always be possible but large waste or borrow quantities are expensive and can cause environmental impacts during construction.
- Since permanent detention basins are being required of certain projects, add guidance in the ROW section indicating that permanent basins should be contained within permanent ROW.

7.3 Assessment of procedures related to storm water infiltration and associated health and safety issues of temporary and permanent basins

Chapter 8 of the TDOT Drainage Manual addresses storm water storage facilities. The manual was recently developed and approved for use. The manual provides guidance for the design engineer to use during the development of construction documents. Numerous sections of the manual discuss safety, public health and infiltration so the design engineer has complete guidance for developing a facility that is both functional and safe. The manual is thorough and provides good overall guidance.

7.4 Recommendation for additions or revision of current procedures related to storm water infiltration and associated health and safety issues of temporary and permanent basins

The following items are recommendations for additions or changes to the State's right-of-way, design, construction or maintenance procedures related to temporary and permanent basins:

- One component of a safe design is educating the public about the health or safety issues related to permanent basins and drainage structures. Consider public

service announcements or development of a pamphlet that discusses these issues for distribution to property owners and the public.

- An inspection plan and maintenance plan for permanent facilities should be developed. If not maintained a permanent basin will not function properly and can become a public nuisance. Shallow water left standing for more than 72 hours is prime breeding habitat for mosquitoes. Routine inspections are needed so problems such as seepage can be found to prevent complete failure of the structure during rain events. Sediment and road debris will build up and need to be removed on a routine basis.
- Either a standard drawing or checklist of items to include in the construction documents should be developed. A good design that is not fully understood by the construction personnel will result in poor results. Once construction is complete, the project engineer should check the basin for accuracy and completeness.
- Develop a standard for some type of permanent marker to be placed in the bottom of the basin to indicate when sediment removal is required.
- When baffles are required to lengthen the flow path, consider using staggered rows of gabion baskets.
- For retention basins that will hold a permanent level of water consider adding an emergency release to the outlet structure so the pond can be drained.
- Consider adding a permanent access drive so the facility can be inspected or emergency maintenance can be performed when the slopes are wet.
- In Karst topography areas that are prone to developing sinkholes, consult with TDOT geotechnical staff to determine if a liner is warranted to prevent infiltration that could result in development of a sinkhole. This liner could be either a layer of clay or an impermeable geotextile liner.
- The guidelines indicate the emergency overflow should be designed for a 100-year storm. Consider adding guidance that downstream impacts should be investigated to determine the consequences of an embankment failure during a large storm event and considered in the final design.

8 Low-Impact Design and BMPs for Erosion and Sediment Control (A.2.a)

This section describes low impact design procedures, guidelines, and criteria that address erosion prevention through source control. The emphasis of this discussion is on minimizing high-risk locations or activities under control of the designer. Examples of items that are addressed include:

- Project sequencing
- Minimizing high risk locations and activities
- Maintaining existing vegetation
- Avoiding highly erodible areas
- Providing buffer areas for aquatic resources
- Providing for temporary and permanent basins
- Sediment control practices

Each of these elements is elaborated on below. They have one element in common and that is that they need to be considered early in the planning process. The first step in controlling erosion and sediment is to plan the construction activities to fit the site features, including topography, soils, drainage ways, and natural vegetation. Important considerations of the planning element include the proper use of vegetative and structural practices, and construction measures that control the location, volume and velocity of runoff.

8.1 Project Sequencing

One source control measure is project sequencing to minimize erosion and this can be a very effective means of reducing the hazards of erosion. Construction activities should be sequenced to minimize the exposed area and the duration of exposure. The objective is to sequence project activities to expose the smallest practical area of land for the shortest possible time. The clearing, grubbing and scalping of excessively large areas of land at one time is an unnecessary invitation to sediment problems. The total amount of disturbed area of a project should be minimized by carefully coordinating the opening of new areas with the restabilization of other areas. On the areas where disturbance takes place, the designers and site operators should consider staging of construction. Areas where construction is suspended for a short period should be temporarily seeded and/or mulched to reduce erosion. Staging of construction involves stabilizing one part of the site before disturbing another. In this way the entire site is not disturbed at once, and the time without ground cover is minimized. Temporary seeding and mulching involves seeding or mulching areas that would otherwise lie open for long periods of time. When the time of exposure is limited the erosion hazard is reduced.

When possible the most severe soil disturbing activities should be scheduled during the time of year that the erosion potential of the site is less. In Tennessee, the months of August through October are generally the driest; consequently, land disturbance in the most environmentally sensitive areas should be scheduled for this period if feasible. During the wetter months (winter and spring), construction vehicles can easily turn the soft, wet ground into mud, which is more easily washed offsite.

8.2 Minimization of High Risk Locations and Activities

Another source control measure to reduce the impact of construction activities is to avoid activities in environmentally sensitive areas or where the erosion potential is high. Potential nonpoint pollutant sources should be located away from steep slopes, streams, and critical areas. Material stockpiles, borrow areas, access roads, and other land-disturbing activities should be located away from critical areas such as steep slopes, highly erodible soils, and areas that drain directly into geologically or ecologically sensitive features. The exposure of litter, construction debris, and chemicals to storm water should be minimized to prevent them from becoming a pollutant source. Daily litter removal and screening outfalls and storm drain inlets may help retain these materials onsite.

Natural drainage patterns that exist on the site should be identified to plan around these critical areas where water will concentrate. Natural drainage ways should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage system. These natural drainage ways should be protected with vegetative buffers whenever possible. Fabricated ditches, diversions, and waterways will become part of the erosion problem if they are not properly stabilized. Care should also be taken to be sure that increased runoff from the site will not erode or flood the existing natural drainage system.

It is especially important to remove and stockpile topsoil for restabilization of the site. Although topsoil salvaged from the existing site can often be used, quantities may not be sufficient and additional topsoil may need to be imported. Since topsoils are also a seed source, imported soils should come from sites in the immediate area with similar vegetation associations.

Topsoil stockpiles should have perimeter protection to prevent loss of sediments and depending on the site, temporary seeding may be appropriate. Covering of topsoil stockpiles is discouraged because it can accelerate composting and high temperatures can kill valuable soil organisms. If cover is needed, spread the material in as shallow a pile as practical and seed with an appropriate temporary mix. Avoid introducing annual species that easily reseed or other unwanted perennial species. Large stockpiles should be stabilized with temporary seeding and/or mulching. In addition, spoils should not be stored within the 100-year floodplain where they can be disturbed during high flow conditions.

8.3 Maintaining Existing Vegetation on Site

Ground cover and root mass are the most important factors for preventing erosion. Any existing vegetation that can be saved will help reduce erosion. Vegetative cover shields

the soil surface from raindrop impact while the root mass holds soil particles in place. Vegetation also can trap sediments suspended in runoff. Grass buffer strips can be used to remove sediment from surface runoff from limited areas of disturbance. Good vegetative cover also slows the velocity of runoff and encourages infiltration.

The area of the watershed that is exposed to construction is important in determining the net amount of erosion. Reducing the extent of the disturbed area will ultimately reduce sediment loads to surface waters. Existing or newly planted vegetation that has been planted to stabilize disturbed areas should be protected by routing construction traffic around the areas and protecting natural vegetation with fencing, tree armoring, retaining walls, or tree wells. To the extent possible, avoid disturbing vegetation on steep slopes or other critical areas.

By clearing only those areas immediately essential for completing site construction, buffer zones are preserved and soil remains undisturbed until construction begins. Physical markers indicating the limits of land disturbance can ensure that equipment operators know the proposed limits of clearing. Before construction begins, the limit of clearing and limit of work identified on the site plan should be suitably marked. Environmentally sensitive areas that need to be protected and preserved should be delineated with construction fencing. Construction activities and construction traffic must be limited to the area identified on the site plan, and no stockpiling of materials, soils, or debris or other activity may occur outside of the limit of work. Where possible, construction traffic should travel over areas that must be disturbed for other construction activity. This practice will reduce the area that is cleared and susceptible to erosion.

The vegetation cover of a site should be evaluated by a qualified professional in the initial design phase of the project. This review should identify any environmentally sensitive vegetation stands that need to be preserved. The review should also identify any culturally sensitive trees that may require special attention over the course of construction activities.

8.4 Minimizing Disturbance to Highly Erodible Areas

Another source control objective is to minimize land disturbance of highly erodible areas. Soil properties that affect erodibility include particle size distribution, permeability, depth to water table and bedrock, plastic index or other stability problems such as interbedding. The most erodible soils generally contain high proportions of silt and very fine sand. The presence of clay or organic matter tends to decrease soil erodibility because of the natural cohesive nature of these soils. On the other hand, clay particles are often negatively charged and, once suspended, are difficult to remove by passive means. During the design development stage of a project, the parts of the site with high erosion potential should be mapped and efforts made to minimize the disturbance in these areas.

Steep slopes are a particular concern for erosion, with the primary considerations being slope steepness and slope length. All transportation projects have considerable area that would be considered steep slopes in normal building construction. For this reason, the rapid restabilization of disturbed areas is an essential source control practice.

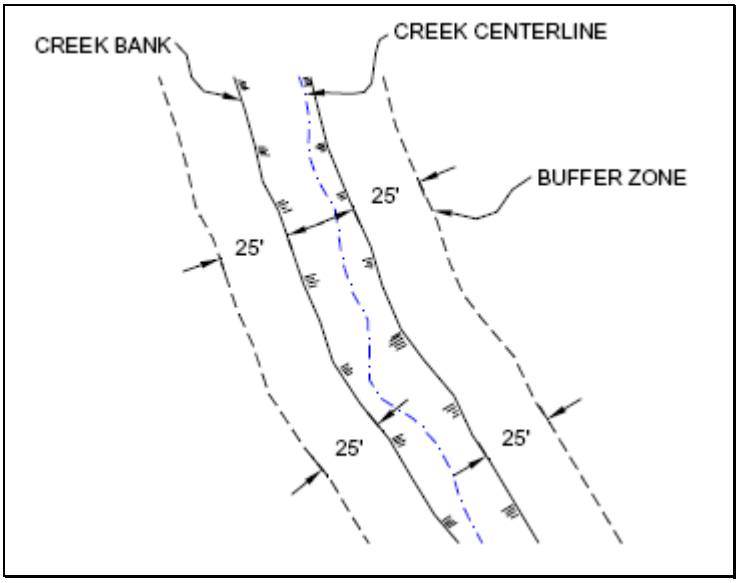
8.5 Buffer Areas for Aquatic Resources

Natural buffer areas are a source control element that should be preserved, to the degree possible, adjacent to sensitive aquatic resources such as streams, lakes, and springs. The size of the buffer can be dependent on the sensitivity of the receiving water, the presence of endangered species, or preservation of natural corridors along scenic rivers. TDEC has a relatively restrictive definition of a stream buffer, which states that they are "a strip of dense undisturbed perennial native vegetation." For the purposes of protecting water quality, stream buffers can assume a variety of configurations that include not only native, but adapted vegetation. In many cases, grassy areas can provide better improvement in runoff quality than areas with a dense canopy and little groundcover, although the presence of trees along the shoreline can help maintain lower temperatures in streams that serve as cold water fisheries. Finally, many areas adjacent to receiving waters may contain substantial amounts of adapted, but not native vegetation. Adapted plants can provide effectively the same water quality benefits and native vegetation, and their removal would only increase the amount of disturbance near the receiving water.

There is a variety of ways to define buffer widths based on setbacks from the creek banks, from the creek centerline, or from the 100-year flood plain.

Figure 8-1 illustrates buffers defined by a 25-ft setback from the creek bank. This configuration may be appropriate in upland areas where the streams are small and floodplain maps have not been developed.

Figure 8-1: Creek Setback from Edge of Channel



Another strategy that has been adopted in other jurisdictions (LCRA 2006) is to vary the setback based on the drainage area of the receiving water as shown in Figure 8-2. In this scenario, the buffers are defined from the creek centerline and the buffer width increases as one moves downstream (see Table 8-1).

These wider buffers provide corridors for wildlife and protection from flooding, in addition to water quality benefits.

Figure 8-2: Creek Setback from Centerline

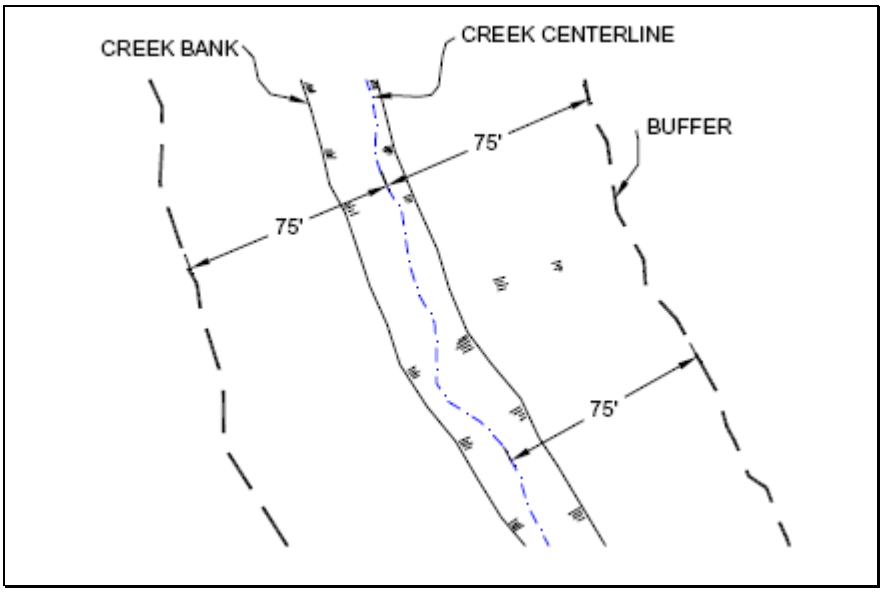


Table 8-1: Creek Setbacks based on Drainage Area

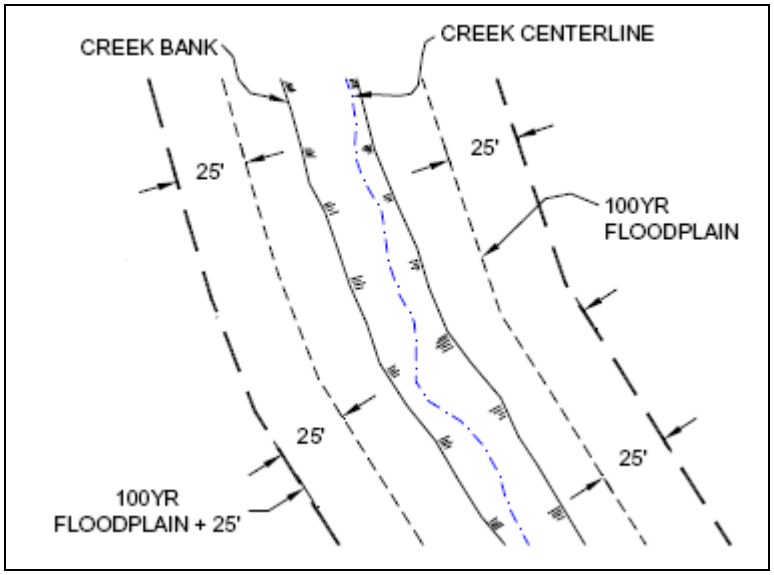
Drainage Area	Buffer Width from Creek Centerline
5 < Drainage Area < 40 acres	25 feet
40 < Drainage Area < 128 acres	75 feet
128 < Drainage Area < 320 acres	100 feet
320 < Drainage Area < 640 acres	200 feet
640 < Drainage Area	300 feet

A final strategy is to base the creek setback on the 100-year floodplain. In areas of relatively low topography, the floodplain width can be substantial, so little additional buffer is needed to protect water quality and other natural resources. Figure 8-3 illustrates a situation where a 25-ft wide buffer is provided from the boundary of the floodplain.

Our recommendation is that TDOT adopt a stream buffer policy that complies with the requirements set out in the Construction General Permit. The CGP requires an average 60 foot buffer with a minimum of 25 feet as measured from the top of the bank. The buffers

should remain undisturbed and be allowed to contain both native and adapted plant species at a density appropriate for the type of vegetation.

Figure 8-3: Creek Setback based on Floodplain



8.6 Providing for Temporary and Permanent Basins

The goal of EPSC measures is to retain sediment on the site. Even with careful planning, some erosion is unavoidable and the resulting sediment must be trapped on the site. The locations where sediment deposition will occur should be identified and access maintained for cleanout. Low points below disturbed areas should be protected by appropriate practices to prevent excess sediment loss. Sediment traps and basins must be in place before other land-disturbing activities begin.

This planning must be done early in the highway design process so adequate right-of-way can be purchased or leased for temporary catchments. Temporary sediment basins, as well as post-construction storm water treatment systems often have substantial footprints that will not fit within the standard right-of-way of a linear project. This is particularly true when runoff from a substantial portion of the highway project is piped to a discrete outfall, which normally occurs adjacent to natural drainages or other watercourses. Consequently, additional land should be considered for purchase or lease adjacent to water bodies to provide treatment space unless the storm water will be discharged via overland flow along the length of the highway. In these cases, adequate perimeter protection must be provided to prevent sediment deposition beyond the limits of the project.

8.7 Sediment Control Practices

Even with the best erosion control plan, some sediment will be generated and controlling it is the objective. Whereas erosion control practices are designed to prevent soil particles from being detached, sediment control involves using practices that prevent the detached particles from leaving the disturbed area and reaching the receiving waterways.

Sediment control practices are designed to slow the flow of water by spreading, ponding, or filtering. By so doing, the capacity of the water to transport sediment is reduced, and sediment settles out of suspension. Commonly used control practices include:

1. Preservation or installation of vegetated buffer areas downslope of the disturbed area to slow and filter the runoff;
2. Construction of small depressions or dikes to catch sediment (particularly coarse-textured material) as close to its point of origin as possible; and
3. Construction of sediment traps or basins at the perimeter of the disturbed area to capture additional sediment from the runoff.

The amount of sediment removed from the runoff is mostly dependent upon (1) the speed at which the water flows through the filter, trap, or basin; (2) the length of time the water is detained; and (3) the size, shape, and weight of the sediment particles. One approach to sediment control is to direct all surface runoff into large sediment basins that are regularly cleaned. Although this approach is arguably the simplest method to control sediment, it is often not the most cost-effective and it often fails to address the other principles described above.

One of the underlying concepts of source control involves breaking up the drainage areas of a site into very small catchment areas to disconnect hydraulically connected areas and to provide opportunities to increase the time of concentration and thus reduce peak discharges. This is reasonably easy on linear projects since they tend to cross multiple watersheds. Accordingly, this approach will benefit sediment control efforts by diffusing surface flow into many directions and providing more flexibility in the use of a variety of sediment control practices. This approach places heavier reliance on silt fences and small traps such as wattles, inlet protection, rock check dams, triangular Silt Dikes, etc. to control small catchment areas generally in the range of 1 to 3 acres in size. It will also allow more opportunity to integrate the use of vegetative buffers in sediment control.

Modifications to typical sediment trap or basin designs will improve sediment capture. A field study of typical sediment traps with rock and gravel outlets captured 59-69% of the incoming sediment over the course of multiple storms (Line and White 2001). Alternative dewatering methods have been demonstrated to improve sediment capture by using a perforated riser (Fennessey and Jarrett 1997; Ward et al. 1979; Edwards et al. 1999) or a floating skimmer (Millen, et al. 1997). Modeling results have also indicated that surface outlets such as the skimmer will greatly increase sediment capture compared to either bottom or full water column dewatering (Ward et al. 1979). Trapping efficiencies greater than 90% have been estimated to be needed to meet typical water quality standards (Ward et al. 1980). Monitoring of actual skimmer basins has indicated an average sediment

retention of 90%, but turbidity remained an order of magnitude above the 50 NTU standard (McLaughlin, unpublished data).

The addition of baffles made of silt fence also improved retention in basins but only about half as well as the skimmer (Millen et al. 1997). The combination of baffles and a skimmer were no better than the skimmer alone. In all cases, more than 90% of sediment >40 um was retained. It should be noted that a 24-hour dewatering time was used for both outlets, along with relatively low loading rates, which explain the high retention levels. Recently, porous baffles made of jute and coir erosion control blanket materials were demonstrated to be more effective than the silt fence baffles, capturing suspended sediment more than 50% smaller than open basins (Thaxton et al. 2004; Thaxton and McLaughlin 2005).

North Carolina has recently adopted the use of skimmers and porous baffles as standard practices and is encouraging their use starting in 2007. The new sections of the Erosion and Sediment Control Design Manual are available online at http://www.dlr.enr.state.nc.us/pages/manualsandvideos.html. Fact sheets on porous baffles (http://www.soil.ncsu.edu/publications/Soilfacts/AGW-439-59/AGW_439_59.pdf) and skimmers (http://www.age.psu.edu/extension/factsheets/f/F252.pdf) are also available. The substitution of a skimmer basin design, with a skimmer primary spillway and a stabilized emergency spillway, for a rock outlet or a perforated riser would not be expected to differ substantially in installation costs.

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9 Review of SSWMP and Public Input (A.5.f)

9.1 Introduction

An essential element of the construction site storm water management program is the periodic review of the guidance, manuals, procedures and policies that shape the program. Regulatory requirements, technology and the standard of care are in a relative state of flux necessitating changes to the construction storm water program at regular intervals. This requirement must be balanced against the need to manage the program on an administrative level including document revisions, training and reporting.

Storm water program review, evaluation and update are characteristically driven by regulatory requirements. Although the SSWMP portion of the Department's storm water program primarily reflects the state Construction General Permit, a construction storm water program is an element of the Phase 2 NPDES permit. The Department will receive its initial Phase 2 MS4 permit in the near future. Consequently, program review requirements and schedules have been structured so they complement and reflect the anticipated Phase 2 permit requirements.

The Department also maintains a Public Involvement Plan (PIP), most recently revised in February 2006. The plan generally addresses programs such as the SSWMP as a 'statewide' initiative categorized as a Level 5 activity. The Plan provides that the state will assess the appropriate level of involvement for Level 5 activities through the development of a separate public involvement program. This section describes the public involvement program for the SSWMP. As a Level 5 activity under the State PIP, the specific program should contain the following primary elements:

- Public Awareness Activities
- Community Outreach Activities
- Education/Feedback Activities
- Dissemination of Information
- Ongoing Assessment of public involvement program effectiveness

9.2 Department Draft NPDES Permit Program Review Requirements

The draft Department NDPES permit requires that the storm water program be reviewed annually to coincide with the preparation and submittal of the Annual Report. The Department is required to assess the effectiveness of the elements of the program and replace, modify or develop new elements to ensure that storm water practices continue to meet the applicable water quality standard.

The draft permit recognizes three categories of changes to the Department's program that must be documented in the Annual Report:

1. Additions to the program that do not replace or modify existing components. Additions to the program must be described in the Department's annual report and may be made by the Department at any time.
2. Changes to the program that will replace an ineffective BMP. A change to the program that replaces an ineffective BMP, provided an alternative BMP is developed, may be made by the Department at any time. The Annual Report must describe the replacement BMP and specifically include:
    a. An analysis of why the former BMP was ineffective or technically infeasible;
    b. A discussion of the effectiveness of the replacement BMP supporting its inclusion into the Department's program and conclusion that it meets the applicable water quality standard;
    c. An analysis, if applicable, of how the program change will ensure optimal use of Department resources.
3. Changes to the program that will eliminate an ineffective BMP or practice. A modification of this type does not replace an ineffective BMP with an alternative. Such a change must be accompanied by an analysis in the Annual Report that demonstrates that the Department's program will continue to meet the appropriate water quality standard, and contain the following specific information:
    a. An analysis of why the BMP or procedure was ineffective or technically infeasible, and
    b. An analysis of how the Department's construction storm water program will continue to meet appropriate receiving water quality requirements

9.3 Program Review Elements

The SSWMP is a compendium of policies, programs (such as training), guidance documents and manuals, specifications and standard drawings. Each of these program elements will be subject to self-audit to continuously improve performance. The Environmental Division will be responsible for coordinating the review of the SSWMP elements. The following documents and program elements will be reviewed annually by the division indicated.

Document or Program Element	**Responsible Division for Review**
Environmental Procedures Manual	Environmental
Construction and Maintenance Manual	Construction/Maintenance
Borrow and Waste Manual	Construction
Drainage Manual (Chapter 10)	Design
Program, Project, and Resource Management Activity Manual (PPRM)	Planning

Document or Program Element	Responsible Division for Review
Standard Specifications	Construction
Standard Drawings including Erosion Control Standard Drawings and Standard Notes	Design
Materials Acceptance and Approvals List (QPL)	Materials and Tests
Design Guidelines	Design
Right-of-way Procedures Manual	Right-of-Way

9.3.1 Prioritization

Annually, the Environmental Division shall prioritize review elements of the SSWMP with the goal of focusing on program areas that are under-performing. All elements of the Department's program will be reviewed each year; however, special priority will be given to those program areas as determined by the Storm Water Coordinators. The prioritization will be carried out by the Department's Storm Water Coordinator and will be provided to the Divisions with program review responsibilities so they can focus efforts and resources in the most urgently needed program areas. The Department's Storm Water Coordinator will implement this prioritization schedule with the goal of ensuring that all high priority elements of the Department's program are reviewed within the five-year permit term.

The Department's first annual program review will include the following priority elements.

- Training
- Erosion Control on Department Projects
- Final Stabilization
- Borrow and waste areas

9.4 Program Evaluation

The objectives of the program are to monitor the level of compliance in the field, evaluate trends, and recommend improvements. These objectives will be accomplished through the evaluation of the following information for each of the identified review elements:

Document or Program Element	Assessment Information
Environmental Procedures Manual	Annual review of SEMS and PPRM data for selected project(s).
Construction and Maintenance Manual	Review of QA assessment reports and review of inspection reports for sites with more frequent QA assessments. Review of regulatory actions (if any).
Borrow and Waste Manual	Review of inspection reports for borrow and waste sites. Review of regulatory actions (if any)
Drainage Manual (Chapter 10)	Literature review of current state of practice of Construction BMPs
Program, Project, and Resource Management Activity Manual (PPRM)	Assessment based on review of other program elements
Standard Specifications	Literature review of current state of practice of Construction BMPs. Assessment also based on review of other program elements
Standard Drawings including Erosion Control Standard Drawings and Standard Notes	Literature review of current state of practice of Construction BMPs. Assessment also based on review of other program elements
Materials Acceptance and Approvals List (QPL)	Literature review of current state of practice of Construction BMPs. Assessment also based on review of other program elements
Design Guidelines	Review of QA/QC and inspection reports.
Right-of-way Procedures Manual	Assessment based on review of other program elements

9.5 Public Participation and Outreach

9.5.1 Awareness

The Department maintains a discussion of the SSWMP process on its home page. There are also links to the Environmental Division's Beautification Office, which maintains many of TDOT's community outreach programs.

TDOT has divided the state into four geographic regions, and each region has a Community Relations Officer assigned to it. The Division of Community Relations has primary responsibility for developing and implementing the Department's public

involvement process. The Division's main role is to serve as the coordinating point for the department's outreach programs. This Division complements and supplements the efforts of other divisions by assisting them with public outreach and public involvement. It is charged with ensuring the public outreach process meets the Department's standards. The Division of Community Relations is charged with a yearly assessment and continuous improvement of the PIP.

9.5.2 Community Outreach

TDOT has assembled a unique collection of community outreach programs focusing on litter and litter prevention, which are a primary element of storm water pollution directly related to public activities. The Adopt-A-Highway, Scenic Highways, and Gateways to Tennessee programs advocate environmental stewardship through partnerships and networking with community groups, individuals, civic groups, non-profits, government agencies, and businesses. These programs feature opportunities for citizens to participate in the preservation of scenic vistas, building and maintaining of new landscapes, and roadside litter pickup activities.

The following programs are targeted for community outreach with the goal of environmental stewardship:

1. Adopt-A-Highway Program
2. Litter Grant Program
3. Junkyard Control Program
4. Outdoor Advertising Control Program
5. Vegetation Control Program
6. Tennessee Roadscapes
7. Scenic Highways/Tennessee Parkways/National Scenic Byways Program
8. Keep Tennessee Beautiful (Keep America Beautiful Affiliate)
9. Keep Tennessee Beautiful Advisory Council

For example, Tennessee's Adopt-A-Highway Program provides an opportunity for individuals and groups concerned about the environment to take an active role in preserving and protecting the state's natural beauty. The Adopt-A-Highway program is administered by the Environmental Division, Beautification Office.

Since the program's inception in 1989, volunteers have collected more than 12 million pounds of litter from Tennessee's roadsides. These valuable contributions are helping produce cleaner roadsides, reduce maintenance costs, and boost litter prevention awareness in the "Volunteer State." The program provides a tangible benefit to water quality while also raising awareness of water quality with the public.

9.5.3 Education/Feedback

The Department will develop and host or co-host technical workshops that focus on jobsite contractor and subcontractor responsibilities relative to the Construction General

Permit and construction jobsite water quality. The purpose of the workshops will be to ensure that contractors have contemporary information relative to BMP construction and maintenance.

Training content will include discussion of new product types, applications, and maintenance for sediment and erosion control practices. The training workshops will be presented by the TDOT Storm Water Coordinators in each of the four Regions. These workshops will be held on an as-needed basis and as resources allow and will be publicized through the Department's website and with printed materials.

A segment of the training program will include a forum to solicit feedback on potential areas of improvement to the Department's program. The feedback will be included in the draft and final Annual Report.

9.5.4 Dissemination of Information

The Department has developed, and is further developing an Internet website that includes information regarding the Storm Water Management Program. The website includes or will include schedule information on upcoming storm water outreach activities, copies of Public Education Program brochures and bulletins, information related to the BMP development process, construction, and maintenance activities, with links to key related sites.

The Department will also post a draft version of the annual report on the storm water web page with a request soliciting public input. Comments received will have responses prepared by Department personnel and included in an appendix of the final annual report, which will also be posted online. The Department will allow a 30-day public comment period of the draft annual report. Comments may be received either via the storm water web page or by written submission.

Glossary

AASHTO. American Association of State Highway and Transportation Officials.

American Society of Civil Engineers (ASCE). National engineering society representing over 130,000 civil engineers worldwide. For more information, visit the ASCE website at **http://www.asce.org**.

ARAP. Aquatic Resource Alteration Permit.

ASTM. American Society for Testing and Materials.

Best Management Practice (BMP). Schedule of activities, technologies, practice, methods, and maintenance procedures to prevent or reduce pollution.

BFM. Bonded Fiber Matrix.

BMP. Best Management Practice.

Code of Federal Regulations (CFR). Document containing all rules of the executive departments and agencies of the federal government and divided into fifty title volumes. Title 40 of the CFR (40 CFR) lists environmental regulations and is available from bookstores operated by the Government Printing Office and on the CFR website at **http://www.epa.gov/epahome/cfr40.htm**.

ED. TDOT Environmental Division.

Environmental Protection Agency (EPA). The federal agency with primary or oversight responsibility for implementing the federal environmental statutes, including the CWA, Clean Air Act, Safe Drinking Water Act and Resource Conservation and Recovery Act. Tennessee is included within EPA Region IV, headquartered in Atlanta.

EPA. (U.S.) Environmental Protection Agency

EPSC. Erosion Prevention and Sediment Control

FHWA. Federal Highway Administration.

Geographic Information System (GIS). Computerized data management system with tools designed to gather, store, retrieve, analyze, transform, and manipulate large amounts of geographic and demographic information to produce color-coded maps, three-dimensional virtual models, tables, and lists.

GIS. Geographic Information System.

MS4. Municipal Separate Storm Sewer System.

Municipal Separate Storm Sewer System (MS4). Storm drain systems regulated by the federal Phase I and Phase II storm water regulations. Municipal *combined* sewer systems are regulated separately. MS4s are defined in the federal regulations at 40 CFR 122.26(b)(8).

Glossary

National Cooperative Highway Research Program (NCHRP). An applied, contract research program administered by the Transportation Research Board (TRB) and sponsored by the member departments (i.e., individual state departments of transportation) of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration (FHWA) to conduct research in acute problem areas that affect highway planning, design, construction, operation, and maintenance nationwide.

NCHRP. National Cooperative Highway Research Program.

NPDES. National Pollutant Discharge Elimination System.

NTPEP. National Technical Product Evaluation Program (AASHTO sponsored).

PPRM. Program, Project, and Resource Management.

QPL. (TDOT) Qualified Products List.

RUSLE. Revised Universal Soil Loss Equation

TDEC. Tennessee Department of Environment and Conservation.

TDOT. Tennessee Department of Transportation.

TIP. Transportation Improvement Plan.

TRM. Turf Reinforcing Mat.

TTI. Texas Transportation Institute.

TVA. Tennessee Valley Authority.

TxDOT. Texas Department of Transportation.

USACE. U. S. Army Corps of Engineers.