APPENDIX I - CALCULATIONS AND DESIGN AIDS FOR NON-STANDARD SCDOT SEDIMENT CONTROLS

When selecting a Standard SCDOT BMP with an applicable SCDOT Supplemental Technical Specification, SCDOT Standard Drawing, or BMPs included on an applicable SCDOT QPL list, the BMP will meet the 80% TSS trapping requirement and the maintenance requirement. This Appendix presents engineering guidelines, calculations and design aids for non-standard SCDOT BMPs.

In addition, engineering guidelines are provided for the calculation of sediment storage volume and the determination of characteristic settling velocity and eroded particle size in the sections indicated below. Characteristic settling velocity is a required variable in each of the design aids. Design aids are provided for four types of temporary sediment controls in this Appendix.

Section I.1 Sediment Storage Volume Calculations

- Section I.1.1 Determination of R Factors and EI Values
- Section I.1.2 Determination of Weight Density, W

Section I.2 Characteristic Settling Velocity and Eroded Particle Size Determination

Section I.3 Rock Ditch Check Design Aids

- Section I.3.1 Ditch Check Ratio
- Section I.3.2 Stage Discharge of Rock Structures

Section I.4 Stage Discharge of Rock Structures

- Section I.4.1 Calculating the Stage-Discharge Relationship for Rockfill Structures

Section I.5 Silt Fence Design Aids

- Section I.5.1 Silt Fence Ratio

Section I.6 Sediment Dam Design Aids

- Section I.6.1 Sediment Dam Ratio

I.1 Sediment Storage Volume Calculations

Calculating the appropriate sediment storage volume is very important in sediment basin and sediment dam design. This volume is the storage occupied by the sediment deposited over the given design period. Design periods may be the life of the basin or the time between scheduled clean outs. Using computed sediment yields, Y_D, from the Universal Soil Loss Equation (USLE) along with the sediment bulk (or weight) density, W, the sediment storage volume can be calculated by:

$$V_{ss} = \frac{Y_D}{W * 27}$$

Where:

V_{SS}	=	sediment storage volume (cubic yards)
Y_D	=	sediment deposited over the design period (pounds)
W	=	weight density (bulk density) of the deposited sediment (lbs/ft^3)

The following steps are used to determine the storage volume, $\mathbf{V_{SS}}$, for a sediment trapping structure.

Determine the sediment yield from the site using the USLE (USLE Data is contained in Appendix H):

$$A = R*K*LS*CP$$

Where:

A	=	Average soil loss per unit area (tons/acre/specified design period)
R	=	Rainfall erosive index (100 foot-tons/acre * inches/hour)
		(EI Value for given design period * average annual R Value; see Section I.1.1)
K	=	Soil erodibility factor (tons/acre per unit R)
LS	=	Length-slope steepness factor (length is the slope distance from the point of origin of overland flow to the point of concentrated flow or until deposition occurs) (dimensionless)
CP	=	Control practice factor (dimensionless)

Determine the weight density, **W**, of the specific soil:

- Use the equation or tables from Section I.1.2,
- Soil bore test and/or county soil survey provide a soil bulk density usually given in grams/cm^3
- Convert (grams/cm^3) to (lbs/ ft^3) by multiplying by 62.43

W = (bulk density in grams/cm^3) * (62.43) = lbs/ft^3

Convert sediment yield, $\mathbf{Y_D}$, from (tons/acre) to acre/feet of sediment storage:

- Determine the total disturbed area, **DA** (acres)
- Determine the sediment yield in tons, calculated by multiplying **A** * **DA**

(tons/acre) * (acres) = tons

- Convert tons to pounds to get $\mathbf{Y_D}$:

Y_D = (tons) * (2000 lbs/ton) = pounds

Calculate the required sediment storage volume, $\mathbf{V_{SS}}$, in cubic yards:

$$V_{ss} = \frac{Y_D}{W * 27} = cubic\ \ yards$$

The designer can now determine to what level the required sediment storage corresponds and require a clean-out marking stake to be installed at that elevation. The contractor shall be required to clean out the basin or sediment dam when this level is reached. Alternatively, the designer may simply state that, based on the calculations, the basin or sediment dam will require cleaning out with a specified frequency.

I.1.1 Determination of R Factors and EI Values

When designing for sediment storage volume, the sediment deposited over the design period (Y_D) must be calculated. This value can be obtained by converting the sediment yield calculated by the USLE into pounds of sediment.

One of the variables used in the USLE is the R factor. R is the factor in the USLE that accounts for the damaging effects of rainfall. The R factor indicates the erosivity of the rainfall, not the average annual precipitation in a locality. The R factor is defined as the number of erosion index (EI) values in a normal year's rain. The EI index value of a given storm is equal to the kinetic energy of the storm (hundreds of foot-tons per acre) multiplied by its maximum 30-minute intensity (inches/hour). The EI values of individual storms may be summed to get an EI value for a month, six months, or for any period of time. When EI values are summed and averaged over a period of years, they become R factors.

The distribution of EI values becomes important when soil losses need to be calculated for a period of time less than one year, such as a construction season. The distribution of the EI values over a known period of time is used to calculate an R factor for that time period. Table I.1 shows the distribution of EI values for specific areas of South Carolina as a percentage of the R factor for that area. This design procedure shall require a minimum EI value of 50 for any construction period.

Table I.1: Example Distribution of Average Erosion Index (EI) Curve Numbers* for Selected Areas of South Carolina

Date	Zone 116 (Greenville, Rock Hill, Spartanburg, Pageland, Greenwood)	Zone 117 (Coastal)	Zone 118 (Columbia, Aiken)
January 1	0.0	0.0	0.0
January 15	1.0	1.0	1.0
February 1	3.0	2.0	2.0
February 15	5.0	3.0	3.0
March 1	7.0	4.0	5.0
March 15	9.0	5.0	7.0
April 1	12.0	7.0	10.0
April 15	15.0	9.0	14.0
May 1	18.0	11.0	18.0
May 15	21.0	14.0	22.0
June 1	25.0	17.0	27.0
June 15	29.0	22.0	32.0
July 1	36.0	31.0	37.0

Date	Zone 116 (Greenville, Rock Hill, Spartanburg, Pageland, Greenwood)	Zone 117 (Coastal)	Zone 118 (Columbia, Aiken)
July 15	45.0	42.0	46.0
August 1	56.0	54.0	58.0
August 15	68.0	65.0	69.0
September 1	77.0	74.0	80.0
September 15	83.0	83.0	89.0
October 1	88.0	89.0	93.0
October 15	91.0	92.0	94.0
November 1	93.0	95.0	95.0
November 15	95.0	97.0	96.0
December 1	97.0	98.0	97.0
December 15	99.0	99.0	97.0
January 1	100.0	100.0	100.0

**Minimum EI Curve Number for any construction period = 50*

Table I.2: Average Annual R-Factors for Selected Areas of South Carolina

	Zone 116 (Greenville, Rock Hill, Spartanburg, Pageland, Greenwood)	Zone 117 (Coastal)	Zone 118 (Columbia, Aiken)
Annual R-Factor	300	400	350

Example Calculation for R factor:

Given: A yearly R factor value of 300 is selected for Greenville County. Construction of a particular Project is scheduled to take place for five months from January 1 to June 1. Construction of another Project in Greenville County is scheduled to take place for five months from March 1 to August 1.

Find: The EI Curve value and corresponding R factor for each Project.

Solution: The EI Curve value for the first site (construction from January 1 to June 1) is calculated to be: 25.0 – 0.0 = 25.0. The corresponding R factor for this time period is calculated to be: (25/100) * 300 = **75.0**.

The EI Curve value for the second site in Greenville County (March 1 to August 1) is calculated to be: 56.0 – 7.0 = 49.0. The corresponding R factor for this time period is calculated to be: (49/100) * 300 = **147.0**.

I.1.2 Determination of Weight Density, *W*

W can be found from county soil survey data (usually given in grams/cm^3), by the following equation, or using the default values in Table I.4:

$$W = W_c P_c + W_m P_m + W_s P_s$$

Where:

W_c, W_m, W_s = unit weights of clay, silt, and sand in (lbs/ft^3) taken from Table I.3

P_c, P_m, P_s = the primary soil matrix percent clay, silt, and sand as listed in soil survey (used as decimals)

Table I.3: Unit Weight Values of Basin Sediment

Type of Basin Operation	**W_c (lbs/ft^3)**	**W_m (lbs/ft^3)**	**W_s (lbs/ft^3)**
Sediment always submerged (wet pond)	26	70	97
Basin normally empty (dry pond)	40	72	97

Table I.4: Default Unit Weight Values for Sediment Storage

Type of Basin Operation	**Zone 116** (Greenville, Rock Hill, Spartanburg, Pageland, Greenwood)	**Zone 117** (Coastal)	**Zone 118** (Columbia, Aiken)
Sediment always submerged (wet pond)	85	90	96
Basin normally empty (dry pond)	87	92	97

Example Calculation for the Determination of Sediment Storage Volume (V_{SS}):

Given: A 60-acre construction site in Greenville County (Zone 116) is to be cleared to a bare soil condition and developed. The contributing runoff slope length is 400 feet with a 2.5 percent slope. The primary soil is Cecil sandy loam. A sediment basin is to be designed to be the primary sediment control structure on the site.

Find: Determine the required sediment storage volume if construction is to take place between March 1 and September 1.

Solution:

1. Determine the sediment yield form the site using the USLE (USLE Data is contained in Appendix H):

A = R * K * LS * CP

R = From Table I.1 for Zone 116, EI for September 1 = 77.0

and EI for March 1 = 7.0. (77.0 – 7.0) = 70%

R factor = 70% of 300 = 210

K = 0.28 for Cecil sandy loam soil

LS = 0.365 for 400-foot slope length with 2.5% slope

CP = 1.0 for a bare soil condition

A = (210) * (0.28) * (0.365) * (1.0) = 21.5 tons/acre

2. Determine the weight density, W, of the Cecil sandy loam soil.

- Soil boring tests give an average soil bulk density of 1.40 grams/cm^3 for Cecil sandy loam soil (can also use equation from section I.1.2 or default values in Table I.4).
- Convert 1.40 (grams/cm^3) to (lbs/ ft^3) by multiplying by 62.43

W = (1.40) * (62.43) = 87.4 lbs/ft^3

3. Convert sediment yield from (tons/acre) to cubic feet of sediment storage.

- Determine the total disturbed area (acres)
- Determine the sediment yield in tons

  21.5 (tons/acre) * 60 (acres) = 1290 tons

- Convert tons to pounds to get $\mathbf{Y_D}$

  Y_D = (1290 tons) * (2000 lbs/ ton) = 2,580,000 pounds

$$V_{ss} = \frac{Y_D}{W*27} = \frac{2,580,000}{87.4*27} = 1093 \ \textit{cubic yards}$$

I.2 Characteristic Settling Velocity and Eroded Particle Size Determination

A common feature of each of the design aids is the determination of the characteristic settling velocity for the eroded soil. For South Carolina requirements the characteristic settling velocity is the settling velocity of the soil particle in the 15th percentile (denoted D_{15}). D_{15} is the particle size such that 15 percent of the sediment particles are smaller, by weight, than the size specified. D_{15} refers to the diameter of this particle.

Estimated eroded size distributions for South Carolina soils using an adaptation of the method described by Foster et al. (1985) were developed. The procedure uses the primary particle size information reported by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) (formerly the Soil Conservation Service (SCS)) as part of county soil surveys. This procedure may be used with NRCS Soil Survey Data or site specific soil boring data.

If D_{15} is less than 0.01 mm, then the settling velocity based on a simplified form of Stokes Law is:

$$V_s = 2.81d^2$$

Where:

V_s	=	settling velocity in ft/sec
d	=	particle diameter in mm

If D_{15} is greater than or equal to 0.01 mm, then settling velocity should be found using:

$$\log_{10}V_s = -0.34246\,(\log_{10}d)^2 + 0.98912\,(\log_{10}d) - 0.33801$$

Where:

V_s	=	settling velocity in ft/sec
d	=	particle diameter in mm (Wilson et al., 1982)

The characteristic settling velocity can also be obtained using Figure I-1 (found at the end of this Appendix). The eroded particle sizes (D_{15}) for selected South Carolina soils are provided in Appendix G.

It is important to remember that the eroded size distribution is the most critical parameter in sizing sediment controls. The eroded size distributions vary greatly from primary particle size distributions that are often determined as a result of soil strength investigations for construction purposes. Primary particle sizes will yield erroneous results and should not be used. The user should note that D_{15} is often smaller for coarse textured (more sandy soils) because of the reduced clay content and lack of aggregation. Soil classifications by texture are summarized in Table I.5.

Table I.5: Soil Classification by Texture

Soil Classification by General Texture			
Texture	Coarse	Medium	Fine
Soil Type	Sandy Loam	Silt Loam	Clay Loam

I.3 Rock Ditch Check Design Aids

The rock ditch check design aids are designed for soils classified as either coarse (sandy loam), medium (silt loam), or fine (clay loam). Constraints for the use of rock ditch check design aids are:

- Watershed area is less than or equal to two (2) acres;
- Overland flow length is less than or equal to 500 feet;
- Overland slope is less than or equal to 15 percent; and,
- Maximum depth of the ditch is less than or equal to six (6) feet.
- Maximum rock ditch check height is two (2) feet.

I.3.1 Rock Ditch Check Ratio

$$Rock\ \ Ditch\ Check\ \ Ratio\ \ = \frac{S_q^{\ (1-b)}}{aV_{15}}$$

Where:

S	=	Channel slope (%)
q	=	Flow per unit width through the check for the 10-year, 24-hour storm event (cfs/ft)
V_{15}	=	Characteristic settling velocity (fps)
a	=	Stone flow coefficient *a*, can be interpolated from Table I.6
b	=	Stone flow exponent *b*, can be interpolated from Table I.6

Table I.6: Stone Flow Coefficient *a* and Exponent *b* *(Source: Haan et. al., 1994, pg. 151)*

D_{50} (m)*	Exponent *b*	Coefficient *a***		
		dl = 1m	dl = 2m	dl = 3m
0.01	0.6371	9.40	6.05	4.60
0.02	0.6540	7.40	4.65	3.55
0.03	0.6589	6.40	4.08	3.08
0.04	0.6609	5.85	3.65	2.80
0.05	0.6624	5.40	3.35	2.60
0.06	0.6635	5.05	3.15	2.40

D_{50} (m)*	Exponent *b*	Coefficient *a***		
		dl = 1m	dl = 2m	dl = 3m
0.08	0.6644	4.50	2.85	2.20
0.09	0.6648	4.28	2.70	2.10
0.10	0.6651	4.13	2.60	2.05
0.20	0.6662	3.20	2.05	1.57
0.30	0.6664	2.80	1.75	1.30
0.40	0.6665	2.50	1.55	1.16
0.50	0.6666	2.30	1.40	1.08

** D_{50} = rock ditch check average stone diameter in meters.*
***dl = average flow length through the rock ditch check in meters.*

The Rock Ditch Check Ratio should be less than or equal to the curve value at any given trapping efficiency for the chart in Figure I-2 (found at the end of this Appendix). Ditch Check Ratios above the design aid curves are not allowable for any application. If the Ditch Check Ratio intersects the curve at a point having a trapping efficiency less than the desired value of 80%, the design is inadequate and must be revised.

Three examples of how the rock ditch check design aid curves are read are as follows:

- A ditch check located on coarse soils has a Ditch Check Ratio equal to 1.10E3 at 80 percent trapping efficiency as shown in Figure I-2.
- A ditch check located on medium soils has a Ditch Check Ratio equal to 5.80E3 at 80 percent trapping efficiency as shown in Figure I-3.
- A ditch check located on fine soils has a Ditch Check Ratio equal to 1.20E4 at 80 percent trapping efficiency as shown in Figure I-4.

Example Calculations for Design of a Rock Ditch Check:

Given:

- A rock ditch check in York County with a channel slope of 1.0 percent is to be installed on an area having Cecil sandy loam soils. The eroded size distribution is for a medium texture soil since it is a sandy loam.
- The runoff coefficient “C” for the rational method is estimated as 0.4 with an intensity of 6.75 inches/hour for the design storm.
- Drainage area to the ditch check is 4.4 acres.
- Average rock diameter of the ditch check is 0.10 meters (4 inches).

- Average width (perpendicular to flow) is 6.7 feet and ditch check length is one meter (refer to Section I.4.1 for an example calculation for flow through a ditch check).

<u>Find</u>: The trapping efficiency for the rock ditch check given.

<u>Solution:</u>

1. A Cecil topsoil's D_{15} is 0.0066 mm (from Appendix G), and the settling velocity is found to be $V_{15} = 1.2E\text{-}4$ fps.

2. Peak flow can be estimated from the given information by substituting into the rational formula:

   $$q_p = C\ i\ A = 0.4\ (6.75)\ (4.4) = 11.9 \text{ cfs}$$

3. The flow rate should be converted to flow per unit width by dividing the peak flow by the check width to obtain the design **q** as:

   $$q = 11.9 \text{ cfs} / 6.7 \text{ ft} = 1.78 \text{ cfs/ft}$$

4. Appropriate values of the coefficient ***a*** and exponent ***b*** can be interpolated from Table I.6.

   - For rock diameter of 0.10 m and flow length of 1.0 m:

     $\boldsymbol{a} = 4.13$

     $\boldsymbol{b} = 0.6651$

   Substitute all values and calculate the ditch check ratio:

   $$\mathbf{S_q^{(1-b)} / (a\ V_{15}) =} (1.0)(1.78^{(1-0.6651)})/(4.13)(1.2E\text{-}4) = 2448$$

5. Enter the rock ditch check design aid curve for medium texture soil (Figure I-3) on the y-axis with Ditch Check Ratio = 2.5E3, go horizontally to curve and turn downward to the x-axis to read trapping efficiency.

6. Trapping efficiency equals **86 percent**.

   Note: The ditch check must also be checked for overtopping using the design guidance is Section I.4 of this Appendix since this is a common occurrence and results in total failure of the check. If the check overtops, the trapping efficiency is assumed to be zero (see Section I.4, Stage Discharge for Rock Structures).

I.4 Stage Discharge of Rock Structures

Rock structures are commonly used as the outlet control structure of smaller sediment basins and sediment traps and in rock ditch checks. The flow through these structures is controlled by the following factors (see Figure I-7 found at the end of this Appendix):

- Static head drop as flow moves through the rockfill **(dh)**
- Upstream water depth **(h_1)**
- Downstream water depth **(h_2)**
- Flow length through the rockfill **(dl)**
- Average stone diameter of the rockfill **(d)**
- Porosity of the rockfill **(ξ)** (0.46 for graded rockfills constructed by dumping)
- Reynolds Number **(R_e)** and friction factor **(f_k)**, which are dictated by flow length through the rockfill, rock size, and porosity of the rockfill

In the original equations proposed by Herrera (1989), porosity was included as a parameter. However, Herrera and Felton (1991) deleted porosity from the equations because it was found to have a constant value of approximately 0.46 in all of their laboratory tests. The Herrera and Felton equations require a trial and error computation process that entails six steps for each stage.

I.4.1 Calculating the Stage-Discharge Relationship for Rockfill Structures

The Herrera and Felton equations incorporate detailed computations requiring computers and spreadsheets that are capable of trial and error programming. However, when quick estimates are needed, graphical procedures are helpful. A graphical procedure for predicting the average gradient through rockfills **(dh /dl)** can be used to develop head loss as a power function of flow, which eliminates any trial and error procedures. The governing equation is:

$$\frac{dh}{dl} = aq^b$$

Where:

dh = Static head drop of water in meters (difference between upstream and downstream water surface elevations)

dl = Average flow path length through the rock in meters

a = Dimensionless coefficient based on flow path length shown in Figure I-6

b = Dimensionless exponent based on average rock diameter (m) shown in Figure I-6

q = Flow per unit width of rockfill in cubic meters per second per meter (cms/m)

****All units must be converted to metric to use the graphical method.**

The equation can be rearranged so there is only one unknown, **q** (csm/m).

$$q = \left[\frac{dh}{a(dl)}\right]^{\frac{1}{b}}$$

Example Calculation for Flow Through a Rockfill Dam:

Given: A rockfill dam is to be used as the principle spillway for a sediment dam. The average width of the dam is 10 feet (3 meters). The dam is 5 feet high with rock side slopes of 1:1. The flow length at the top of the dam is 3.3 feet, while the flow length at the bottom of the dam is 9.9 feet. The average stone diameter is 6 inches.

Find: Stage discharge relationship for the rock dam. Assume that the downstream depth is negligible so dh = upstream stage (see Figure I-5).

Solution:

1. Determine the number of desired stage elevations for computations.
   - For this example, calculations will be made every foot.
2. Set up a table for each stage (as shown in Table I.7).
   - Convert all units to **metric** before reading values from the graphs in Figure I-6.
3. Calculate the discharge rate at each stage.
   - At a stage = 1 foot
     - dh = 0.31 meters
     - dl = 3.0 meters
     - stone diameter of 6 inches = 0.15 meters
       - a = 1.80 (from Figure I-6)
       - b = 0.6657 (from Figure I-6)

$$q = \left[\frac{dh}{a\,(dl)}\right]^{\frac{1}{b}} = \left[\frac{0.31}{1.80 * (3.0)}\right]^{\frac{1.0}{0.6657}} = 0.0137\ \ cms/m$$

   - Convert cms/m to cms by multiplying by the average flow width at the stage

     (0.0137 cms/m) * (3 m) = **0.041 cms**

- Convert cms to cfs

  (0.041 cms) * (35.315 cfs/cms) = **1.447 cfs**

Table I.7: Calculation Table for Flow through Rockfill Dam

Stage (ft)	0	1	2	3	4	5
Flow Length (ft)	9.9	9.9	8.3	6.6	5	3.3
Flow Width (ft)	10	10	10	10	10	10
dh (m)	0	0.31	0.61	0.91	1.22	1.52
dl (m)	3	3	2.52	2	1.52	1
a	3.12	3.12	2.06	2.31	2.97	3.63
b	0.6657	0.6657	0.6657	0.6657	0.6657	0.6657
Flow (cms/m)	0	0.0137	0.0407	0.087	0.14	0.2704
Width (m)	3	3	3	3	3	3
Flow (cms)	0	0.041	0.122	0.261	0.42	0.811
Flow (cfs)	0	1.4	4.4	9.2	14.8	28.7

Example Calculation for Flow Through a Rock Ditch Check

Given: A Rock Ditch Check with the following characteristics:

Dimension	Standard Units	Metric Conversion
Bottom Width	3 feet	0.91 meters
Side Slopes	3:1	3:1
Depth	2 feet	0.61 meters
Top Width	15 feet	4.57 meters
Top Flow Length	3 feet	0.91 meters
Bottom Flow Length	7 feet	2.13 meters
Rock Fill Diameter	6 inches	0.15 meters

Find: Stage discharge relationship for Rock Ditch Check.

Solution:

1. To properly apply the rock fill flow equation all values must be converted to **metric units.** Determine the number of desired stage elevations for computations. For this example calculations will be made every 0.5 feet.

2. Based on the rock size and the flow lengths, an appropriate value for the exponent ***b*** must be selected from Table I.8.

   - Linear interpolation can be used to find ***b*** when the rock diameter = 0.15 m.

     b = 0.6651 + [(.15 - .10) / (.20-.10)] * (0.6662 – 0.6651)

     b = 0.6657

3. Based on a rock size of 0.15 meters and the flow lengths at different stages, the appropriate values for the coefficient ***a*** can be selected from Table I.8 by using linear interpolation.

Stage (ft)	Stage (m)	Flow Length (m)	Coefficient *a*
0.0	0.00	2.13	2.26
0.5	0.15	1.83	2.55
1.0	0.31	1.52	3.00
1.5	0.46	1.22	3.37
2.0	0.61	0.91	3.67

Table I.8: Values for Rock Check Flow Coefficient *a* and Exponent *b*

Stone Diameter(m)	Exponent *b*	Coefficient *a*		
		dl= 1m	dl = 2m	dl = 3m
0.01	0.6371	9.40	6.05	4.60
0.02	0.6540	7.40	4.65	3.55
0.03	0.6589	6.40	4.08	3.08
0.04	0.6609	5.85	3.65	2.80
0.05	0.6624	5.40	3.35	2.60
0.06	0.6635	5.05	3.15	2.40
0.08	0.6644	4.50	2.85	2.20
0.09	0.6648	4.28	2.70	2.10
0.10	0.6651	4.13	2.60	2.05
0.20	0.6662	3.20	2.05	1.57
0.30	0.6664	2.80	1.75	1.30
0.40	0.6665	2.50	1.55	1.16
0.50	0.6666	2.30	1.40	1.08

Source: Design Hydrology and Sedimentology for Small Catchments, Hann et. al., 1995

4. Determine the total flows for each staging using the values determined above. The total flow is computed by multiplying the unit flow by the flow width.

$$q = \left[\frac{dh}{a\,(dl)}\right]^{\frac{1}{b}} = \left[\frac{0.61}{3.67 * (0.91)}\right]^{\frac{1.0}{0.6657}} = 0.0778\ cms/m$$

- At the stage of 2 feet (0.61 meters) the flow is calculated to be: 0.0778 cms/m
- Convert cms/m to cms by multiplying by the average flow width at the stage

  (0.0778 cms/m) * (4.57 m) = **0.355 cms**

- Convert cms to cfs

  (0.355 cms) * (35.315 cfs/cms) = **12.5 cfs**

Stage (m)	Flow Length (m)	Unit Flow (cms/m)	Flow Width (m)	Total Flow (cms)	Stage (ft)	Total Flow (cfs)
0.00	2.13	0.000	0.91	0.000	0.0	0.0
0.15	1.83	0.006	1.83	0.011	0.5	0.4
0.31	1.52	0.018	2.74	0.048	1.0	1.7
0.46	1.22	0.037	3.66	0.136	1.5	4.8
0.61	0.91	0.078	4.57	0.355	2.0	12.5

I.5. Silt Fence Design Aids

The silt fence design aid applies to silt fences placed in areas down slope from disturbed areas where they serve to retard flow and cause settling. The two conditions that must be met for satisfactory design of a silt fence are: (1) trapping efficiency must meet the desired level of control, and (2) overtopping of the fence must not occur.

Constraints for the use of a silt fence design aid are:

- Watershed area is less than or equal to five (5) acres
- Overland flow length is less than or equal to 500 feet
- Overland slope is less than or equal to six (6) percent
- Slurry flow rate through the fence is less than or equal to 10 gallons per minute per foot (gpm/ft)
- The minimum height of the silt fence is (2) feet

I.5.1 Silt Fence Ratio

The silt fence design aid is a single line grouping all soil textures together. For the silt fence, the ratio is:

$$\frac{q_{po}}{V_{15} P_{area}}$$

Where:

q_{po} = Peak outflow through the fence for the 10-year, 24-hour storm event (cfs)

V_{15} = Characteristic settling velocity (fps)

P_{area} = Potential ponding area up slope of the fence (ft^2)

The ponding area can be estimated by using the height of the fence available for flow through and extending a horizontal line from the fence to an intersection with the ground surface upslope of the fence. The unit available area is calculated by dividing the fence height by the ground slope (in vertical feet / horizontal feet). Multiply this unit area by the available fence length for ponding to obtain the potential ponding area.

Using the calculated ponding area, calculate the Silt Fence Ratio and use Figure I-7 to determine the trapping efficiency. Once an acceptable trapping efficiency is determined, a calculation for overtopping must be performed. The overtopping calculation must be performed using the slurry flow rate through the fence. This rate must be checked against the incoming flow to determine if enough storage exists behind the fence to prevent overtopping.

Silt Fence Ratios above the silt fence design aid curves are not allowable for any application. If the silt fence ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

One example of how the silt fence design aid curve is read is as follows:

A Silt Fence Ratio equal to **0.20** has an **80%** trapping efficiency as shown in Figure I-7.

Example Calculations for Design of a Silt Fence:

Given:

- A wire-backed silt fence is to be built in Richland County from 2.5-foot wide silt fence fabric at the toe of a 2.0 percent slope draining a linear construction site.
- Topography will cause runoff to drain through 400 feet of total fabric length.
- Peak flow from the 1.0 acre upslope area is estimated at 2.5 cfs using the rational equation with "C" equal to 0.25 and intensity equal to 10.0 inches/hour.
- The usable height of the fence above ground is 2.0 feet.
- Slurry flow rate for the filter fabric is 10 gpm/ft^2 of fabric according to manufacturer specifications or other source.

Find:

(a) The trapping efficiency if the soil is Lakeland Sand with an eroded size distribution having a D_{15} equal to 0.0463 mm.

(b) The trapping efficiency if the soil is Cecil with an eroded size distribution having a D_{15} equal to 0.0066 mm.

Solution:

Part (a):

1. The settling velocity of the D_{15} particle (0.0463 mm) can be estimated as:

$$V_{15} = 5.1E\text{-}3 \text{ ft/sec.}$$

2. The ponded area can be estimated using the geometry at the installation site. With a fence length of 400 feet, maximum depth equal to 2.0 feet, and slope upstream of the fence equal to 2.0 percent, there will be a maximum unit ponded area of:

$$(2.0 \text{ ft}) / (0.02 \text{ ft/ft}) = 100 \text{ ft}^2\text{/linear foot of fabric}$$

This gives a total ponded area of:

$$P_{area} = (100 \text{ ft}^2\text{/ft}) * (400 \text{ ft}) = 40{,}000 \text{ ft}^2$$

Based on this ponding calculation, a Silt Fence Tie-Back up the slope at each end of the silt fence run of 100 feet (2 ft / 0.02) feet is required to provide this ponding area.

3. The Silt Fence Ratio is calculated as:

$$\text{Silt Fence Ratio} = q_{po} /(V_{15}\ P_{area}) = 2.5 / [(5.1E\text{-}3) * (40{,}000)] = 0.013$$

4. Reading the trapping efficiency from the silt fence design aid provided in Figure I-7 with the ratio equal to 0.013, the trapping efficiency is approximately **95 percent**.

The fence must be checked for its ability to pass the design flow without overtopping.

5. Convert the peak flow from cfs to gpm so that:

$$q_{po} = (2.5\ ft^3/sec) * (7.48\ gal/ft^3) * (60\ sec/min) = 1{,}122\ gpm$$

6. Required length of fabric to carry this flow can be found by dividing the peak flow rate by the effective height (2.0 feet) and the slurry flow rate of 10 gpm/ft^2 of fabric. Hence, the length of fence required to carry the peak flow without overtopping is:

$$L = (1{,}122) / (2.0) * (10) = 57\ feet$$

7. Since 57 feet is less than the 400 feet available, the fence as designed should not overtop if it is properly maintained. Note: This analysis does not account for concentration of flows or strength of the posts or fabric. Since the fence should not overtop as designed, the estimated trapping efficiency is 95 percent.

Part (b):

1. A Cecil topsoil has D_{15} of 0.0066 mm. The settling velocity is found to be:

   $V_{15} = 1.2\ E\text{-}4\ fps$

2. The Silt Fence Ratio is calculated as:

$$\text{Silt Fence Ratio} = q_{po} /(V_{15}\ P_{area}) = 2.5 / [(1.2E\text{-}4) * (40{,}000)] = 0.52$$

3. Reading the trapping efficiency from the silt fence design aid curve (Figure I-7) with the ratio equal to 0.52, the trapping efficiency is approximately 74 percent.

4. Since the calculation to determine overtopping is the same as *Part (a)*, the fence will not overtop. The trapping efficiency is 74 percent.

I.6. Sediment Dam Design Aids

Sediment dams, for the purposes of this document, are small excavated impoundments with rock fill outlets. Their outlet hydraulics are different from a drop inlet structure; thus the design aid is slightly different – the area is defined as the area at the bottom of the outlet structure.

Constraints for the use of sediment dam design aids are:

- Watershed area less than ten (10) acres
- Overland slope less than or equal to 20 percent
- Rock fill diameter greater than 0.2 feet and less than 0.6 feet
- Rock fill height less than five (5) feet
- Top width of rock fill between two (2) and four (4) feet
- Maximum side slopes 1:1 to 1.5:1

I.6.1 Sediment Dam Ratio

The sediment dam design aid is a single line grouping all soil textures together. Trapping efficiencies for sediment dams are plotted in Figure I-8 as a function of the Sediment Trap Ratio:

$$\frac{q_{po}}{AV_{15}}$$

Where:

q_{po} = peak outflow for the 10-year, 24-hour storm event (cfs)

A = surface area at the elevation equal to the bottom of the rock fill outlet (acres)

V_{15} = characteristic settling velocity (fps)

Sediment Dam Ratios above the design aid curves are not allowable for any application. If the Sediment Dam Ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

Storm flows shall be routed through the sediment dam to calculate the required depth and storage volume of the sediment dam.

A sediment storage volume shall be calculated and provided below the bottom of the rock fill outlet structure.

One example of how the sediment dam design aid curve (Figure I-8) is read is as follows:

A Sediment Dam Ratio equal to **9.0E4** has an 80 percent trapping efficiency.

Example Calculations for Design of a Sediment Dam:

Given:

- A Sediment Dam in Newberry County designed for a 10-year, 24-hour storm is to be constructed as a temporary sediment control measure for a 3 acre drainage area that is entirely disturbed.
- The outlet is to be a rock fill constructed of rock with a mean diameter of 0.5 feet.
- The soil is a Cecil sandy loam, the slope of the watershed is 5 percent, and the time of concentration is 6 minutes.

Find: If the desired trapping efficiency is 80 percent, what is the required peak discharge for sediment dam areas of 0.10, 0.25, and 0.50 acres.

Solution:

1. Determine the Sediment Dam Ratio. From the sediment dam design aid provided in Figure I-8, the ratio for a design trapping efficiency of 80 percent is 9.0E4.

2. Determine the ratio of q_{po}/A required from the Sediment Dam Ratio.

$$\text{Sediment Dam Ratio} = 9.0E4 = q_{po} / (A*V_{15})$$

3. The D_{15} for a Cecil soil is 0.0066 mm and the corresponding V_{15} for a Cecil sandy loam soil is 1.2E-4 ft/sec. Hence,

$$q_{po}/A = 9.0E4 * V_{15}$$

$$q_{po}/A = (9.0E4)(1.2x10^{-4}) = 11 \text{ cfs /acre of pond}$$

4. Determine q_{po}/A values. The following results can be tabulated for the acreage shown:

Sediment Dam Bottom Area (acres)	q_{po} Through Rock Fill (cfs)
0.10	1.1
0.25	2.8
0.50	5.5

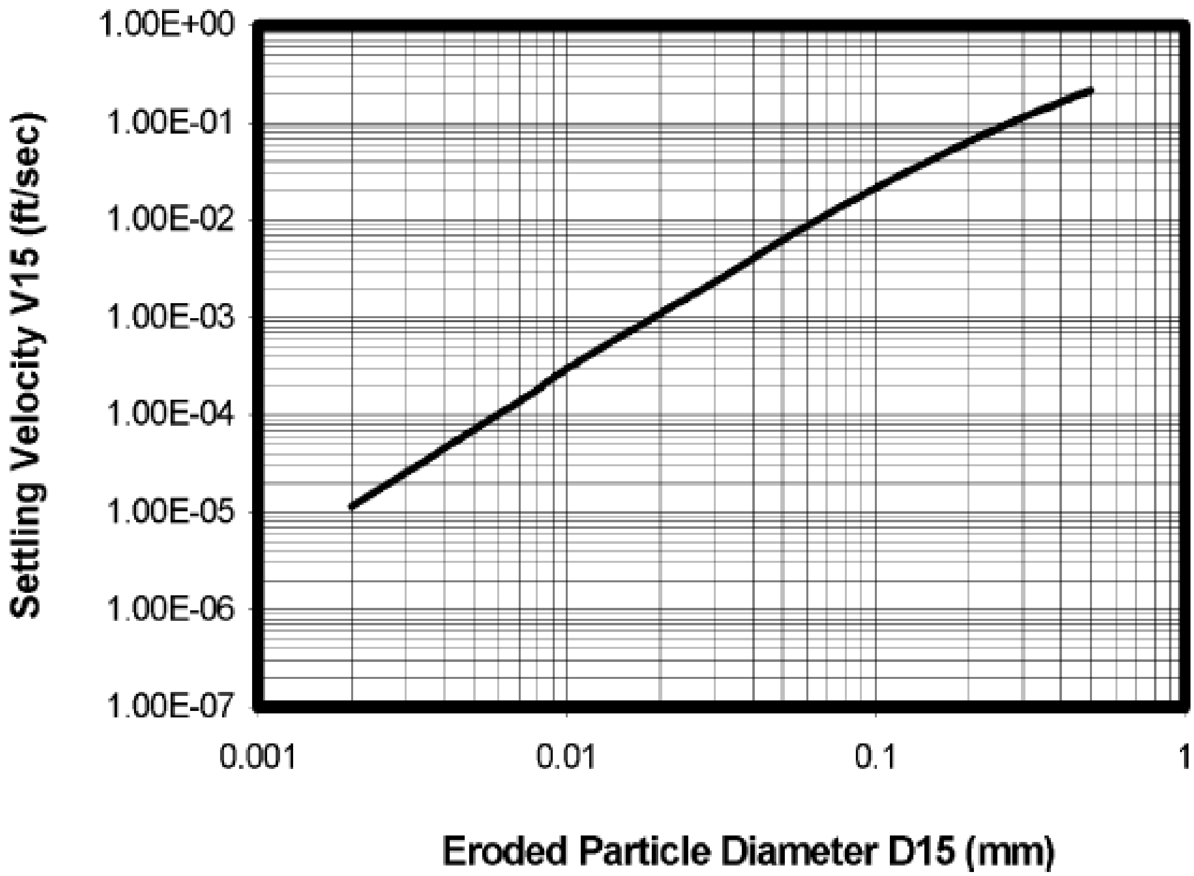
Each of these combinations will give the desired trapping efficiency because they were calculated based on the sediment dam ratio that would result in 80 percent.

The rock fill outlet structure must be designed to convey the peak flow shown in column two of the table above. If the rock fill check overtops, the trapping efficiency is assumed to be zero.

Storm flows shall be routed through the sediment dam to calculate the required depth and storage volume of the sediment dam. The sediment storage volume shall be provided below the bottom of the rock fill outlet structure.

FIGURE I-1
CHARACTERISTIC SETTLING VELOCITY AS A FUNCTION OF ERODED PARTICLE DIAMETER

EFFECTIVE DATE: OCTOBER, 2013

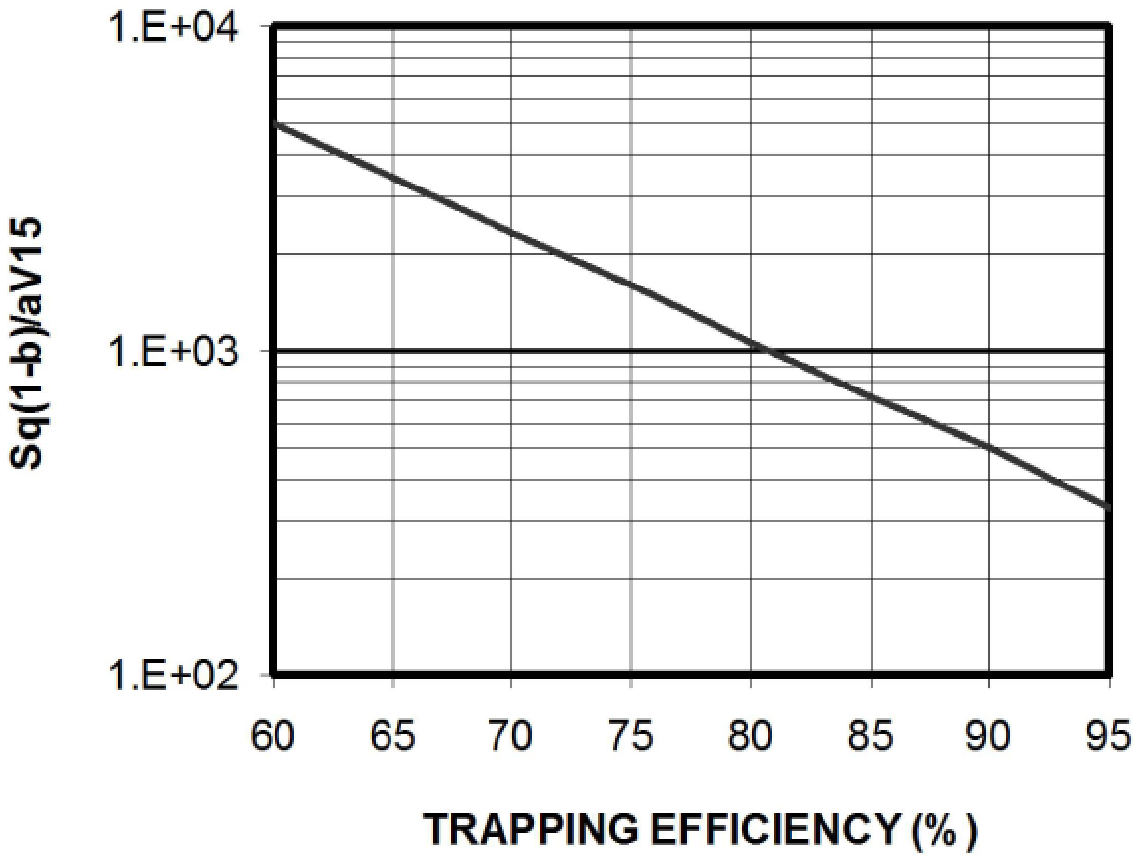


SOURCE: SCDHEC, 2005

CHARACTERISTIC SETTLING VELOCITY AS A FUNCTION OF ERODED PARTICLE DIAMETER

FIGURE I-2
TRAPPING EFFIENCY FOR ROCK DITCH CHECKS WITH COARSE TEXTURE SOILS

EFFECTIVE DATE: OCTOBER, 2013

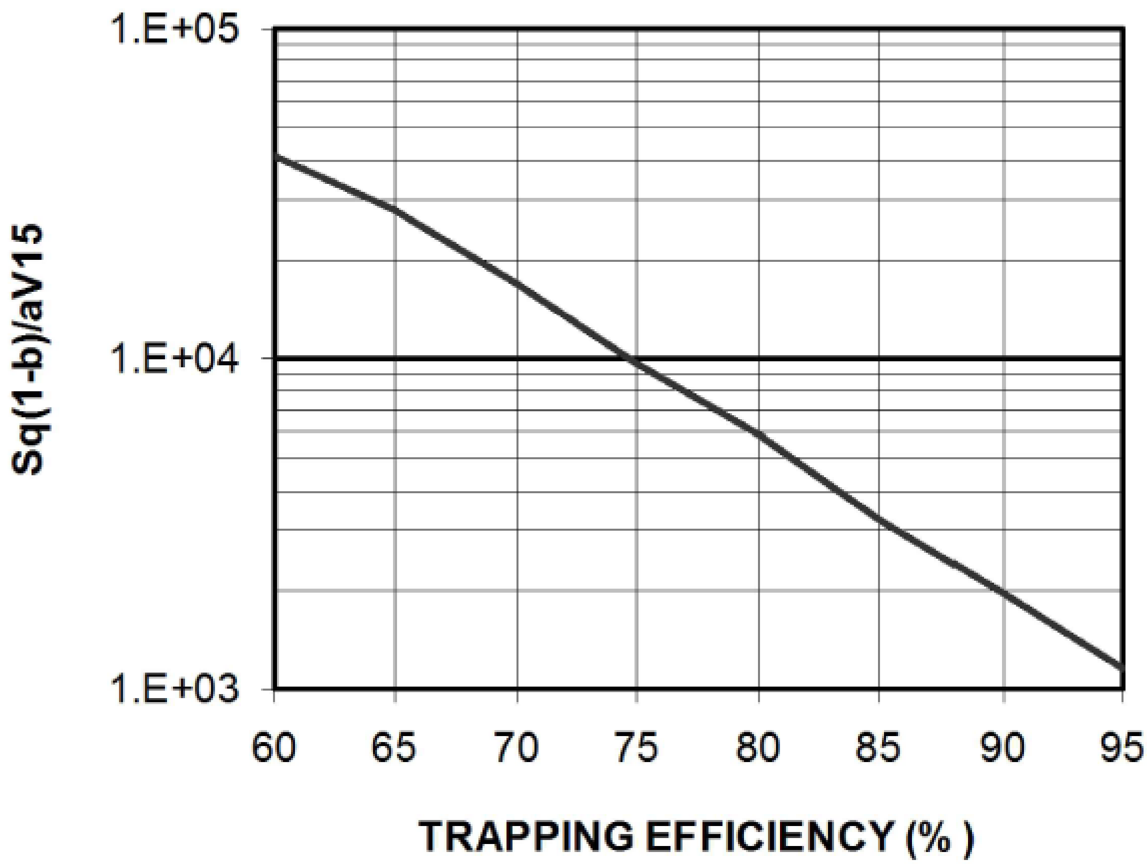


SOURCE: SCDHEC, 2005

DESIGN AID FOR ESTIMATING TRAPPING EFFICIENCY OF ROCK DITCH CHECKS WITH COARSE TEXTURE SOILS

FIGURE I-3
TRAPPING EFFIENCY FOR ROCK DITCH CHECKS WITH MEDIUM TEXTURE SOILS

EFFECTIVE DATE: OCTOBER, 2013



SOURCE: SCDHEC, 2005

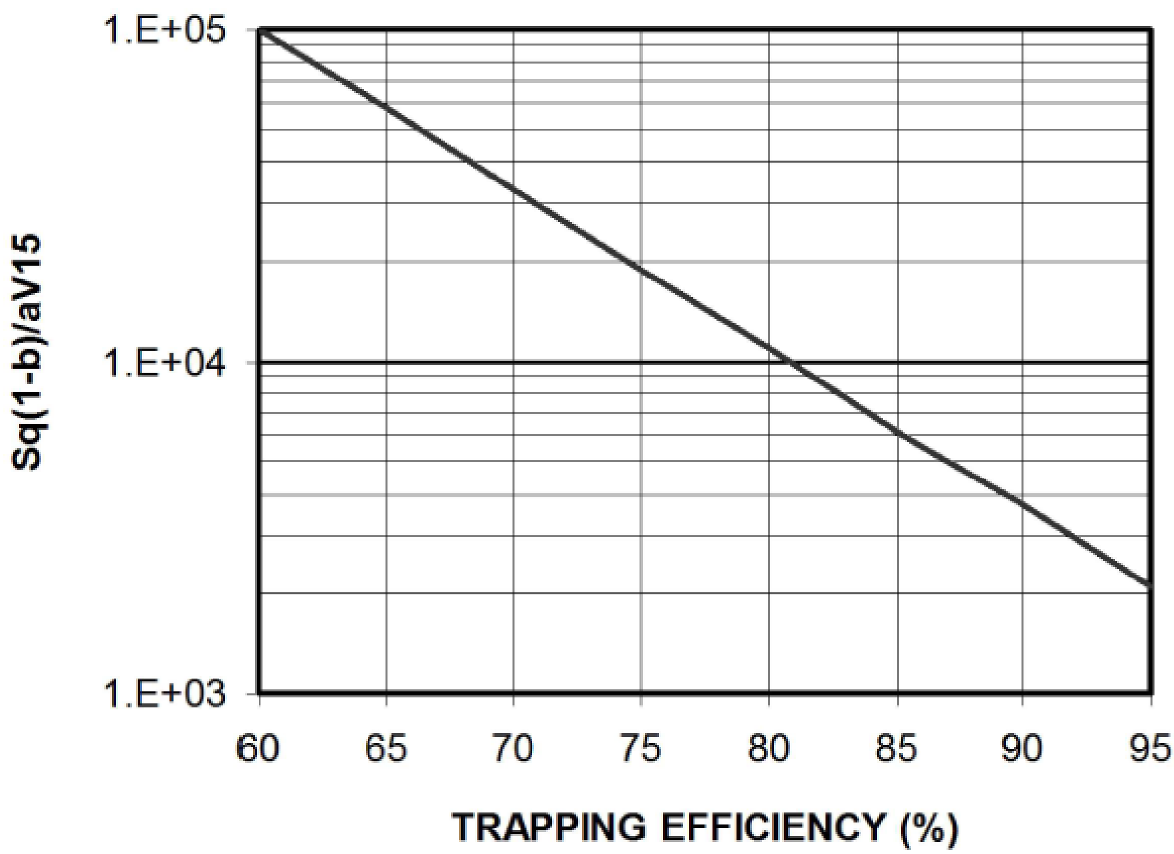
DESIGN AID FOR ESTIMATING TRAPPING EFFICIENCY OF ROCK DITCH CHECKS WITH MEDIUM TEXTURE SOILS

SCDOT

South Carolina Department of Transportation

FIGURE I-4
TRAPPING EFFIENCY FOR ROCK DITCH CHECKS WITH FINE TEXTURE SOILS

EFFECTIVE DATE: OCTOBER, 2013



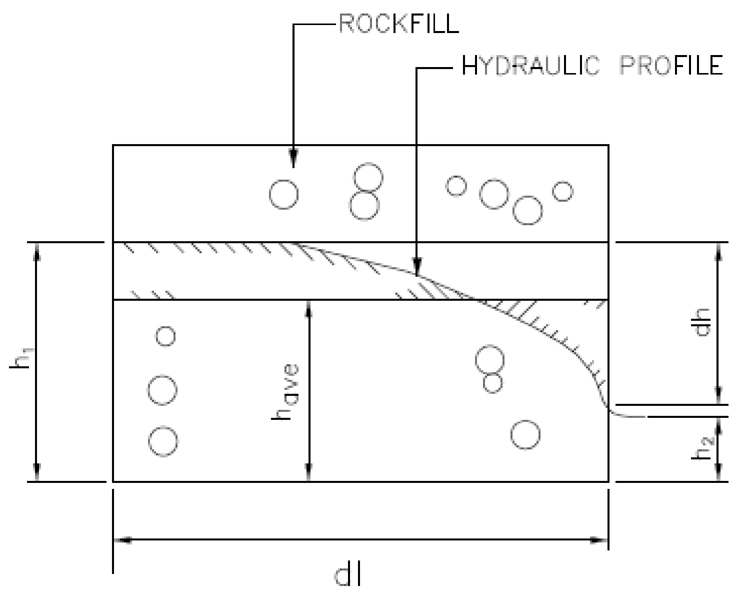
SOURCE: SCDHEC, 2005

DESIGN AID FOR ESTIMATING TRAPPING EFFICIENCY OF ROCK DITCH CHECKS WITH FINE TEXTURE SOILS

South Carolina Department of Transportation

FIGURE I-5
DEFINITION SKETCH FOR ROCKFILL EQUATIONS

EFFECTIVE DATE: OCTOBER, 2013

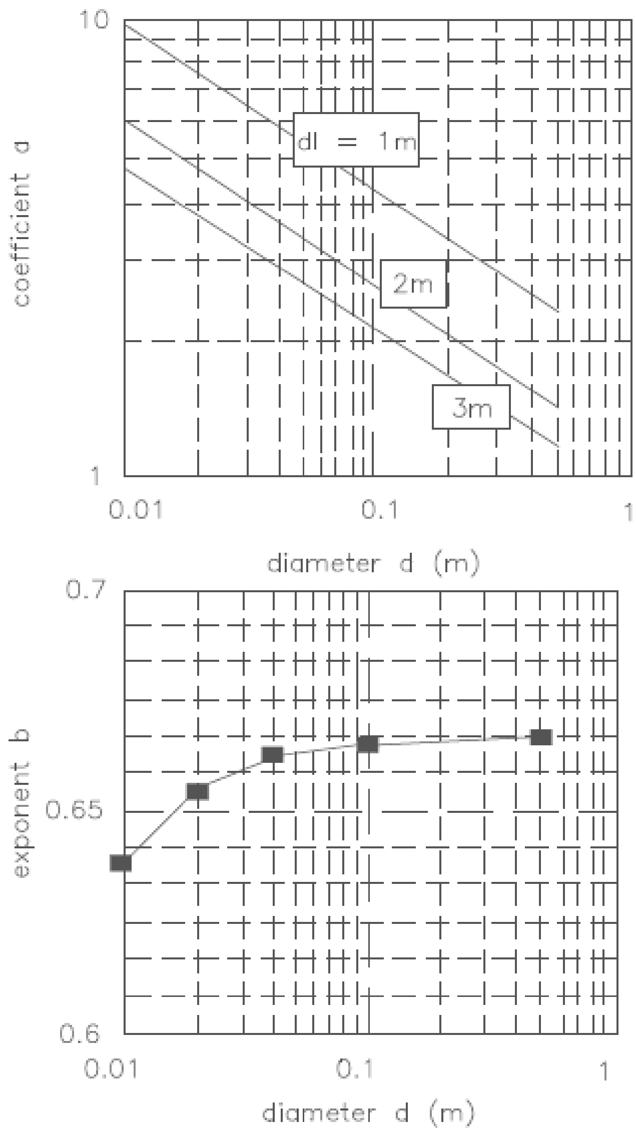


Source: Design Hydrology and Sedimentology for Small Catchments. Haan et. al, 1994.

DEFINITION SKETCH FOR ROCKFILL EQUATIONS

FIGURE I-6
ROCKFILL HEAD LOSS COEFFICIENTS
AND EXPONENTS

EFFECTIVE DATE: OCTOBER, 2013



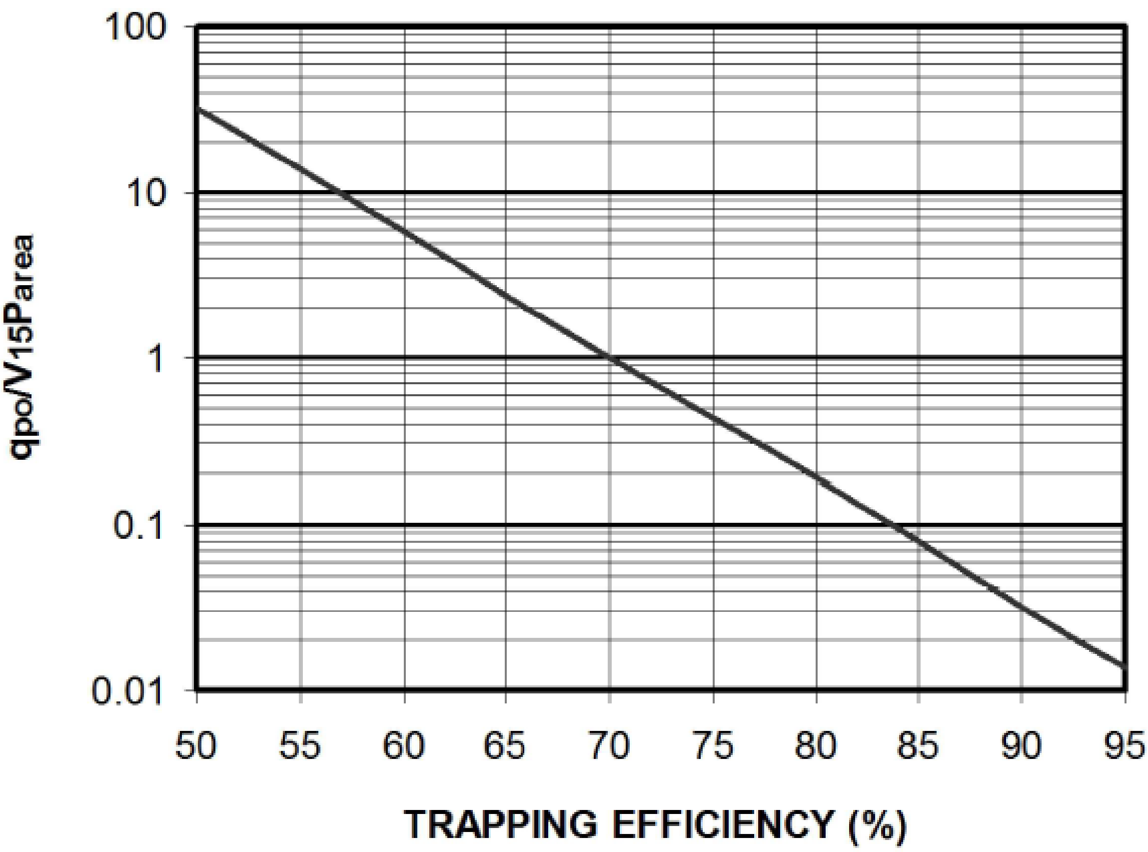
Source: Design Hydrology and Sedimentology for Small Catchments. Haan et. al, 1994.

CONSTANTS FOR ROCKFILL HEAD LOSS EQUATIONS

FIGURE I-7

TRAPPING EFFICIENCY OF SILT FENCE

EFFECTIVE DATE: OCTOBER, 2013



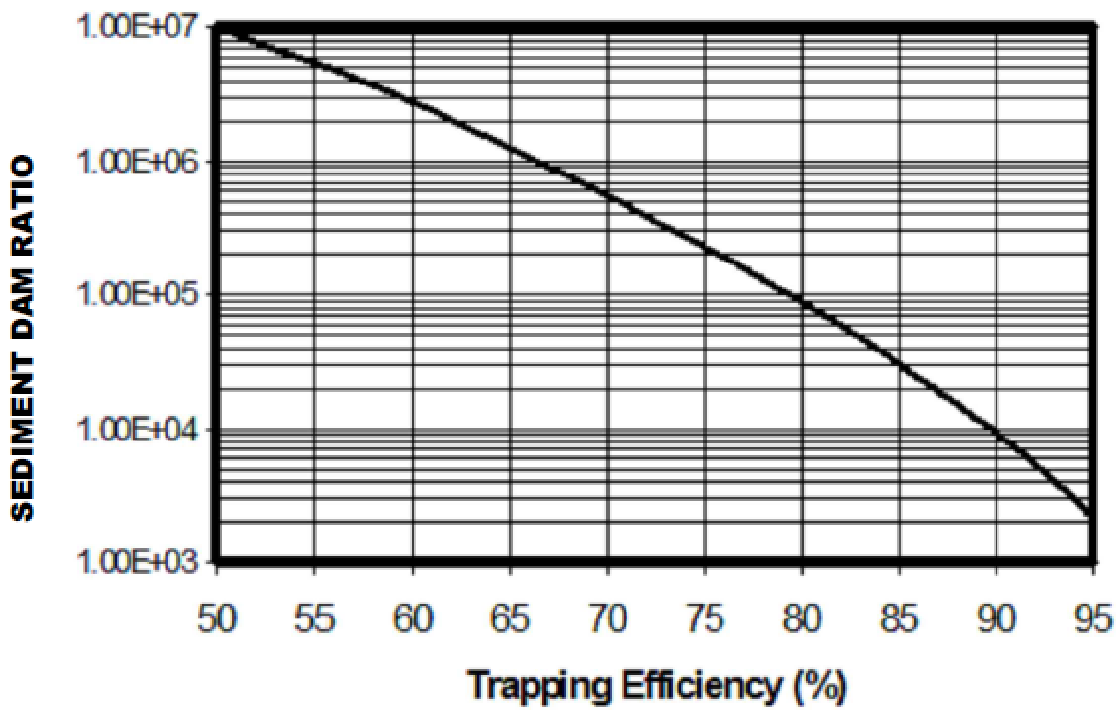
SOURCE: SCDHEC, 2005

DESIGN AID FOR ESTIMATING TRAPPING EFFICIENCY OF SILT FENCE

FIGURE I-8

TRAPPING EFFICIENCY OF SEDIMENT DAMS

EFFECTIVE DATE: OCTOBER, 2013



SOURCE: SCDHEC, 2005

DESIGN AID FOR ESTIMATING TRAPPING EFFICIENCY

OF SEDIMENT DAMS