**REPORT for OBJ2.TASK 8 iv:**

**DESIGN SPECIFICATIONS**

**To: MPCA**

From: The Kestrel Design Group Team:

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Date: July 31, 2013

Re: Contract CR5332 Objective 2

**SCOPE**

Update and incorporate new information, consistent with NPDES stormwater permit requirements and the most recent version of the MIDS calculator, on design specifications for bioretention and infiltration BMPs.

1. Review literature pertaining to design specifications for the following topics. As part of the review identify conditions that could lead to scour, re-suspension and pollutant load flushing during high flow events. The review shall consider the following:
2. The maximum ponding depth for infiltration basins;
3. Underdrain sizing;
4. Drainage area contributing to the BMP;
5. Use of engineered media;
6. Off-line design (high flow bypass);
7. Vegetation;
8. Maximum flow path through a BMP; and
9. Use of multiple cells in a BMP.

**Note: This report only addresses Task 8.a. iv; see separate report for the remainder of Task 8**

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**CURRENT MANUAL GROWING MEDIA RECOMMENDATIONS:**

***Soils****: No restrictions; engineered media HIGHLY RECOMMENDED*

*It is HIGHLY RECOMMENDED that soils meet the design criteria outlined later in this section, and contain less than 5% clay by volume.*

*4.1.1 Mix A: Water Quality Blend*

*A well blended, homogenous mixture of 55-65% construction sand: 10-20% top soil; and 25-*

*35% organic leaf compost is necessary to provide a soil medium with a high infiltration/filtration*

*capacity.*

***Sand****: Provide clean construction sand, free of deleterious materials. AASHTO M-6 or ASTM*

*C-33 with grain size of 0.02”- 0.04”*

***Top Soil****: Sandy loam, loamy sand, or loam texture per USDA textural triangle with less than*

*5% clay content*

***Organic Leaf Compost****: (MnDOT Grade 2) 2 (see also a fact sheet in Chapter 12-3, entitled Using Compost as a Soil Amendment)*

*4.1.2 Mix B: Enhanced Filtration Blend*

*A well-blended, homogenous mixture of 50-70% construction sand and 30-50% organic leaf*

*compost is necessary to provide a soil medium with a higher infiltration/filtration capacity.*

***Sand****: Provide clean construction sand, free of deleterious materials. AASHTO M-6 or ASTM*

*C-33 with grain size of 0.02”-0.04”*

***Organic Leaf Compost****: Mn/DOT Grade 2*

*Topsoil in the mix will help with some nutrient removal, especially nutrients, but extra care must*

*be taken during construction to inspect the soils before installation and to avoid compaction.*

***4.2. Soil Medium / Filter Media Depth***

*Field experiments show that pollutant removal is accomplished within the top 30” of soil depth*

*with minimal additional removal beyond that depth (Prince George’s County, 2002). Therefore,*

*the recommended depth of the prepared soil is 30 inches. However, if large trees are preferred in*

*the design, a soil depth of 48”-52” should be utilized. The soil depth generally depends upon the root depth of the prescribed vegetation and content of underlying soils.*

**PROPOSED ADDITION TO 4.2 SOIL MEDIUM/FILTER MEDIA DEPTH**

Research has shown that minimum bioretention soil media depth needed varies depending on the target pollutant(s). Table 1 summarizes minimum depths recommended for common stormwater pollutants.

Table 1: Minimum bioretention soil media depths recommended to target specific stormwater pollutants

|  |  |  |  |
| --- | --- | --- | --- |
| **Pollutant** | **Depth of Treatment with upturned elbow or elevated underdrain** | **Depth of Treatment without underdrain or with underdrain at bottom** | **Minimum Depth** |
| TSS | Top 2-3” of bioretention soil media | Top 2-3” of bioretention soil media | Not applicable for TSS because minimum depth needed for plant survival and growth is greater than minimum depth needed for TSS reduction |
| Metals | Top 8” of bioretention soil media | Top 8” of bioretention soil media | Not applicable for metals because minimum depth needed for plant survival and growth is greater than minimum depth needed for metals reduction |
| Hydrocarbons | 3-4” Mulch layer, top 1” of bioretention soil media | 3-4” Mulch layer, top 1” of bioretention soil media | Not applicable for hydrocarbons because minimum depth needed for plant survival and growth is greater than minimum depth needed for hydrocarbons reduction |
| Nitrogen | From top to bottom of bioretention soil media; Internal Water Storage Zone (IWS) improves exfiltration, thereby **reducing pollutant load** to the receiving stream, and also improvesnitrogen removal because the longer retention time allows denitrification to occur under anoxic conditions. | From top to bottom of bioretention soil media | Retention time is important, so deeper media is preferred (3-ft minimum) |
| Particulate phosphorus | Top 2-3” of bioretention soil media. | Top 2-3” of bioretention soil media. | Not applicable for particulate phosphorus because minimum depth needed for plant survival and growth is greater than minimum depth needed for particulate phosphorus reduction |
| Dissolved phosphorus | From top of media to top of submerged zone. Saturated conditions cause P to not be effectively stored in submerged zone. | From top to bottom of bioretention soil media | Minimum 2 ft, but 3 ft recommended as a conservative value; if IWS is included, keep top of submerged zone at  least 1.5-2’ from surface of media |
| Pathogens | From top of soil to top of submerged zone. | From top to bottom of bioretention soil media | Minimum 2’; if IWS is included, keep top of submerged zone at  least 2’ from surface of media |
| Temperature | From top to bottom of bioretention soil media; Internal Water Storage Zone (IWS) improves exfiltration, thereby reducing volume of warm runoff discharged to the receiving stream, and also improves thermal pollution abatement because the longer retention time allows runoff to cool more before discharge. | From top to bottom of bioretention soil media | Minimum 3 ft, with 4 ft preferred |

Above based on Hunt et al. 2012 and Hathaway et al. 2011.

**UPDATED BIORETENTION SOIL MEDIA PERFORMANCE SPECIFICATIONS PROPOSED BY KESTREL TEAM**

1. **Performance Specifications applicable to all bioretention media:**
2. Growing media must be suitable for supporting vigorous growth of selected plant species.
3. pH range (Soil/Water 1:1) 6.0 to 8.5
4. Soluble salts (soil/Water 1:2) not to exceed 500 ppm
5. All bioretention growing media must have a field tested infiltration rate between 1-8 inches per hour. Growing media with slower infiltration rates could clog over time and may not meet drawdown requirements. Target infiltration rates should be no more than 8 inches per hour, to allow for adequate water retention for vegetation as well as adequate retention time for pollutant removal. If specific pollutants are targeted in a watershed, Table 2 should be used to tailor an infiltration rate to the pollutant(s) of concern.

Table 2: Optimal infiltration rates for reduction of specific pollutants (from Hunt and Lord, 2006)

|  |  |
| --- | --- |
| **Target Pollutant** | **Target Infiltration Rate** |
| TSS | Any rate is sufficient, 2 to 6 inches recommended |
| Pathogens | Any rate is sufficient, 2 to 6 inches recommended |
| Metals | Any rate is sufficient, 2 to 6 inches recommended |
| Temperature | Slower rates are more preferable (less than 2 inches per hour) |
| Total Nitrogen (TN) | 1-2 inches per hour. 1” is best for TN) |
| Total Phosphorus (TP) | 2 inches per hour |

1. **Additional bioretention growing media performance specifications required to receive P reduction credit**
2. Option A for Obtaining P Reduction Credit: use bioretention soil with phosphorus content between 12 and 36 mg/kg per Mehlich III test

Research shows moderate/high P removal rates when soil phosphorus content is less than 36 mg/kg per Mehlich III test (see *Specific Storm Water Credit Systems Memo* for summary of supporting research and precedents)

1. Option B for Obtaining P Reduction Credit: use a soil low in phosphorus as described in Option A above

AND

Include any of the following soil additives as described in *Specific Storm Water Credit Systems Memo*

**Guidance for Bioretention Media Composition**

Current Mixes A and B: Keep these the same as in the current manual except for the following changes:

* Change sand from “AASHTO M-6 or ASTM C-33 with grain size of 0.02”- 0.04” to “AASHTO M-6 or ASTM C-33 washed sand”, i.e. drop grain size requirement of 0.02”- 0.04”, and add “washed”
* Change percent composition as shown in Table 3 below.
* Add: “adjust proportions as needed to meet project’s target infiltration rate”

Mix C (based on North Carolina State University bioretention soil media in based on North Carolina State University bioretention soil media (North Carolina Department of Environment and Natural Resources. 2009):

Homogenous soil mix of:

* 85-88 percent by volume sand (USDA Soil Textural Classification),
* 8 to 12 percent fines by volume (silt and clay),
* 3 to 5 percent organic matter by weight (ASTM D 2974 Method C)

Higher (12 percent) fines content should be reserved for areas where TN is the target pollutant. In areas where phosphorus is the target pollutant, lower (8 percent) fines should be used.

Table 3: Comparison of Pros and Cons of Mixes A-C

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Mix** | **Current Composition** | **Proposed Updated Composition** | **Pros** | **Cons** |
| A | 55-65% construction sand  10-20% top soil  25-35% organic leaf compost | 60-70% construction sand  15-25% top soil  15-25% organic leaf compost | Likely to sorb more dissolved P and metals than mix B because it contains some fines; best for growth of most plants | Likely to leach P; if topsoil exceeds maximum allowed clay content, higher fines content could result in poor hydraulic performance and long drawdown times |
| B | 50-70% construction sand  30-50% organic leaf  compost | 70-85% construction sand  15-30% organic leaf  compost | Easy to mix; least likely to clog | Likely to leach P, lack of fines in mix results in less dissolved pollutant removal; harder on most plants than mix A because it dries out very quickly |
| C | Not currently in MN Stormwater Manual | 85-88 percent by volume sand and  8 to 12 percent fines by volume,  3 to 5 percent organic matter by dry weight  P content between 12 and 36 mg/kg per Mehlich III test | Likely to sorb more dissolved P and metals than mix B because it contains some fines; less likely to leach P than mixes A or B because of low P content | Harder on most plants than mix A because it dries out very quickly. Research in Wisconsin indicates that in cold climates, salt can promote displacement of Mg and Ca in the soil, which breaks down soil structure and decreases infiltration rate, and can also cause nutrient imbalances. |

**Other Promising Soil Configurations Currently Being Monitored (no data available yet, check for preliminary data end of summer 2013)**

Several other media are currently being tested. A few examples are listed below.

Test 1: Using Peat Moss instead of Compost in Wisconsin (Bannerman 2013)

12% peat moss

2% Imbrium Sorptive®MEDIA

86% sand

This mix aims to maximize phosphorus removal in 2 ways:

* Substituting peat moss for compost, since peat moss has lower phosphorus content than compost and does not leach phosphorus.
* including Sorptive®MEDIA to sorb phosphorus and minimize phosphorus in effluent

Several researchers are currently testing layered systems designed to minimize phosphorus in bioretention effluent. Two examples are described below.

Test 2: Wisconsin layered system with compost only in top 5”, and iron filings in 10” deep layer at the bottom of the system (Bannerman 2013)



Figure 8-media-1: Section showing Wisconsin layered system with compost only in top 5”, and iron filings in 10” deep layer at the bottom of the system (From Mike Trojan’s February Workshop Meeting Minutes)

Advantages of this mix include:

* Compost is used only where it is needed for soil water retention for healthy plant growth. Using sand without compost below the top five inches of the soil profile, where vegetation does not need compost, minimizes total compost volume in the system, and thereby reduces potential for leaching of phosphorus from compost (however, see disadvantages for potential downside).
* Iron filings in bottom layers sorb phosphorus

Disadvantages include:

* Higher cost due to layering
* Greater potential for installation error compared to a system that is not layered.
* Plants may not grow as vigorously because soil water holding capacity will be very low below the top 5” of soil, since there is no organic matter below the top 5”

Test 3: Dakota County layered systems with compost only in top six inches, 20% coir pith, and 5% iron filings in bottom layer (Isensee 2013)

Dakota County is monitoring bioretention systems with the following layers, installed fall 2012:



Figure 8-media-2: Sections showing Dakota County layered systems with compost only in top six inches, 20% coir pith, and 5% iron filings in bottom layer (From Dakota County Soil and Water Conservation District 2012)

Where:

* Mix B is 70% Washed Sand / 30% Compost
* Mix C is 80% Washed Sand / 20% Coir Pith
* Mix IESF is 95% Washed Sand / 5% Iron Filings

Source: Dakota County Soil and Water Conservation District 2012

Each of the above cells is three feet deep.

Advantages of this mix include:

* Compost is used only where it is needed for soil water retention for healthy plant growth. Using sand without compost below the top foot of the soil profile, where vegetation does not need compost, minimizes total compost volume in the system, and thereby reduces potential for leaching of P from compost.
* Iron filings in bottom layers sorb P
* Coir supplements organic matter provided by compost but does not leach P

Disadvantages include:

* Higher cost due to layers
* More potential for installation error compared to a system that is not layered.

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