DATE: August 7, 2014 FILE REF: 3200

TO: Mary Anne Lowndes – WT/3; SOC

FROM: Roger Bannerman – DNR/USGS

SUBJECT: Four proposed changes to Technical Standard 1004, Bioretention for Infiltration

The purpose of this memo is to describe four draft revisions to the Technical Standard 1004, Bioretention for Infiltration. The draft revisions are as follows:

1. V.B.5.a.(3) - Specify a planting density of one foot on center. Dane County recommended this change, because consultants were trying to save money by spacing the plants too far apart.
2. V.B.5.b. - Allow Class II erosion control mats to be substituted for shredded hardwood mulch or chips. Dane County recommended this change, because the wood chips float away when submerged.
3. V.B.6.d.(5) - Increase the acceptable pH range of the soil mix from between 5.5 and 6.5 to between 5.5 and 8.0. Jame (Sandy) Syburg with Purple Cow Organics, LLC in Oconomowoc, WI suggested the pH change.
4. V.B.6.c. - Decrease the depth of the engineered soil mix from 3 feet to 2 feet. This change was prompted by the results of research conducted in Neenah, WI by the Department and our many partners, such as the USGS and McMahon Engineers and Architects.

The justification for these four changes is outlined in the rest of this memo.

1. Recommendation for Identifying a Planting Density

Background

One of Dane County's responses to our request for comments on the technical standards was the standard 1004 should have a specified planting density. They state the optimum planting density is one foot on center. Consultants designing bioretention systems have challenged this planting density by using a design with a decreased planting density. A plant spacing greater than one foot on center has the benefit of saving money.

The current version of 1004 does not specify a planting density, except for shrubs and trees (VI Considerations - Q). A specified density for shrubs and trees does not address the forbs and grasses, which are the type of plants most used in bioretention systems. There is a reference to plant density in the Design Section (V.B.5.a.(3)) that would apply to all plants. It states a bioretention system serving a non-residential area or streets must have a plant density low enough at maturity to accommodate long-term maintenance of the surface mulch layer. For residential area it states the mulch layer can be discontinued at maturity if the plant density is high. These statements do not provide clear guidance on how far apart the plants should be installed to accomplish the maintenance goals.

Discussion

To verify the planting density recommended by Dane County it was hoped the comprehensive stormwater manuals prepared for different states around the country would recommend a planting density for bioretention. Manuals that were reviewed included the ones for New York, New Jersey, Denver, Delaware, Minnesota, North Carolina, New Zealand, and WERF. All of these manuals included detailed descriptions of proper bioretention design, but none of them specified a planting density. The only manual with a specified planting density is Wisconsin's rain garden manual (Bannerman, 2003). The planting density of one foot apart recommended in this manual was suggested by landscape experts at Applied Ecological Services in Brodhead, WI.

Landscaping experts from two other companies were asked to comment on the planting density suggested by the landscape experts at Applied Ecological Services. Neil Diboll with Prairie Nursery in Westfield, WI and Eric Jacobson with Formecology in Evansville, WI have extensive experience working with our native plants and they were kind enough to share their expertise. They both thought a planting density of one foot on center for the forbs and grasses is a good choice. In their experience this would promote a sustainable plant community in a reasonable amount of time.

Recommendation

Our Bioretenition Technical Standard has relied on the consultants to select a planting density that will promote a healthy community of forbs and grasses. Based on the experiences in Dane County the desire to reduce the cost of the bioretention system will sometimes be justification to select a reduced planting density. It seems important to specify a reasonable planting density in 1004, but allow some flexibility to accommodate the variety of plants that could be used in a bioretention system. Only Criteria V.B.5.a.(3) of 1004 contains a general statement about plant density and the first sentence in the paragraph will not make sense if the standard contains a specific planting density (see below). The second sentence would be more appropriate in a section of the standard that describes requirements for mulching.

> The existing language for B.5.a.(3) is as follows: "If the bioretention device receives runoff from non-residential source areas or streets, the plant density at maturity must be low enough to accommodate long-term maintenance or replenishment of the surface mulch layer. If the bioretention device receives runoff only from residential land uses other than streets, the mulch layer can be discontinued at maturity provided that a dense vegetation layer is formed."

It is recommended that the paragraph describing planting density for maintenance purposes in Section B.5.a.(3) of Technical Standard 1004 be changed as follows.

"A planting density of one foot on center is required unless the type of plants selected would justify a larger space between the plants. As stated in Section Q of the Considerations, shrubs and trees would be planted with more than one foot between them."

It is recommended that the second sentence in B.5.a.(3) be moved to Considerations under the Operation and Maintenance – Section VIII. The operation and maintenance section contains a table describing the frequency of adding mulch to the surface. The sentence would be labeled "E" under Operation and Maintenance.

"If the bioretention device receives runoff only from residential land uses other than streets, the mulch layer can be discontinued at maturity provided that a dense vegetation layer is formed."

2. Recommendation for Substituting Erosion Control Mat for Hardwood Mulch

Background

Another one of Dane County's responses to our requests for comments on the technical standards was the standard 1004 should allow the use of an erosion control mat as a substitute for shredded hardwood mulch or chips. They state that erosion control mat is being commonly used with good success. Consultants from other parts of the state have been telling the Department the same thing, such as the use of erosion control mat for several bioretention systems along highway VV in Waukesha County. Consultants have complained to the Department and Dane County that the hardwood mulch floats away when submerged during larger runoff events. Replacing the mulch is expensive and a new bioretention system without a mulch layer is less likely to function properly. It would be subjected to erosion and the plants will not have the protection needed to become established.

Discussion

Erosion control mats or blankets will not float away (they are stapled down) and they provide good erosion control protection until the plants are sufficiently established. Erosion control mats can provide from 1 to 5 years of erosion protection based on the type of product (MS Department of Environmental Quality). Usually the forbs and grasses are well established in two to three years. After the mat has degraded and the plants provide a dense cover, an application of hardwood mulch can be used to reduce weed growth and provide some erosion protection.

The official definition of erosion control mat provided by the Erosion Control Technology Council is: "a temporary degradable rolled erosion control product composed of processed natural or polymer fibers mechanically, structurally, or chemically bound together to form a continuous matrix to provide erosion control and facilitate vegetation establishment (Lancaster and Austin, 2003). The most widely used erosion control mats are composed of fibers, such as straw, wood excelsior, coconut, or polypropylene, that are stitched or glued to degradable nettings. The durability and longevity of the mats can vary with the fiber, netting, and bonding components. Care must be taken to select the type of mat that will allow time for a stable plant community to grow.

Dane County has suggested a Class II erosion control mat will last long enough and provided sufficient erosion control for bioretention systems. This choice is consistent with the guidance provided in the Departments Channel Erosion Mat Technical Standard 1053 (WDNR, 2004). A Class II mat is described as designed for a duration of 3 years or more. The other two classes of products are either less durable (Class 1 - 6 months duration) or are considered permanent (Class III). A number of Class II products are recommended by the Wisconsin Department of Transportation (DOT, 2014).

Recommendation

Erosion control mats are widely used in the State of Wisconsin. In Design Criteria V.B.5.b. of Technical Standard 1004 there is a requirement of applying a surface mulch layer and shredded hardwood mulch or chips are specified for the mulch layer. Given the problem of shredded hardwood mulch or chips floating away, it seems reasonable to give a consultant the choice of using an erosion control mat. This choice will be especially important to a consultant designing a bioretention system where more intensive runoff is expected, such as a parking lot. It is recommended that the paragraph specifying shredded hardwood mulch or chips as a mulch in Criteria B.5.b. of Technical Standard 1004 be changed as follows.

V.B.5.b. Surface Mulch Layer – Shredded hardwood mulch or chips, aged a minimum of 12 months or a Class II erosion control mat (blanket), shall be placed on the surface of the bioretention area. The shredded hardwood mulch or chips shall be 2 to 3 inches in depth. The mulch shall be free of foreign material, including other plant material.

3. Recommendation for Expanding the pH Range of the Engineered Soil Mix

Background

Jame (Sandy) Syburg with Purple Cow Organics, LLC in Oconomowoc, WI called the Department saying the engineered soil mix pH requirement in Criteria V.B.6.d.5. of Technical Standard 1004 is too difficult to achieve by reasonable methods. He thought the upper range should be higher than 6.5 stated in the standard. Purple Cow Organics produces high quality compost and has supplied engineered soil mix to many bioretention installations in Wisconsin including the mix the Department has used for bioretention monitoring projects. Mr. Syburg says the media they make usually has a pH between 7 and 8 and they would have to add sulfur to lower the pH. Adding sulfur could change the pollutant removal characteristics of the media.

Discussion

To better understand how the pH values were selected for the standard, John Pfender (He wrote most of the standard) was asked to comment on the proposed change. He said it might have been for the compost not the media, but he is not sure. In retrospect he thought it was probably inappropriate to put a pH range in the standard. He also thought adding something to lower the pH is a bad idea. He thought changing the range of pH or removing the numbers made sense.

Further insight as to the impact of the proposed pH change was gained by asking the opinion of Dr. Philip Barack with the Soil Science Department at the University of Wisconsin Madison. The following is his response:

"stating that the pH is between 5.5 to 6.5 means that it is non-calcareous". Most of the soils around Wisconsin are non-calcareous and the vegetation associated with them would be acclimated to those pH values. That said, it is my understanding that most of the sand that is quarried has at least a few percent calcium carbonate associated with (at least that's what my turf grass colleagues say) and that works well for putting greens. I would doubt that there would be many local plants that would fail on calcareous sand...usually it's tropical species that have a hard time on calcareous materials (because of unavailability of iron). Indeed, bringing the pH into range would require considerable effort and present a large cost w/o much, if any, benefit. I would recommend a pH range between 5.5 and 8.0."

Recommendation

There appears to be a consensus that increasing the required pH range for the soil mix will not only make it more reasonable to produce, but it will also not impair the function of the mix. It is recommended the sentence stating the pH range for the engineered soil mix stated in Criteria V.B.6.d.(5) of Technical Standard 1004 be changed to:

"The engineered soil mix shall have a pH between 5.5 and 8.0."

4. Recommendation for Decreasing the Required Engineered Soil Depth

Background

When the Standards Oversight Council (SOC) committee for Technical Standard 1004 was deciding on what is an appropriate depth for the engineered soil in a bioretention system, the best available information suggested 3 feet would provide enough depth to remove pollutants and support the plant growth. Especially helpful was the guidance from Larry Coffman, who at that time was involved with the installation of bioretention systems in Prince George County, Maryland. Since the 3 foot depth is in the technical standard, it is tied to the achievement of the TSS performance standards in NR 151. The Department provided guidance that allows an 80% Total Suspended Solids (TSS) reduction for stormwater treated by the 3 feet of engineered soil.

As bioretention became a more popular way to achieve Wisconsin's TSS performance standards, the 3 foot depth requirement became an obstacle at many sites. People representing engineering firms and cities were contacting the Department to find out how much TSS reduction credit is possible if the engineered soil has a depth less than 3 feet. What they had discovered is that many sites had depth limitations because of high bed rock, a high ground water table, or the elevation of the surrounding drainage channels was too high to daylight the drain tile. The

Department did not want the selection of a 3 foot depth to become a liability, but it was important to understand how much the TSS credit might be impacted by a reduction in the engineered soil depth.

To determine how the depth of the engineered soil might impact the removal of TSS, the Department brought together many partners to support the monitoring of three bioretention systems with different depths of engineered soil – 1 foot, 2 feet, and 3 feet. The partners included the USGS, McMahon Engineers and Architects, SCA Tissue, Miron Construction, Waupaca Sand and Solutions, White Oak Farm, Whittman Construction, LLC, Fox-Wolf Watershed Alliance and the City of Appleton. Three companies, McMahon & Associates, SCA, and Miron Construction, agreed to pay for the construction of a bioretention system on their individual parking lots. The engineered soil depths on the SCA Tissue, McMahon Engineers and Architects, and Miron Construction parking lots are 1, 2, and 3 feet deep respectively. The USGS conducted the monitoring and is preparing a final report (Horwatich and others, 2014), The monitoring began in April 2010 and it was completed in August of 2011.

Site Description

The three neighboring businesses of SCA Tissue, Miron Construction and McMahon Engineers Architects are located in Neenah, Wisconsin (Figure 1). The drainage area to each device is mostly parking lot with a small amount of lawn (Table 1 and Figure 2). The installation of the SCA and McMahon sites was completed June 5, 2009 and the Miron site was completed in August 2009.

Figure1.The locations of the three businesses in Neenah, WI. Figure 2.The bioretention system at McMahon site.

Table1. The specifications selected for each bioretention system.

Site Name	Eng. Soil Depth	Drainage area, acres	Surface area of Device, sq. ft.	Surface area as % of drainage area
SCA (Cell 1)	1 foot	0.34	501	3.4% (29:1)
McMahon (Cell 2)	2 feet	0.75	530	1.6% (62:1)
Miron (Cell 3)	3 feet	0.61	515	1.9% (52:1)

Each bioretention system consisted of a layer of engineered soil mix over a drain tile at the bottom (Figure 3). The soil mix used for the first year and one half of monitoring was a mixture of 50% sand and 50% compost (provided free by White Oak Farm). At the time this was the mix recommended in 1004. A plastic liner was installed along the sides and the bottom of each system, so none of the flow could infiltrate into the native soil underneath (Figure 4). Preventing any infiltration was important, since the monitoring program was designed to isolate the amount of pollutants retained by the engineered soil mix. To accomplish this kind of mass balance for TSS, all the runoff water had to go out the drain tile.

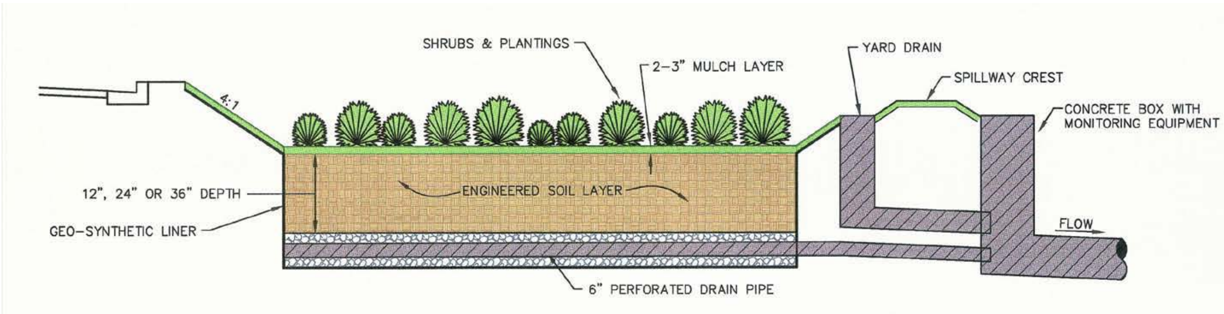

Figure3. Diagram of bioretention features installed on each site.

Figure4. Plastic liner used for each system.

Monitoring Program

Water quantity (flow) and quality was measured with automatic equipment installed at the inlet and outlet (drain tile) of each bioretention system (Figure 5). Each automatic sampler was programmed to collect flow-weighted samples at inlets and outlets of the three cells. This approach resulted in a single flow-weighted or "event mean" concentration for each sampling point. The constituents analyzed include, total suspended solids (TSS), suspended sediment (SS), volatile suspended solids (VSS), total dissolved solids (TDS), particle-size distribution (PSD), total phosphorus (TP), dissolved phosphorus (DP), total calcium (Ca), total magnesium (Mg), total zinc (TZn), dissolved zinc (DZn), total copper (TCu), dissolved copper (DCu), ammonia (NH_4), Nitrate + Nitrite (NO_2+NO_3), and chloride (Cl). An effort was made to collect samples for every runoff event during the study period. Additional data collected at each site included rainfall depths, engineered soil chemistry, surface infiltration rates, weather information, such as temperature and wind speed, and soil moisture. Sample collection began about 10 months after the systems were installed.

Figure5. The inlet, outlet, and automatic monitoring equipment installed at each site.

Results and Discussion

The number of water quality samples collected for SCA (Cell 1), McMahon (Cell 2), and Miron (Cell 3) between April 5, 2010 and August 6, 2011 years was 17, 19, and 21 respectively. Most of the samples were collected during rainfalls ranging from 0.2 to 1.0 inches in depth. All of the samples were analyzed for TSS, SS, and VSS. Fewer samples were analyzed for the other constituents, because the volume of sample collected was too small to do all the analysis or the lack of sufficient funds. For example, the number of samples analyzed for TP and DP ranged from 10 to 13, because too little sample volume was available for some of the smaller storms. The number of samples analyzed for heavy metals and nitrogen species was also limited by budget restraints. The results for the other constituents will be included in the final USGS report (Horwatich and others, 2014). Because the methods for determining the efficiency of stormwater control measures do not provide enough information to do a test of statistical significance, it is important to do a test that indicates whether differences between the inlet and outlet TSS concentrations are statistically significant.

TSS Concentrations

A statistical test provides support to the observation that all the inlets concentrations are higher than the outlet concentrations (Table 2). Since the TSS concentrations were log normally distributed, a nonparametric one-sided Wilcoxon signed-rank test was applied to see if the TSS median concentrations at the inlets were significantly greater than at the outlet (Helsel and Hirsch, 1992). The results of the test indicated the median TSS concentrations were higher at the inlet than the outlet. Based on these results it can be assumed the efficiency calculations will also be significant.

Table2. A comparison of median inlet and outlet TSS concentrations for the bioretention cells.

Sampling Location	Median TSS Concentration, mg/l		
	Cell 1	Cell 2	Cell 3
Inlet	72	20	20
Outlet	8	5	7

Engineered Soil Depth and TSS Reduction

Two methods typically used by investigators to determine the removal efficiency of constituents by a stormwater control practice are the efficiency ratio and summation of loads (SOL) (National Cooperative Highway Research Program, 2006). The efficiency ratio compares the average of the inlet and outlet event mean concentrations, while the SOL method compares the total loads from the inlet and outlet. Each method uses data from the inlet and outlet to produce a single number that is designed to represent removal efficiency of practices. Because the constituent loads are based multiplying the runoff volume times the event mean concentration, the SOL is weighted by the runoff events with the largest volumes. In most cases the two methods produce similar results (Horwatich and others, 2010; Horwatich and others, 2010), so it was decided to use the loads to compare the efficiencies of the different depths of engineered soil. Outlet runoff volumes were summations of the volumes that passed through the outlet flume and overflow flume. The following equation is used for calculating the SOL.

Summation of Loads = 100*[1 – (sum of outlet loads/sum of inlet loads)]

The percent TSS reductions based on the SOL for Cells 1, 2, and 3 were 88, 78, and 63 respectively. The results suggest that both a one and two foot depth of engineered soil are better for controlling TSS than the three foot depth currently recommended in the technical standard. Although this trend in SOLs supports the idea of reducing the depth requirement for Technical Standard 1004, some analysis of the data must done to determine if this trend is significant and why the SOLs of TSS increased with decreasing depth of media. Of course, a trend of increasing TSS reductions might be expected with increasing thickness of a filter media.

In order to evaluate the significance of the observed trends a Wilcoxon Rank Sum two-tailed test was applied to the SOLs as a detailed investigation of pairwise multi-comparison test. The test showed the SOLs for TSS were not different between Cells 2 and 3. Cell 1, however, had a higher SOL for TSS than the other two cells. To understand why Cell 1 SOL was higher than the other two, it is important to look at the consistently high inlet concentrations observed for Cell 1 and how they compare to the outlet concentrations. The statistically similarity between SOLs for Cells 2 and 3 seems more a function of how their TSS reductions become similar as the media ages and the fact the ranking process in the statistical analysis does not rank the outliers very high.

Impact of Inlet Concentrations on TSS Reductions

If all the outlet TSS concentrations for the cells were similar, than the magnitude of the TSS reductions could be more a function of the inlet concentrations. Throughout the study period the inlet concentration for Cell 1 was always higher than the other cells (Figure 6). Average inlet TSS concentrations for Cell 1 were at least 5 times higher than the other cells in the first two months of monitoring and they were still twice as high in the second year of sample collection (Table 3). In contrast the TSS the outlet concentrations for samples past the first 2 months are very similar (Figure 7; Table 3). A statistical comparison of all the outlet concentrations showed the concentrations are not different. By ranking the outliers in the first two months lower and similarities in the other time periods higher, the statistical analysis reflects the trend in outlets concentrations over time (Table 3; Figure 7). The higher SOL for Cell 1 is probably a function of the higher inlet concentrations.

These relatively high inlet concentrations were a result of the deteriorated condition of the parking lot and construction activities during the sampling period (Michael Dillon, 2014). Soil was observed eroding from the installation of a windmill during the course of the monitoring. There were no unusually sources of TSS at the other test sites. The SOL for Cell 1 would probably have been similar to the other cells if there had not been additional sources of TSS.

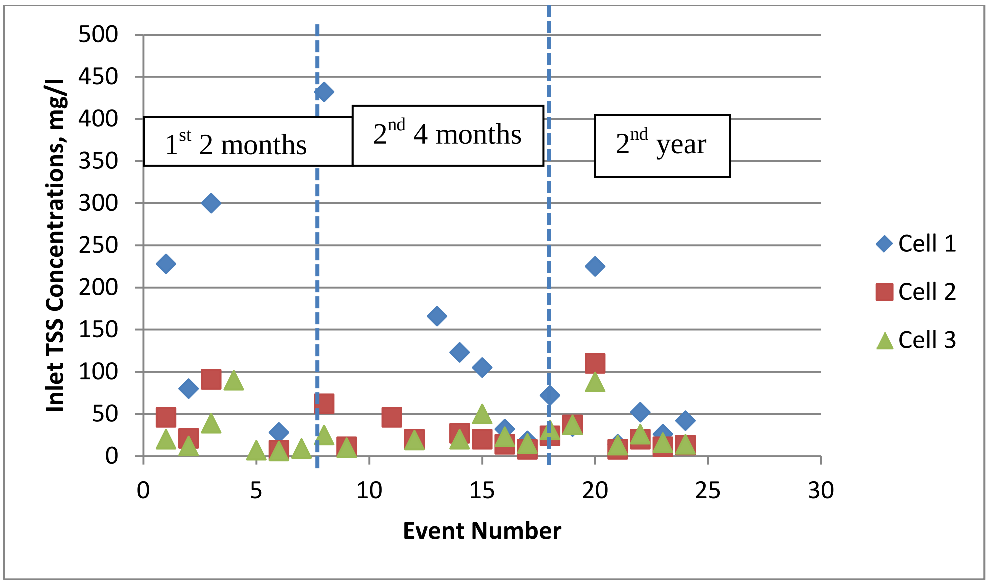

Figure6. The variability of inlet TSS concentrations of the three cells as a function of time.

Table3. A comparison of median TSS concentrations between cells for selected times during the sampling collection.

Selected Combinations of Monitoring Dates	Median TSS Concentrations, mg/l		
	Cell 1	Cell 2	Cell 3
	Inlet		
All Events	72	20	20
1st 2 months	228	42	11
2nd 4 months	56	20	22
2nd Year	38	16	21
	Outlet		
All Events	8	5	7
1st 2 months	28	10	10
2nd 4 months	6	5	5
2nd Year	2	3	3

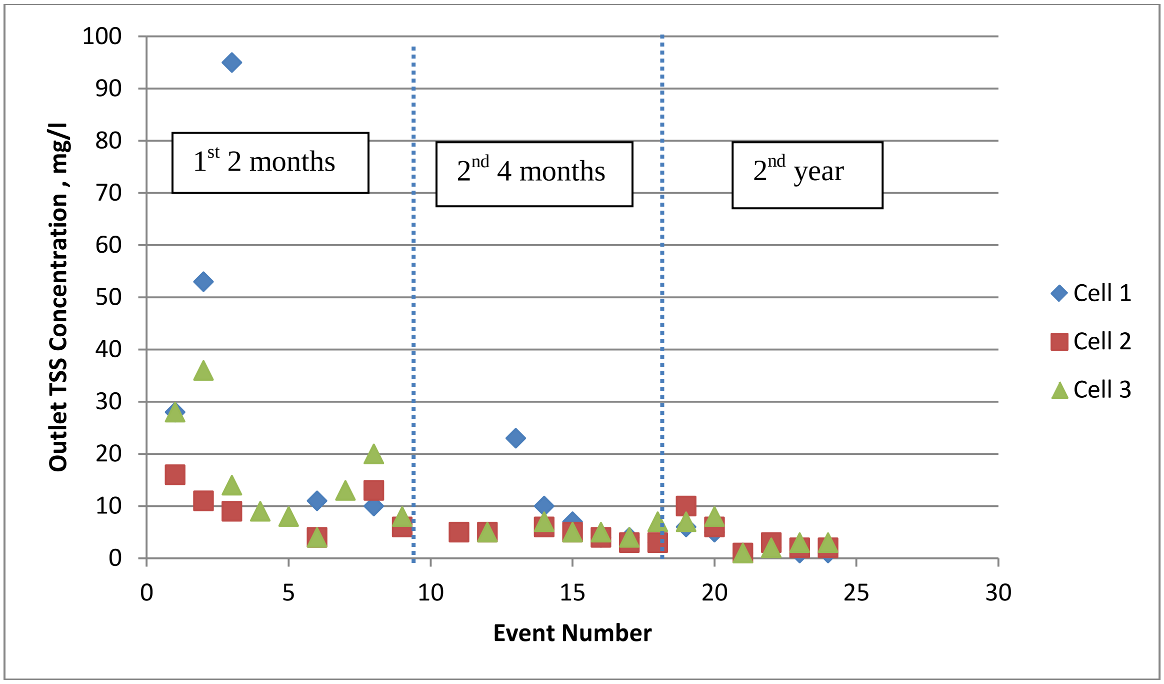

Figure7. The TSS outlet concentrations as a function of time.

Improvements in the Engineered Soil Effectiveness Over Time

As mentioned above, the SOLs for Cells 2 and 3 are statistically similar despite Cell 3 having a SOL value 15 percentage points less than Cell 2. The statistics are reflecting the increasing similarity in the TSS load reductions with time (Figure 8). By the second year all but one of the TSS load reductions for Cells 2 and 3 are between 80 and 96 percent, while the range in reductions for the first two months of sampling was between a negative 188 and positive 90 percent. The few outliers in the first 2 months of the monitoring are given a lower rank in the statistical analysis than all the similar TSS load reductions in the second four months and the second year of sampling. When SOLs are determined for these same time periods, the pattern of increasing reduction with the age of the media is repeated (Table 4). After the first two months the SOLs for Cells 2 and 3 are essentially the same. Some changes in the engineered soil with time definitely increase the TSS reduction of all the cells.

Increasing TSS reductions with time are probably a response to the decline in outlet TSS concentrations over time (Figure7; Table 3). One of the reasons a filter media might have lower outlet concentrations over time is the media might become a better filter as it clogs. Some clogging of the filter sock on the drain tile could be contributing to the lower TSS outlet concentrations. Another possible reason is the amount of fines flushed from the media declines with additional runoff events. This is part of the natural settling process observed for most bioretention systems. If the declining outlet concentrations are mostly a result of the changes in the media, then the media becomes the most important source of the TSS at the outlet.

To test this theory a fire hose test was done on Cells 2 and 3 on May 18, 2011. City water was discharged into the cells until they were full of water (Figure 9). Water quality samples were collected at the outlet and from the fire hose. The TSS concentrations at the outlet were the same as the median outlet concentration collected during runoff events in the second year (Table 5). The source of the TSS at the outlet appears to be the media itself. So as the media stabilizes, the TSS load reductions increase.

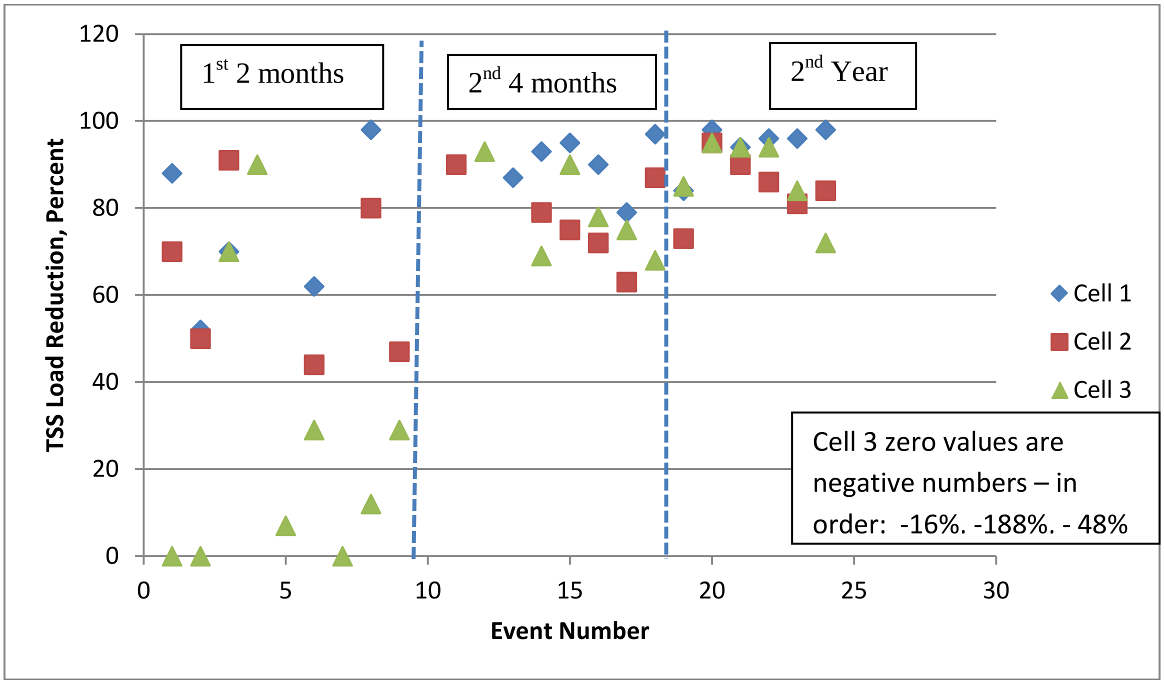

Figure8. TSS Load Reductions for Each Cell as a Function of Time.

Table4. Sum of the Loads Values for Selected Combinations of Monitoring Dates.

Selected Combinations of Monitoring Dates	TSS SOL Reductions, %		
	Cell 1	Cell 2	Cell 3
All Events	88	78	63
1st 2 months	85	74	31
2nd 4 months	91	82	82
2nd Year	96	87	90

Table5. Results of flushing cells 2 and 3 with city water.

Figure9. Fire Hose flushing test at Cell 3.

Type of Value	TSS Concentration, mg/l	
	Cell 2	Cell 3
City Water – Inlet	< 2	< 2
Hose Test – Outlet	3	3
Median Event 2011 - Outlet	3	3

Recommendation

The percent TSS reduction for bioretention systems does not appear to be a function of the engineered soil thickness, but the concentrations of the TSS from the source areas and the time since the system was installed. Others have raised the concern that the percent efficiency is not always a good indicator of how a stormwater control measure works, since it can depend on the input concentrations (Strecker et al. 2001). In this study the TSS reduction was highest for the cell with the least thickness, because it had the highest inlet concentration. Investigations into the removal mechanisms for TSS in an engineered soil media also downplay the importance of media thickness for TSS reduction. Most of the TSS appears to be removed by settling in the surface storage area and by filtration in the first few inches of the media (Hunt et al., 2006).

The results of this study and the literature clearly support reducing the thickness requirement in Technical Standard 1004. How much to reduce the thickness must take into consideration the need to support plant growth and the need to remove other pollutants, such as heavy metals and phosphorus. An overview of bioretention studies indicated a 2 foot thickness is adequate for most pollutants, but 18 inches is adequate for heavy metals and pathogens (Hunt et al., 2006). Literature values for phosphorus vary tremendously and the Department has just finished a study evaluating the impact of engineered soil thickness on phosphorus reduction. So far, the results indicate the thickness of the media is not as important to phosphorus reduction as the type of media. A thickness of 18 to 24 inches will support the growth of prairie plants and a three foot thickness would only be needed when trees are being used.

Although changing the depth to 2 feet has good support, some Wisconsin engineers have requested a depth of 18 inches be allowed for sites with more restrictive elevation requirements. The problem is that the drain tile cannot be day lighted in many stormwater conveyance systems, because their elevations are too high. The recommended depth of pure sand filters is also 18 inches. Research results indicate the sand filters at that depth can do a good job of removing most pollutants.

It is recommended the sentence stating the depth for the engineered soil mix stated in V.B.6.c. of Technical Standard 1004 be changed to:

> "Engineered Soil Depth – After settling, there shall be sufficient soil to support the rooting depth of the vegetation. If the storage layer (V.B.7.) uses gravel, a lens of pea gravel not to exceed 4 inches shall separate the engineered soil from the storage layer. The soil layer (including the pea gravel lens) shall be at least 2 feet deep. A depth of 18 inches will also be allowed for sites with more restrictive elevation requirements."

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