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TECHNICAL MEMORANDUM

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Subject: Analysis of Source Materials for Bioretention Media in the MHFD Region

INTRODUCTION

The purpose of this memorandum is to document an assessment of regionally available topsoil suitable for use in stormwater control measures (SCMs) as described in the soon-to-be-published Bioretention Fact Sheet in Volume 3, Chapter 4 of the Urban Storm Drainage Criteria Manual (USDCM). Unless the onsite soils match the specifications provided in Table BR-1 of the Fact Sheet, the engineered media described in this fact sheet will consist of (1) sand and (2) topsoil, which is blended by a material supplier and delivered to the site. This analysis used available soil sample results (soil graduation and soil nutrient analysis) of topsoil provided by suppliers and native soils collected from MHFD project sites and other locations in the MHFD region to determine if topsoil in the MHFD region could be mixed with sand to produce engineered media that meet the new specification.

The primary objectives of developing the revised mix in the updated USDCM chapter were to balance the functional use of bioretention media for stormwater applications:

- Increase the fines in the media to aid in stormwater treatment and support vegetation,
- Minimize potential nutrient export, and
- Evaluate regional availability of source materials (topsoil) for bioretention media mixes.

In 2015, MHFD published a media specification containing 80-90 percent sand. In an investigation of existing bioretention basins in the MHFD region, MHFD found that most media gradations were closer to 90 percent sand, potentially due to the specification's very low nutrient allowance that may impact vegetation health. The engineered media specified in the draft 2023 fact sheet contains increased fines and nutrient allowances to support the combined goals listed above (see Figure A1 in the Appendix).

METHODS

Part 1: Data Collection

MHFD collected and reviewed available soil sampling test results (soil nutrient and gradation analyses) from past projects and submitted by local suppliers and partners. Soil samples from different collection locations were classified as (a) topsoil from local suppliers, (b) sand, or (c) native soils. Of the soil sample test results provided, fifteen (15) sets of soil data were used for this assessment. Ten (10) samples included gradation and soil nutrient information and five (5) samples had nutrient analysis but no gradation data. The five samples without gradation data did include a soil type/texture; therefore, a general gradation breakdown was assumed for each sample based on the average for the soil type from the USDA Soil Triangle. All data given are presented on a percentage-by-weight (% weight) basis. Information about soil samples is shown in the Appendix. Table A1 provides additional metadata about each soil sample result. Table A2 presents related soil sampling lab results for each sample submitted to MHFD and used in the analysis, including soil gradation and soil nutrient analyses from different suppliers and sources (topsoil, sand, and natural soil).

Part 2: Data Analysis

To perform the assessment, MHFD developed an Excel-based workbook that calculates three soil properties (Nitrogen, Phosphorus, and organic matter) along with the soil composition based on the percentage of topsoil in a topsoil and sand mixture. The calculations determine whether a given topsoil could be used to produce engineered media meeting the revised 2023 specification. The calculator considers all ranges and ratios of sand-to-topsoil and provides resulting upper and lower ranges as a percentage of sand-to-topsoil that could be used to theoretically meet the engineered media mix. The calculator inputs require nutrient content and gradation of sand and topsoil. For this assessment, MHFD assumed sand to be free of nutrients, silt, and clay. The resulting outputs use conditional formatting to identify if/when the various nutrients or composite percentages by weight are within the bounds of the recommended specifications. Additionally, the parameters for Potassium, Copper, and Zinc requirements were evaluated; however, these soil parameters were excluded from the calculators for the bioretention media mix for reasons further discussed in the Results & Discussion section.

RESULTS & DISCUSSION

The results from the analysis are presented in Table 1 and discussed in this section.

- Of the soil samples included in the analysis, 11 of the 15 could theoretically be used to produce engineered media per the proposed 2023 USDCM specifications.
- Two (2) of the 15 soil samples (S11 & S12) could meet the 2023 specification without additional sand or mixing requirements.

- Two (2) media mixes using topsoil from local suppliers could not meet the given criteria ranges by adding sand. Note that these were part of the five samples that did not have lab-based gradation data.
- Three (3) media mixes had a wide range of sand-to-topsoil mix ratios that met all criteria. Six of seven soils with a lab-based gradation met all new engineered media specification parameters.

Based on the above results, the ranges and limits for sand, silt, clay, nitrogen, phosphorous, and organic matter listed in the 2023 engineered media specification should be attainable using a combination of sand and topsoil that is readily available in the MHFD region.

Additional recommendations based on this work consist of the importance of proper guidance and attention to detail when requesting analysis from a lab and performing a soil assessment using the MHFD Bioretention Mix Calculator. Specifically:

- Soil sampling procedures (including test methods of soil parameters) must align with the soil parameters and methods presented in the specification. Not all labs use the same methods. The test method for each nutrient analysis is critical and should align with recommended industry standards and practices, especially when analyzing for the Nitrate Nitrogen and Phosphorus soil parameters.
- When analyzing topsoil from local suppliers or natural/native soils within the region, a proper particle size distribution is required for gravel (>2 mm), sand (0.05 mm – 2 mm), silt (0.002 – 0.05 mm), and clay (<0.002). One of the labs included as part of this study used different gradation ranges for sand, silt, and clay. Based on the ranges used, engineered media resulting from this gradation could produce media that is too sandy. Additionally, some laboratories remove gravel prior to particle size distribution analysis and some do not. This difference can produce significantly different numbers, especially as the percentage of gravel increases.
- Soil parameters and ranges recommended in MHFD's topsoil guidance document were excluded from this analysis. While these parameters are important from a standpoint supporting vegetation, they do not present a water quality concern at levels typically found in topsoil in the MHFD region. Additionally, they are not always included as part of a soil nutrient analysis. For these reasons, MHFD does not recommend rejecting topsoil for use in engineered media when these parameters do not meet the ideal ranges specified in the topsoil management guidance.

Table 1. Bioretention Media Mix Analysis with Topsoil and Class C (Sand)

Mix ID	Supplier/Source	Limit	Mix Ratio "sand"	Mix Ratio "topsoil"	Sand (%)	Silt (%)	Clay (%)	OM (%)	N (ppm)	P (ppm)
S1	N/A (Native/natural) Oak Trib 1	LL	64%	36%	74.4	11.0	14.6	1.2	1.7	2.1
		UL	72%	28%	79.9	8.7	11.5	1.0	1.3	1.6
S2	N/A (Native/natural) Wulliman Backyard	LL	36%	64%	70.2	15.5	14.3	3.1	15.9	8.6
		UL	57%	43%	79.7	10.5	9.7	2.1	10.7	5.8
S3	Golf & Sport G&S Stockpile	LL	66%	34%	73.4	11.8	14.9	1.4	5.4	2.7
		UL	74%	26%	79.5	9.1	11.4	1.1	4.1	2.1
S4	Golf & Sport G&S InPlace	LL	70%	30%	76.4	8.9	14.6	1.4	0.5	5.4
		UL	74%	26%	79.5	7.8	12.7	1.2	0.4	4.7
S5	Golf & Sport G&S Inside	LL	23%	77%	70.1	21.6	8.3	1.4	17.6	23.1
		UL	47%	53%	79.2	14.9	5.9	1.0	12.1	15.9
S6	Golf & Sport G&S Surface	LL	23%	77%	70.0	22.0	7.9	1.4	17.4	20.7
		UL	49%	51%	79.2	15.3	5.6	1.0	12.0	14.3
S8	A-1 Organics A1 Top Soil STP	LL	6%	94%	71.8	18.8	9.4	1.4	30.0	22.4
		UL	34%	66%	80.0	13.3	6.7	1.0	21.1	15.7
S9	A-1 Organics A1 Amended Topsoil	N/A (cannot meet specs) Unable to meet new standards due to high nitrogen and phosphorus levels in topsoil								
S10	Pioneer Sand Screen Topsoil (Ft Lupton)	N/A (cannot meet specs) Unable to meet new standards due to low clay percentage and organic matter content in topsoil								
S11	Pioneer Sand Top Soil (Quincy)	LL	0%	100%	70.0	20.0	10.0	1.2	15.3	17.9
		UL	20%	80%	75.9	16.1	8.1	1.0	12.2	14.3
S12	Pioneer Sand Pioneer Topsoil	LL	0%	100%	70.0	20.0	10.0	1.0	10.1	11.2
		UL	5%	95%	71.5	19.0	9.5	1.0	9.6	10.6
S13	Silver Crown Stockpile (Platte Valley Pit)	N/A (cannot meet specs) Unable to meet new standards due to high phosphorus levels in topsoil								
S15	Silver Crown Silver Crown – Cornell	N/A (cannot meet specs) Unable to meet new standards due to high nitrogen levels in topsoil								
S16	Silver Crown Silver Crown – East	LL	60%	40%	75.6	9.8	15.0	1.8	11.0	5.2
		UL	67%	33%	79.7	8.2	12.4	1.5	9.0	4.3
S17	Silver Crown Silver Crown – West	LL	52%	48%	70.4	14.6	14.6	2.4	11.7	0.0
		UL	68%	32%	80.0	9.8	9.8	1.6	7.8	0.0

Notes: The OM, N, and P refer to organic matter, nitrate nitrogen, and Phosphorus, respectively. The lower limit (LL) and upper limit (UL) are the minimum and maximum ranges at which the corresponding sand-to-topsoil mix ratios can theoretically meet the bioretention mix specifications per the revised USDCM Volume 3 Chapter 4.

Appendix

Table A1. Recommended Bioretention Media Properties

**Based on revised specifications (Table BR-3) in USDCM Volume 3 Chapter 4 (draft 10/2023)*

Soil Parameter	Test Name	Bioretention Media Properties
Texture/Gradation	ASTM D7928 Sedimentation (Hydrometer) Method	Particle Size Distribution: 70-80% Sand (0.05-2.0 mm diameter) 5-25% Silt (0.002-0.05 mm diameter) 5-15% Clay (<0.002 mm diameter) Notes: Sand, silt and clay percentages are by dry weight. Particle sizes are based on the USDA soil classification system. Distribution is measured after gravel > 2 mm is removed from sample. Media should have no more than 25% material > 2 mm. Equivalent sieve sizes for the upper and lower limit of sand are #10 and #240, respectively.
Organic Matter	ASTM D2974	1-5% by dry weight
pH	ASA/AASHTO	6.0 - 8.5
Salinity/Salts (EC) dS/m or mmhos/cm	Saturated Paste	<3
Nitrate Nitrogen (ppm)	ASA2 33-3	<30
Phosphorus (ppm)	Use Olsen when pH>6.2, otherwise use Mehlich-3	Olsen: <20 or Mehlich-3: <30

Appendix

Table A2. Summary of Regional Soil Sampling Lab Results Collected for Bioretention Media Mix Analysis

Master ID	Supplier/Source	Soil Sample Name	Source Material Type	Sample Date	Lab Analysis By	Gradation Analysis	Soil Nutrient Analysis	Included in bioretention media mix analysis?
S1	Muller	Oak Trib 1	Natural soil	2/5/2021	CAL	x	x	**Yes**
S2	Muller	Wulliman Backyard	Natural soil	2/5/2021	CAL	x	x	**Yes**
S3	Golf & Sport	Golf & Sport- Stockpile	Topsoil	2/5/2021	CAL	x	x	**Yes**
S4	Golf & Sport	Golf & Sport- InPlace	Topsoil	2/5/2021	CAL	x	x	**Yes**
S5	Golf & Sport	Golf and Sport- Surface	Topsoil	9/3/2019	CAL	x	x	**Yes**
S6	Golf & Sport	Golf and Sport- Inside	Topsoil	9/3/2019	CAL	x	x	**Yes**
S7	Muller/SEMSWA	SEMSWA Filter - Sand	Sand	9/3/2019	CAL	x	-	**Yes (sand)**
S8	A-1 Organics	Top Soil STP 71712	Topsoil	7/17/2012	CAL	o	x	**Yes**
S9	A-1 Organics	Amended Top Soil	Topsoil	6/3/2014	CAL	o	x	**Yes**
S10	Pioneer Sand Co	Quincy - Top Soil	Topsoil	3/28/2014	CAL	o	x	**Yes**
S11	Pioneer Sand Co	Ft Lupton Pit - Screened Topsoil	Topsoil	4/8/2014	CAL	o	x	**Yes**
S12	Pioneer Sand Co	Pioneer Topsoil	Topsoil	10/17/2014	CAL	o	x	**Yes**
S13	Silvercrown	Platte Valley Pit Stockpile	Topsoil	1/10/2017	CSU-SWP	x	x	**Yes**
S14	Silver Crown	Castle Rock Rock-Concrete Sand	Sand	unknown	JM	x	-	-
S15	Silver Crown	Silver Crown-Cornell	Topsoil	7/26/2022	Rutgers Soil Lab	-	x	**Yes**
S16	Silver Crown	Silver Crown-East	Topsoil	8/15/2022	CSU-SWP	x	x	**Yes**
S17	Silver Crown	Silver Crown-West	Topsoil	8/15/2022	CSU-SWP	x	x	**Yes**
S24	unknown	Class C Filter	Sand	9/3/2013	CAL	x	-	**Yes (sand)**
S25	unknown	Screened Sand	Sand	9/3/2013	CAL	x	-	**Yes (sand)**
S26	CC (Iliff-Quebec)	CC_SOILS1_UP1	Natural soil	3/7/2018	TestAmerica	-	x	-
S27	CC (Iliff-Quebec)	CC_SOILS2_BA1	Natural soil	3/7/2018	TestAmerica	-	x	-
S28	CC (Iliff-Quebec)	CC_SOILS3_BA2	Natural soil	3/7/2018	TestAmerica	-	x	-
S29	CC (Iliff-Quebec)	CC_SOILS4_BA3	Natural soil	3/7/2018	TestAmerica	-	x	-
S30	CC (Iliff-Quebec)	CC_SOILS5_BA4	Natural soil	3/7/2018	TestAmerica	-	x	-
S31	CC (Iliff-Quebec)	CC_SOILS6_BA5	Natural soil	3/7/2018	TestAmerica	-	x	-
S32	CC (Iliff-Quebec)	CC_SOILS7_UP2	Natural soil	3/7/2018	TestAmerica	-	x	-
S33	CC (Iliff-Quebec)	CC_SOILS8_BA6	Natural soil	3/7/2018	TestAmerica	-	x	-

Notes: The term "o" represents no gradation analysis. Soil Type determined in Soil Nutrient Analysis. Soil samples S26-S33 represent soils collected along channel banks (BA) and upland areas (UP) of Cherry Creek between E. Iliff Ave and Quebec St. No soil texture or soil gradation analysis is available, used for comparison only.

Appendix

Table A3. Summary of Soil Sampling Lab Results

Master ID	Supplier/Source	Soil Sample Name	Soil Type (Field Texture)	pH	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Organic Matter (%)	Nitrate Nitrogen (ppm)	Phosphorus (ppm)[5]
S3	Muller/Golf & Sport	Golf & Sport- Stockpile	Clay	8	<.01	23	34	43	4.2	15.8	8
S4	Muller/Golf & Sport	Golf & Sport- InPlace	Clay	7.8	<.01	23	29	48	4.6	1.6	18.1
S5	Muller/Golf & Sport	Golf and Sport- Inside	Silt Loam[2 3]	7.8	3.8	61.4	27.9	10.7	1.8	22.9	30
S6	Muller/Golf & Sport	Golf and Sport- Surface	Silt Loam[2 3]	7.7	1	61.3	28.5	10.2	1.8	22.6	26.9
S8	A-1 Organics	Top Soil STP 71712	Sandy Loam[4]	7.7	0	*~70*	*~20*	*~10*	1.5	31.9	23.8
S9	A-1 Organics	Amended Top Soil	Sandy Loam[4]	7.2	0	*~70*	*~20*	*~10*	5.1	382.7	61
S10	Pioneer Sand Co	Ft Lupton Pit - Screened Topsoil	Silt Loam[4]	7.7	0	*~30*	*~60*	*~10*	1.2	11.8	15.8
S11	Pioneer Sand Co	Quincy - Top Soil	Sandy Loam[4]	6.5	0	*~70*	*~20*	*~10*	1.2	15.3	17.9
S12	Pioneer Sand Co	Pioneer Topsoil	Sandy Loam[4]	7.7	0	*~70*	*~20*	*~10*	1	10.1	11.2
S13	Silver Crown	Platte Valley Pit Stockpile	Loam	7.5	0	48	29	23	10.2	58.8	81.9
S15	Silver Crown	Cornell	Sandy Clay Loam	7.96	0	51	26	23	4.8	250	39
S16	Silver Crown	Silver Crown-East	Clay Loam	8	0	40	24	37	4.43	27.4	13.1
S17	Silver Crown	Silver Crown-West	Clay Loam	8.1	0	39	30	30	5.03	24.3	0.001
S7	Muller/SEMSWA	SEMSWA Filter - Sand	Sand	-	1	99	0.01	0.01	-	-	-
S24	unknown	Class C Filter	Sand	-	0.6	99.4	0	0	-	-	-
S25	unknown	Screened Sand	Sand	-	0	100	0	0	-	-	-
S1	Muller	Oak Trib 1	Clay Loam	7.4	<.01	30	30	40	3.4	4.7	5.8
S2	Muller	Wulliman Backyard	Sandy Clay Loam	7.6	<.01	53.8	24	22.2	4.9	24.9	13.5

NOTES:

1) Colorado Analytical gradation analysis - Sieve Analysis- %weight after sieved by diameter; “Particle size distribution is expressed as a percent retained or percent passing by weight on each sieve size."
2) Gradation values redistributed after gravel (> 2mm diameter or retained by #6 sieve) is removed from the sample.
3) The field texture may need to be more accurate as soil gradation results in a sandy loam classification.
4) No size distribution was provided with soil sampling test results. Percentages were estimated based on the soil type/texture and an average value from the USDA Soil Triangle.
5) A conversion factor (0.5) to ppm for phosphorus values reported in lbs./acre.