APPENDIX F

MTD DESIGN STORM SUMMARY

Stormwater Manufactured Treatment Devices (MTDs) – General Information

Stormwater Manufactured Treatment Devices (MTDs) are water quality structures designed to filter out sediment and other pollutants prior to runoff being discharged off-site or to receiving water bodies, and may be incorporated into a series of water quality best management practices. MTD pollutant removal efficiencies are variable and are highly dependent on storm size, influent pollutant concentrations, rainfall intensity and other factors. MTDs are designed to filter and trap trash, sediment, totals suspended solids (TSS), oil and grease, metals, hydrocarbons and other pollutants. MTDs combine settling, filtration, and various biological processes into one controlled system. MTDs are not designed, or are intended to store a volume of water for water quality treatment. When the storage of a water quantity volume is required, additional or separate BMPs must be implemented.

MTD pollutant removal efficiencies are variable and are highly dependent on storm size, influent pollutant concentrations, rainfall intensity and other factors. MTDs are classified in to three Types:

- MTD Type 1 - Separation Devices (Standard Stormwater MTD). Contains a sump for sediment deposition with a series of chambers, baffles or weirs to trap trash, oil, grease and other contaminants.

- MTD Type 2 - Filtration Devices (Impaired Water Bodies, TMDL Requirements). Contains a sedimentation chamber and a filtering chamber. MTD Type 2 contains filter materials or vegetation to remove specific pollutants such as nitrogen, phosphorus, copper, lead, zinc, and bacteria.

- MTD Type 3 - Catch Basin Inserts (Limited Right-of-Way). May contain filter media including polypropylene, porous polymers, treated cellulose, and activated carbon designed to absorb specific pollutants such as oil, grease, hydrocarbons and heavy metals. MTD Type 3 must provide overflow features that do not reduce the original hydraulic capacity of the catch basin.

MTDs are designed to treat, at a minimum, the peak flow rate of the stormwater runoff for the water quality design event (WQE) from the entire drainage area to the MTD. Offsite flows may be directed to and treated by the MTD, or they may bypass the MTD. If offsite flows are directed to the MTD, then the MTD water quality design and overall design must account for these flows.

Use MTDs designed to treat the entire WQE with no by pass for a minimum **80%** Total Suspended Solids (TSS) removal efficiency (ASTM D-3977-97 SSC). The WQE flow rate is a separate flow rate from the Level of Service (LOS) flow rate. In addition to meeting the required treatment efficiency for the WQE, the MTD must be capable of passing the specified LOS flow rate (i.e. 10-year storm event) without causing adverse hydraulic impact to upstream portions of the drainage system and without causing any re-suspension or scour of previously trapped pollutants, or the MTD may be required to be placed off-line. Ensure site constraints (available right of way and available depth) allow the installation of a single MTD for design peak water quality flow rates up to 8 cfs. Additional MTDs may be required for water quality event flow rates greater than 8 cfs.

Ensure tail water conditions are accounted for in the MTD design.

When applicable, use MTDs designed to meet any other additional watershed, TMDL, or site-specific water quality requirements. MTDs may include a high flow bypass mechanism for rainfall events larger than the water quality event to prevent scouring and re-suspension of previously trapped pollutants. MTDs not providing a high flow bypass mechanism must provide specific lab or field testing results verifying no re-suspension or scour of previously trapped pollutants during the level of service design event for the MTD.

Use MTD Type 1 sized using area scaling with a maximum Hydraulic Loading Rate of ***25 gpm/sf (0.0557 cfs/sf)***, and an optimal target Hydraulic Loading Rate of ***20 gpm/sf (0.0446 cfs/sf)***. MTDs designed with higher Hydraulic Loading Rates must provide specific lab or field testing results verifying the required removal efficiency for the water quality event at the Hydraulic Loading Rate.

Stormwater MTDs Single Event Design Storm Determination

In order to establish a standardized procedure for the MTD design to meet the 80% TSS removal efficiency criteria, the appropriate water quality event (WQE) design storm must be determined. It is recommended that MTDs be designed to treat, at a minimum, the peak flow rate of the stormwater runoff from the ***1.8-inch, 1-year, 24-hour storm event,*** from the entire drainage area to the BMP. This is defined as the water quality event (WQE) and the determination of this design storm event is presented in this report.

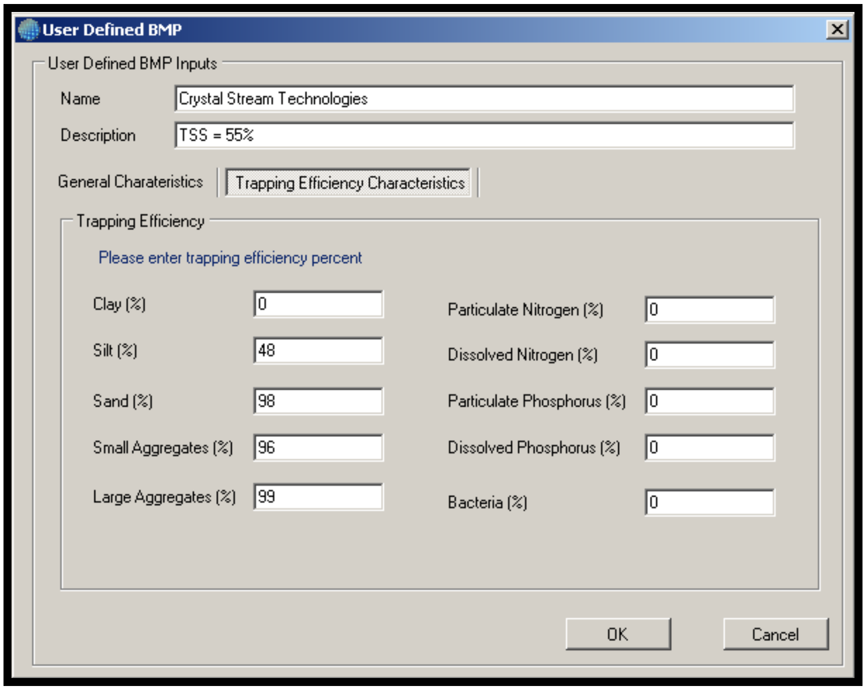
The single event design storm of six MTDs was determined using IDEAL (Integrated Design, Evaluation and Assessment of Loadings), a water quality software program. The following MTDs were selected, and their total suspended solids (TSS) removal efficiencies, as shown in Table 1, were based on a literature review of manufacturer publications and testing results. Some of these efficiencies were derived from a study conducted in Beaufort, SC. See http://pubs.usgs.gov/sir/2008/5150 for more information.

Table 1: Literature Review TSS Removal Efficiencies of Engineered Devices

Engineered Device	TSS Removal Efficiency
Crystal Stream Technologies	55%
Vortechs	80%
CDS	78%
Stormceptor	66%
VortCentury	76%
Bay Saver	49%

The MTDs were modeled in IDEAL as a user-defined BMP. The particle size distribution of the contributing soils and the ability of the MTD to trap the different particle classes significantly affect the TSS trapping efficiency. The user-defined BMP in IDEAL calculates the TSS trapping efficiency through the input of the trapping efficiency of the different particle sizes. Figure 1 is a screenshot of the input form of the user-defined BMP. The user can also input the trapping efficiencies of nutrients and bacteria, but since the focus of this study was on TSS, no other inputs were included.

Figure 1: User-Defined BMP Inputs



In order to model the MTDs listed in Table 1, the trapping efficiencies of the particles classes for each MTD were determined from Figure 2. The graph was developed based on a review of New Jersey Corporation for Advanced Technology (NJCATS) and EPA Environmental Technology Verification (ETV) Program testing protocol results for MTDs. This review included test results from many different MTDs and was not created exclusively for the analysis of the six MTDs listed above. NJCATS has developed a process for verification and certification of manufactured stormwater device technologies to evaluate vendor specific performance claims.

The ETV Program also develops test protocols and verifies the performance of innovative technologies. The testing protocol results were typically given in TSS trapping efficiencies, but in some cases, the particle distribution could be determined from the study. Since the exact size of the various particles classes such as clay, silt, small aggregates, sand, and large aggregates were not given in all of the ETV documents, some approximation (ranges) were used to break down TSS into discrete components in order to correlate the TSS trapping efficiency with the individual particle size trapping efficiencies. All of the MTDs included in these studies used an auto sampler to sample inflow and outflow rather than grab samples. Grab samples taken from the entire water flow column have the ability to result in a better representation of the actual eroded particle distribution. Auto samplers typically have the sample inlet located at the bottom of the water column and therefore are not always proficient at collecting suspended particles less than 75 microns (i.e., silt) and are only somewhat proficient at collecting particles between 75 and 125 microns.

Because clay is an extremely small particle (<5 microns) that does not settle easily when suspended in water, MTDs are not capable of capturing these eroded particles. MTDs will, however, capture nearly all of the large particles that are contained in the inflow, and a very high percentage (>90%) of the small aggregates and sand particles. Therefore, it was assumed that the variation in trapping efficiency between MTDs would be based on their ability to capture silt. Using the principles of Stokes' Law and the results of the NJCATS and ETV tests that provided enough information to break down TSS into discrete particle size ranges, the graph in Figure 2 was developed to accurately predict the trapping efficiencies of the individual particle sizes by MTDs, given only the MTD overall TSS trapping efficiency.

In Figure 2, there are various curves (20% - 80%) corresponding to the TSS trapping efficiency of the MTDs. The x-axis represents five particle sizes (Clay, silt, Small Aggregates, Sand, and Large Aggregates) and the y-axis represents trapping efficiency (%) of those particle classes. To use the graph, first determine the TSS trapping efficiency for the MTD and then find the curve corresponding to the published value. Next find the five points along that curve corresponding to the five particles classes on the x-axis. At each point, read the trapping efficiency value off the y-axis. Some interpolation may be necessary.

Figure 2: TSS Graph for Trapping Efficiency for Particle Classes

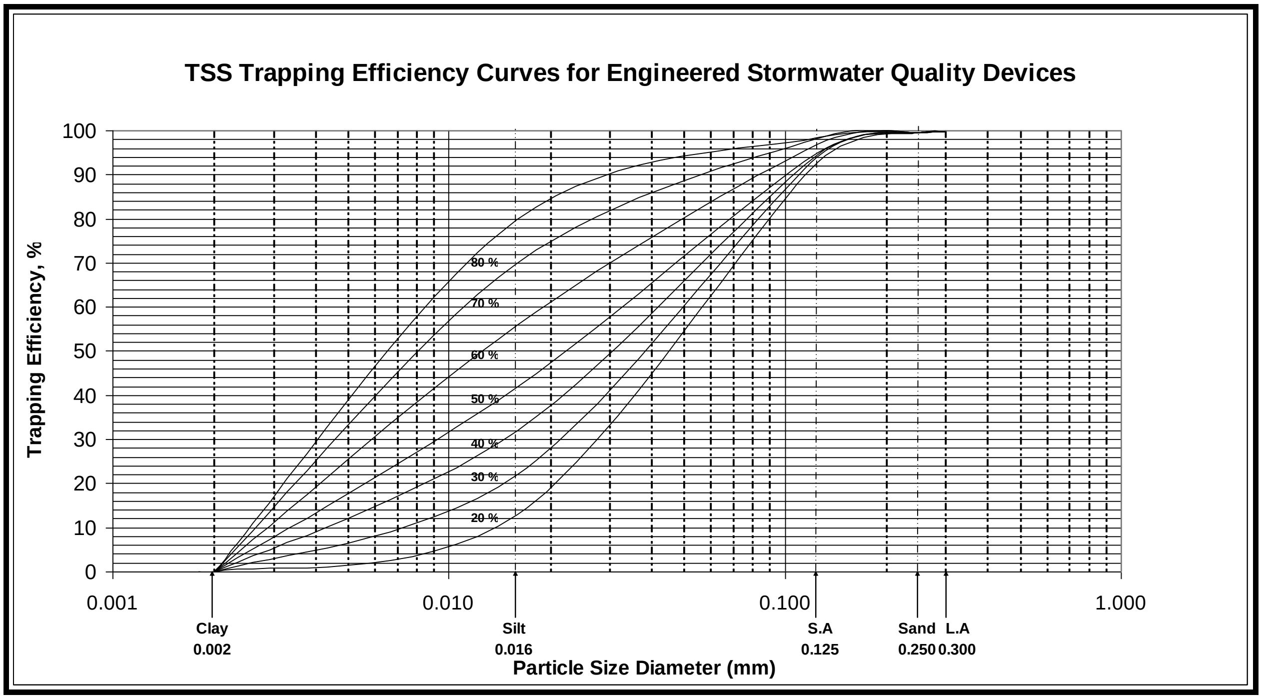


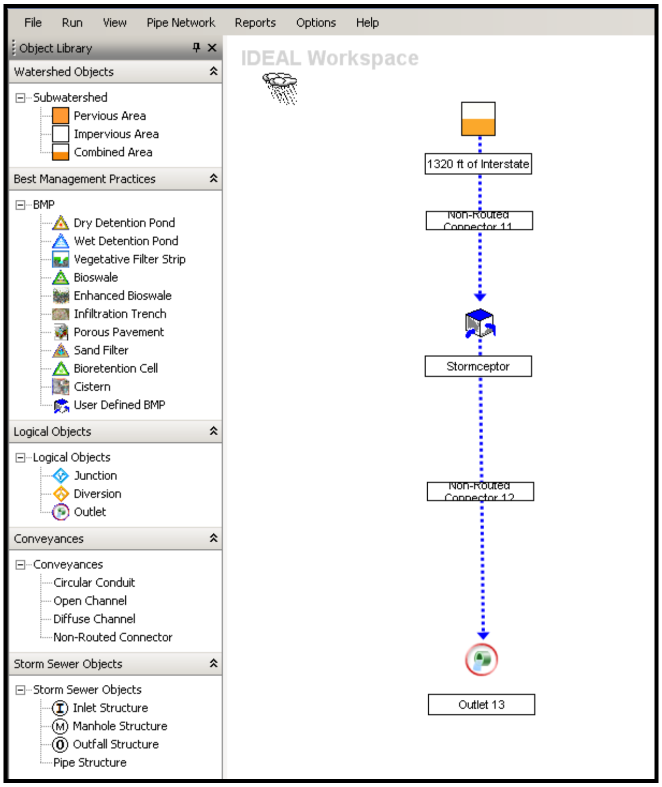
Table 2 shows the breakdown of the particle size trapping efficiencies used as the inputs for the six MTDs.

Table 2: Particle Size Trapping Efficiencies of MTDs

Engineered Device	Clay	Silt	Sand	Small Aggregates	Large Aggregates
Crystal Stream	0%	48%	98%	96%	99%
Vortechs	1%	80%	99%	98%	100%
CDS	1%	80%	98%	98%	99%
Stormceptor	0%	64%	98%	97%	99%
VortCentury	1%	78%	98%	98%	99%
Bay Saver	0%	42%	98%	94%	99%

The next input into IDEAL was the subwatershed attributes contributing the runoff that is routed through the MTD. The subwatershed was modeled with characteristics of the Upstate of South Carolina, such as Cecil soils. The total size of the subwatershed varied, but all were modeled as being 95% impervious. The watershed sizes were based on typical SCDOT roadway widths and various roadway lengths ranging from 500 feet to 1 mile. Figure 3 shows the subwatershed draining to a user-defined BMP (MTD) in IDEAL.

Figure 3: IDEAL Screenshot of Subwatershed Draining to a MTD



The models were first run with Greenville's annual probability distribution of storms. The TSS trapping efficiency of the MTD during the annual simulation was calculated and recorded. A single, 1-year, 24-hour, type II storm, was then found that matched the TSS trapping efficiency attained from the annual probability distribution of storms. Effectively, this determined the single design storm event that represents the expected performance of the MTD on an annual basis. Some of the results are shown in Table 3.

Table 3: Single, 1-year, 24-hour, Type II Design Storms

Engineered Device	Contributing Area (acres); 95% Impervious			
	0.29 ac	0.77 ac	1.53 ac	3.06 ac
Crystal Stream	1.75 inch	1.77 inch	1.76 inch	1.74 inch
Vortechs	1.75 inch	1.76 inch	1.76 inch	1.75 inch
CDS	1.75 inch	1.77 inch	1.76 inch	1.75 inch
Stormceptor	1.75 inch	1.77 inch	1.76 inch	1.75 inch
VortCentury	1.75 inch	1.77 inch	1.76 inch	1.75 inch
Bay Saver	1.75 inch	1.77 inch	1.76 inch	1.75 inch

The annual probability distribution of storms in IDEAL is selected when the user wants to consider annual loadings. Statistical average values for runoff, sediment, and nutrient loadings are calculated based on a site-specific joint probability distribution of precipitation, season, and antecedent moisture condition. This conditional probability distribution is a part of the database in the model and is calculated from (a) rainfall records for the site of interest and includes values for 12 possible rainfall ranges, (b) the probability the given precipitation value will occur in either the growing or dormant seasons (2 possibilities), and (c) the probability that the given precipitation event will occur in either dry, average, or wet antecedent moisture conditions (3 possibilities). IDEAL runs all 72 (12 x 2 x 3) conditions and calculates runoff, loadings, and effectiveness of practices for each. By combining the results for each of the 72 combinations and their respective probabilities, sediment yield and nutrient yields are calculated at the exit of each subwatershed and at the exit of all BMPs.

The MTD manufacturers must be able to provide data and testing results that show their product can treat the peak flows associated with that single design storm event at the efficiency they claim.

The results indicate that the design storm varies slightly with the size of the contributing drainage area; therefore the design storm is rounded up to 1.8 inches. Although this conclusion was drawn for the Upstate of South Carolina, a 1.8 inch, 1-year, 24-hour storm would be a conservative design storm for the coastal areas where the eroded sediment particle distributions are generally larger in size and therefore have faster settling velocities.

It is recommended that stormwater manufactured treatment devices be designed to treat at a minimum the peak flow rate of the stormwater runoff from the ***1.8-inch, 1-year, 24-hour storm event,*** from the entire drainage area to the BMP. This is defined as the water quality event. This water quality event is distributed into the rainfall intensities in Table 4. The MTDs must also be designed to carry the peak flow rates for the level of service event of the stormwater drainage system discharging to the MTD, or this flow must be bypassed around the MTD.

Table 4: Water Quality Event (WQE) Design Intensities

Frequency	**a**	**b**	**c**	**i[1] (t_c = 5 min) (in/hr)**	**i[1] (t_c = 10 min) (in/hr)**	**i[1] (t_c = 15 min) (in/hr)**	**i[1] (t_c = 30 min) (in/hr)**
Water Quality Event	135.65	40.2	1.0863	2.16	1.93	1.74	1.34

[1] Where:

$$i = \frac{a}{(b+t_c)^{c}}$$

i = rainfall intensity (inches per hour)
Tc = time of concentration (minutes)
a, b, c = water quality event coefficients