Engineering Aids and Design Guidelines for Sediment Controls

This section presents design aids developed for use in designing four types of sediment control BMPs in South Carolina;

1. Sediment basins
2. Sediment traps
3. Silt fence
4. Rock check dams.

Each of these design aids is briefly described in this section. Specific BMP examples are located in the specific BMP sections of this Handbook to demonstrate their use in realistic problems. First a common feature of each design aid, settling velocity, is discussed.

Characteristic Settling Velocity and Eroded Particle Size

A common feature of each of the design aids is that a characteristic settling velocity for the eroded soil is obtained. For South Carolina conditions, this velocity corresponds to an eroded size such that 15 percent of the sediment has particles smaller than the size specified. The procedure for empirically estimating eroded size distributions is described by Hayes et. al (1996).

The characteristic settling velocity corresponds to an eroded particle diameter that is referred to as D_{15}. This diameter represents the point on the eroded particle size distribution curve where 15 percent of the particles (by weight) are equal to or smaller than this size. 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 USDA Soil Conservation Service (SCS) as part of county soil surveys. This procedure may be used with USDA Soil Survey Data or site specific soil boring data. Other procedures are given by Haan et. al. (1994) for physically based estimating procedures.

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

$$\mathbf{V_s = 2.81d^2}$$

Where:

V_s = settling velocity (ft/sec)
d = soil eroded particle size diameter (mm).

If the eroded particle size D_{15} is greater than or equal to 0.01 mm, then settling velocity is found using:

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

Where:

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

The characteristic settling velocity is obtained using Figure SV-1. The eroded particle sizes (D_{15}) for soils found in South Carolina are provided in Appendix E.

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 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 the lack of aggregation.

Soil Classification by Texture

Land Resource Region	Coarse	Medium	Fine
Piedmont, Coastal	Sandy Loam	Silt Loam	Clay Loam
Sandhills	Sand	Sandy Loam	Silt Loam
Tidal with High Water Table	Sandy Loam	Silt Loam	Clay Loam

Sediment Basin Design Aids

The Sediment Basin Design Aids are designed for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam). The design ratio should be less than or equal to the curve value at any given trapping efficiency. The sediment basin Design Aids have been developed for the following two separate conditions:

- Basins **not** located in low lying areas and/or not having a high water table, and
- Basin located in low lying areas and/or having a high water table.

Design Aid Ratio

$$\text{Basin Ratio} = \frac{q_{po}}{A V_{15}}$$

Where:

q_{po} = Peak outflow rate from the basin for the 10-year 24-hour storm event (cfs)
A = Surface area of the pond at riser crest (acres)
V_{15} = Characteristic settling velocity (fps) of the characteristic D_{15} eroded particle (mm).

Constraints for use of Sediment Basin Design Aids:

- Watershed area less than or equal to 30 acres
- Overland slope less than or equal to 20 percent
- Outlet diameter less than or equal to 6-feet

Basin Ratios above the design curves are not recommended for any application of the design aids. If the basin ratio q_{po}/AV_{15} intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

- A basin **not** located in a low lying area and not having a high water table, has a basin ratio equal to 2.20 E5 at 80 percent trapping efficiency as shown in Figure SB-1.
- A basin that **is** located in a low lying area or in an area that has a high water table, has a basin ratio equal to 4.70 E3 at 80 percent trapping efficiency as shown in Figure SB-2.

Rock Check Dam Design Aids

Design aids for rock check dams were developed similarly to those for ponds. Again, the D_{15} eroded particle size is used for the calculation of the characteristic settling velocity.

The Rock Check Dam Design Aids have been designed for the following soil classifications:

- Coarse (sandy loam)
- Medium (silt loam)
- Fine (clay loam).

The design ratio should be less than or equal to the curve value at any given trapping efficiency. The ratio for rock check dams is defined by:

Design Aid Ratio

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

Where:

S	=	Channel slope (%)
q	=	Unit width flow through the check for the 10-year 24-hour storm event (cfs/ft)
V_{15}	=	Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Coefficients *a* and Exponent *b* is interpolated from the following table.

Stone 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

D_{50} = rock check dam average stone diameter in meters.
***dl* = average flow length through the rock ditch check in meters.**
Source: Haan et. al. (1994) pg. 151.

Constraints for the use of Rock Check Dam Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 15 percent
- Maximum depth of the ditch is less than or equal to 6-feet

Rock Check Ratios above the design curves are not recommended for any application of the design aids. If the Rock Check Ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A rock check dam located on coarse soils has a ditch check ratio equal to 1.10 E3 at 80 percent trapping efficiency as shown in Figure DC-C.

A d rock check dam located on medium soils has a ditch check ratio equal to 5.80 E3 at 80 percent trapping efficiency as shown in Figure DC-M.

A d rock check dam located on fine soils has a ditch check ratio equal to 1.20 E4 at 80 percent trapping efficiency as shown in Figure DC-F.

Silt Fence Design Aids

This design aid for applies to silt fences placed in areas down slope from disturbed areas where it serves to retard flow and cause settling. Two conditions must be met for satisfactory design.

- Trapping efficiency must meet the desired level of control.
- Overtopping of the fence must not occur.

Design Aid Ratio

The silt fence design aid is a single line grouping all soil textures together. A similar procedure was used for development of the ratio as used for the ponds and rock checks. For the silt fence, the ratio is:

$$\text{Silt Fence Ratio} = \frac{q_{po}}{V_{15} P_{area}}$$

Where:

$\mathbf{q_{po}}$	=	Peak outflow through the fence for the 10-year 24-hour storm event (cfs)
$\mathbf{V_{15}}$	=	Characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm)
$\mathbf{P_{area}}$	=	Potential ponding area up slope of the fence (ft^2).

The ponding area is 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 multiplying the fence height by the ground slope. Multiply this unit area by the available fence length for ponding to obtain the potential ponding area.

Using the calculated ponding area, calculate the ratio and enter the value to Figure SF-1 to determine the 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 exist behind the fence to prevent overtopping.

Constraints for the use of Silt Fence Design Aids:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500-feet
- Overland slope is less than or equal to 6 percent
- Slurry flow rate through the fence is less than or equal to 10 gpm / ft
- Maximum height of the silt fence is less than or equal to 3-feet

Silt Fence Ratios above the design curves are not recommended for any application of the design aids. 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.

A silt fence ratio equal to 0.23 has an 80 percent trapping efficiency as shown in Figure SF-1.

Sediment Trap Design Aids

Sediment traps, for the purposes of this document, are small excavated ponds with rock fill outlets. Their outlet hydraulics are different from a drop inlet structure, thus the Design Aid is slightly different with the area defined as being the area at the bottom of the outlet structure. Trapping efficiencies for sediment traps are plotted in Figure ST-1 as a function of the sediment trap ratio:

Design Aid Ratio

The sediment trap design aid is a single line grouping all soil textures together. A similar procedure was used for the development of the ratio as used for basins. For the sediment trap, the ratio is:

$$\text{Sediment Trap Ratio} = \frac{q_{po}}{A\,V_{15}}$$

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), of the characteristic D_{15} eroded particle (mm).

Constraints for the use of Sediment Trap Design Aids are:

- Watershed area less than or equal to 5 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 5-feet
- Top width of rock fill between 2- and 4-feet
- Maximum Side slopes 1:1 to 1.5:1.

Sediment Trap Ratios above the design curves are not recommended for any application of the design aids. If the sediment trap ratio intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

A sediment trap ratio equal to 9.0 E4 has an 80 percent trapping efficiency as shown in Figure ST-1.

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

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