TECHNICAL MEMORANDUM

Regional Bioretention Soil Guidance & Model Specification
Bay Area Stormwater Management Agencies Association

Prepared For:

Bay Area Stormwater Management Agencies Association (BASMAA)

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INTRODUCTION

Recently the San Francisco Bay Regional Water Quality Control Board issued the Municipal Regional Stormwater Permit. The Bay Area Stormwater Management Agencies Association (BASMAA) engaged WRA to provide guidance and specification for bioretention soils to assist stormwater agencies at the associated municipalities in meeting the requirements of the permit.

This report provides model soil guidance and specification with the goal of providing a long-term infiltration rate of 5 to 10 inches per hour, providing stormwater treatment and supporting plant health. The guidance and specification is provided such that Permittees can apply the minimum specifications in a consistent and appropriate manner.

This report is organized into two parts. Part 1 provides the justification for recommendations made for the Regional Bioretention Soil Mix Guidance to better meet the requirements of the Municipal Regional Stormwater Permit. Part 2 provides guidance and a draft Model Specification for Bioretention Soil.

PART 1 - JUSTIFICATION

1.0 COMPOST

Compost has been a focus of many bioretention soil mixes because it has been shown to increase water holding capacity and attenuate pollutants from stormwater.

1.1 Compost Particle Size

Fines play an important role in bioretention facilities. Cation exchange capacity (CEC) is known to improve the removal of metals in bioretention soils (Jurries 2003). CEC refers to the quantity of negative charges in soil. The negative charges attract positively charged ions, or cations, hence the name 'cation exchange capacity'. In addition to metals, many essential plant nutrients exist in the soil as cations. The primary factor determining CEC is the clay and organic matter content of the soil. Fines will raise the CEC of a soil and thus the pollutant removal capacity as well as the nutrient availability for plant health.

However, there is mixed information on how fines relate to permeability. In part this is due to the different ways the fine fraction of a soil may be characterized. Some research indicates that hydraulic conductivity of bioretention soil mixes is correlated to percent passing the 200 sieve (0.003"), i.e. fines. Curtis Hinman's bioretention soil mix review and recommendations for Western Washington states that fines passing the 200 sieve should ideally be between 2 and 4 percent to produce a bioretention soil mix with a long-term infiltration rate of between 1 and 12 inches per hour (Hinman 2009). In contrast, Scott Wikstrom of the City of Walnut Creek states that the mineralogy and particle size of the fines is critical to the degree of impact they will have on permeability. Although both silt and clay pass the 200 sieve, his experience is that silt will have minimal impact while highly plastic clay will have a significant effect on permeability. In practice, he has observed that the bioretention soils formulated using Contra Costa County's specification are more likely to easily meet the minimum standard 5 inches per hour than they are to fail (Personal Communication 2010). Current Contra Costa guidance only specifies 0 - 5% passing the 200 sieve size for the fine aggregate and has no specification for compost particle gradation.

A third hypothesis is proposed by Frank Shields of Soil Control Lab. He points to particle size gradation, not particle size distribution, as determining a soil's infiltration rate (Personal

Communication 2010). He has implied that to limit the risk of compost plugging the bioretention soil mix, we should target the correct gradation. Perhaps both size and gradation are important to consider. Screening compost to remove fines effectively creates an ‘open graded' compost. ‘Open graded' refers to a gradation that contains only a small percentage of aggregate particles in the small range relative to the overall mix. This results in more air voids because there are not enough small particles to fill in the voids between the larger particles. Open graded aggregate is used to create pervious concrete, for example.

Anecdotally, in mixing soils to meet the Contra Costa County performance specification for infiltration rate, Rob Hawkins of LH Voss Landscape Materials in Dublin and Stockton, California has experienced problems when using whole compost that was not screened to remove some fines. His company uses a blend of different compost types to create a custom coarse compost. He provided analytical testing results for his bioretention soil mix conducted from earlier this year. Particle size distribution test results show that his bioretention mix contains over 12% passing the 200 sieve size. Yet, the percolation rate using the ‘dirt bong' method developed by Contra Costa County, was between 14 and 72 inches per hour. More recently, his compost blend has been the following blend: 1/3 BFI ‘whole compost,' 1/3 Zanker wood fines (screened compost with particle sizes between ¼" to ½") and 1/3 recycled redwood fencing in its bioretention soil mix. He will provide particle size analysis and infiltration rate testing of his new blend as soon as it becomes available in the next few weeks.

Screening whole compost will reduce percentages of fine particles in the compost but this screened ‘coarse' compost is only available from some suppliers. Adding to the lack of clear information on this topic, compost is not routinely tested for particle size distribution to below the size 10 sieve (0.079"). Earl Boyd of Lyngso Garden Materials in Redwood City, California stocks ‘Verma Green' compost that is a coarser blend than their premium compost. Boyd stated that Verma Green compost has less than 10% passing the 200 sieve (Personal communication 2010). If used with ASTM C33 fine aggregate which has a maximum of 5% passing the 200 sieve, the overall bioretention soil mix would therefore have more than 5% passing the 200 sieve size. However, without comprehensive testing of compost and ASTM C33 blends, we may not have a clear answer about how the permeability relates to fines.

In summary, existing literature suggests that fines in the overall mix should include fines in the range 2 – 4% but even within this range, the permeability will vary from 1 to 12 inches per hour. Scott Wikstrom suggests that fines in the range of 6-12% may produce an acceptable infiltration rate. This hypothesis is confirmed by the analytical testing provided by LH Voss Materials. Compost is widely available with fines in the range of 8 - 12%. Municipalities have observed that previously constructed biofiltration basins are meeting the minimum infiltration rate specification without limiting the fines in compost.

1.2 Nutrient Leaching from Compost

Compost amended soils are generally good or very good at retaining metals, hydrocarbon, organics, and bacteria (Davis 2006, Hinman 2009). Total phosphorous and total nitrogen removal in bioretention is good compared to other stormwater treatment practices; however, phosphate and nitrate reduction is variable in bioretention basins with underdrains (Davis 2006, Chi-hsu 2005, Hunt 2003, Hunt 2006). Until recently, loadings of nitrogen and phosphorous to San Francisco Bay have not been a high-priority regulatory concern; however, the State Water Resources Control Board, supported by USEPA Region IX is implementing an Estuarine Nutrient Numeric Endpoint Project.

Hinman (2009) and Hunt (2006) suggest that the design of bioretention facilities is at the heart of the issue of nutrient export rather than compost or media design.Hinman suggests that depth of media should be 24” to 36” to minimize export of phosphorous (2009). Current specification requires a minimum depth of 18”. Recent research by Hunt (2006) also suggests that a laboratory analysis for bio-available phosphorous may correlate with phosphorous export from bioretention areas. Biosolids and manure composts can be higher in bio-available phosphorous than compost derived from yard or plant waste. Accordingly, biosolids or manure compost in bioretention areas are not recommended to reduce the possibility of exporting bio-available phosphorous in effluent.

Hunt’s studies (2006) indicate that bioretention designs with underdrains do not reduce nitrate-nitrogen levels sufficiently, as such bioretention facilities are constructed without any zone designed to be saturated and anaerobic. For nitrate-nitrogen to be converted to nitrogen gas, thus enhancing total nitrogen removal, an anaerobic zone is necessary (Hunt 2003, Hunt 2006). An elevated underdrain, allowing for a saturated zone beneath the drain, may improve nitrate removal more consistently than changing the bioretention soil mix.

Because design changes are beyond the scope of this report, we researched ways to minimize nitrate export from bioretention soils. Compost is intermediate between soil organic matter and fertilizers in its release rates of nitrate in the first season of application (Claassen and Young 2010). However, diversity in the types and sources of raw organic solid waste combined with the various processing procedures used to produce composted materials results in different physical and chemical properties in the composted products (Frank Shields, personal communication 2010). It is therefore difficult to generalize nutrient leaching from compost with the variety of sources of composted materials.

However, one recent study by CalTrans has identified some trends in compost and leaching. They propose that organic carbon, phosphorous and metal leaching losses steadily decline as compost ages; but that losses of nitrogen-rich compounds peak with mature compost (4 weeks old) and then decline with curing (except nitrate, which remains at very low levels). In addition, potassium increases with compost age, as does nitrate slightly. (Claassen and Young 2010).

In contrast, Frank Shields of Soil Control Lab states that while compost age and texture may generally relate to nutrient leaching, he hypothesizes that these factors will not always predict leaching potential. He explains that it is possible to estimate nitrate leaching potential by evaluating compost for its stability. He therefore provides some background on how nitrate is released from compost: Young compost that has not been cured contains many different forms of organic matter. Many of these types are readily available to soil organisms (fats, oils, polysaccharides, etc) and some are not (lignin, cellulose, proteins). As organisms consume carbon they must also consume nitrogen. The bio-available forms of carbon are consumed first and nitrogen is not released. As the consumption of carbon slows the compost may then begin to leach nitrates. With cured or aged compost, all the bio-available forms of carbon have already been consumed. Such compost is therefore said to be ‘stable.’ Stable composts will release nitrogen at a slow and steady rate (Shields, personal communication, 2010). Current specification already requires that compost be stable because this is a basic requirement for certification by the US Composting Council.

Shields further recommends that the Carbon to Nitrogen (C:N) ratio should be evaluated. Some composts are stable but are high in nitrogen (such as those from grass clippings or chicken manure). A C:N ratio below 10:1 can supply nitrogen even if it is stable. Hinman (2009) recommends a C:N ratio of between 20:1 and 25:1 for compost used in bioretention basins.

Soil and Compost Lab states that a compost with a C:N ratio above 20:1 can deplete nitrogen from the soil (Broadmoor 2010). Therefore, a compost with a C:N ratio of between 15:1 and 25:1 may balance the need for nitrogen for plant health with the desire to limit nitrate leaching.

Claassen and Young state that compost only boosts nutrient export temporarily. In the long-term (perhaps three or four years), most plant-based composts appear to develop similar rates of nitrogen release that are generally similar to soil organic matter (Claassen and Young 2010). By specifying compost that is stable, peaks in nitrogen export should be minimized. The specification should therefore balance the need for added nutrients for plants while they are getting established and the need to limit exporting nutrients.

In summary, nutrient export from bioretention soil media appears to be an issue related more to the design of the bioretention areas rather than the media itself. Greater depths of treatment media and anaerobic areas appear to be promising developments in the design of bioretention facilities that could limit nutrient export more predictably than in changing the compost specification.

1.3 Inert Materials in Compost

Current specifications for inert materials in compost range from a maximum of 0.1% by weight in Alameda County to 1% by weight in Contra Costa County. Frank Shields of Soil Control Lab suggests that his visual assessment test is more appropriate because the inert materials are an aesthetic issue (for example, glass, plastics and paper) more than one of function. Dan Cloak, in working with Contra Costa County, comments that he has not encountered problems with trash in bioretention soils (Personal communication 2010). This suggests that the current specifications are already stringent enough to eliminate composts from green waste sources which tend to have high percentage of inert materials.

1.4 Recommendations for Guidance

<u>Particle Size</u>: Fines in compost may cause clogging of the bioretention soil mix. In contrast, fines offer enhanced metals retention, fertility, and water-holding capacity. Current specifications require that the aggregate component to have between 0-5% fines. Contra Costa County has not experienced problems with the infiltration rate of bioretention soils as currently specified but there may be some risk of low infiltration rate if compost with a high percentage of fines is used.

We recommend one of three options:

- No change to the specification OR
- Provide a required particle size gradation for the compost component including a maximum of 10% passing the 200 sieve OR
- Require the overall mix to have between 2% and 5% passing the 200 sieve as recommended in Western Washington.

<u>Nutrient Leaching</u>: Nutrient leaching may be unavoidable without changes to the design of bioretention facilities such as increased media depth and raising the underdrain. However, we identified some guidance to limit leaching of nutrients from compost. We recommend that guidance continue to specify compost certified by the US Composting Council certified to

ensure stability. In addition, we recommend that the C:N ratio of compost be specified between 15:1 and 25:1.

Inert Materials: We recommend specifying a performance level of “no visual impact” from inert materials. Each municipality can interpret the specification as desired to avoid high content of inert materials in compost.

2.0 SOIL ADDITIVES

2.1 Water Retention and Cationic Exchange Capacity in Bioretention Soils

Cation exchange capacity (CEC) is known to improve the removal of metals in bioretention soils (Jurries 2003). CEC refers to the quantity of negative charges in soil existing on the surfaces of clay and organic matter. The negative charges attract positively charges ions, or cations, hence the name ‘cation exchange capacity’. In addition to metals, many essential plant nutrients exist in the soil as cations. A high CEC can indicate a more fertile soil. As discussed earlier, the primary factor determining CEC is the clay and organic matter content of the soil.

Water-holding capacity helps to improve plant survival during dry periods and reduce irrigation needs. Water is held in soil in two ways: as a thin coating on the outside of soil particles and in the pore spaces. Soil water in the pore spaces can be divided into two different forms: gravitational water and capillary water. Gravitational water generally moves quickly downward in the soil due to the force of gravity. Capillary water is the most important for plant growth because it is held by soil particles against the force of gravity. Soil texture is related to water-holding capacity with loams and silt loams having the greatest available water for plants. Clays hold water very tightly so less is available to plants and sands hold very little water so even less is available to plants. Composted organic material is the most common soil amendment because it offers improved water holding capacity and supplies nutrients for soil.

2.2 Perlite and Vermiculite Blends

Vermiculite and perlite are both mined materials that are quickly heated to expand the mineral. Recently, perlite and vermiculite have been utilized in stormwater treatment facilities. Perlite improves drainage and wicks water well. Vermiculite has a tremendous water holding capacity but can drown roots when used alone. Perlite dries out quickly between rain events or waterings. Vermiculite and perlite are often used together in horticultural applications because of these complimentary attributes.

Granular perlite is sometimes used as a filter media for stormwater treatment. El Dorado County Department of Transportation is currently researching the effectiveness of perlite filters for stormwater as compared to fine sand filters for areas where infiltration is not feasible (Kooyman and Wigart 2009). Perlite is used in proprietary stormwater treatment systems including Aqua Filter. Preliminary small scale tests with perlite show effectiveness of reducing turbidity in stormwater between 40% and 90% (Kooyman and Wigart 2009). It is unclear if perlite, when included in a soil mix would have the same effectiveness. It seems that it would perform similarly to the sand component of the bioretention soil mix.

Additionally, vermiculite is commonly used to treat waste waters from mining activities to remove waterborne heavy metals. Vermiculite may be attractive for use in watersheds that are known to have a problem with heavy metals. Research is not available regarding the benefits vermiculite offers in reducing heavy metals within watersheds that have lower levels of heavy metals typical of runoff from urban areas as compared to runoff from areas with contaminated soils or mining areas.

In summary, perlite appears to be equivalent to the sand component in the engineered bioretention soil mix. Vermiculite may improve water-holding capacity of a soil, but without further study it is difficult to prescribe the proper amount to include in the mix. Furthermore, the drawbacks of perlite and vermiculite are that these minerals do not contain nutrients needed for plant growth. Costs may also exceed that of compost.

2.3 Calcined Clay

Eliminating fines from the soil mix is likely to increase the infiltration rate as discussed under Section 1.1. On the other hand fine particles increase the cation exchange capacity of a soil which in turn increases metals retention. Fines also improve fertility and water-holding capacity by slowing the drainage through the media. Further study on the use of calcined clay was therefore suggested during the April 2010 roundtable discussion as a way to ensure that fines are not eliminated from the bioretention soil mix.

Calcined clay is clay that has been heated to drive out volatile materials. It is commonly used in potting soil mixes and as a garden bed amendment. In heavy clay soils and compacted soils, it can improve aeration, as well as water and nutrient holding capacity. Calcined clay has high levels of calcium and sulfur but doesn't have additional nutrient value for plants.

As discussed earlier, the primary factor determining CEC is the clay and organic matter content of the soil. Higher quantities of clay and organic matter beget higher CEC. Calcined clay is sometimes added to sand-based fields to increases CEC. No research exists on the use of calcined clay in bioretention soils. .

2.4 Recommendations for Guidance

Limited research exists on these soil amendments for use in bioretention soil mixes. It is also unclear that they provide greater benefits than compost alone, and they will have an unpredictable effect on the infiltration rate of the bioretention soil mix. Compost is proven to improve water holding capacity, increase CEC, and to support plant health, and has been studied to provide some measure of predictability in infiltration. At this time, the existing research does not warrant adding vermiculite, perlite or calcined clay to the bioretention soil mix.

3.0 NON-FLOATING MULCH MATERIAL

Generally, soft woods like fir and pine trees are less dense than water. Wood chip mulch made from softwoods will float because the specific gravity is less than that of water. Some hardwood trees are very dense and will float less or even sink. Locally, only Mountain mahogany (Cercocarpus betuloides) will sink in water, but not likely to be available commercially (Armstrong 2010). Some oaks and acacias are also very dense and only barely float, but these materials are also unlikely to be commercially available as mulch. The most common material for commercially available wood chip mulch is pine and fir.

Shredded redwood bark mulch does not float because the fibrous strands tend to stick together and to the soil surface. Unfortunately, some fire departments will not allow shredded bark mulches due to the perceived fire hazard.

Some success has been noted in surface mulching with compost. The City of Seattle recommends mulching with compost because it is less likely to float than wood chips. The University of Maine Cooperative extension recommends two types of mulch: Super Humus brand of compost and Erosion Control mulch. Super Humus is commercially available from local soil products suppliers.

In-organic mulches such as pea gravel, are also non-floating. However, they only provide some of the benefits of mulch. Organic mulches add organic matter and nutrients for plant health.

We therefore recommend that the guidance specify applying non-floating mulch, such as compost, or other non-floating mulch as specified by the landscape-architect and approved by the local jurisdiction, as mulch within bioretention basins and wood chips adjacent to basins (above the maximum water line).

4.0 METHODS FOR EVALUATION OF ALTERNATE MIXES

Alternative mixes should be required to meet performance criteria if they do not fulfill the prescriptive 'recipe' for bioretention soil. We recommend that municipalities be discouraged from using alternative mixes because the specifications are fine tuned to produce a bioretention soil that achieves the desired performance in infiltration rate and fertility. However, if it is necessary to include alternative options we recommend that alternate mixes are evaluated for infiltration rate and certified for appropriate fertility.

Infiltration tests should be conducted by a qualified geotechnical soil testing laboratory. Field infiltration rates will differ from permeability rates measured in the laboratory. Variables during construction can have a significant influence on as-constructed and long-term infiltration rates. However, laboratory permeability testing is a relative indicator of the overall drainage performance of a particular aggregate compost mix. As discussed at the April 14, 2010, soil specifications roundtable meeting, the objectives of onsite infiltration testing can be met alternatively by reviewing the soil mix, overseeing installation, and observing the functioning of the facility. The soil should be required to have a percolation rate between 5 and 12 inches per hour to provide adequate drainage but not be too fast draining to support plants.

The following tests are suggested:

- Moisture – density relationships (compaction tests) should be conducted on a minimum of two samples of bioretention soil. We recommend compacting the bioretention soil to 85 to 90 percent of the maximum dry density (ASTM D1557). This level of relative compaction of bioretention soil mixes should be similar to field conditions.

- Constant head permeability – testing in accordance with ASTM D2434 should be conducted with a 6-inch mold and vacuum saturation. Municipalities should require at least two samples be tested.

- Particle size analysis – particle size analysis on the mixed bioretention soil should be provided.

Due to the expense associated with laboratory testing, the suggested testing may discourage developers from using alternative mixes. The above tests cost about $900. If the alternative mix fails, retesting will be required.

Fertility is also an important aspect of the bioretention soil. Rather than specifying performance benchmarks for all the various elements that contribute to soil fertility (pH, salinity, nitrate, ammonium nitrogen, phosphate phosphorous, potassium, calcium, magnesium, sodium, copper, zinc, manganese, iron, sulfate, and boron, etc), we recommend that alternative soil mixes should be certified as appropriate for plants by a qualified soil analysis laboratory or landscape architect. The qualified expert should submit a signed letter certifying that the bioretention soil will support the selected species of plants.

PART 2 – GUIDANCE AND SPECIFICATIONS

The following text is based on the guidance found in Appendix B of Contra Costa County Clean Water Program's Stormwater C.3 Guidebook, 4th Edition. **Bold and underlined text** indicates additions to the specifications.

SOILS FOR BIORETENTION FACILITIES

Soils for bioretention areas must meet two objectives:

- Be sufficiently permeable to infiltrate runoff at a minimum rate of 5" per hour during the life of the facility, and
- Have sufficient moisture retention to support healthy vegetation.

Achieving both objectives with an engineered soil mix requires careful specification of soil gradations and a substantial component of organic material (typically compost).

The San Francisco Regional Water Board has developed specifications for a bioretention soil mix. Local soil products suppliers have expressed interest in developing 'brand-name' mixes that meet these specifications. At their sole discretion, municipal construction inspectors may choose to accept test results and certification for a 'brand-name' mix from a soil supplier. Updated soil and compost test results may be required; tests must be **conducted** within 120 days prior to the delivery date of the bioretention soil to the project site.

Typically, batch-specific test results and certification will be required for projects installing more that 100 cubic yards of bioretention soil.

SOIL SPECIFICATION

Bioretention soils should meet the following criteria.

1. General Requirements
   Bioretention soil shall achieve a long-term, in-place infiltration rate of at least 5 inches per hour. Bioretention soil shall also support vigorous plant growth.

   Bioretention Soil shall be a mixture of fine sand, and compost, measured on a volume basis:

   60%-70% Sand
   30%-40% Compost

1.1. Submittals
The applicant must submit to the municipality for approval:

A. A sample of mixed bioretention soil.

B. Certification from the soil supplier or an accredited laboratory that the Bioretention Soil meets the requirements of this guideline specification.

C. Grain size analysis results of the fine sand component performed in accordance with ASTM D 422, Standard Test Method for Particle Size Analysis of Soils.

D. Quality analysis results for compost performed in accordance with Seal of Testing Assurance (STA) standards, as specified in Section 1.4.

E. Organic content test results of mixed Bioretention Soil. Organic content test shall be performed in accordance with by Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, "Loss-On-Ignition Organic Matter Method".

F. Grain size analysis results of compost component performed in accordance with ASTM D 422, Standard Test Method for Particle Size Analysis of Soils.

G. A description of the equipment and methods used to mix the sand and compost to produce Bioretention Soil.

H. Provide the following information about the testing laboratory(ies) name of laboratory(ies) including

1) contact person(s)

2) address(es)

3) phone contact(s)

4) e-mail address(es)

5) qualifications of laboratory(ies), and personnel including date of current certification by STA, ASTM, or approved equal

1.2. Sand for Bioretention Soil

A. General

Sand shall be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size shall be non-plastic.

B. Sand for Bioretention Soil Texture

Sand for Bioretention Soils shall be analyzed by an accredited lab using #200, #100, #40, #30, #16. #8, #4, and 3/8 inch sieves (ASTM D 422 or as approved by municipality), and meet the following gradation:

Sieve Size	Percent Passing (by weight)	
	Min	*Max*
3/8 inch	100	100
No. 4	90	100
No. 8	70	100
No. 16	40	95
No. 30	15	70
No. 40	5	55
No. 100	0	15
No. 200	0	5

Note: all sands complying with ASTM C33 for fine aggregate comply with the above gradation requirements.

1.3. Composted Material

Compost shall be a well decomposed, stable, weed free organic matter source **derived from waste materials including yard debris, wood wastes or other organic materials not including manure or biosolids** meeting the standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).

A. Compost Quality Analysis

Before delivery of the soil, the supplier shall submit a copy of lab analysis performed by a laboratory that is enrolled in the US Composting Council's Compost Analysis Proficiency (CAP) program and using approved Test Methods for the Evaluation of Composting and Compost (TMECC). The lab report shall verify:

1) Feedstock Materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.

2) Organic Matter Content: 35% - 75% by dry wt.

3) Carbon and Nitrogen Ratio: C:N < 25:1 **and C:N >15:1**

4) Maturity/Stability: shall have a dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120F) upon delivery or rewetting is not acceptable. In addition any one of the following is required to indicate stability:

a. Oxygen Test < 1.3 O2 /unit TS /hr

b. Specific oxy. Test < 1.5 O2 / unit BVS /

c. Respiration test < 8 C / unit VS / day

d. Dewar test < 20 Temp. rise (°C) e.

e. Solvita® > 5 Index value

5) Toxicity: any one of the following measures is sufficient to indicate non-toxicity.

a. NH4- : NO3-N < 3

b. Ammonium < 500 ppm, dry basis

c. Seed Germination > 80 % of control

d. Plant Trials > 80% of control

e. e. Solvita® > 5 Index value

6) Nutrient Content: provide analysis detailing nutrient content including N-P-K, Ca, Na, Mg, S, and B.

a. Total Nitrogen content 0.9% or above preferred.

b. Boron: Total shall be <80 ppm; Soluble shall be <2.5 ppm

7) Salinity: Must be reported; < 6.0 mmhos/cm

8) pH shall be between 6.5 and 8. May vary with plant species.

B. Compost for Bioretention Soil Texture

Compost for Bioretention Soils shall be analyzed by an accredited lab using #200, 1/4 inch, 1/2 inch, and 1 inch sieves (ASTM D 422 or as approved by municipality), and meet the following gradation:

Sieve Size	**Percent Passing (by weight)**	
	Min	***Max***
1 inch	**99**	**100**
1/2 inch	**90**	**100**
1/4 inch	**40**	**90**
No. 200	**2**	**10**

C. Bulk density: shall be between 500 and 1100 dry lbs/cubic yard

D. Moisture Content shall be between 30% - 55% of dry solids.

E. Inerts: compost shall be relatively free of inert ingredients, including glass, plastic and paper, < 1 % by weight or volume.

F. Weed seed/pathogen destruction: provide proof of process to further reduce pathogens (PFRP). For example, turned windrows must reach min. 55C for 15 days with at least 5 turnings during that period.

G. Select Pathogens: Salmonella <3 MPN/4grams of TS, or Coliform Bacteria <10000 MPN/gram.

H. Trace Contaminants Metals (Lead, Mercury, Etc.) Product must meet US EPA, 40 CFR 503 regulations.

I. Compost Testing

The compost supplier will test all compost products within 120 calendar days prior to application. Samples will be taken using the STA sample collection protocol. (The sample collection protocol can be obtained from the U.S. Composting Council, 4250 Veterans Memorial Highway, Suite 275, Holbrook, NY 11741 Phone: 631-737-4931, www.compostingcouncil.org). The sample shall be sent to an independent STA Program approved lab. The compost supplier will pay for the test.

VERIFICATION OF ALTERNATIVE BIORETENTION SOIL MIXES

Bioretention soils not meeting the above criteria may be evaluated on a case by case basis. Alternative bioretention soil must meet the following specification: "Soils for bioretention facilities must be sufficiently permeable to infiltrate runoff at a minimum rate of 5 inches per hour during the life of the facility, and must provide sufficient retention of moisture and nutrients to support healthy vegetation."

The following guidance is offered to assist municipalities with verifying that alternative soil mixes meet the specification:

1. General Requirements

Bioretention soil shall achieve a long-term, in-place infiltration rate of at least 5 inches per hour. Bioretention soil shall also support vigorous plant growth.

1.1. Submittals

The applicant must submit to the municipality for approval:

A. A sample of mixed bioretention soil.

B. Certification from the soil supplier or an accredited laboratory that the Bioretention Soil meets the requirements of this guideline specification.

C. Certification from an accredited geotechnical testing laboratory that the Bioretention Soil has an infiltration rate between 5 and 12 inches per hour as tested according to Section 1.2.

E. Organic content test results of mixed Bioretention Soil. Organic content test shall be performed in accordance with by Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, "Loss-On-Ignition Organic Matter Method".

F. Grain size analysis results of mixed bioretention soil performed in accordance with ASTM D 422, Standard Test Method for Particle Size Analysis of Soils.

G. A description of the equipment and methods used to mix the sand and compost to produce Bioretention Soil.

H. Provide the following information about the testing laboratory(ies) name of laboratory(ies) including

1) contact person(s)

2) address(es)

3) phone contact(s)

4) e-mail address(es)

5) qualifications of laboratory(ies), and personnel including date of current certification by STA, ASTM, or approved equal

1.2. Bioretention Soil

A. Bioretention Soil Texture

Bioretention Soils shall be analyzed by an accredited lab using #200, and 1/2” inch sieves (ASTM D 422 or as approved by municipality), and meet the following gradation:

Sieve Size	Percent Passing (by weight)	
	Min	*Max*
1/2 inch	97	100
No. 200	2	5

B. Bioretention Soil Permeability testing

Bioretention Soils shall be analyzed by an accredited geotechnical lab for the following tests:

1. Moisture – density relationships (compaction tests) shall be conducted on bioretention soil. Bioretention soil for the permeability test shall be compacted to 85 to 90 percent of the maximum dry density (ASTM D1557).

2. Constant head permeability testing in accordance with ASTM D2434 shall be conducted on a minimum of two samples with a 6-inch mold and vacuum saturation.

MULCH FOR BIORETENTION FACILITIES

Mulch is not required by this guidance but is recommended for the purpose of retaining moisture, preventing erosion and minimizing weed growth. It should be noted that projects subject to the State’s Model Water Efficiency Landscaping Ordinance (or comparable local ordinance) will be required to provide at least two inches of mulch. Aged mulch, also called compost mulch, reduces the ability of weeds to establish, keeps soil moist, and replenishes soil nutrients. Aged mulch can be obtained through soil suppliers or directly from commercial recycling yards. Apply 1" to 2" of composted mulch, once a year, preferably in June following weeding.

Compared to green wood chip or bark mulch, aged mulch has somewhat less of a tendency to float into overflow inlets during intense storms. Bark or wood chip mulch may be used on the side slopes of basins above the maximum water line. The project landscape architect may also specify another type of non-floating mulch, subject to approval by the local jurisdiction.

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Contra Costa Clean Water Program 2008. Stormwater C.3 Guidebook. Contra Costa County. Available at: http://www.cccleanwater.org/c3-guidebook.html

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Hinman, Curtis, 2009. Bioretention Soil Mix Review and Recommendations for Western Washington. Puget Sound Partnership. Available online: http://www.pierce.wsu.edu/Lid/reports/BSMResults-Guidelines.pdf
Also available at: http://www.psparchives.com/publications/our_work/stormwater/BSMResults-Guidelines%20Final.pdf

Hsieh, Chi-hsu and Davis, Allen P., 2005. "Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff." *Journal of Environmental Engineering*. November: pp. 1521-1531.

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http://www.psparchives.com/publications/our_work/stormwater/lid/bio_docs/bio_docs.htm

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Mcmullen, Chad, 2007. Technical Memorandum: Bioretention Specification Development. Seattle Public Utilites. Provided courtesy Tracy Tackett of Seattle Public Utilites.

Paul, J. L. et. al. 1971. "Effects of Organic and Inorganic Amendments on the Hydraulic Conductivity of Three Sands Used for Turfgrass Soils" *California Turfgrass Culture*. Volume 21, No. 2. p.9-13. Accessed from University of California Riverside Turf Research Facility: http://ucrturf.ucr.edu/publications/CTC/ctc21_2.pdf

Pitt, Robert and S. Chen, 1999. *Compacted Urban Soils Effects on Infiltration and Bioretention Stormwater Control Designs*. Department of Civil and Environmental Engineering, The University of Alabama at Birmingham.

Seattle Public Utilites 2008. "SPU Bioretention Soil Specification" courtesy of Tracy Tackett (SPU NDS Program Manager)

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TECHNICAL MEMORANDUM

Regional Bioretention Installation Guidance
Bay Area Stormwater Management Agencies Association

Prepared For:

Bay Area Stormwater Management Agencies
Association (BASMAA)

Contact:

Megan Stromberg
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Date:

November 12, 2010

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INTRODUCTION

Recently the San Francisco Bay Regional Water Quality Control Board issued the Municipal Regional Stormwater Permit. The Bay Area Stormwater Management Agencies Association (BASMAA) engaged WRA to provide guidance and specification for bioretention soils to assist stormwater agencies at the associated municipalities in meeting the requirements of the permit.

This report provides guidance for the installation of bioretention soils with the goal of preserving the integrity of the soil media to support a long-term infiltration rate of 5 to 10 inches per hour, provide stormwater treatment and support plant health.

INSTALLATION OF BIORETENTION SOILS

The following section provides considerations for proper bioretention soil installation.

Prior to Installing Bioretention Soil:

- Is the contractor familiar with constructing bioretention systems?
- Plan how inspections will be handled as part of the construction process.
- Verify soil meets specification prior to delivering and or placing in the facility.
- Prevent over-compaction of native soils in the area of the basin. Delineate the facility area and keep construction traffic off. Protect soils with fencing, plywood, etc.
- Provide erosion control in the contributing drainage areas of the facility. Stabilize upslope areas.
- Facilities should not be used as sediment control facilities.
- Drainage should be directed away from bioretention facilities until upslope areas are stabilized, if possible. The concentration of fines could prevent post-construction infiltration.
- If drainage is to be allowed through the facility during construction, leave or backfill at least 6” above the final grade. Temporarily cover the underdrain with plastic or fabric. Line or mulch the facility.
- Ideally, bioretention facilities should remain outside the limit of disturbance until construction of the bioretention begins to prevent soil compaction by heavy equipment. Protect bioretention areas with silt fence or construction fencing.
- Verify installation of underdrain is correct prior to placing soil.

Soil Mixing and Placement:

- Do not excavate, place soils, or amend soils during wet or saturated conditions.
- Operate equipment adjacent to (not in) the facility.
- If machinery must operate in the facility, use light weight, low ground-contact pressure equipment.

- It may be necessary to rip or scarify the bottom soils to promote greater infiltration or excavate any sediment that may have built up during construction.

- Consider the time of year and site working area when determining whether to mix bioretention soil on-site or to import pre-mixed soil.

- If mixing bioretention media onsite, use an adjacent impervious area or on plastic sheeting.

- Place soil in 12” lifts with machinery adjacent to the facility. If working within the facility, to avoid over-compacting, place first lifts at far end from entrance and place backwards toward entrance.

- Do not place or work bioretention soil if it is saturated or raining

- Allow bioretention soil lifts to settle naturally, boot pack (walk around to firm) lifts to achieve 85% compaction effort. After all lifts are placed, wait a few days to check for settlement, and add additional media as needed.

- An alternative to boot compaction is to settle bioretention soils by lightly watering until soils are just saturated. Allow soil to dry between lifts. It may take a day or more to dry adequately between lifts. Soil cannot be worked when saturated so this method should be used with caution. Allow for extra time to let soils dry between each lift. After all lifts are placed, wait a few days to check for settlement, and add additional media as needed.

- Verify bioretention soil elevations before applying mulch or installing plants.

<u>Other Considerations</u>:

- Protect adjacent trees.

- Protect adjacent infiltration systems including swales, soils and porous pavement from sediment.

REFERENCES

Buck, Jonathan 2010. “Design of Bioretention Areas at Serramonte Library, Daly City.” Alameda Countywide Clean Water Program 2010 New Development Workshop. September 29, 2010.

Hinman, Curtis, 2009. “Bioretention Soil Mixes.” LID Technical Workshop – San Francisco. Washington State University Extension. January 18, 2009.

Lancaster, Alice, 2009. “Bioretention: Construction, Inspection and O&M.” LID Technical Workshop – San Francisco. Herrera Environmental Consultants. January 18, 2009.

Wikstrom, Scott and Niemuth, Paul, 2010. “The Nitty Gritty on Soils for Successful Stormwater BMPs.” Bay-Friendly Landscape Conference. September 17, 2010.

Stenn, H. 2010. Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington. Seattle Public Utilities: Seattle. Available at: http://www.buildingsoil.org/tools/Soil_BMP_Manual.pdf

ANNOTATED BIBLIOGRAPHY

Regional Biotreatment Soil Guidance
Bay Area Stormwater Management Agencies Association

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The following bibliography provides a summary of existing literature, field and analytical data prepared in conjunction with the preparation of Regional Bioretention Soil Guidance.

1.0 COMPOST

Claassen, V. and Young, T. 2010. Model Guided Specification for Using Compost to Promote Establishment of Vegetation and Improvement in Stormwater Quality. California Department of Transportation (CalTrans). Available online: http://www.dot.ca.gov/hq/LandArch/research/erosion_control.htm

This study establishes parameters for compost use on slopes based on performance criteria including soil type, climate, slope length and steepness, aspect, and location. The research addresses how compost affects water quality and erosion, and if compost improves the establishment of permanent vegetation cover. Results indicate that in many cases, degraded, nutrient-poor soils can be regenerated with yard waste compost amendment with minimal risk of nutrient loss, especially if the composts are incorporated into the slope surface and covered with a mulch layer. Finer and more aged composts leach nitrogen at slightly higher rates than non-aged composts. However, more aged composts are more likely to retain heavy metals. Surface application of compost decreases nutrient loss.

Faucette, L.B. et. al. 2005. "Evaluation of stormwater from compost and conventional erosion control practices in construction activities." Soil and Water Conservation Society. November 2005 vol. 60 no. 6 288-297.

The use of surface applied organic amendments has been shown to reduce runoff and erosion, however, with the exception of animal manure, little research has focused on nutrient loss from these amendments. Four types of compost blankets, hydroseed, silt fence, and a bare soil (control) were applied in field test plots. Treatments were seeded with common bermuda grass. A rainfall simulator applied rainfall at an average rate equivalent to a 50 yr 1 hr storm event (7.75 cm hr^{-1}). After three months, the compost generated five times less runoff than hydroseed with silt fence, and after one year, generated 24 percent less runoff. All treatments proved better than the control at reducing solids loss. Materials high in inorganic nitrogen (N) released greater amounts of nitrogen in storm runoff; however, these materials showed reduced N loss over time. Hydroseeding generated significantly higher total phosphorus (P) and dissolved reactive P loads compared to compost in storm runoff during the first storm event.

Stenn, H. 2010. Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington. Seattle Public Utilities: Seattle. Available at: http://www.buildingsoil.org/tools/Soil_BMP_Manual.pdf

The guide describes techniques for construction site soil handling, reducing soil compaction, and amending site soils with compost to meet BMP T5.13 "Post Construction Soil Quality and

Depth” in the WA Dept. of Ecology’s Stormwater Management Manual for Western Washington. This guide also includes field inspection techniques, WA suppliers of compost and soil testing laboratories, and specification language in APWA and CSI formats.

2.0 SOIL AMENDMENTS

Kooyman, Steve and Wigart, Russ, 2009. Urban Stormwater fine sediment filtration using granular perlite. El Dorado County Department of Transportation.

Perlite can be used as an alternative to fine sand for stormwater filtration to reduce turbidity.

Paul, J. L. et. al. 1971. “Effects of Organic and Inorganic Amendments on the Hydraulic Conductivity of Three Sands Used for Turfgrass Soils” *California Turfgrass Culture*. Volume 21, No. 2. p.9-13. Accessed from University of California Riverside Turf Research Facility: http://ucrturf.ucr.edu/publications/CTC/ctc21_2.pdf

Calcined clay-l (CC-l) : montmorillonite clay is calcined at high temperatures to make porous, mechanically strong particles of mainly very coarse sand-fine gravel texture. Calcined clay-2 (CC-2) : an unspecified mineral is calcined to produce a porous, more or less spherical particle which falls mostly in the textural class of medium sand. Vermiculite (V) : the material was an industrial chemical grade (No. 1) of expanded mineral. While the particle size consisted mainly of very coarse and coarse sand sizes, particles were readily deformed and compressed by compacting forces. In this study, calcined clay acted in the same way as sand. Depending on the gradation of the sand and the particle size of the calcined clay, hydraulic conductivity was either increased or decreased. Vermiculite decreased hydraulic conductivity the most of the amendments studied. In addition, appreciable changes in hydraulic conductivity were not observed until 30-40% of the amendment was added to the sand.

3.0 POLLUTANT REMOVAL

Davis et. al. 2006. “Water Quality Improvement through Bioretention Media: Nitrogen and Phosphorous Removal.” *Water Environment Research.* Vol. 78, No. 3: pp.284-293.

High nutrient inputs and eutrophication continue to be one of the highest priority water quality problems. This work provides an in-depth analysis on removal of nutrients from a synthetic stormwater runoff by bioretention. Results have indicated good removal of phosphorus (70 to 85%) and total Kjeldahl nitrogen (55 to 65%). Nitrate reduction was poor (,20%) and, in several cases, nitrate production was noted. Variations in flowrate (intensity) and duration had a moderate affect on nutrient removal. Mass balances demonstrate the importance of water attenuation in the facility in reducing mass nutrient loads. Captured nitrogen can be converted to nitrate between storm events and subsequently washed from the system. Analysis on the fate of nutrients in bioretention suggests that accumulation of phosphorus and nitrogen may be controlled by carefully managing growing and harvesting of vegetation. Water Environ. Res., 78, 284 (2006).

Hsieh, Chi-hsu and Davis, Allen P., 2005. "Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff." *Journal of Environmental Engineering*. November: pp. 1521-1531.

The objective of this study is to provide insight on media characteristics that control bioretention water management behavior. Eighteen bioretention columns and six existing bioretention facilities were evaluated employing synthetic runoff. In columns, the runoff infiltration rate through different media mixtures ranged from 0.28 to 8.15 cm/min at a fixed 15 cm head. For pollutant removals, the results showed excellent removal for oil/grease __96%_. Total lead removal _from 66 to _98%_ decreased when the total suspended solids level in the effluent increased _removed from 29 to _96%_. The removal efficiency of total phosphorus ranged widely _4–99%_, apparently due to preferential flow patterns, and both nitrate and ammonium were moderate to poorly removed, with removals ranging from 1 to 43% and from 2 to 49%, respectively. Two more on-site experiments were conducted during a rainfall event to compare with laboratory investigation. For bioretention design, two media design profiles are proposed; _96% TSS, _96% O/G, _98% lead, _70% TP, _9% nitrate, and _20% ammonium removals are expected with these designs.

Hunt, William F. III, 2003. *Pollutant Removal Evaluation and Hydraulic Characterization for Bioretention Stormwater Treatment Devices.* Pennsylvania State University. Available online: http://www.psparchives.com/publications/our_work/stormwater/lid/bio_docs/bio_docs.htm

Current bioretention designs do not reduce nitrate-nitrogen levels sufficiently, as bioretention is constructed without any zone designed to be saturated. For nitrate-nitrogen to be converted to nitrogen gas, thus enhancing total nitrogen (TN) removal, an anaerobic zone may be necessary. This research determined the effect of an anaerobic layer within bioretention devices on the concentrations and loadings of TN, nitrate-nitrogen (NO3-N), and other nutrient and pollutant species in stormwater runoff including ammonia-nitrogen (NH3-N), total kjeldahl nitrogen (TKN), total phosphorus (TP), ortho-phosphate (Ortho-P), zinc (Zn), iron (Fe), copper (Cu), lead (Pb), and total suspended solids (TSS). Results from the laboratory experiment showed high removal rates for TN (mean efficiencies ranging from 70% to 85%) and NO3-N (over 90%). The presence of an intentional anaerobic zone and the anaerobic zone's thickness did not have a significant impact ($p<0.10$) on the microcosm's nutrient removal abilities. There was a significant impact ($p<0.10$) when comparing hydraulic retention times of 2 and 4 days. The longer retention time had significantly lower TN and NO3-N concentrations.

Hunt, W.F. et al. 2006. "Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina." *Journal of Irrigation and Drainage Engineering*. November/December: 600-608.

Three bioretention field sites in North Carolina were examined for pollutant removal abilities and hydrologic performance. The cells varied by fill media type or drainage configuration. The field studies confirmed high annual total nitrogen mass removal rates at two conventionally drained bioretention cells _40% reduction each_. Nitrate-nitrogen mass removal rates varied between 75 and 13%, and calculated annual mass removal of zinc, copper, and lead from one Greensboro cell were 98, 99, and 81%, respectively. All high mass removal rates were due to a substantial decrease in outflow volume. The ratio of volume of water leaving the bioretention cell versus that which entered the cell varied from 0.07 _summer_ to 0.54 _winter_. There was a significant _p_0.05_ change in the ratio of outflow volume to inflow volume when comparing warm seasons to winter. Cells using a fill soil media with a lower phosphorus index _P-index_, Chapel Hill cell C1 and Greensboro cell G1, had much higher phosphorus removal than Greensboro cell G2, which used a high P-index fill media. Fill media selection is critical for total phosphorus removal, as fill media with a low P-index and relatively high CEC appear to remove phosphorus much more readily.

4.0 BIOFILTER MEDIA DESIGN & SPECIFICATIONS

Burge, K. et. al. 2007. “Finding the Right Bioretention Soil Media” 13th International Conference on Rainwater Cathcment Systems. Available at: http://www.hidro.ufcg.edu.br/twiki/pub/ChuvaNet/13thInternationalConferenceonRainwaterCatchmentSystems/Burge.pdf

This paper describes the soil media characteristics that are critical to the successful functioning of a bioretention system and outlines the methodology behind the development of the Guideline Specifications for Soil Media in Bioretention Systems (FAWB, 2006).

Hinman, Curtis, 2009. Bioretention Soil Mix Review and Recommendations for Western Washington. Puget Sound Partnership. Available online: http://www.psparchives.com/publications/our_work/stormwater/BSMResults-Guidelines%20Final.pdf

The soil mix used in bioretention systems is central for determining flow control and water quality treatment performance. The purpose of this study is to provide bioretention soil mix (BSM) guidelines that: 1) meet performance objectives; 2) include materials readily available in the Puget Sound region; 3) include materials that aggregate and compost suppliers can provide with adequate quality control and consistency; and 4) are affordable. The focus of this study is on the aggregate component of the BSM. Four candidate aggregate samples were collected from various suppliers and locations around Puget Sound. Laboratory analysis was conducted to determine aggregate gradation, as well as the organic matter content, hydraulic conductivity, cation exchange capacity, and available phosphorus of a specified aggregate compost bioretention soil mix. Hydraulic conductivity of bioretention soil mixes is strongly correlated to percent mineral aggregate passing the 200 sieve and that the fines should be less than five and ideally between two and four percent. Organic matter content and associated available phosphorus and nitrogen cycling in these mixes may lead to phosphate and nitrate exported in under-drain effluent. Current research shows variable nitrate and phosphate retention and additional work is needed to study methods to optimize bioretention soil mixes for phosphate and nitrate retention and removal capability.

Jurries, Dennis, 2003. Biofilters (Bioswales, Vegetative Buffers, & Constructed Wetlands) for Storm Water Discharge Pollution Removal. State of Oregon Department of Environmental Quality. Available at: http://www.deq.state.or.us/wq/stormwater/docs/nwr/biofilters.pdf

Compilation of available information on the design and use of biofilters. Clays and organic matter have highest cation exchange capacities. Organic matter has twice the rate of cation exchange capacity as clay.

5.0 HYDRAULIC SIZING CRITERIA

Colwell, S. and Fowler J. 2009. Technical Memorandum re: Updated SPU Bioretention Soil – Modeling Inputs and Water Quality Treatment. Seattle Public Utilities. Available at: http://www.seattle.gov/util/groups/public/@spu/@usm/documents/webcontent/spu02_019972.pdf

This memorandum provides SPU's recommendations and justifications for modeling inputs for the bioretention soil and discusses how it meets Washington State Department of Ecology's (Ecology) requirements for treatment. Infiltration rate is highly variable for designed bioretention soils. A long-term correction factor of infiltration rate is recommended to be 2 for catchment areas containing less than 5000 sf of pollution generating surface or less than 10,000 sf impervious surface.

Herrera Environmental Consultants, 2007 "First Controlled Infiltration Test for High Point Phase I Block-Scale Monitoring Project" Seattle Public Utilities. Courtesy of Tracy Tackett (SPU NDS Program Manager)

Results of field study of infiltration and treatment performance of large-scale bioretention system project in Seattle. Design infiltration rate for the bioretention soil mix was 2" per hour and field tested rate was 4.2" per hour.

Herrera Environmental Consultants, 2007 "Results from Second Controlled Infiltration Test for High Point Phase I Block-Scale Monitoring Project" Seattle Public Utilities. Courtesy of Tracy Tackett (SPU NDS Program Manager)

Results of field study of infiltration and treatment performance of large-scale bioretention system project in Seattle. Design infiltration rate for the bioretention soil mix was 2" per hour and field tested rate was 6.1" per hour. Differences from the first and second test are attributed to rainfall event occurring just prior to test 1.

Mcmullen, Chad, 2007. Technical Memorandum: Bioretention Specification Development. Seattle Public Utilites. Provided courtesy Tracy Tackett of Seattle Public Utilites.

This memorandum provides grain size analysis for hydraulic capacity of several available aggregates in Western Washington. Compaction, organic content and permeability testing was performed on aggregate-compost mixtures. Provides draft bioretention soil specification for SPU.

6.0 BIOFILTER SOIL SPECIFICATIONS

Alameda Countywide Clean Water Program, 2007. "Soil Specifications for Stormwater Treatment Measures," Alameda County.

Alameda's soil specification to help applicants specify soils that will provide suitable growing conditions for appropriate plantings and meet the percolation requirements. Target percolation rate is 5 to 10 inches per hour.

Seattle Public Utilites 2008. "SPU Bioretention Soil Specification" courtesy of Tracy Tackett (SPU NDS Program Manager)

Specification for bioretention soil with infiltration rate of 5 in/hour (to be confirmed with Tracy). Specification geared towards locally available materials to Seattle that can be installed by contractors or homeowners.

7.0 LAB SOIL TEST RESULTS

To be provided with final draft.

8.0 PLANTS

Bornstein, C., Fross, D., and O'Brien, B. 2005. *California Native Plants for the Garden* Cachuma Press: Solvang.

Plant recommendations, plant care, nursery resources.

CalTrans 2001. "Advisory Guide to Plant Species Selection for Erosion Control." Cal Trans, District 5.

Hardcopy format of a geographic information system (GIS) that combines state and district-level climatalogical, geological, topographical, and plant biogeographical data to define ecologically meaningful subdistrict Plant climate Zones. These climate zones form the foundation for rapid access to lists of plant species for revegetation that are both ecologically appropriate for a project site and useful in minimizing erosion, primarily on slopes up to 2:1 H:V.

Harlow, Nora 2004. *Plants and Landscapes for Summer-Dry Climates*. East Bay Municipal Utility District.

Plant recommendations for the Bay Area.

Los Angeles County Public Works 2004. "LA River Masterplan: Landscaping Guidelines and Plant Palettes." County of Los Angeles.

Landscape design guidelines for the LA River corridor. Includes plant list of plants that should never be planted along the river and suggested plant lists, plants by plant communities and info about each plant such as estimated water needs, height, spread, and frequency of occurrence.

San Mateo County 2007. "Appendix B: Plant List and Planting Guidance for Landscape-Based Stormwater Measures" *San Mateo Countywide Water Pollution Prevention Program: C.3 Technical Guidance*. Accessed from: http://www.flowstobay.org/bs_new_development.php

Summary: Guidance for planting techniques and selection of appropriate plant materials for stormwater measures.

SVR Design Company 2006. "High Point Community Site Drainage Technical Standards" Prepared for Seattle Public Utilities. Accessed from: http://www.svrdesign.com/high_pt.html

Suggested plant list for various BMPs.

9.0 BIORETENTION SOILS INSTALLATION

SVR Design Company 2006. "High Point Community Right of Way and Open Space Landscape Maintenance Guidelines" Prepared for Seattle Public Utilities. Accessed from: http://www.svrdesign.com/high_pt.html

Materials recommendations and trouble shooting.

Lancaster, Alice, 2009. "Bioretention: Design and Construction" Presentation at Low Impact Development Workshop. City of San Francisco.

Construction sequencing, prevention of compaction, erosion control, contractor training, and public relations.

Hinman, Curtis, 2009. "Low Impact Development Technical Workshop Series: Bioretention Soil Mixes." Presentation at Low Impact Development Workshop. City of San Francisco.

Construction recommendations specific to installing bioretention soils.