Chapter 1
Introduction

Project Description

This report covers the activities completed under Contract # 3C-R023-NTEX, Filter Fence Design Aid for Sediment Control at Construction Sites. Filter fence and silt fence are used interchangeably in this report. The objective of the project was to better understand and model the failure mode of a silt fence as a result of flow along the toe of the fence. Such flow can result in erosion of the soil that holds the fence's toe in the ground, resulting in eventual undercutting.

The project was divided into three phases as follows:

Phase I:

- Create, test, and revise a preliminary design model to assess silt fence installations and guide the planning of the field testing.
- Conduct field assessments of existing silt fence sites.

Phase II:

- Evaluate the preliminary design model using data from the site visits.
- Use the preliminary design model to determine final design of filter fence and protocol for field testing.
- Develop final procedures for field testing.

Phase III:

- Conduct field testing under a range of conditions to clarify the hydraulics, sediment transport, conditions leading to failure, and overall performance of silt fences.
- Combine information from the field testing with previously developed hydrology, hydraulic, and sedimentation models to develop a model of silt fence performance.
- Develop practice recommendations and a design aid based on the model.

Background

Sediment is a pollutant of concern because it is one of the leading causes of stream impairment across the United States and results in degradation of aquatic life. At a recent EPA invitation-only conference on sediment control in Cincinnati, OH (EPA, 2002), the lack of effective and economic technologies for sediment control was identified as a major issue. This paucity of technologies is a significant problem for all construction and maintenance operations in residential, commercial, and industrial development, the petroleum industry, highway and other infrastructure construction, and other activities requiring earth moving.

Currently, a silt fence is the most frequently used structural best management practice (BMP) technology that does not cause disruption of additional off-site space. As currently constructed, filter fences consist of a geotextile filter fabric supported by posts and (ideally) anchored along the toe. Its purpose is to retain sediment from small-disturbed areas by providing a detention time to allow for sediment deposition (Smolen et al., 1998). Sediment ponds, for example, are also used, but require the use and disruption of additional land. Although silt fences are widely used, it has been found, in a recent national study (EPA, 2002), that they are usually ineffective. Further, on some construction operations, silt fences have been found to cause a concentration of overland flow, creating worse problems than having no BMP at all.

Although several laboratory studies have proposed that a silt fence can be effective in trapping a high percentage of sediment, the very few limited field evaluations that have been conducted indicate that field installations of silt fences trap a very low percentage of sediment (Barrett et al., 1995). Field inspections (Barfield and Hayes, 1992; 1997) have also found that silt fences were seldom installed according to standards and specifications, and when actually installed according to the best current standards, they were still not effective in controlling sediment. Further, overland flow concentrated by the silt fence can seek the weakest spot on the fence and undercut the fence or flow through cuts in the fabric. The result is that shallow overland flow coming into the site is transformed into concentrated flow downslope from the fence, actually increasing the amount of erosion.

Studies have shown that by removing the surface cover and disturbing the parent soil material, construction operations increase sediment yield by as much as 10,000 times that of undisturbed sites (Haan et al., 1994). As this excess sediment moves into streams and waterways it not only increases the cost of water treatment and reduces reservoir storage capacity through deposition, but also modifies the stream systems and destroys the habitat of many of our desirable aquatic species (Smith et al., 1992; EPA, 2001). Ongoing research by the Agricultural Research Service (ARS) showed that the reduction in species diversity is strongly related to the number of hours sediment load exceeds 1,000 mg/L, a sediment concentration that is frequently two orders of magnitude below that in runoff from most construction sites (EPA, 2002). Clearly, methodologies are needed to reduce sediment loads to levels that maintain habitat and species diversity. The only method currently available that does not disturb large amounts of additional landscape is a silt fence, which has not proven to be effective, as will be discussed below.

Laboratory studies of the performance of silt fences using carefully controlled conditions have cited trapping efficiencies in the range of 40 to 100%, depending on the type of fabric, overflow rate, and detention time (Barrett et al., 1995; Wyant, 1980; Wishowski et al., 1998; Britton et al., 2001). Based on these data, the EPA reported in 1993 (EPA, 1993) that a silt fence can have trapping efficiencies for total suspended solids of 70%, for sand of 80 to 90%, for silt loam of 50 to 80%, and for silty clay loam of 0 to 20%. A recent evaluation of sediment control technologies conducted by the EPA has not substantiated these claims (EPA, 2002). The results cited in this study show that field-trapping efficiencies are very low. In fact, Barrett et al. (1995) obtained a value of 0% trapping, averaged over several samples with a standard error of 26%. Barrett et al. (1995) speculate that the field tests do not show results similar to lab tests because of: 1) inadequate fabric splices; 2) sustained failure to correct fence damage resulting from overtopping; 3) large holes in the fabric; 4) under-runs or under-cutting due to erosion of the toe ditch; and 5) silt fence damage and partially covered by the temporary placement of stockpiles of materials.

Field inspections conducted by Barfield and Hayes (1992; 1997) in which more than 50 construction sites were visited in South Carolina and Kentucky revealed that silt fences were frequently not installed according to standards and specifications, and further, were frequently ineffective when actually installed according to standards. In those areas where installations did meet standards and specifications, lateral flow often occurred along the toe of the fence until finding the weakest spot on the fence. At that point, it either undercuts the fence, flowed through cuts in the fabric, or overtopped. Thus, the fence converted shallow-overland flow into downslope concentrated flow, frequently causing significant, concentrated-flow (gully) erosion.

One recent long-term study has shown promise for the use of silt fences. The US Forest Service at their Rocky Mountain Research Station (Robichaud and Brown, 2002; Robichaud et al., 2000) investigated the use of a silt fence as a tool to measure erosion. In this study, they placed the silt fence across the slope and curled the ends uphill to prevent flow from going around the ends of the fence. In addition, they buried the toe of the fence upslope from the location of the fabric and wrapped the fabric around the toe trench to prevent flow over the exposed toe. An average trapping efficiency of 93% was measured over the season. They cited cleanout and maintenance as requirements to make the silt fence perform reliably.

Reasons for the poor performance of a traditional silt fence include:

1. Erosion and failure of the toe of the fence from concentrated flow caused by cross contour installations.
2. Failure to trap fines due to inadequate detention time.
3. Structural problems, including;
    a. inadequate strength of the fence fabric resulting in failure from excessive stretching in the downstream direction, and
    b. breaking and overturning of the support post due to inadequate strength and stability of the footing.
4. Post-installation problems, such as;
    a. vandalism as well as destruction by construction equipment, and
    b. lack of maintenance.

Problems 1 to 3 can be solved by more effective design as can parts of problem 4. Complete solution of problem 4 will also require more effective regulation and inspection.

Although current silt fences have a high frequency of failure, their continued use has some positive aspects, such as being relatively inexpensive, adaptable to a wide variety of sites, and suitable for implementation without major additional disturbances to the landscape beyond those required for construction. Thus it seems prudent to evaluate the performance of a silt fence under a range of controlled conditions leading to procedures for the user community to:

- Assess the conditions under which a silt fence can be applied to a particular site.
- Develop a design that is specific to that site.

Development of such procedures was the ultimate objective of this project. In the development of the procedures, the following steps were taken:

- A preliminary model was selected and used to design a test facility where rainfall could be generated on an erosive surface and flow directed toward a silt fence oriented at varying angles to the contour.

- The test facility was constructed and calibrated.
- Data were collected on three silt fence fabrics with varying cross contour angles using three different textured soils.
- A final model was developed and tested on data generated at the test facility.
- The model was incorporated into a spreadsheet computer program that is available as a design aid.
- Recommendations were made for improvements to silt fence design and installation.

Each of these items will be covered in this report.