

Development of Silt Fence Tieback Design Methodology for Highway Construction Installations

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This research effort focuses on improving sediment control practices used at highway construction projects by employing properly designed and correctly installed silt fence applications. Previous research indicated that tying silt fence installations back into the contour and creating a J-shaped hook (or a tieback) is an effective way to improve the efficiency of silt fence installations. Silt fences with tiebacks form a temporary detention basin, which helps facilitate sediment removal by sedimentation. The purpose of this research was to develop a rational numerical method for designing such silt fence tiebacks at highway construction sites. The proposed method employs a hydrological model to estimate the volume of runoff water generated by the watershed and balances the water with the storage capacity of the silt fence installed with a tieback. First, the Soil Conservation Service's method is used to estimate the amount of storm water generated during a design storm event. Then, with the cross-sectional data from a highway construction project, a graph is generated to estimate the storage volume available behind a silt fence for various ditch and highway slopes. Using these data, the designer can determine the proper placement frequencies of silt fence tiebacks along a linear highway construction project. This paper provides the mathematical details of this novel design procedure. An example problem is also provided to illustrate its practical applicability.

Because of the rapid rate of urbanization occurring within the United States, contamination of surface waters by construction site storm water runoff has become a major environmental concern. After a storm event, construction site runoff can flush various types of environmental pollutants into the storm water drainage systems, which ultimately will be discharged into waterways. Among the pollutants commonly discharged from construction sites, suspended sediments are the main pollutant of concern (1). The sediment-laden runoff waters discharged from construction sites can cause reservoirs and harbors to clog with silt, cause the loss of recreational areas and wildlife habitat, and reduce the beneficial uses of water for humans by harming the plant, animal, and fish species that live in the water.

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The construction site runoff management measures that are designed to provide practical field-scale solutions to various types of nonpoint pollution problems are known as best management practices (BMPs). A BMP either can be a device, practice, or method used to remove, reduce, retard, or prevent storm water pollutants from reaching water bodies. Common BMPs used at highway construction sites include check dams, rip rap, sediment basins, turbidity curtains, and sediment barriers (e.g., wattles, haybales, sandbags, and silt fences).

During a construction project, a construction best management practices plan (CBMPP), also known as an erosion control plan, is developed to incorporate all of the practices and temporary sediment control measures. The objective of these measures is to reduce or prevent erosion on construction sites and to minimize the impacts of sediment and hydrological changes off-site (2). CBMPPs are developed and utilized by designers to provide proper guidance to owners, inspectors, and contractors “in preventing erosion and controlling sediment during construction” (3). CBMPPs consist of drawings developed during design that identify the type of BMP and installation location that will provide an effective means of erosion and sediment control on the construction site.

Among available erosion control methods, silt fences are the most commonly employed BMP in the CBMPP on highway construction projects. Silt fences are small, temporary structures typically constructed of geotextile filter fabric supported by steel or wood posts. Silt fence installations typically function as a perimeter sediment control that filters suspended solids out of impounded storm water runoff before leaving the construction site. To be successful, the silt fence must be designed and installed in a manner that creates a containment system, allowing suspended particles to be deposited. As a result, proper installation and rigorous maintenance practices are essential (4). This research effort focuses on improving sediment control along highway construction projects using properly designed, correctly installed, and rigorously maintained silt fence installations. Our literature review indicated that tying silt fence installations back into the contour (creating a J-shaped hook) to form a temporary detention basin that can trap sediments is an effective way to improve the conventional silt fence designs (5–7). Previous studies also have suggested that approximately 75% of the suspended solids contained in construction site runoff were removed by the process of sedimentation in the ponds that formed behind fences (8). More recently, Zech et al. (9) investigated the effectiveness of silt fence tiebacks in removing sediment from storm water runoff on an intermediate-scale highway erosion model. The model was able to simulate off-site sediment migration from a highway construction site equipped with a silt fence installation configured with and

without a tieback. After comparing sediment data from a linear silt fence installation with and without a tieback, the authors concluded that silt fence tiebacks, if installed correctly, are effective in removing approximately 90% of the sediment contained in the storm water runoff. The authors also concluded that further research is required to develop objective design methods that will relate the frequency of tiebacks along a linear silt fence installation to the ditch slope, rainfall intensity, and soil properties of a typical highway construction site.

Currently, no rational design methods are available for determining the specified interval spacing for placing tiebacks along a silt fence installation. The *Kentucky Erosion Prevention and Sediment Control Field Guide* recommends installing J-hooks every 40 to 80 ft (10), while the Tommy® Silt Fence Machine recommends not having a linear silt fence installation longer than 200 ft when installing tiebacks (11). The *Iowa Statewide Urban Design Standards Manual* recommends that a 20-ft length of silt fence (i.e., J-hook) should be turned uphill at 200-ft intervals (12). These empirical tieback designs and the lack of consistency among the documented design recommendations are major drawbacks of the tieback application during the design and installation of silt fence as a perimeter sediment control. It appears that a gap exists in the body of knowledge as to the proper placement and design of silt fence tiebacks along highway construction projects. Therefore, research is needed to develop objective design methods that will relate the frequency of tiebacks along silt fence installations to the site-specific parameters, such as the roadway and ditch slope, rainfall intensity, and soil properties.

The goal of this research is to develop a silt fence tieback design methodology to assist designers, inspectors, and contractors in the proper placement of silt fence tieback installations along highway construction projects. The specific objectives of this research are to

1. Perform field investigations to identify the specific needs required for improving silt fence BMPs on highway construction projects,
2. Develop a silt fence tieback design method that models the storage capacity versus the length of silt fence before the installation of a tieback at various toe-of-slope grades, and
3. Demonstrate the use of the design procedure using an example problem.

SITE INVESTIGATIONS

The first objective was to obtain a better understanding of the erosion process, identify commonly utilized BMPs, and evaluate the overall effectiveness of the various BMPs. The first stage of the research focused on conducting several site investigations of highway construction sites. Although highway construction projects employ a multitude of erosion control measures, the use of silt fence as a sediment barrier at the base of fill slopes along the right-of-way (ROW) boundary appeared to be the most utilized BMP. In most cases, this erosion control boundary is the last erosion control measure installed to prevent any sediment generated on a construction site from entering the surrounding stream network. The primary functional responsibility of silt fence installations is to reduce the impact of sediment pollution on the environment, wildlife species, and adjacent property owners by containing sediment and impounding storm water.

The site investigation efforts quickly revealed five common failure modes of silt fence applications:

1. The watershed area above silt fence installations generated excessive storm water that exceeded the silt fence storage capacity.
2. Undercutting of the silt fence toe allowed sediment to migrate underneath the silt fence.
3. When the silt fence was improperly tied to the contour, it allowed sediment to travel around the end of the fence boundary.
4. Improper maintenance practices allowed sediment to accumulate higher than the silt fence, eventually overtopping it.
5. Improper installation caused the silt fence to fail.

Of the five major failure modes, avoidance of the last two depends on the vigilance of the owner, contractor, engineer, and inspector of the construction project. The first three failure modes occur primarily because of improperly designed silt fence installations. Incorporation of silt fence tiebacks, essentially turning the silt fence back upslope at predetermined intervals along fill slopes, can address all three of these failure modes on typical highway construction projects. The first failure mode will be addressed by effectively designing, sizing, and configuring the silt fence tieback system to satisfy the capacity required by the upslope watershed. The tieback system addresses the second failure mode by creating intermittent check dams that reduce the velocity of concentrated flow along the toe of the fence, minimizing erosive forces. Finally, if the silt fence tieback is properly anchored into the fill slope at the proper elevation equal to the top of the silt fence at the toe, sediment will not be allowed to bypass the end of the fence, therefore addressing the third failure mode. In practice, a definite need exists for the development of silt fence tieback design methodology that can be used by designers, inspectors, and contractors to assist in the proper design, placement, and installation of silt fence tiebacks along highway construction projects.

In order for the design methodology to be effective, practitioners need to directly address the three major failure modes identified in the site investigation. An effective silt fence tieback design must properly size the upslope watershed; attain a balance between the storm water runoff volume and the computed storage capacity of the silt fence per unit length of silt fence installation; and demonstrate how to properly anchor the silt fence tieback into an elevation equal to the top of the fence at the toe. If implemented correctly, the silt fence tiebacks will essentially act as small sediment basins for detaining storm water runoff and allowing sediment to settle out of suspension, thereby reducing the sediment load leaving highway construction projects and entering natural waterways.

SILT FENCE TIEBACK DESIGN METHODOLOGY

The tools used for developing the silt fence tieback design methodology include a hydrological model based on the Soil Conservation Service's (SCS) curve number (CN) method. This model is used to estimate the amount of storm water runoff generated from a watershed or construction site during a specified storm event per unit length of roadway. The overall objective is to develop a silt fence tieback design methodology flexible enough to be adapted to individual construction projects on a case-by-case basis.

Design Step 1. Methodology for Predicting Storm Water Runoff Volume

To determine the storm water runoff volume, the SCS method was used. According to this method, the relationship between excess

rainfall, P_e , and total rainfall, P , on a 24-h basis is computed using the expression (13):

$$P_e = \frac{(P - I_a)^2}{(P - I_a) + S} \quad (1)$$

where

- P_e = excess rainfall (in.),
- P = total rainfall in 24-h period (in.),
- I_a = initial abstraction (in.), and
- S = maximum potential retention (in.).

From the results of studies on many small watersheds, an empirical relationship was developed for the initial abstraction before ponding, I_a :

$$I_a = 0.2S \quad (2)$$

Using Equation 2, Equation 3 can be modified as:

$$P_e = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad (3)$$

The maximum potential retention is related to the CN by the following relationship:

$$S = \frac{1,000}{\text{CN}} - 10 \quad (4)$$

where S is the maximum potential retention (in.) and CN is the curve number.

The runoff CN for varying land uses needs to be selected from the appropriate hydrological table. After computing the maximum potential retention, S , and the initial abstraction, I_a , the excess rainfall, P_e , from a storm event can be calculated using Equation 3. The total volume of storm water runoff flowing over the watershed under consideration is obtained by multiplying the excess rainfall by the watershed area using the formula:

$$V_{\text{total}} = \frac{(P_e \times A_{\text{watershed}})}{12} \quad (5)$$

where

- V_{total} = total volume of storm water runoff (ft³),
- P_e = excess rainfall (in.), and
- $A_{\text{watershed}}$ = area of watershed (ft²).

To simplify the computation of the storm water runoff volume from a typical highway construction site, the following procedure can be used. The parameters required from the designer or inspector include site-specific data, such as the roadway geometry, the design storm precipitation for the local project, and the CN associated with hydraulic characteristics of the watershed area that the silt fence is being design to contain.

The geometry of the construction site is required to compute the area of the watershed under consideration. The parameters required by the designer when computing the area of the watershed include the width of the roadway, shoulder, and fill slope, along with the length of the section for which the silt fence is being installed. The watershed area can be calculated using Equation 6:

$$A_{\text{watershed}} = (W_1 + W_2 + W_3) \times L_1 \quad (6)$$

where

- $A_{\text{watershed}}$ = area of watershed (ft²),
- W_1 = roadway width (ft),
- W_2 = shoulder width (ft),
- W_3 = fill slope width (width from shoulder to ROW) (ft), and
- L_1 = length of the fill section (ft).

The second parameter required by the designer is the amount of rainfall that can be expected from a 24-h storm event, P , that the project might experience based on historical local rainfall data.

The final parameter required to compute the volume of runoff that can be expected on-site is the CN for the typical project cross section. The CN for a typical highway construction site is a weighted average combining the hydrological characteristics of the roadway, the shoulder, and the fill slope on the project. The weighted CN values can be computed using the equation

$$\text{CN}_{\text{weighted}} = \frac{[(\text{CN}_1 \times W_1) + (\text{CN}_2 \times W_2) + (\text{CN}_3 \times W_3)]}{(W_1 + W_2 + W_3)} \quad (7)$$

where

- $\text{CN}_{\text{weighted}}$ = weight average of watershed curve numbers,
- CN_1 = roadway curve number,
- CN_2 = shoulder curve number, and
- CN_3 = fill slope curve number.

Example Problem: Computation of Storm Water Runoff Volume

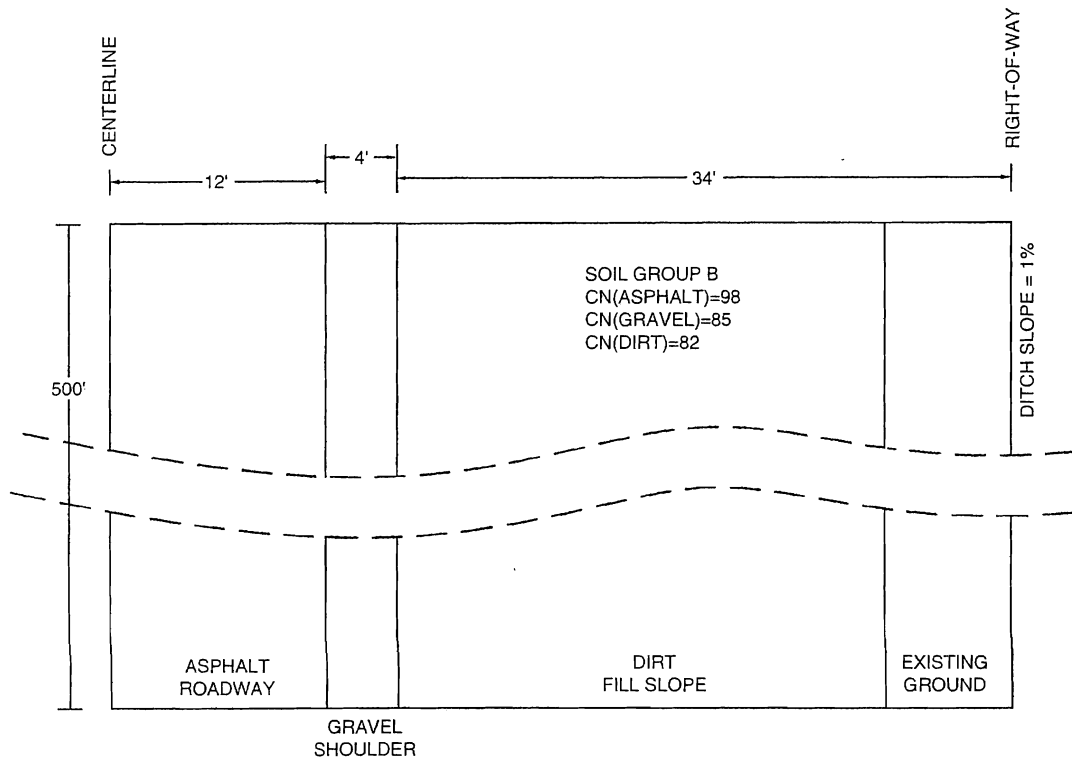
The U.S. Environmental Protection Agency (EPA) states that silt fence should be designed to withstand the runoff from a 2-year, 24-h storm event (14). Using this design guidance in conjunction with Technical Paper 40, the precipitation for a 2-year, 24-h storm event is approximately 4.25 in. for Auburn, Alabama (15). With this information, the first part of the design methodology can be applied by using the problem information detailed in Figure 1 to compute the total volume of storm water runoff for this example highway construction project.

From Figure 1, the widths of roadway, shoulder, and fill slope along with the length of the section under consideration are 12 ft, 4 ft, 34 ft, and 500 ft, respectively. Using Equation 6, the area of the watershed for which the silt fence system is being designed can be computed as below:

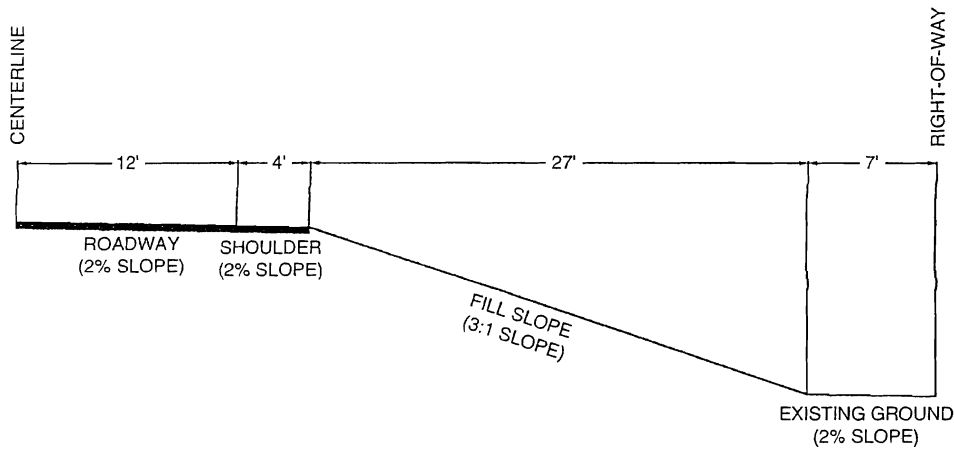
$$A_{\text{watershed}} = (12 \text{ ft} + 4 \text{ ft} + 34 \text{ ft}) \times 500 \text{ ft} = 25,000 \text{ ft}^2 \quad (8)$$

The SCS CNs for the roadway, shoulder, and fill slope can be selected by the designer from the appropriate hydrological table (13). The CN values, assuming Soil Group B in this example, for the roadway, shoulder, and fill slope are 98, 85, and 82, respectively. Using these CN values and the width dimensions of all three components, the weighted CN value can be computed for the watershed area using Equation 7. The computation is shown below:

$$\text{CN}_{\text{weighted}} = \frac{[(98 \times 12 \text{ ft}) + (85 \times 4 \text{ ft}) + (82 \times 34 \text{ ft})]}{(12 \text{ ft} + 4 \text{ ft} + 34 \text{ ft})} = 86 \quad (9)$$



(a)



(b)

FIGURE 1 Example problem illustrations: (a) plan view and (b) cross-section view.

Next, the excess precipitation needs to be computed to determine the total runoff volume that can be expected from the watershed under consideration. First, the designer must compute the maximum potential retention (S) of the watershed using Equation 4 and the weighted CN number computed in Equation 9. The computation for S is

$$S = \frac{1,000}{86} - 10 = 1.62 \text{ in.} \quad (10)$$

With the value for the maximum potential retention of 1.62 in. and Equation 2, the initial abstraction can be computed as follows:

$$I_o = 0.2(1.62 \text{ in.}) = 0.32 \text{ in.} \quad (11)$$

Now the excess precipitation (P_e) can be calculated with Equation 3. The calculation for P_e is

$$P_e = \frac{(4.25 \text{ in.} - 0.32 \text{ in.})^2}{[4.25 \text{ in.} + 0.8(1.62 \text{ in.})]} = 2.78 \text{ in.} \quad (12)$$

Using an excess precipitation of 2.78 in. and a watershed area of 25,000 ft², the total volume of runoff expected for this highway construction site can be determined using Equation 5 as

$$V_{\text{total}} = \frac{(2.78 \text{ in.} \times 25,000 \text{ ft}^2)}{12} = 5,792 \text{ ft}^3 = 43,340 \text{ gal} \quad (13)$$

After completing the first part of the methodology and using the project-specific data illustrated in Figure 1, the total runoff volume for the 2-year, 24-h design storm is 5,794 ft³ or 43,340 gal. Now the designer must estimate the required length of silt fence that will contain the computed storm water volume before installing a tieback.

Design Step 2. Methodology for Predicting Silt Fence Storage Capacity

The second step of the general design methodology for determining the proper placement of silt fence tiebacks along a highway construction project is to compute the storage volume behind the silt fence system per linear foot of silt fence installed along the ROW. The storage volume calculations are based on the silt fence installation concepts shown in Figure 2. We propose that the silt fence tieback should be anchored into an elevation equal to or greater than the top height of the silt fence at the toe of slope, as illustrated in Figure 2. This is an optimal design for installing the tieback configuration because, as demonstrated in Zech et al. (9), this design ensures that (a) storm water runoff will accumulate behind the tieback, (b) the storm water runoff will not be able to bypass the toe of the silt fence tieback, and (c) simultaneous failure will occur over the top of the silt fence along the ROW and around the toe of the tieback. Finally, this installation technique guarantees the maximum

amount of storage volume along the length of the silt fence and hence increases the silt fence installation length before requiring a tieback along the ROW.

Figure 3 illustrates the required design parameters that must be known by the designer to determine the length of silt fence required to calculate the cumulative total storage volume per linear foot along the silt fence installation. To estimate the silt fence length that is adequate to impound the storm water runoff, the design requires the existing ground slope (S_1), the fill slope (S_2), the ditch slope (S_3), the length of the existing ground (L_1), the unit length of fence (L_3), and the height of the silt fence (H_1). In this research effort, we use these geometric parameters to compute numerically the length of silt fence and the number of tiebacks required to contain the runoff volume generated from the watershed for a typical highway construction site. The computations were done in a spreadsheet program.

The spreadsheet calculations used various geometric parameters to determine the total silt fence storage volume for project-specific conditions. The length of the silt fence was segmented into typical cross-sectional elements, shown in Figure 3, to compute the volume of water contained within one unit length of silt fence (L_3). The unit length of silt fence (L_3) represents infinitesimal longitudinal increments arbitrarily selected by the designer. The unit length is selected based on the desired amount of accuracy required by the designer for computing the total storage volume. Once the area of water was calculated per unit length of silt fence for two cross sections, the values were averaged and multiplied by the unit length of silt fence to determine a cumulative volume per unit length. As the length of silt fence increases toward the upslope end, the height of the water decreases at the face of the silt fence. Eventually, the height of the water at the toe of the silt fence will diminish to zero, signifying that the maxi-

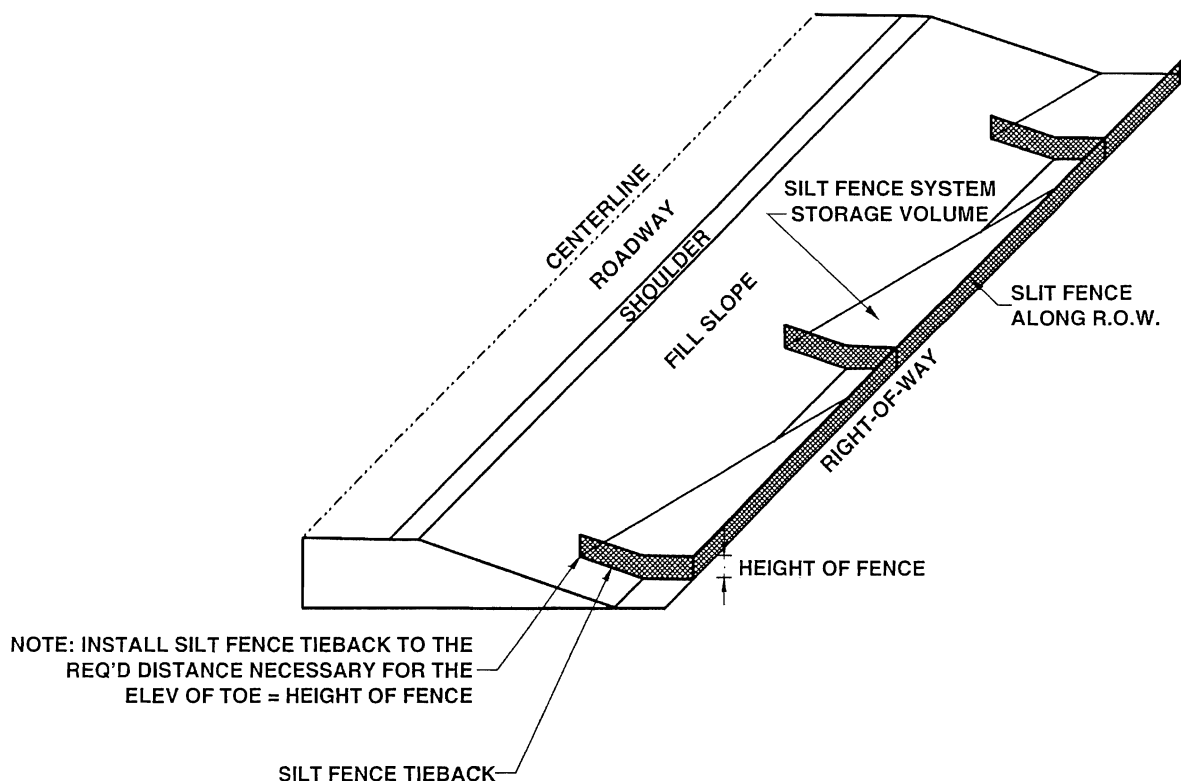


FIGURE 2 Silt fence tieback configuration.

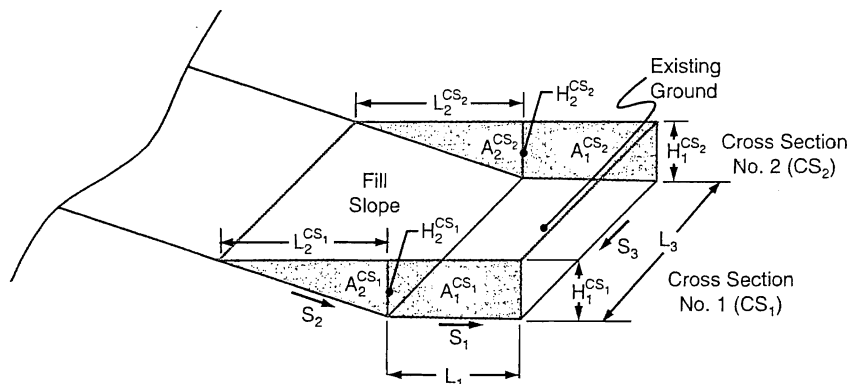


FIGURE 3 Required typical section data per unit length of silt fence.

imum storage volume of the silt fence system has been obtained. Once this parameter is met, the incremental volumes are summed to compute the total cumulative volume attained by the silt fence length and tieback configuration. From these numerical calculations, a graph was developed by plotting the silt fence length versus cumulative volume per unit silt fence length. The graph can provide an estimate for the linear length of silt fence that will satisfy a specific total storage volume requirement. The detailed calculation procedure for implementing this method is shown in the example below.

Example Problem: Computation of Silt Fence Storage Capacity

In the first part of the example problem, we estimated the total runoff volume for our site as 43,340 gal. The second part of the methodology is to design a tieback silt fence system that can effectively contain this runoff volume. Given the information from the example problem provided in Figure 1, the designer can specify the parameters required to compute the silt fence length that has adequate storage volume based on the various slopes at the project site. Figure 1 stipulates a ditch slope (S_3) of 1%, an existing ground length (L_1) of 6 ft, a fill slope (S_2) of 3:1, an existing ground slope (S_1) of 2%, and a silt fence height of 3 ft. Using geometry, numerical calculations can be performed to determine the volume of runoff that a particular silt fence system can contain per unit length of silt fence installed.

The following is the numerical procedure for determining the volume capacity for one incremental unit of silt fence length. Cross Section No. 1 (CS_1) from Figure 3 represents the down slope end of the silt fence system where the tieback will be installed. The height of the water volume at the toe of the fence at CS_1 ($H_1^{CS_1}$) is 3.0 ft. The length of the existing ground (L_1) is 6.0 ft, which is sloped (S_1) at 0.02 ft/ft. To determine the area of the first area ($A_1^{CS_1}$), the designer will need to compute the height of the water at the intersection of the fill slope and the existing ground ($H_2^{CS_1}$) for CS_1 as

$$\begin{aligned} H_2^{CS_1} &= H_1^{CS_1} - (L_1 \times S_1) = 3.0 \text{ ft} - (6.0 \text{ ft} \times 0.02 \text{ ft/ft}) \\ &= 2.88 \text{ ft} \end{aligned} \quad (14)$$

Once $H_2^{CS_1}$ has been determined, an average water height for CS_1 can be computed with the following expression:

$$H_{Avg_1}^{CS_1} = \frac{(H_1^{CS_1} + H_2^{CS_1})}{2} = \frac{(3.0 \text{ ft} + 2.88 \text{ ft})}{2} = 2.94 \text{ ft} \quad (15)$$

With the average water height of CS_1 found in Equation 15, the trapezoidal area of water ($A_1^{CS_1}$) for CS_1 can be computed as

$$A_1^{CS_1} = H_{Avg_1}^{CS_1} \times L_1 = 2.94 \text{ ft} \times 6 \text{ ft} = 17.64 \text{ ft}^2 \quad (16)$$

To compute the triangular area ($A_2^{CS_1}$) for CS_1 , the length of the fill slope ($L_2^{CS_1}$) for CS_1 is calculated by

$$L_2^{CS_1} = \frac{H_2^{CS_1}}{S_2} = \frac{2.88 \text{ ft}}{0.33 \text{ ft/ft}} = 8.64 \text{ ft} \quad (17)$$

With $L_2^{CS_1}$ from Equation 17, $A_2^{CS_1}$ can be calculated as

$$A_2^{CS_1} = \frac{1}{2}(L_2^{CS_1} \times H_2^{CS_1}) = \frac{1}{2}(8.64 \text{ ft} \times 2.88 \text{ ft}) = 12.44 \text{ ft}^2 \quad (18)$$

By combining the values for $A_1^{CS_1}$ and $A_2^{CS_1}$, the total area for CS_1 ($A_T^{CS_1}$) can be determined as

$$A_T^{CS_1} = A_1^{CS_1} + A_2^{CS_1} = 17.64 \text{ ft}^2 + 12.44 \text{ ft}^2 = 30.08 \text{ ft}^2 \quad (19)$$

A similar procedure is followed to find the total area of Cross Section No. 2 (CS_2), which is outlined below. The height of the water at the toe of the fence for CS_2 ($H_1^{CS_2}$) is calculated by Equation 20.

$$\begin{aligned} H_1^{CS_2} &= H_1^{CS_1} - (L_3 \times S_3) = 3.0 \text{ ft} - (0.5 \text{ ft} \times 0.01 \text{ ft/ft}) \\ &= 2.995 \text{ ft} \end{aligned} \quad (20)$$

where L_3 is the incremental unit length of silt fence (ft). Next the designer will need to compute the height of the water at the intersection of the fill slope and the existing ground ($H_2^{CS_2}$) for CS_2 as

$$\begin{aligned} H_2^{CS_2} &= H_1^{CS_2} - (L_1 \times S_1) = 2.995 \text{ ft} - (6.0 \text{ ft} \times 0.02 \text{ ft/ft}) \\ &= 2.875 \text{ ft} \end{aligned} \quad (21)$$

Once $H_2^{CS_2}$ has been determined, an average height for CS_2 can be computed with the following expression:

$$H_{Avg_2}^{CS_2} = \frac{(H_1^{CS_2} + H_2^{CS_2})}{2} = \frac{(2.995 \text{ ft} + 2.875 \text{ ft})}{2} = 2.935 \text{ ft} \quad (22)$$

With the average height of CS₂ found in Equation 22, the trapezoidal area of water (A₁^{CS₂}) for CS₂ can be computed as

$$A_1^{CS_2} = H_{Avg}^{CS_2} \times L_1 = 2.935 \text{ ft} \times 6 \text{ ft} = 17.61 \text{ ft}^2 \quad (23)$$

To compute the triangular area (A₂^{CS₂}) for CS₂, the length of the fill slope (L₂^{CS₂}) for CS₂ is calculated by

$$L_2^{CS_2} = \frac{H_2^{CS_2}}{S_2} = \frac{2.875 \text{ ft}}{0.33 \text{ ft/ft}} = 8.625 \text{ ft} \quad (24)$$

With L₂^{CS₂} from Equation 24, A₂^{CS₂} can be calculated as

$$A_2^{CS_2} = \frac{1}{2}(L_2^{CS_2} \times H_2^{CS_2}) = \frac{1}{2}(8.625 \text{ ft} \times 2.875 \text{ ft}) = 12.40 \text{ ft}^2 \quad (25)$$

With the values for A₁^{CS₂} and A₂^{CS₂} combined, the total area for CS₂ (A_T^{CS₂}) can be determined as

$$A_T^{CS_2} = A_1^{CS_2} + A_2^{CS_2} = 17.61 \text{ ft}^2 + 12.40 \text{ ft}^2 = 30.01 \text{ ft}^2 \quad (26)$$

With both the total areas for CS₁ and CS₂ computed in Equations 19 and 26, respectively, the total volume for this incremental unit length of silt fence can be computed as

$$V_{avg} = \left(\frac{A_T^{CS_1} + A_T^{CS_2}}{2} \right) \times L_3 = \left(\frac{30.08 + 30.01}{2} \right) \times 0.5 \text{ ft} \\ = 15.023 \text{ ft}^3 = 112.37 \text{ gal} \quad (27)$$

Once all incremental unit length volumes along the silt fence are computed and the water height at the toe of the upslope side of the silt fence reaches zero, a cumulative volume is calculated by summing all the incremental volumes along the silt fence system. The cumulative volume was plotted against the silt fence length for a ditch slope of 1% to create a graph that can be used by the designer to select the appropriate length of the silt fence system to impound the estimated volume of storm water runoff expected from the 1% ditch slope.

A spreadsheet was used to calculate the total silt fence storage volume for various project ditch slope situations beyond 1% for a 2%, 3%, 4%, and 5% condition. The output of silt fence length versus total storage volume was plotted for these various slopes with the cross-section data assumed in the example problem (Figure 1). The example ditch slope of 1% is illustrated as the bold line. Figure 4 is a graph for this problem, and it provides the storage capacity of the silt fence system as opposed to the silt fence length for various possible ditch slopes. It should be noted in Figure 4 that as the ditch slope increases, the storage volume capacity of the silt fence tieback system decreases. Therefore, as the ditch slope increases, the designer will need to install tiebacks more frequently over longer runs of silt fence.

Table 1 provides the storage capacities of the tieback system at predetermined, fixed incremental lengths. The data from Table 1 may be used directly, instead of the graph illustrated in Figure 4, to evaluate and select the appropriate silt fence design.

From Figure 4 and Table 1, it is clear that the longest length of a silt fence that can be installed at a 1% ditch slope before installing a tieback before failure occurs is 300 ft. Additionally, the maximum

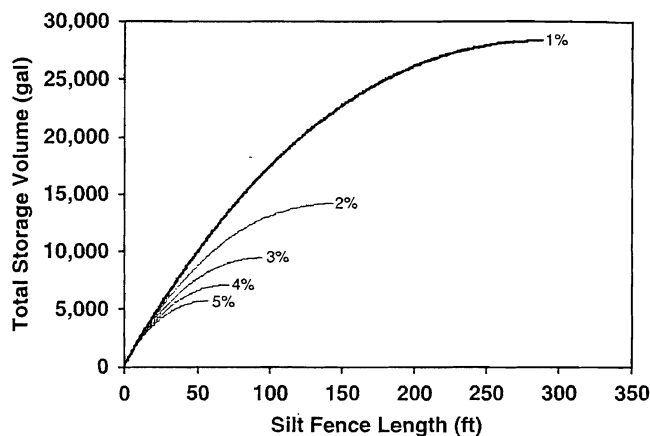


FIGURE 4 Example problem: total storage volume versus silt fence length.

storage volume that 300 ft of silt fence can hold is approximately 28,500 gal.

Example Problem: Computation of Tieback Frequency

From the SCS CN method, the total runoff volume for the 2-year, 24-h example design storm is 43,340 gal. In the example problem definition, the watershed length was 500 ft. As seen in Figure 4, a number of alternative tieback configurations can be selected to effectively contain the storm water runoff on the construction site. However, the most cost-effective configuration incorporates only two tiebacks along the entire ROW. Consequently, the recommendation is made to install two silt fence tiebacks approximately every 250 ft. Each of the two silt fence tiebacks, in conjunction with a silt fence length of 250 ft, has a total storage volume of approximately 28,000 gal. The combined storage volume of both the silt fence and

TABLE 1 Silt Fence Tieback Storage Capacities (gal) per Unit Length of Silt Fence for Various Ditch Slopes

Silt Fence Length (ft)	Ditch Slope (%)				
	1	2	3	4	5
25	5,395	5,064	4,745	4,438	4,143
50	10,028	8,788	7,643	6,592	5,637
75	14,047	11,425	9,121	7,138	5,721
100	17,488	13,115	9,498		
125	20,384	13,999			
150	22,772	14,218			
175	24,686				
200	26,162				
225	27,234				
250	27,937				
275	28,307				
300	28,379				

NOTE: Values appearing above the solid line represent actual storage volumes achieved by the corresponding silt fence length. Values appearing below the solid line represent the maximum storage volume attainable for a given slope and silt fence length.

silt fence tiebacks at a 250-ft spacing is 56,000 gal, which is greater than the required 43,340 gal, therefore effectively containing the storm water runoff flowing over the example watershed.

CONCLUSIONS

The objective of this research is to develop an efficient design methodology for the proper design and placement of silt fence tiebacks along highway construction projects. The methodology used in developing the design guidelines centered on using the SCS curve number method to estimate the amount of storm water runoff from a construction site during a specified storm event per unit length of roadway. The key design approach is to attain a balance with the computed storage capacity of the silt fence system per unit length of silt fence. Ultimately, this approach successfully resulted in the creation of a rational model able to predict both the total storm water runoff and the storage capacity per unit length of silt fence installation for project-specific highway construction sites. Equipped with this information, a designer is able to select the tieback configuration and interval spacing most appropriate for the construction site conditions. In most cases, the designer will select the most cost-effective silt fence tieback configuration that achieves the required storage capacity using the least amount of tieback installations. However, if there are physical site constraints, the designer is afforded the option of installing multiple tieback configurations customized to each particular construction site. The proposed design method is an effective procedure for assisting designers, inspectors, and contractors in designing and installing silt fence tiebacks along highway construction projects.

To assist practitioners in implementing the proposed design methodology in the field, further research is needed to integrate the design calculations within a user-friendly computer tool. The tool should be able to use parameters such as basic roadway geometry, soil properties, and precipitation data to generate the appropriate storage graph for project-specific applications. This graph will help designers, inspectors, and contractors develop reliable silt fence tieback designs that include the unique characteristics and constraints of each construction project.

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