Ensuring Bioretention System Performance Success: Guidance for Verification of Bioretention Media via Quality Assurance and Control Testing

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Presented by: Mindy Hills, Contech Engineered Solutions
Engineered media is the heart of bioretention system performance, and therefore preserving media integrity is of the utmost importance.

A successful bioretention installation involves oversight not just onsite, but having a framework in place for transferring base materials to a blended, commercially installed product.

A general outline for documentation should be developed and followed before, during and after production.
Recipe for a successful media certification program

SPECs
- Blending
- Base Materials

SOPs
- Sourcing
- Producing
- Storage
- Handling

VERIFICATION
- QA/QC
- Post Construction

CERTIFICATION
- Historical Records
- Batch Letters

Bioretention Media Framework
Media Specifications

- Public domain BMP design manuals will often identify generic media specifications to avoid sole sourcing.
- Media suppliers should have very specific base material specifications for each component to ensure little product variation.
- As with other materials specified in manuals and construction specs to ensure quality performance, specs should be developed for hydraulic and water quality capacity and submittals made available from the media manufacturer upon request. Even if not specified, it should be questioned how these parameters were evaluated.
- Third party reporting should be utilized for validating a bioretention media meets specification.
Media Specifications

SPECs

- Blending
- Base Materials

- Generic Blended Media Specs*
  - Physical Composition
    - Sand, silt, clay
    - Organic matter
    - Bulk density
  - Chemical Composition
    - Available P
    - CEC
  - Permeability

- Generic Base Material Specs*
  - Sand
  - Topsoil
  - Organics

*Based on VA DEQ Stormwater Design Specification No. 9, Version 2.0 (2013) - DRAFT
# Generic Blended Media Specifications

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Media Composition</td>
<td>Filter Media to contain:</td>
<td>The volume of filter media based on 110% of the plan volume, to account for settling or compaction.</td>
</tr>
<tr>
<td></td>
<td>• 80% - 90% sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 10%-20% soil fines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 3%-5% organic matter</td>
<td></td>
</tr>
<tr>
<td>Filter Media Testing</td>
<td>Available P between L+ and M per DCR 2005 Nutrient Management Criteria.</td>
<td>The media should be certified by the supplier.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fertility Rating</th>
<th>P – lbs/ac</th>
<th>P - PPM</th>
<th>P₂O₅ – lbs/ac*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-</td>
<td>0-3</td>
<td>0-2</td>
<td>0-7</td>
</tr>
<tr>
<td>L</td>
<td>4-8</td>
<td>2-4</td>
<td>9-18</td>
</tr>
<tr>
<td>L+</td>
<td>9-11</td>
<td>5-6</td>
<td>21-25</td>
</tr>
<tr>
<td>M-</td>
<td>12-20</td>
<td>6-10</td>
<td>28-46</td>
</tr>
<tr>
<td>M</td>
<td>21-30</td>
<td>11-15</td>
<td>48-69</td>
</tr>
<tr>
<td>M+</td>
<td>31-35</td>
<td>16-18</td>
<td>71-80</td>
</tr>
<tr>
<td>H-</td>
<td>36-55</td>
<td>18-28</td>
<td>82-126</td>
</tr>
<tr>
<td>H</td>
<td>56-85</td>
<td>28-43</td>
<td>128-195</td>
</tr>
<tr>
<td>H+</td>
<td>86-110</td>
<td>43-55</td>
<td>197-252</td>
</tr>
<tr>
<td>VH</td>
<td>110+</td>
<td>55+</td>
<td>252+</td>
</tr>
</tbody>
</table>

*Based on VA DEQ Stormwater Design Specification No. 9, Version 2.0 (2013) - DRAFT*
To ensure consistency in production and performance, additional blended media parameters to consider:

- **Chemical Composition**
  - Available macro & micro nutrients (not just available P)
  - Leachate analysis – nutrients and metals from unqualified sources
  - pH – plant survivability, pollutant retention

- **Physical Composition**
  - Moisture – plant survivability, media handling

- **Toxicity** – avoid contamination of receiving waters

- **WQ & Hydraulic Performance**
  - spec should be performance driven!
Hydraulic Performance Specification

- **Generic Permeability Spec**
  - Min. 1 – 2 inches per hour hydraulic conductivity

- **Additional Considerations**
  - Infiltration rate versus saturated hydraulic conductivity
    - **Infiltration**: the rate at which stormwater enters the surface of the soil. Controlled by:
      - Head development
      - Media depth
      - Physical characteristics: Soil structure, density, OM, moisture
    - **Permeability**: rate at which percolating stormwater flows through the soil after it has infiltrated. A constant rate of infiltration aka saturated hydraulic conductivity (Ksat).
    - Darcy’s Law \[Q = (k_{sat})(h)(g)\]
    - How designed will affect annual runoff volume treatment

*Based on VA DEQ Stormwater Design Specification No. 9, Version 2.0 (2013) - DRAFT
**VA Bioretention Spec # 9**

*Table 9.5. Sand Composition*

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 in</td>
<td>9.50 mm</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.75 mm</td>
<td>95 to 100</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.36 mm</td>
<td>80 to 100</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18 mm</td>
<td>45 to 85</td>
</tr>
<tr>
<td>No. 30</td>
<td>0.6 mm</td>
<td>15 to 60</td>
</tr>
<tr>
<td>No. 50</td>
<td>0.3 mm</td>
<td>3 to 15</td>
</tr>
<tr>
<td>No. 100</td>
<td>0.15 mm</td>
<td>0 to 4</td>
</tr>
</tbody>
</table>

```
Effective Particle size (D10) > 0.3mm
Uniformity Coefficient (D60/D10) < 4.0
```

**Additional Considerations**

- Particle Size Distribution
- Porosity
- Particle Shape
- Moisture
- Chemical Composition

2 medias with same the PSDs can operate at 2 different flow rates!
Generic Spec:*
  - Loamy sand, sandy loam, or loam (USDA Textural Triangle)

Additional Considerations:
  - Screened?
  - Free of debris?
  - Sourced material?
  - Amount of sand, silt, clay and organic matter?
  - Chemical composition?

*Based on VA DEQ Stormwater Design Specification No. 9, Version 2.0 (2013) - DRAFT
Base Material Specification - Organic

- **Compost***
  - Plant-derived materials
  - Well composted and free of viable weed seeds
  - Moisture content that has no visible free water or dust produced when handling
  - Mature and stable with regard to O$_2$ consumption and CO$_2$ generation per US Composting Council’s (USCC) “Seal of Testing Assurance” (STA) testing protocols
  - 100% pass ½” screen
  - pH: 5.5 – 8.5
  - Manufactured inert material (plastic, concrete, ceramics, metals, etc.) < 1% by wt.
  - Organic matter content > 35%
  - Soluble salt content < 6.0 mmhos/cm
  - C:N ratio < 25:1
  - Meet USEPA part 503 levels for heavy metals
  - Dry bulk density: 40 – 50 lbs/cuft

- **Additional considerations**
  - Chemical composition – studies identify leaching
  - Particle size distribution
  - Feedstock

*Based on VA DEQ Stormwater Design Specification No. 9, Version 2.0 (2013) - DRAFT*
- US EPA Part 503

**Table 3 of §503.13—Pollutant Concentrations**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Monthly average concentration (milligrams per kilogram)(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>41</td>
</tr>
<tr>
<td>Cadmium</td>
<td>39</td>
</tr>
<tr>
<td>Copper</td>
<td>1500</td>
</tr>
<tr>
<td>Lead</td>
<td>300</td>
</tr>
<tr>
<td>Mercury</td>
<td>17</td>
</tr>
<tr>
<td>Nickel</td>
<td>420</td>
</tr>
<tr>
<td>Selenium</td>
<td>100</td>
</tr>
<tr>
<td>Zinc</td>
<td>2800</td>
</tr>
</tbody>
</table>

\(^1\) Dry weight basis.

http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=b246025bc896be26a9681f83ab021528&mc=true&n=sp40.30.503.b&r=SUBPART&ty=HTML#se40.30.503_113
Internally developed procedures tailored specifically to managing bioretention media from its inception to installation, as well as ASTM, EPA, or other approved testing methods for verification testing of:

- Composition
- Hydraulic capacity
- Quality performance.
Media Sourcing SOP Considerations

- Suppliers should follow SOPs dictating how to properly source and qualify new components to make certain the final product performs per design specs.
- Conducting appropriate analysis of potential pollutants within source materials identifies leachable nutrients, metals, organics or even toxicity characteristics.
- Consider where base materials are sourced?
  - Quarry sands
  - Feedstock source
  - Fertility testing to qualify source materials
- Availability
  - Requalification efforts can be time consuming and result in using an alternative source not previously qualified due to project time constraints
  - Could result in design flaws if significantly deviate from original spec
- Consistency
  - Allows for less variability in the final media product and ensure alignment with the product specifications
- Location
  - Transportation costs can increase pricing depending on location
Media Production SOP

- Describes the components and tools necessary to manufacture media to meet specification

- Guarantees media is
  - Procured from approved suppliers
  - Proper equipment
  - Qualified components

- Provide directives on
  - Prequalification of suppliers
  - Contact info
  - Equipment settings
  - Specific components
  - Ratio of components
  - Reference specifications and testing standards

- Media specs are a critical part of the documentation framework for media recipe consistency
Media Storage

- If bioretention media is to be stored before use, especially if being stored onsite before installation, an SOP should be provided to contractors or other purchasers on how to properly store media.
  - **Issues**
    - Cross contamination from other stored materials
    - Tainted water and debris
  - **Prevention**
    - Bagging
    - Tarps
    - Concrete pad
    - Similar bedding material
    - Bin w/ walls
Media Storage

- Media & UD must be separated with a wall
- Media must be kept separated from other materials to prevent contamination.
- Muddy water, dirt & debris must be kept away from media to prevent contamination.
Bioretention in the Town of Bedrock…
Media Handling SOP

- **Media Moisture**
  - Component segregation
  - Decreased porosity
  - Alter flow characteristics

- **Media Transport**
Media Sampling SOP

- **Media Sampling**
  - ASTM D 75-97 or AASHTO T2
    - Require sampling at different heights of media pile, and preferably, media be placed in sampling bin before sampling to homogenously mix PSD
      - Surface should not be sampled.
  - Batch # for tracking purposes
  - Reference samples inventoried
Specs are performance driven, but how do we verify performance?

- QA/QC
- Post Construction
Verification Testing

- Rigorous QA/QC procedures
  - Allow for less problems caused by older, public domain design standards
  - Critical to ensuring the media functions as designed
  - Identifies media outside specification
  - Identifies the issue as media production, storage or other media process
Verification Testing

- There needs to be just as much oversight into blending the media as there is in ensuring product consistency throughout the use of the media stockpile.

- QA is *process* oriented
  - ensures development process is adequate to ensure media specs are met, improves production to prevent issues later on.

- QC is *product* oriented
  - designed to evaluate a developed media batch to reveal product defects.
Why do we need it?

- To discover media outside spec, and determine cause
- Bioretention media is comprised from natural products which exhibit natural variation, thereby requiring more QA/QC than a more consistent or synthetic product may require.
  - Sand sourced from different places or more than one sand used
  - Same material can change at quarry depending on mining location/depth
  - Particle size and shape greatly affect hydraulic characteristics
- Different methods of blending can be used by different suppliers
- Directions can get lost in translation and therefore strict oversight of new suppliers is critical
- Media substitutions
- Incorrect material delivery
- Media production is a batch process, each batch should be tested
- Media is the heart of bioretention performance
Media Source Qualification Testing

- More emphasis on source qualification through confirmation of properties of base materials
  - Particle size distribution (PSD) & Moisture
  - Organic content
  - Hydraulic column and pilot tests
  - Bulk density
  - Porosity
  - Particle shape
  - Silt content
  - Clay content
  - pH
  - CEC
  - Fertility
  - Soluble Salts
  - Water quality
  - Leachate
  - Microscopy
  - Toxicity
## Verification Testing – Media QA/QC

<table>
<thead>
<tr>
<th>Media Tests</th>
<th>*Standard Bioretention</th>
<th>Filterra Bioretention Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>√*</td>
<td>√</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>√*</td>
<td>√</td>
</tr>
<tr>
<td>Fertility</td>
<td>√*</td>
<td>√</td>
</tr>
<tr>
<td>Soluble Salts</td>
<td>√*</td>
<td>√</td>
</tr>
<tr>
<td>PSD</td>
<td>√*</td>
<td>√</td>
</tr>
<tr>
<td>CEC</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Moisture</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Porosity</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Particle Shape</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>% silt/clay</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Leachate</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Toxicity</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Microscopy</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Hydraulic Performance</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Water Quality Performance</td>
<td>X</td>
<td>√</td>
</tr>
</tbody>
</table>

*Ohio Dept. of Natural Resources Rainwater and Land Development Manual (May 2012)
Verification Testing

- Laboratory Hydraulic Test Example
  - Calibration tests and then quarterly hydraulic tests to follow
  - Hydraulic conductivity
  - Developed new flow test lab method for high flow rate media
  - Dry and saturated tests performed
  - Measures rising, constant and fall head
QA/QC Verification Testing Considerations

- All sources of media should be subjected to the same QA/QC methods and provided as SOPs
- Exact specification of the media is performance specification driven
- Since media production is a batch process, each batch should be tested to demonstrate it meets performance specs.
- Determine the shelf life of the media
 Commands hydrualic capacity was not compromised during construction
- In-situ flow rate verification should be conducted at several locations across the bioretention media surface area
- For slow flow bioretention media, double ring infiltrometers often suffice
- High flow bioretention media requires a larger testing apparatus to enable a greater volume of water to be introduced to capture higher flow rates
CERTIFICATION

• Historical Records
• Batch Letters

- Batch Historical Records
  - Exact amounts of all components for each batch
  - Track when each batch is blended, usage rates
  - Equip settings and ratios for each batch
  - Verification test results
  - Production cost per batch
When proof of media certification is requested, a media batch certification letter should be provided.

- Media batch numbers should be referenced to know the certification is relevant to current inventory and can be referenced.
- Historical certifications should be filed as media batches are produced should a future issue arise.
- Certify hydraulic and pollutant removal performance and media composition meet specifications per QC verification testing.
- If the media is being provided to meet a design manual specification, certificate should reference requirements in the media specification.
Filterra Media Batch Certification Letter

Contech Engineered Solutions Research & Development:

Filterra Bioretention Media Quality Control Certification

Filterra Media Batch: NW1504

Project:

Pass

Meets the hydraulic performance specifications for media quality control

Meets the media composition specifications for media quality control

Meets the pollutant removal performance specifications for media quality control

Meets the fertility specifications for media quality control

This letter certifies that Media Batch NW1504 performs per the above specifications as supplied in delivered form. This letter should be used as certification verifying the media meets both the required flow characteristics and pollutant removal rates.

Certified:

Mindy Hills
Project Manager – R&D
Contech Engineered Solutions

Date
Conclusions

- A successful bioretention media installation must have a framework in place for transferring raw materials to a blended, commercially installed product. While there are a number of variables that can contribute to media failure prior to installation, proper design and installation are equally important for ensuring operational success.

- In addition to a lack of consistent design standards for bioretention, soil media specifications are variable nationwide. In combination with little water quality performance data, this has resulted in a situation where bioretention performance cannot be presumed consistent or efficient. Therefore more rigorous media specs and verification testing is required.

- In following the appropriate media certification test program, the stormwater designer can be confident that use of media in his/her bioretention plan will yield the same performance as specified in the bioretention design manual.
QUESTIONS

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