Statewide LID Training Program

INSTRUCTORS

Curtis Hinman
Senior Scientist
Key project experience: Research specialist in the performance and design of LID practices.

David McDonald
Sustainable Sites Core
Resource Conservation Planner
Key project experience: soils, site planning, landscape best practices

ADVANCED TOPICS IN LID DESIGN:
BIORETENTION MEDIA AND COMPOST AMENDED SOILS
LEARNING OBJECTIVES

1. Gain an advanced level understanding of the physical and chemical characteristics of bioretention media components and blends necessary to meet specific performance objectives.

2. Understand the flow control and water quality treatment performance of current bioretention media specifications.

3. Know the options for meeting BMP T5.13, and strategies for determining site soil conditions and developing a soil management plan.
• 2012: Public and private partners engage state legislature to fund program
• June 2012: LID Training Steering Committee convoked
• 2012-2013: Washington State LID Training Plan developed: www.wastormwatercenter.org/statewide-lid-training-program-plan
• 2014: Training program built from state LID Training Plan.

• Implement first phase of trainings (September 2014 through May 2015)
• 64 trainings offered in first phase
• Three levels: Introductory, Intermediate, and Advanced

<table>
<thead>
<tr>
<th>PROJECT LEAD</th>
<th>CORE TEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herrera</td>
<td>Cascadia</td>
</tr>
<tr>
<td>Veda</td>
<td></td>
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<table>
<thead>
<tr>
<th>ADDITIONAL TRAINING SUPPORT</th>
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<tr>
<td>CH2M HILL</td>
</tr>
<tr>
<td>Kindred Hydro</td>
</tr>
<tr>
<td>Bennington</td>
</tr>
</tbody>
</table>
BACKGROUND

Today’s focus:

- Bioretention media for advanced water quality treatment (direct release to receiving waters, over shallow drinking water aquifers, industrial sites, remedial sites...)
- There are many applications where a conventional sand and compost or topsoil-based media will perform well
BACKGROUND

Context

• For advance treatment media we are opening a complex black box...
• And attempting to reliably replicate a dynamic biological system with complex structures and processes to treat a broad range of contaminants to very low levels...a worthy challenge!

INTRODUCTION

- Flow Entrance
- Pre-Settling
- Ponding Area
- Bioretention Soil
- Mulch/Compost
- Vegetation
- Filter Fabric (?)
- Liner (optional)
- Underdrain (optional)
- Overflow

1 introduction
2 media primer
3 water quality treatment strategies
4 performance
5 wrap-up
Factors influencing hydraulic conductivity

- Percent fines
- Particle size distribution

Hydraulic conductivity strongly related to percent fines (passing #200 sieve)

Hydraulic conductivity strongly related to coefficient of uniformity
Factors influencing hydraulic conductivity

- Percent fines
- Particle size distribution
- Compaction
- Organic material
- Plants

Control structures

- ASTM D2434
Break

WATER QUALITY TREATMENT PRIMER

All primary pathways for removing pollutants from storm flows are active in bioretention

- Stormwater volume reduction
- Sedimentation
- Filtration
- Phytoremediation
- Thermal attenuation
- Sorption
- Complexation
- Volatilization

Factors influencing water quality treatment

- pH
- Temperature
- Hydraulic residence time
- Media (organic material, particle size, porosity, chemistry)
- Competing ions, ionic chemistry
- Soil water condition
- Influent concentration
Is the following statement correct?

• If an influent concentration of 5 µg/L into a bioretention area results in an effluent concentration of 10 µg/L then

• an influent concentration of 50 µg/L will result in an effluent concentration of 100 µg/L.

Sorption

- Ionic charge and speciation
- Functional groups (moiety)
- Organic material (TOC and DOC)
- Competing ions and ion exchange
- Clay (particle size)

<table>
<thead>
<tr>
<th>Metal Fraction</th>
<th>Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchangeable Fraction</td>
<td>High: Changes in major cationic compositions may cause release due to ion exchange.</td>
</tr>
<tr>
<td>Fe-Mn Oxides Bound</td>
<td>Medium: Changes in redox conditions may cause release.</td>
</tr>
<tr>
<td>Carbonate Bound</td>
<td></td>
</tr>
<tr>
<td>OM Bound</td>
<td>Medium/high: Decomposition/oxidation with time.</td>
</tr>
<tr>
<td>Residual Fraction</td>
<td>Low: Available after weathering.</td>
</tr>
</tbody>
</table>

System*

<table>
<thead>
<tr>
<th></th>
<th>Copper, µg/L</th>
<th>Lead, µg/L</th>
<th>Zinc, µg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>140 ± 32</td>
<td>61 ± 3</td>
<td>600 ± 8</td>
</tr>
<tr>
<td>Average</td>
<td>12 ± 3.4</td>
<td>2.9 ± 1.4</td>
<td>43 ± 15</td>
</tr>
<tr>
<td>± Standard deviation</td>
<td>3.4 ± 1.6</td>
<td>&lt;2 ± 2</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Range</td>
<td>3.2-18</td>
<td>&lt;2-6.7</td>
<td>&lt;25-70</td>
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<tr>
<td>Min.</td>
<td>3.2</td>
<td>&lt;2</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Reduction, %</td>
<td>91 ± 2</td>
<td>95 ± 2</td>
<td>93 ± 3</td>
</tr>
</tbody>
</table>
TREATMENT STRATEGIES

- Sorption and metal complexes
  - Metal atom associated with group of molecules or anions
  - Organically bound Cu often dominant fraction in soils

  “Cu however, has a high affinity for soluble organic ligands and the formation of these complexes may greatly increase Cu mobility in soils.” (EPA 1992)

TREATMENT STRATEGIES

- Implications for copper
  - To best manage Cu we will likely have to manage DOC
  - Fe and Ca may be (likely), important for DOC capture
  - Identify aggregate and organic materials with low Cu content and flushing potential
• Primary mechanisms for P management
  - Plant and microbial uptake
  - Sorption and precipitation. Sorption materials include Al and Fe hydroxides and Ca
  - Reactions are pH dependent. Calcium likely not a reliable material for binding P (higher pH best for precipitation)

Methods for retaining phosphate
- Organic matter, fertilizers
- Sorption and precipitation
- Sorption materials include Al and Fe hydroxides and Ca
- Reactions are pH dependent. Calcium likely not a reliable material for binding P (higher pH best for precipitation)

TREATMENT STRATEGIES

MEDIA BASICS

- P removal efficiency v input concentration
  - During initial loadings with tap water (< 0.06mg/l) there was export of P
  - Stormwater loadings commenced after 18 months
TREATMENT STRATEGIES

Implications for phosphorus

- Design with lower organic material content and upper range for C/N ratio (i.e. 35/1)
- Use organic material that is refractory (probably the older the better)
- Bind P with Al or Fe hydroxides
- Identify aggregate material with little to no P flushing
- Likely will need a polishing layer/filter if using compost
- Above design considerations likely most important for at least three years of installation

TREATMENT STRATEGIES

Methods for managing nitrate (biological transformations)

- Organic matter
- Denitrification (N₂, N₂O)
- Nitrification (NH₄⁺)
- Ammonium (NH₄⁺)
- Nitrites (NO₂⁻)
- Nitrate (NO₃⁻)
- Plant consumption
- Leaching
- Denitrification (N₂, N₂O)
- Electron acceptor not O₂ in anaerobic conditions

2NO₃⁻ + 10e⁻ + 12H⁺ → N₂ + 6H₂O

Electron donor may be sugar, hydrocarbon (simple) or complex (mulch).

TREATMENT STRATEGIES
TREATMENT STRATEGIES

Methods for managing nitrate (60-15-15-10 columns)

**MEDIA BASICS**

### TREATMENT STRATEGIES

**Implications**

- Design with an elevated under-drain (multiple advantages to this approach)
- Caution: we don’t fully understand the potential for metal and P desorption in the anoxic zone

**MEDIA BASICS**

**TREATMENT STRATEGIES**

Filtration: 60/40 bioretention media provides excellent filtration of TSS (depending on PSD and permeability)...

Does not appear to be concentration dependent
HYDRAULIC PERFORMANCE

ASTM D2434 tests performed 2011 as part of a project to standardize test methods across regional labs (60/40 media)

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Dry Density (pcf)</th>
<th>N% Compaction</th>
<th>Mold Diameter (in)</th>
<th>Day 1 (in/hr)</th>
<th>Day 2 (in/hr)</th>
<th>Day 3 (in/hr)</th>
<th>Day 4 (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARS</td>
<td>94.3</td>
<td>85.0</td>
<td>6</td>
<td>3.6</td>
<td>3.6</td>
<td>4.1</td>
<td>4.7</td>
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<tr>
<td>GeoTest</td>
<td>91.3</td>
<td>84.5</td>
<td>6</td>
<td>10</td>
<td>13</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Geogringers</td>
<td>96.3</td>
<td>85.5</td>
<td>6</td>
<td>3.8</td>
<td>2.7</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>(60% of WTRs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MWUA</td>
<td>102.0</td>
<td>90.5</td>
<td>6</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HWA</td>
<td>95.2</td>
<td>84.9</td>
<td>6</td>
<td>19</td>
<td>25</td>
<td>21</td>
<td>22</td>
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<tr>
<td>Sharron &amp; Wilson</td>
<td>95.0</td>
<td>84.1</td>
<td>6</td>
<td>6.2</td>
<td>5.4</td>
<td>5.2</td>
<td>5.5</td>
</tr>
<tr>
<td>MWUA</td>
<td>95.1</td>
<td>84.8</td>
<td>6</td>
<td>17</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPU</td>
<td>95.3</td>
<td>82.5</td>
<td>6</td>
<td>19</td>
<td>19</td>
<td>40</td>
<td>42</td>
</tr>
</tbody>
</table>

HYDRAULIC PERFORMANCE

- Soil treatments
  - 60% sand – 40% compost
  - 80% sand – 20% compost
  - 60% sand – 30% compost – 10% WTRs
  - 60% sand – 15% compost – 15% shredded bark – 10% WTRs
  - 60% sand – 10% biosolids – 15% shredded bark – 5% sawdust – 10% WTRs
• Mesocosm Falling Head Permeability Test (May-June 2011)
HYDRAULIC PERFORMANCE

ASTM D2434 tests performed 2015 as part of a project to develop a high performance water quality treatment media

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Ksat Rates per ASTM 2434</th>
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<tbody>
<tr>
<td>70vs/20fe/10de</td>
<td></td>
</tr>
<tr>
<td>70vs/20fe/10ash</td>
<td></td>
</tr>
<tr>
<td>70vs/20cp/10de</td>
<td></td>
</tr>
<tr>
<td>70vs/20cp/10gac</td>
<td></td>
</tr>
<tr>
<td>70ws/20cp/10ash</td>
<td></td>
</tr>
<tr>
<td>90vs/10comp/player</td>
<td></td>
</tr>
</tbody>
</table>

Ksat (in/hr)

IMPACTS

- Consider carefully acceptance/verification requirements...the system may be hydraulically functional, but not meet specific guidelines at that time
- Consider how to size and operate a system that may be evolving over time

SIDE NOTE
- The region may becoming more accepting of high flow media with control structures

Lunch
**HYDRAULIC PERFORMANCE**

Compost-based media

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**WATER QUALITY TREATMENT PERFORMANCE**

TSS Effluent Concentration

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**WATER QUALITY TREATMENT PERFORMANCE**

TSS Effluent Concentration
**WATER QUALITY TREATMENT PERFORMANCE**

- All mesocosms (Phase 1 flushing regime)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Median Influent</th>
<th>Min</th>
<th>Median Effluent</th>
<th>Max</th>
<th>n</th>
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</thead>
<tbody>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>4.9</td>
<td>1</td>
<td>5.3</td>
<td>22.5</td>
<td>36</td>
</tr>
<tr>
<td>Diss Zn</td>
<td>µg/L</td>
<td>71</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Diss Cu</td>
<td>µg/L</td>
<td>3</td>
<td>1.7</td>
<td>8.6</td>
<td>15.9</td>
<td>40</td>
</tr>
<tr>
<td>PO4</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.086</td>
<td>0.236</td>
<td>0.461</td>
<td>40</td>
</tr>
<tr>
<td>NO3-NO2</td>
<td>mg/L</td>
<td>0.361</td>
<td>0.05</td>
<td>0.145</td>
<td>1.03</td>
<td>32</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>CFU/100mL</td>
<td>229</td>
<td>5</td>
<td>21.5</td>
<td>65</td>
<td>32</td>
</tr>
</tbody>
</table>
Developing a high-performance WQ treatment media

Media treatments

- 60% sand/40% compost (control).
- 70% volcanic sand/20% iron-fused wood chips/10% diatomaceous earth.
- 70% volcanic sand/20% iron-fused wood chips/10% high carbon wood ash.
- 70% volcanic sand/20% coco coir/10% diatomaceous earth.
- 70% volcanic sand/20% coco coir/10% granulated activated charcoal.
- 70% washed sand/20% coco coir/10% high carbon wood ash.
- 70% volcanic sand/20% coco coir/10% high carbon wood ash.
- 90% volcanic sand/10% compost/polishing drainage layer (volcanic sand, activated alumina and bone char).
WATER QUALITY TREATMENT PERFORMANCE

Flushing findings

- 60% sand/40% compost (control) flushing concentrations 1-2 orders of magnitude greater than treatments.
- All treatments exhibit a standard flushing pattern for N and Cu; however, ortho-P flushing increases before decreasing in 60/40. Other research showing extended flushing of ortho-P in compost mediads.
- In general, the coco coir pith and GAC or high carbon wood ash best performers for minimal flushing.
## Ortho-P (mg/L)

<table>
<thead>
<tr>
<th>Date</th>
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<th>70% Vf/20% cp/10% gac</th>
<th>70% Vf/20% cp/10% ash</th>
<th>70% Vf/20% cp/10% ash</th>
<th>90% Vf/10% comp/player</th>
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<tr>
<td>12/11/2014</td>
<td>1.13</td>
<td>0.095</td>
<td>0.016</td>
<td>0.023</td>
<td>0.082</td>
</tr>
<tr>
<td></td>
<td>0.999</td>
<td>0.02</td>
<td>0.011</td>
<td>0.019</td>
<td>0.015</td>
</tr>
<tr>
<td>Mean</td>
<td>0.994</td>
<td>0.019</td>
<td>0.021</td>
<td>0.018</td>
<td>0.019</td>
</tr>
<tr>
<td>Median</td>
<td>0.997</td>
<td>0.02</td>
<td>0.021</td>
<td>0.018</td>
<td>0.019</td>
</tr>
<tr>
<td>Percent Reduction</td>
<td>91</td>
<td>98</td>
<td>81</td>
<td>91</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>influent</th>
<th>70% Vf/20% cp/10% gac</th>
<th>70% Vf/20% cp/10% ash</th>
<th>70% Vf/20% cp/10% ash</th>
<th>90% Vf/10% comp/player</th>
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<tr>
<td>12/11/2014</td>
<td>0.145</td>
<td>0.058</td>
<td>0.018</td>
<td>0.068</td>
<td>0.082</td>
</tr>
<tr>
<td></td>
<td>0.061</td>
<td>0.025</td>
<td>0.046</td>
<td>0.067</td>
<td>0.098</td>
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<tr>
<td>Mean</td>
<td>0.063</td>
<td>0.022</td>
<td>0.067</td>
<td>0.094</td>
<td>0.098</td>
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<tr>
<td>Median</td>
<td>0.061</td>
<td>0.022</td>
<td>0.067</td>
<td>0.098</td>
<td>0.098</td>
</tr>
<tr>
<td>Percent Reduction</td>
<td>58</td>
<td>85</td>
<td>54</td>
<td>32</td>
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</tbody>
</table>

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## Nitrate + Nitrite

Effluent Concentration by Treatment

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## Dissolved Copper

Effluent Concentration by Treatment

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PERFORMANCE WATER QUALITY TREATMENT PERFORMANCE

Dissolved Cu (µg/L)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>12.3</td>
<td>12.7</td>
<td>12.6</td>
<td>12.9</td>
</tr>
<tr>
<td>Median</td>
<td>12.3</td>
<td>12.7</td>
<td>12.6</td>
<td>12.9</td>
</tr>
<tr>
<td>Percent Reduction</td>
<td>96</td>
<td>97</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Sample</td>
<td>13.9</td>
<td>12</td>
<td>8.1</td>
<td>14.5</td>
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<table>
<thead>
<tr>
<th>Date</th>
<th>12/11/2014</th>
<th>12/12/2014</th>
<th>12/13/2014</th>
<th>12/14/2014</th>
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<tbody>
<tr>
<td>Mean</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Median</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Percent Reduction</td>
<td>54</td>
<td>54</td>
<td>54</td>
<td>54</td>
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</tbody>
</table>

Dosing findings

• 60% sand/40% compost (control) effluent concentrations 1-2 orders of magnitude greater for N and P than treatments.

• Significant release of dissolved Cu in treatments with iron coated wood chips during dosing.

• Very good dissolved Cu management at low and high influent concentrations for coco coir pith and GAC or high carbon wood ash treatments.

• Good N and P management at low and high influent concentrations for coco coir pith and GAC or high carbon wood ash.

• Coco coir and GAC or high carbon wood ash best performers for N, P and Cu capture.

PERFORMANCE BIOLOGICAL EFFECTIVENESS
BIOLOGICAL EFFECTIVENESS

- More context...

![Graph showing % Reduction in Dissolved Metals](image)

**Animal Model** | Effect       | Exposure | Reduced | Eliminated
--- | --- | --- | --- | ---
Juvo. coho    | Mortality   | 96 h    | 100%    | ✓
Mayfly nymph  | Mortality   | 48 h    | 100%    | ✓
Zebrafish    | Mortality   | 96 h    | 100%    | ✓
Daphnid      | Mortality   | 48 h    | 100%    | ✓
              | Reproductive Impairment | 7 d | 100% | ✓
Zebrafish    | Cardiac dysfunction | 48 h | 100% | ✓
              | Growth impairment | 96 h | 100% | ✓
              | Cardiac edema    | 96 h    | 100%    | ✓
              | Swim bladder     | 96 h    | 100%    | ✓
              | Microphthalmia   | 96 h    | 81%     |
              | CYP1a induction  | 48 h    | TBD     | TBD
              | Cardiac genes    | 48 h    | TBD     | TBD
## Statewide LID Training Program

### OTHER COURSE OFFERINGS

<table>
<thead>
<tr>
<th>COURSE AREA</th>
<th>LEVEL</th>
<th>TITLES</th>
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<tbody>
<tr>
<td><strong>INTRODUCTORY</strong></td>
<td></td>
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<tr>
<td>1.0</td>
<td>Intermediate</td>
<td>LID for Inspection &amp; Maintenance Staff</td>
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<tr>
<td>1.1</td>
<td>Introduction to LID for Developers &amp; Developers Working with LID Designers</td>
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</tr>
<tr>
<td>1.2</td>
<td>Intermediate LID Design Principles &amp; Requirements</td>
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<td>1.3</td>
<td>Intermediate LID Design Monitors</td>
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<td>2.2</td>
<td>Intermediate LID Design: Rainwater Collection Systems &amp; Vegetated Roofs</td>
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<tr>
<td>2.3</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
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<td><strong>ADVANCED</strong></td>
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<td>3.1</td>
<td>Advanced Topics in LID Design: Vegetation &amp; Stormwater Management Plan Development for the Local Planner</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Advanced Topics in LID Design: Best Management Practices for the Service Provider</td>
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</tr>
<tr>
<td>3.3</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
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<td>4.1</td>
<td>Intermediate LID Design: Hydrologic Modeling</td>
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<td>4.2</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout for Developers</td>
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<td>4.3</td>
<td>Intermediate LID Design: Permeable Pavement</td>
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<td>4.5</td>
<td>Advanced Topics in LID Design: Rainwater Collection Systems &amp; Vegetated Roofs</td>
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<tr>
<td>4.6</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout for Developers</td>
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<td>4.7</td>
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</tbody>
</table>

#### TRAIN THE TRAINERS

- **9.1** Service Providers
- **9.2** DD Topic Experts

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**ONLINE EVALUATION**

- An on-line evaluation will be sent to you within 5 days following this training
- Feedback will help to refine future trainings
- Feedback is also important to pursue funding to support a long-term statewide LID training program

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**CERTIFICATE**

- Two certificates:
  - LID Design certificate
  - Long-term LID Operations certificate
- Stay tuned for developing certificate policies

Sign out!
For information on training and other resources, visit the Washington Stormwater Center website:

http://www.wastormwatercenter.org

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Further questions? Contact:
training@cascadiaconsulting.com
(206) 449-1163