Statewide LID Training Program

INSTRUCTORS

REBECCA DUGOPOLSKI, PE
Senior Engineer
Key project experience:
Stormwater monitoring, design, and NPDES Permit compliance

DUSTIN ATCHISON, PE
Water Resources Project Manager
Key project experience: LID design, stormwater master planning, stream and wetland restoration design, hydrologic and hydraulic modeling
Statewide LID Training Program

LOGISTICS

SCHEDULE
8-hour training
Lunch on your own
45 minute site visit

OTHER LOGISTICS
• Restrooms
• Food
• Turn off cell phones
• Sign in and sigh out
• 2012: Public and private partners engage state legislature to fund program

• June 2012: LID Training Steering Committee convened

• 2012-2013: Washington State LID Training Plan developed: [www.wastormwatercenter.org/statewide-lid-training-program-plan](http://www.wastormwatercenter.org/statewide-lid-training-program-plan)

• 2014: Training program built from state LID Training Plan
Statewide LID Training Program

PROGRAM OVERVIEW

- Implement first phase of trainings (September 2014 through May 2015)
- 64 trainings offered in first phase
- Three levels: Introductory, Intermediate, and Advanced
- Train the Trainer program for service providers and LID topic experts
# Statewide LID Training Program

## TEAM

<table>
<thead>
<tr>
<th>PROJECT LEAD</th>
<th>CORE TEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>HERRERA</td>
<td>CASCADIA</td>
</tr>
<tr>
<td></td>
<td>Veda</td>
</tr>
</tbody>
</table>

## ADDITIONAL TRAINING SUPPORT

- CH2M HILL®
- Aspect Consulting
- Leaping Frog Films
- SvR Design Company
- Washington Stormwater
- Stormwater One
## Statewide LID Training Program

### TRAINING SEQUENCE

<table>
<thead>
<tr>
<th><strong>INTRODUCTORY</strong></th>
<th><strong>INTERMEDIATE</strong></th>
<th><strong>ADVANCED</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>3.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Introduction to LID for Eastern Washington</td>
<td>Intermediate LID – NPDES Phase I &amp; II Requirements</td>
<td>Advanced Topics in LID Design: Bioretention</td>
</tr>
<tr>
<td>2.1</td>
<td>3.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Introduction to LID for Inspection &amp; Maintenance Staff</td>
<td>Intermediate LID Design: Bioretention</td>
<td>Advanced Topics in LID Design: Permeable Pavement</td>
</tr>
<tr>
<td>2.2</td>
<td>3.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Introduction to LID for Developers &amp; Contractors: Make Money be Green</td>
<td>Intermediate LID Design: Permeable Pavement</td>
<td>Advanced Topics for LID Operations: Bioretention</td>
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<tr>
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<td>5.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
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<tr>
<td>4.1</td>
<td>5.5</td>
<td>8.1</td>
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<td>8.2</td>
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<tr>
<td>Intermediate LID Design: Hydrologic Modelling</td>
<td>Intermediate LID Design: Bioretention Media</td>
<td>Advanced Topics in LID Design: Bioretention Media</td>
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</table>

### TRAIN THE TRAINERS

- 9.1 Service Providers
- 9.2 LID Topic Experts
## Statewide LID Training Program

### Training Sequence

<table>
<thead>
<tr>
<th>Introduction to LID for Eastern Washington</th>
<th>Introduction to LID for Inspection &amp; Maintenance Staff</th>
<th>Introduction to LID for Developers &amp; Contractors: Make Money be Green</th>
</tr>
</thead>
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<tr>
<td><strong>1.0</strong></td>
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<td><strong>2.2</strong></td>
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<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1</strong></td>
<td><strong>3.2</strong></td>
<td><strong>3.3</strong></td>
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</tbody>
</table>

<table>
<thead>
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<th></th>
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<tbody>
<tr>
<td><strong>3.4</strong></td>
<td><strong>4.1</strong></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Advanced Topics in LID Design: Bioretention</th>
<th>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</th>
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</thead>
<tbody>
<tr>
<td><strong>5.1</strong></td>
<td><strong>5.3</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Advanced Topics in LID Design: Permeable Pavement</th>
<th>Advanced Topics for LID Operations: Bioretention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.2</strong></td>
<td><strong>5.4</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Advanced Topics in LID Design: Rainwater Collection Systems &amp; Vegetated Roofs</th>
<th>Advanced Topics in LID Design: Bioretention Media</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.5</strong></td>
<td><strong>5.6</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Train the Trainers</th>
<th>Train the Trainers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>9.1</strong> Service Providers</td>
<td><strong>9.2</strong> LID Topic Experts</td>
</tr>
</tbody>
</table>
Statewide LID Training Program

INTERMEDIATE LID DESIGN
BIORETENTION

3.2
LEARNING OBJECTIVES

1. Gain an intermediate level knowledge necessary for proper entry level design of bioretention systems.

2. Learn skills necessary for basic site assessment and locating bioretention areas in residential and commercial settings.

3. Learn practical skills necessary for construction of basic bioretention systems.
AGENDA

1. Introduction to course and bioretention
2. Water quality treatment
3. Bioretention siting, design and construction
4. Inspection & verification
5. Wrap-up
introduction to course and bioretention

water quality treatment

bioretention siting, design and construction

inspection & verification

wrap-up
INTRODUCTION

TOPICS

Intro to LID

NPDES Permit

Bioretention Basics

Statewide LID Training Program

3.2 BIORETENTION

INTERMEDIATE LID DESIGN
WHAT IS LOW IMPACT DEVELOPMENT?

- A land use development strategy that emphasizes protection and use of on-site natural features to manage stormwater.

- Careful assessment of site soils and strategic site planning to best use those soils for stormwater management.

- Integrates engineered and non-engineered, small scale stormwater controls into the site design to closely mimic pre-development hydrologic processes.
WHAT IS LOW IMPACT DEVELOPMENT?

• Used at the parcel and subdivision scale. Site scale necessary but not sufficient. Regional land use planning critical for effective stormwater management.

• Primary goal: no measurable impacts to receiving waters by maintaining or approximating pre-development surface flow volumes and durations.
Undeveloped - Forest

- During winter months evaporation continues to be active while the transpiration component is minimal.
- Storm events moderated by infiltration, evaporation, and evapotranspiration.
- Water is available in substrata to sustain stream base flows during summer months.
- As winter progresses, the interflow component of stream flow increases.
- During the Summer and Fall streams are maintained primarily by glacial melt water and/or groundwater flow.
Developed Conditions

- Overland flow increases and time of concentration decreases
- Less water in substrata available to sustain base stream flows
- Interflow highly variable depending on development

precipitation

evapo-transpiration 20-30%

20-30% surface runoff

water table

groundwater 10-20%

0-30% interflow
INTRODUCTION

WHAT IS LOW IMPACT DEVELOPMENT?

Objectives

• Protect and restore native soils/vegetation

• Reduce development envelope

• Reduce impervious surfaces and eliminate effective impervious areas

• Manage stormwater as close to its origin as possible

• Integrate stormwater controls into the design—create a multifunctional landscape
INTRODUCTION
TOPICS

Intro to LID

NPDES Permit

Bioretention Basics

Eastern Washington Phase II Municipal Stormwater Permit

National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Small Municipal Separate Storm Sewers in Eastern Washington

State of Washington
Department of Ecology
Olympia, Washington 98504-7009

In compliance with the provisions of:
The State of Washington Water Pollution Control Law
Chapter 90.48 Revised Code of Washington
and
The Federal Water Pollution Control Act
(42 U.S.C. 1360 et seq.)

Title 35 United States Code, Section 1221 et seq.

Expiration Date: August 1, 2012
Effective Date: August 1, 2014
Expiration Date: July 31, 2019

Until this permit expires, is modified, or revoked, Permittees that have properly obtained approval under this permit are authorized to discharge to some of the sites in accordance with the special and general conditions which follow.

[Signature]
Senior Quality Program Manager
Department of Ecology

Statewide LID Training Program
DEPARTMENT OF ECOLOGY
State of Washington

3.2 BIORETENTION
INTERMEDIATE LID DESIGN 19
INTRODUCTION

NPDES PERMIT REQUIREMENTS

• Phase I*
  • Populations ≥ 100,000

• Phase II
  • Generally populations > 10,000

• Issuance date: August 1, 2012
• Effective date: August 1, 2014
• Permit term: 5 years (through July 31, 2019)

*No Phase I jurisdictions in Eastern WA
## INTRODUCTION

### NPDES PERMIT REQUIREMENTS

<table>
<thead>
<tr>
<th>Phase II Cities</th>
<th>Phase II Counties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asotin</td>
<td>Asotin</td>
</tr>
<tr>
<td>Clarkston</td>
<td>Chelan</td>
</tr>
<tr>
<td>East Wenatchee</td>
<td>Douglas</td>
</tr>
<tr>
<td>Ellensburg</td>
<td>Spokane</td>
</tr>
<tr>
<td>Kennewick</td>
<td>Spokane Valley</td>
</tr>
<tr>
<td>Moses Lake</td>
<td>Sunnyside</td>
</tr>
<tr>
<td>Pasco</td>
<td>Union Gap</td>
</tr>
<tr>
<td>Pullman</td>
<td>Walla Walla</td>
</tr>
<tr>
<td>Richland</td>
<td>Wenatchee</td>
</tr>
<tr>
<td></td>
<td>West Richland</td>
</tr>
<tr>
<td></td>
<td>Yakima</td>
</tr>
</tbody>
</table>
NPDES PERMIT REQUIREMENTS: Core Elements

#1 Preparation of a Stormwater Site Plan

#2 Construction Stormwater Pollution Prevention

#3 Source Control of Pollution

#4 Preservation of Natural Drainage Systems and Outfalls

#5 Runoff Treatment

#6 Flow Control

#7 Operations and Maintenance

#8 Local Requirements
INTRODUCTION

NPDES PERMIT REQUIREMENTS:
Core Element 5 and 6 Thresholds

Core Element 5 – Runoff Treatment

• New: > 5,000 sq. ft. pollutant-generating impervious surface (PGIS)
• Redevelopment: > 5,000 sq. ft. PGIS for specific industrial, commercial, high-use, and high traffic sites

Core Elements 6 – Flow Control

• New: > 10,000 sq. ft. new impervious surfaces
• Redevelopment: Not required for redevelopment unless required under a basin plan or other federal, state, or local requirement
INTRODUCTION

TOPICS

Intro to LID
NPDES Permit
Bioretention Basics

Eastern Washington Phase II Municipal Stormwater Permit

Immense Date: August 1, 2012
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arrangements under this permit are authorized to discharge to waters of the state in accordance with
the specific general conditions which follow.

[Signature]
Senior Quality Program Manager
Department of Ecology
BIORETENTION: Definition and Types

- Shallow landscaped depressions that are engineered (bioretention) or non-engineered (rain gardens) to receive stormwater from small contributing areas
- Small scale, dispersed facilities
- Types:
  - Bioretention cells
  - Bioretention swales
  - Infiltration planters
  - Flow-through planters
BIORETENTION: Components

- Pre-Settling/Flow Entrance
- Bioretention Soil/Amended Soil
- Mulch/Compost
- Native Vegetation
- Ponding Area (earthen depression or impermeable reservoir)
- Underdrain (optional)
- Overflow

2012 LID Technical Guidance Manual for Puget Sound
INTRODUCTION

BIORETENTION vs. RAIN GARDENS

• Bioretention:
  • Often includes surface and subsurface infrastructure
  • Designed soil mix

• Rain gardens:
  • Usually do not include under-drains
  • May use less restrictive soil mix guidelines (e.g., existing soil augmented with compost and sand)
INTRODUCTION

BIORETENTION vs. RAIN GARDENS

• Primary functions
  • Hydrologic benefits
  • Water quality treatment
  • Aesthetic amenity
Statewide LID Training Program

City of Spokane SURGE

3.2 BIORETENTION
introduction to course and bioretention

water quality treatment

bioretention siting, design and construction

inspection & verification

wrap-up
All primary pathways for removing pollutants from storm flows active in bioretention

- Stormwater volume reduction
- Sedimentation
- Filtration
- Phytoremediation
- Thermal attenuation
- Adsorption
- Volatilization

Note: rain gardens can also provide these pollutant capture pathways, but should only be used for small projects that do not trigger Core Elements #5 or #6.
### VOLUME REDUCTION

<table>
<thead>
<tr>
<th>Project</th>
<th>Completed</th>
<th>Infiltration</th>
<th>Sizing</th>
<th>Volume Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siskiyou Green Street</td>
<td>Oct 2003</td>
<td>1.5 - 2.0 in/hr</td>
<td>6%</td>
<td>*(1/04 – 12/05) 83%</td>
</tr>
<tr>
<td>Glencoe Rain Garden</td>
<td>Oct 2003</td>
<td>1.8 - 3.0 in/hr</td>
<td>6%</td>
<td>(1/04 – 12/05) 94%</td>
</tr>
<tr>
<td>Greensboro NC</td>
<td>2001</td>
<td>0.2 – 0.6 in/hr</td>
<td>5%</td>
<td>(2002) 78%</td>
</tr>
<tr>
<td>SEA Street</td>
<td>2001</td>
<td>variable</td>
<td>~2%</td>
<td>(2001 – present) 98%</td>
</tr>
<tr>
<td>110th Cascade</td>
<td>2003</td>
<td></td>
<td></td>
<td>(10/04 – 06) 74%</td>
</tr>
<tr>
<td>Meadow on the Hylebos</td>
<td>2006</td>
<td>0.0 – 0.8 in/hr</td>
<td>15%</td>
<td>(10/07 – 5/08) 99.99%</td>
</tr>
</tbody>
</table>
### Soil Contaminant Levels

<table>
<thead>
<tr>
<th>Project</th>
<th>e. Coli (MPN/g)</th>
<th>Cu (mg/kg)</th>
<th>Pb (mg/kg)</th>
<th>Hg (mg/kg)</th>
<th>Zn (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Siskiyou Green Street</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6”</td>
<td>280</td>
<td>34.4</td>
<td>56.8</td>
<td>0.103</td>
<td>170</td>
</tr>
<tr>
<td>6-12”</td>
<td>--</td>
<td>17.0</td>
<td>12.2</td>
<td>0.032</td>
<td>100</td>
</tr>
<tr>
<td>12-18”</td>
<td>--</td>
<td>17.6</td>
<td>10.9</td>
<td>0.054</td>
<td>96</td>
</tr>
<tr>
<td><strong>SW 12th &amp; Montgomery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6”</td>
<td>7</td>
<td>30.1</td>
<td>29.9</td>
<td>0.043</td>
<td>120</td>
</tr>
<tr>
<td>12-18”</td>
<td>--</td>
<td>22.2</td>
<td>18.9</td>
<td>0.082</td>
<td>92</td>
</tr>
</tbody>
</table>

**MTCA**  
Pb: 250 mg/kg  
Hg: 2 mg/kg
## PERCENT REMOVAL OF NUTRIENTS

<table>
<thead>
<tr>
<th></th>
<th>TKN (mg/L)</th>
<th>NO3 (mg/L)</th>
<th>TP (mg/L)</th>
<th>Hydrocarbons (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis et al 2006*</td>
<td>38% (u) 68% (l)</td>
<td>-96% (u) 24% (l)</td>
<td>1% (u) 81% (l)</td>
<td></td>
</tr>
<tr>
<td>Greenbelt</td>
<td>57%</td>
<td>16%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Largo</td>
<td>67%</td>
<td>15%</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>Mass removal</td>
<td>97%</td>
<td>97%</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>Hunt et al 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greensboro</td>
<td>-4.9%</td>
<td>75%</td>
<td>-240%</td>
<td></td>
</tr>
<tr>
<td>Chapel Hill</td>
<td>45%</td>
<td>13%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Hsieh 2005</td>
<td></td>
<td></td>
<td></td>
<td>&gt;97%</td>
</tr>
<tr>
<td>PNW Bioswales (Herrera 2006)</td>
<td></td>
<td></td>
<td>18%</td>
<td>-10%</td>
</tr>
<tr>
<td>Nat’l Bioswales**</td>
<td></td>
<td></td>
<td></td>
<td>-88%</td>
</tr>
</tbody>
</table>

Event mean concentrations

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)

** Herrera from Barrett
### WATER QUALITY TREATMENT

#### PERCENT REMOVAL OF TSS & METALS

<table>
<thead>
<tr>
<th>Study Details</th>
<th>TSS (mg/L)</th>
<th>Cu (µg/L)</th>
<th>Pb (µg/L)</th>
<th>Zn (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis et al 2001*</td>
<td>89% (u) 92% (l)</td>
<td>&gt;98% (u) &gt;98 (l)</td>
<td>&gt;98% (u) &gt;98 (l)</td>
<td></td>
</tr>
<tr>
<td>Davis et al 2003**</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
<td></td>
</tr>
<tr>
<td>Greenbelt</td>
<td>97%</td>
<td>&gt;95%</td>
<td>&gt;95%</td>
<td></td>
</tr>
<tr>
<td>Largo</td>
<td>43%</td>
<td>70%</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td>Hunt et al 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greensboro</td>
<td>-180%</td>
<td>99%</td>
<td>81%</td>
<td>98%</td>
</tr>
<tr>
<td>Chapel Hill</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Hsieh, Davis 2005</td>
<td>91%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNW Bioswales (Herrera 2006)</td>
<td>64%</td>
<td></td>
<td>47%</td>
<td></td>
</tr>
<tr>
<td>National Bioswales (Herrera from Barrett)</td>
<td>43%</td>
<td></td>
<td>53%</td>
<td></td>
</tr>
</tbody>
</table>

**Event mean concentrations**

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)  ** Percent mass removal (lab)
BIORETENTION FLUSHING

WATER QUALITY TREATMENT

Total Phosphorus (mg/L)

- Potting soil extraction (2-22-13)
- Compost extraction (4-27-12)
- Mulch extraction (4-27-12)
- Industrial Permit Benchmark
- Sand extraction (4-27-12)

IN
OUT
## BIORETENTION FLUSHING EXPERIMENTS

<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>
<th>Sand Result</th>
</tr>
</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>
<td></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>
<td></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>
<td></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>
<td></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>
<td></td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>CFU/100mL</td>
<td>229</td>
<td>5</td>
<td>22.5</td>
<td>65</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>
Dissolved Cu Effluent Concentration

WSU large-scale lysimeter study (unpublished)
TSS Capture

Filtration: bioretention provides excellent sediment filtration...

Does not appear to be concentration dependent.
WSU large-scale lysimeter study (unpublished)
SUMMARY

• Initial flushing of nitrogen, phosphorus and low levels of copper at low influent concentrations.

• Excellent zinc at installation and very good copper capture at typical influent concentrations after initial flushing.

• Reasonable TN capture at typical influent concentrations.

• Very good TSS capture

• TP and PO4 remain challenges

• Overall, very good performance in relation to other treatment technologies
Break
introduction
water quality treatment
bioretention siting, design and construction
inspection & verification
wrap-up
1 Siting

2 Design

3 Construction

Top Width

Inlet Protection

Bottom Width

(See Note 1)

Design Ponding Depth

Statewide LID Training Program

3.2 BIORETENTION

INTERMEDIATE LID DESIGN
## Site Suitability Criteria: Infiltration Setbacks

<table>
<thead>
<tr>
<th>Feature</th>
<th>Setback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water well</td>
<td>100 feet</td>
</tr>
<tr>
<td>Spring used for drinking water</td>
<td>100 feet</td>
</tr>
<tr>
<td>Known deep soil contamination</td>
<td>100 feet</td>
</tr>
<tr>
<td>Closed or active landfill</td>
<td>100 feet</td>
</tr>
<tr>
<td>Small on-site septic drainfield</td>
<td>10 feet</td>
</tr>
<tr>
<td>Wellheads, on-site septic systems, basements, foundations, utilities,</td>
<td>Consult local jurisdiction</td>
</tr>
<tr>
<td>slopes, contaminated areas, and property lines</td>
<td>guidelines</td>
</tr>
</tbody>
</table>
# SITE SUITABILITY CRITERIA: Infiltration Setbacks

<table>
<thead>
<tr>
<th>Feature</th>
<th>Setback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building foundations</td>
<td></td>
</tr>
<tr>
<td>Downslope</td>
<td>≥ 20 feet</td>
</tr>
<tr>
<td>Upslope</td>
<td>100 feet</td>
</tr>
<tr>
<td>Native Growth Protection Easement</td>
<td>≥ 20 feet</td>
</tr>
<tr>
<td>Top of slopes &gt;15%</td>
<td>≥ 50 feet</td>
</tr>
</tbody>
</table>
SITE SUITABILITY CRITERIA

• Groundwater Protection Areas
  • Not allowed if it will cause a violation of GW quality stds.

• Depth to bedrock, seasonal high-water mark, or impermeable layer
  • ≥ 5 feet from facility base
  • ≥ 3 feet on case-to-case basis

• Infiltration rate/Drawdown time
  • 0.5 in/hr to 2.4 in/hr
  • Soil groups B & C
  • 72 hr drawdown
• Understand the fate of infiltrated water
  • Intent is to infiltrate to native underlying soil
  • Arterial ROW with dense underground infrastructure (preferential pathway → utility trenches)
  • Potential for excessive shallow interflow emerging at slopes, development cuts, or in basements
• Use engineering controls
  • Ex. trench water stops to prevent re-infiltration to pipes
  • Ex. liners to protect adjacent infrastructure
BIORETENTION SITING, DESIGN & CONSTRUCTION

SITING CONSIDERATIONS

- Native soil and vegetation preservation
- Site Slopes
  - Cross & longitudinal slopes
  - Positive drainage from drainage area to bioretention to overflow
- Setbacks (e.g., utilities & other infrastructure, wetland and streams)
- May require pre-settling
- Public acceptance/ participation (retrofits)

2012 LID Technical Guidance Manual for Puget Sound
Why soils affect siting

Soil variability

Initial infiltration rates

Design infiltration rates
• Important for infiltrating facilities ONLY
• Infiltrating facilities sized based on infiltration rates
• Locate infiltrating BMPs in areas with best soils
SITING CONSIDERATIONS: Soil Variability

Broadview Green Grid, Seattle, WA
SITING CONSIDERATIONS: Soil Variability

Site 1: Loam

Broadview Green Grid, Seattle, WA
BIORETENTION SITING, DESIGN & CONSTRUCTION

SITING CONSIDERATIONS: Soil Variability

Site 2: Sand

Broadview Green Grid, Seattle, WA
Site 3: Glacial till

Broadview Green Grid, Seattle, WA
INfiltration Rates: Overview

Measure or estimate initial saturated hydraulic conductivity

Apply correction factor

Long-term (design) infiltration rate
INFILTRATION RATES: Methods

- Estimate based on soil properties
  - Soil grain analysis*
  - Atterberg limits and ASTM D4318-84 visual/manual procedure

- In-situ field measurements
  - Small-scale PIT methods*
  - Large-scale PIT methods*
  - Borehole methods
  - Single-ring infiltrometer
  - Constant head conditions

* Included in SWMMEW and in the Eastern WA LID Guidance Manual
ECOLOGY SMALL-SCALE PIT METHOD

- Excavate pit
  - Depth ~ surface elevation of native soil (before BSM placement)
  - Horizontal bottom area ~ 12 to 32 sf
  - Side slopes laid back, but vertical to test ponding depth (6 – 12in)
- Install vertical measuring rod
- Install splash plate
  - Reduce side wall erosion and disturbance of bottom (clogging)

*Associated Earth Sciences*
ECOLOGY SMALL-SCALE PIT METHOD

- Fill pit for pre-soak period
  - Standing water (at least 12 inches) for 6 hours

- Adjust flow rate for steady state period
  - Constant water depth (6 – 12 inches) for 1 hour

- Turn off water and record rate of infiltration every 30 - 60 minutes until one hour after the flow has stabilized

- Lowest hourly flow rate is the initial (measured) infiltration rate
ECOLOGY SMALL-SCALE PIT METHOD

• Depth to groundwater
  • Over excavate below pit bottom to check for hydraulic restrictive layers (e.g., bed rock, till/clay lenses) or groundwater
ECOLOGY SMALL-SCALE PIT METHOD

• **Number of PITs**
  
  • Recommend one PIT at each bioretention site
  
  • For larger site, one PIT every 5,000 sf
  
  • For long narrow facilities, one PIT every 200 lineal feet (unless borings indicate consistent soil characteristics)
BIORETENTION SITING, DESIGN & CONSTRUCTION

ECOLOGY SMALL-SCALE PIT METHOD

Regulate flow (Ex. Ball Valve)
BIORETENTION SITING, DESIGN & CONSTRUCTION

ECOLOGY SMALL-SCALE PIT METHOD

Vertical measuring rod

Pit (lay back side slopes)

5 gal. bucket (energy dissipation)

Water level recorded every 15 minutes
ECOLOGY SMALL-SCALE PIT METHOD

March 8 and 9, 2012
Initial rate = 0.25 in/hr

1.5 in/hr

March 8 and 9, 2012
BIORETENTION SITING, DESIGN & CONSTRUCTION

DESIGN INFILTRATION RATES

- Correction factors applied to initial rate to estimate long-term rate for design

- Partial Correction factors:
  - CFv (Site variability and number of locations tested) = 0.33 to 1
  - CFt (Test method) = 0.4 to 0.75
  - CFm (Degree of influent control to prevent siltation and bio-buildup) = 1 (overlying BSM provides excellent protection)

- Total Correction Factor (CF) = CFv x CFt x CFm

- Design rate = Initial Rate x CF
BIORETENTION SITING, DESIGN & CONSTRUCTION

APPLICABILITY

• Residential Parcels
  • Landscaped areas
  • Planters

• Right-of-Way
  • Planting strip
  • Curb bulbs
  • Medians

• Commercial Parcels
  • Landscaped areas
  • Planters
  • Parking Lots
Note: rain gardens should only be used for small projects that do not trigger Core Elements #5 or #6.
BIORETENTION SITING, DESIGN & CONSTRUCTION

SINGLE FAMILY: Stormwater Planters

Inflow
Conveyance

Overflow
RIGHT OF WAY: Seattle SEA Street

Before

After
BIORETENTION SITING, DESIGN & CONSTRUCTION

RIGHT OF WAY: Seattle SEA Street

Before

After
BIORETENTION SITING, DESIGN & CONSTRUCTION

RIGHT OF WAY: Curb Bulbs

NE Siskiyou Green Street Portland, OR

23rd Ave SE & 171st Pl SE
City of Spokane SURGE – Lincoln Street
BIORETENTION SITING, DESIGN & CONSTRUCTION
MULTI-FAMILY DEVELOPMENTS: Block Level Design

High Point, Seattle, WA
MULTI-FAMILY DEVELOPMENTS: Block Level Design

High Point, Seattle, WA
BIORETENTION SITING, DESIGN & CONSTRUCTION

COMMERCIAL PARCELS: Conveyance

Downtown CSO Demand Management, Seattle, WA
BIORETENTION SITING, DESIGN & CONSTRUCTION

COMMERCIAL PARCELS: Parking Lots

Walla Walla Police Department
Walla Walla, WA
COMMERCIAL PARCELS: Parking Lots

Northgate Mall, Seattle, WA
BIORETENTION SITING, DESIGN & CONSTRUCTION

COMMERCIAL PARCELS: Parking Lots

Northgate Mall, Seattle, WA

Curb Cut Inflow

Beehive Structure
Overflow
Combining landscape requirements with bioretention

Lewis Creek Park, Bellevue, WA
Combining conveyance with bioretention

Bagley Elementary, Seattle, WA
COMMERCIAL PARCELS: Bioretention and Rain Gardens

YMCA Silverdale, WA

Villanova Campus
BIORETENTION SITING, DESIGN & CONSTRUCTION

COMMERCIAL PARCELS: Stormwater Planters

Taylor 28 Apartments
Seattle, WA
SNOW STORAGE

- Can be used for snow storage in cold climates

- If used for snow storage or to treat parking lot runoff:
  - Plant with salt tolerant and non-woody plant species
  - Minimize use of sand, cinders, and other winter abrasives
PERFORMANCE STANDARDS

• Runoff Treatment (MR #5)
  • Treat 90% of annual runoff
  • Specific treatment required depending on site type and/or location:
    • Basic (TSS)
    • Metals (dissolved Cu and Zn)
    • Phosphorus
    • Oil

• Flow Control (MR #6)
  • Based on a pre-developed condition (prior to settlement) or existing condition
BIORETENTION SITING, DESIGN & CONSTRUCTION

LAYOUT OPTIONS

Series of Connected Cells

Broadview Green Grid, Seattle, WA

Single Cell
FLOW ENTRANCE: Design Criteria

- Flow entering should be non-erosive
  - Velocity less than 1.0 fps
- Dispersed flow entrance → Preferred!
  - Vegetated buffer strip
  - Sheet flow across pavement/gravel
  - Sheet flow b/t wide wheel stops
- Concentrated flow entrance → Requires erosion protection (e.g., rock)
  - Piped flow
  - Curb cuts
  - Trench drains
FLOW ENTRANCE: Design Criteria

Sheet Flow

Walla Walla
Wheel stops prevent vehicle entry and restrict vehicle loading at edge while allowing sheet flow to bioretention.

Bagley Elementary, Seattle, WA

Coupeville High School, Coupeville, WA
FLOW ENTRANCE

Minimum of 18-inches wide

Depressed gutter at inlet

Finish grade should be 2-3” lower than curb line to allow for settling.
Armor flow entrance with concrete pad or stone.
Trench Drain Curb Cut

Do not use woody plants at inlet (can restrict or concentrate flows)
Trench Drain

For higher/surface elevation inlets
City of Spokane SURGE – Broadway
FLOW ENTRANCE

- For roadside, driveway, or parking lot area curb cuts
  - Finish grade is 2-3” lower than curb line to allow for settling
  - Minimum curb cut width is 12-inches; 18-inches preferred
  - Armored flow entrance with concrete pad and stone

Armored flow entrance with curb cut

Walla Walla, WA
BIORETENTION SITING, DESIGN & CONSTRUCTION

FLOW ENTRANCE

Trench Drain

PLAN VIEW

SECTION A-A

SECTION B-B

City of Portland, OR
Field Exercise
Infiltration Tests
BIORETENTION SITING, DESIGN & CONSTRUCTION

PRE-SETTLING

• To capture debris/sediment and reduce potential for clogging of BSM

• May be required for:
  • For concentrated flow entrances
  • For larger drainage areas
  • Where sediment loading is expected (e.g., high-use parking lots and roadways)
PRE-SETTLING

• Pre-settling methods:
  • Open forebay
  • Catch basin
BIORETENTION SITING, DESIGN & CONSTRUCTION

PONDING AREA

High Point, Seattle, WA

Earthen Depression

Pinehurst, Seattle, WA

Rockery Walls

Statewide LID Training Program

State of Washington
PONDING AREA: Design/Performance

• Without Underdrain
  • Earthen depression (w/o liner) or open-bottomed planter
  • Relies on infiltration to native soil
  • Can provide effective on-site stormwater management, flow control and WQ treatment

Notes:
1. Bottom width shall be a minimum of 2 feet and bottom area shall be flat (0% slope).
2. Imported bioretention soil shall meet City of Seattle specifications (minimum design infiltration rate of 3 inches per hour and 40% porosity).
PONDING AREA: Design/Performance

• With Underdrain
  • Some infiltration to native soil (w/out liner)
  • Can provide on-site stormwater management
  • Can provide effective WQ treatment for some pollutants
  • Cannot meet forest duration flow control alone, but can contribute as part of a system to achieve flow control goals (orifice improves performance)
PONDING AREA: Sizing Criteria

- Size to meet performance standards
  - Use single event modeling to size for runoff treatment (CE #5) or flow control (CE #6)

- Max. surface pool drawdown time (24-48 hours)
  - Soil allowed to dry out periodically
  - Restore hydraulic capacity of system
  - Maintain adequate soil oxygen levels
  - Prevent conditions supportive of mosquito breeding

*Surface Pool Drawdown = Ponding Depth \( \div \) Design Infiltration Rate
BIORETENTION SITING, DESIGN & CONSTRUCTION
PONDING AREA: Sizing Criteria

• Size to meet performance standards
  • Use single event modeling to size for runoff treatment (CE #5) or flow control (CE #6)

• Max. surface pool drawdown time (24-48 hours)
  • Soil allowed to dry out periodically
  • Restore hydraulic capacity of system
  • Maintain adequate soil oxygen levels
  • Prevent conditions supportive of mosquito breeding

*Surface Pool Drawdown=
Example: 6 inch ÷ 0.25 inch/hour = 24 hours
PONDING AREA: Footprint Area

- Larger footprint area for:
  - Larger contributing area
  - Higher site precipitation
  - Lower native soil infiltration rate
  - Shallower ponding depth
  - Shallower BSM depth
PONDING AREA: Cross-Section Criteria*

- Max ponding depth (12 inches)
- Min bottom width (1 foot)
- Max planted side slope (2.5:1) (for depth ≥ 3 ft)
- Min freeboard?
- Max contributing area or bottom area?

Max contributing area to single cell is 5,000 sf impervious*

* Seattle requirements provided for example design criteria
BIORETENTION SITING, DESIGN & CONSTRUCTION

PONDING AREA: Roadway Facility Criteria*

- 2-foot shoulder
- Grade at 3H:1V
- Grade at 4H:1V for intersections (Seattle)
- Compact shoulder to 90 percent standard proctor

*Seattle requirements provided for example design criteria
PONDING AREA: Roadway Facility Criteria*

- Rockery >1’ high, min 10’ from curb/edge of road
- Rockery <1’ high min 5’ from curb/edge of road

*Seattle requirements provided for example design criteria
PONDING AREA: Roadway Facility Criteria*

Max 4’ drop from vehicular lane

*Seattle requirements provided for example design criteria
Bioretention with curb

Seattle Standard Details

- Top of bank EL
- Bottom swale width
- 2' - 0' MIN
- 1' - 0' VAR
- 1' MIN
- 3.9' MAX*
- Ex ground (varies)
- Conc curb
- Soil, compacted to 90% density
- 3' depth of shredded bark mulch (medium or coarse) or composted material
- 3' depth of composted material
- Bioretention soil, landscape mix
- W/ Curb
- NTS

* Depth over 4' require guard rail.
Bioretention without curb

Seattle Standard Details

- **TOP OF BANK EL**
- **BOTTOM SWALE WIDTH**
- **3.9' MAX**
- **1' MIN**
- **2' - 0' MIN**
- **VAR**
- **EDGE OF PAVEMENT**
- **CONC BAND OR GUTTER**
- **BIORETENTION TURF, SOIL, COMPACTED TO 90% DENSITY**
- **BOTTOM SWALE EL**
- **W/O CURB NTS**
- **3' DEPTH OF SHREDDED BARK MULCH (MEDIUM OR COARSE) OR COMPOSTED MATERIAL**
- **3' DEPTH OF COMPOSTED MATERIAL**
- **BIORETENTION SOIL, LANDSCAPE MIX**
- *** DEPTH OVER 4' REQUIRE GUARD RAIL.**
- **** 4:1 MAX WHEN WITHIN 50- FEET FROM INTERSECTIONS
PONDING AREA: Design Resources

Rockery wall

MINIMUM ROCK SIZES

<table>
<thead>
<tr>
<th>(H)</th>
<th>SIZE(BASE)</th>
<th>SIZE(TOP)</th>
<th>(D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5'</td>
<td>2-MAN</td>
<td>1-MAN</td>
<td>3&quot;</td>
</tr>
<tr>
<td>4'</td>
<td>3-MAN</td>
<td>2-MAN</td>
<td>6&quot;</td>
</tr>
<tr>
<td>7'</td>
<td>4-MAN</td>
<td>2-MAN</td>
<td>9&quot;</td>
</tr>
</tbody>
</table>

NOTE:
1. GRAPHIC ADAPTED FROM CITY OF SEATTLE, BROADVIEW GREEN GRID PROJECT DETAIL.
2. WALLS GREATER THAN 4 FEET IN HEIGHT REQUIRE WALL DESIGN. SEE LOCAL BUILDING CODE REQUIREMENTS.

Eastern Washington LID Manual
BIORETENTION SITING, DESIGN & CONSTRUCTION

PONDING AREA: Design Resources

Roadside Planter

2014 San Francisco Typical Details
Roadside Planter

2014 San Francisco Typical Details

CONSTRUCTION NOTES:
1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW PLANTER DURING CONSTRUCTION.
2. SCARIFY SUBGRADE TO A DEPTH OF 6 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF GRAVEL STORAGE AND BIORETENTION SOIL.
3. MAXIMUM DROP FROM TOP OF CURB TO TOP OF BIORETENTION SOIL SHALL INCLUDE CONSIDERATIONS FOR BIORETENTION SOIL SETTLEMENT.

BIORETENTION PLANTER WITH UNDERDRAIN (ALTERNATE SECTION)

PHASE I DETAILS

GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

BIORETENTION PLANTER ROADSIDE PLANTER WITH PARKING SECTIONS

BP
2.2
UNDERDRAINS: Purpose

• Near sensitive infrastructure with high flood potential
• Filtering storm flows from gas stations and pollutant hotspots
• Areas with contaminated groundwater/soils
• Minimum infiltration rate allowed by local jurisdiction is not adequate to meet drawdown requirements
• Route outflow around phosphorus sensitive water body

Broadview Green Grid, Seattle, WA
UNDERDRAINS: Types of Pipes

- **Slotted, thick-walled plastic pipe**
  - Minimum 4” diameter Schedule 40 PVC

- **Slot openings**
  - Smaller than smallest aggregate gradation of filter material
  - Slots perpendicular to long axis of pipe
UNDERDRAINS: Types of Pipes

- Slotted PVC Pipe with Aggregate Filter/bedding material
- Aggregate filter/bedding material
  - Prevent migration of fine material into drain
  - WSDOT Standard Specification 9-03.12(4)
- Do not wrap in filter fabric
UNDERDRAINS: Slotted Pipe Placement

- Slotted pipe placement within aggregate filter/bedding material (Seattle)
  - 6” under pipe
  - 12” on top of pipe
  - 12” each side
UNDERDRAINS: Slotted Pipe Benefits

• Increased media area provides better filtering
  • Reduced potential for clogging (versus perforated pipe wrapped in filter fabric)

• More durable and easier to clean (rotary root cutter or water jet)
  • Versus perforated PVC or flexible slotted HDPE
UNDERDRAINS: Slotted Pipe Guidance

- Observation pipe/clean out
  - 6” rigid non-perforated
  - Every 250 to 300 feet
  - Clean out port
  - Observation well for dewatering rates

- Raised under-drain
  - Maximize infiltration
  - Fluctuating aerobic/anaerobic conditions → Denitrification
UNDERDRAINS: Slotted Pipe Guidance

- Minimum underdrain slope = 0.5%
- Orifice/control structures
  - Improve flow control performance
  - Minimum 0.5” orifice diameter
  - Maintenance access to orifice required
- Design with access for future modification
  - “Adaptive management”
  - Cap drain pipe
  - Throttle flows with orifice

Photo courtesy of Seattle Public Utilities
Bioretention with curb
OVERFLOW: Design Criteria/Types

• Necessary to safely convey flows that exceed capacity
  • Protect downstream property and resources
  • Overflow configuration depends on design objectives
• Overflow elevation set at max. ponding depth
• Directed to downstream BMP or approved discharge point
OVERFLOW: Surface Overflow

• Sizing
  • Minimum 6-inches of freeboard

• Vertical stand pipe
  • Can be connected to underdrain system

• Horizontal pipe

• Armored overflow channels
ELEVATIONS AND GRADE: Considerations

• Cross Slope
• Longitudinal Slope
• Positive Grade
• Series of Cells
• Check Dams

Broadview Green Grid, Seattle, WA
ELEVATIONS AND GRADE: Cross Slope

- Larger footprint area and berming or wall(s) to achieve ponding area

Required width on flat area

Zero Cross Slope
ELEVATIONS AND GRADE: Cross Slope

Cross Slope

Berm

Required width on slope
ELEVATIONS AND GRADE: Longitudinal Slope

- For long, linear configurations, create series of flat-bottomed cells
- Optimum slope is 2%  
  Maximum slope = 8%
- Steep slopes: control gradient with intermittent weirs or berms or standpipe overflow to provide ponding and dissipate energy
- Flat slopes: may need weir to create ponding
ELEVATIONS AND GRADE: Positive Grade

• Need positive grade for gravity flow
  • Inflow from contributing area to bioretention cell
  • Overflow from bioretention cell
• Check dams / weirs or vertical stand pipe overflow
• Reduce flow velocities & erosion potential/dissipates energy
• Create ponding to promote infiltration
ELEVATIONS AND GRADE: Series of Cells

- Types of check dams / weirs
  - Compacted earthen berms covered with vegetation
  - Vegetated hedgerows
  - Rock
  - Wood
  - Concrete

- Optimum spacing determined by longitudinal slope, performance goals and cost
ELEVATIONS AND GRADE: Mild Longitudinal Slope

Earthen berms

High Point, Seattle, WA
ELEVATIONS AND GRADE: Mild Longitudinal Slope

Rock berms

Wood berms
ELEVATIONS AND GRADE: Moderate Longitudinal Slope
ELEVATIONS AND GRADE: Steeper Longitudinal Slope

Concrete weirs for longitudinal slopes

Walls for cross slopes

110th Street Cascade, Seattle, WA

107th Street Cascade, Seattle, WA
ELEVATIONS AND GRADE: Steeper Longitudinal Slope

Beehive grate over vertical pipe/structure

Broadview Green Grid, Seattle, WA
ELEVATIONS AND GRADE: Design Resources

Check Dams

2014 San Francisco Typical Details
CONSTRUCTION CONSIDERATIONS

- Minimize site disturbance
- Tree protection
- Preventing over compaction
- Erosion and sediment control
- Construction sequencing (next section)
CONSTRUCTION CONSIDERATIONS: Minimize Site Disturbance

• Stream biota significantly reduced at SS levels of 50-80 mg/L (Corish 1995).

• Schueler reported median TSS concentrations of 4,145 mg/L leaving construction sites with no TESC and 283 mg/L with TESC.
CONSTRUCTION CONSIDERATIONS: Minimize Site Disturbance

- Site design
- Construction Planning
- Training
- Equipment
CONSTRUCTION CONSIDERATIONS: Tree Protection

- Trees are valuable!
- Arborist evaluation
- Valuation posted on each tree
- Vegetation protection in TESC
CONSTRUCTION CONSIDERATIONS: Tree Protection

• Critical Root Zone (CRZ)
  • No disturbance
  • Arborist present for construction in CRZ

• Dripline
  • Fence during construction
CONSTRUCTION CONSIDERATIONS: Tree Protection

- **Feeder Root Zone**
  - Limit heavy equipment/stockpiling
  - Limit Trenching

- **Utility Boring**
  - Tunnel/bore under trees to avoid open cut trench through CRZ and dripline
CONSTRUCTION CONSIDERATIONS: Native Soil Variability

- Do cells look like test pit?
- If lower permeability:
  - Increase size
  - Over-ex and add more BR soil
  - Increase ponding depth (if drawdown can be maintained)
  - Add underdrain

Broadview Green Grid, Seattle, WA
CONSTRUCTION CONSIDERATIONS: Over-compaction

- Prevent over compaction (CRITICAL FOR PERFORMANCE)

- No excavation, soil placement, or soil amendment 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
CONSTRUCTION CONSIDERATIONS: Over-compaction

Vehicular loading prism – some compaction is necessary

For road or parking lot stability, need heavy compaction from road prism-2H:1V from edge

Target compaction for BSM in cell: 85% of max dry density

High Point, Seattle, WA
CONSTRUCTION CONSIDERATIONS: Subgrade permeability

Scarify subgrade to re-fracture soil and till in BSM at interface

Smeared and sealed by bucket
CONSTRUCTION CONSIDERATIONS: Erosion & Sediment Control

• Protect adjacent properties
• Protect public waterways and storm systems
• Protect installed work
• Protect infiltration systems including swales, soils and permeable pavement

High Point, Seattle, WA
Q&A
Break
MEDIA: Media for Optimum Performance

• High enough infiltration rates to meet desired surface water drawdown and system dewatering

• Infiltration rates that are not too high in order to optimize pollutant removal capability

• A growth media to support long-term plant and soil health and water quality treatment capability

• Balance nutrient availability and retention and copper retention at low effluent levels
MEDIA: Common Soil Media Guidelines

• 40% topsoil, 30% sand, 30% compost common recommendation nationally and in (in the past) this region

• Issues with this and other guidelines
  • Fines (< 5% passing the #200 sieve)
  • Minimum organic matter content 10% by dry weight per ASTM D 2974
  • Material control
  • Contaminant flushing
Driver:

- Top soil specifications can be difficult to apply consistently.
- The need for relatively consistent materials that are readily available, affordable and meet necessary criteria.
Hydraulic conductivity strongly related to percent fines (passing #200 sieve)
Sands collected from suppliers – typically stocked “natural” or minimally processed sands to meet common specifications

Hydraulic conductivity strongly related to coefficient of uniformity
MEDIA: Existing Soil Media Guidelines

- Current guideline is 60% sand and 40% compost (this will likely be changing)
- For default media blend, use 6”/hr initial infiltration rate (this may also be changing)
- 18” minimum soil depth for metals treatment. Minimum of 24” for improved nitrogen or phosphorus removal.
The following gradation provides a relatively consistent Ksat and coefficient of uniformity for bioretention soil mixes. This is the mineral aggregate spec included in the Eastern WA LID Guidance Manual.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
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<tbody>
<tr>
<td>3/8”</td>
<td>100</td>
</tr>
<tr>
<td>#4</td>
<td>95-100</td>
</tr>
<tr>
<td>#10</td>
<td>75-90</td>
</tr>
<tr>
<td>#40</td>
<td>25-40</td>
</tr>
<tr>
<td>#100</td>
<td>4-10</td>
</tr>
<tr>
<td>#200</td>
<td>2-5</td>
</tr>
</tbody>
</table>
MEDIA: Infiltration Rates

If not using the default media blend determine long-term infiltration rate for sizing and flow control capacity

- 1 in/hr minimum for acceptable ponding and system de-watering in typical setting (long-term hydraulic conductivity per ASTM D 2434 at 85% compaction per ASTM D 1557)
- If contributing area has <5,000 sf of PGS; and <10,000 sf TIA; and <¾ acre landscaping then use correction factor of 2
- If over the above thresholds use correction factor of 4
If not using the default media blend determine sizing and water quality treatment flow

- 2.4 in/hr was maximum rate...guideline likely established for existing native soils not designed soil mixes
- Research indicates that higher infiltration rates provide performance necessary to meet metals treatment requirements
- Ecology now accepts maximum measured (initial) WQ treatment rate of 12 in/hr with an OM content of 5-8% by weight, CEC ≥ 5 milliequivalents/100 grams dry soil, 2-5% mineral fines content, and 18” minimum soil depth
- Apply same correction factor as for flow control capacity
MEDIA: Recent Media Guideline Updates

• Recommended modifications to permeability testing (ASTM 2434) for bioretention soil media

• If 60% aggregate/40% compost specification is followed, then use a measured Ksat of 6”/hr (1.4” to 3”/hr depending on correction factor)
  • 6”/hr may change (stay tuned)

• Previous recommendation of 10% OM content too high. Current recommendation 4% or 5% to 8% max
MEDIA SUMMARY: What Do We Think We Know

• Sandy bioretention soil mixes should provide excellent water quality performance for Zn, hydrocarbon and bacteria removal. Design with caution for systems with under-drains in P and N sensitive basins.

• 2 to 4 percent passing the 200 sieve ideal. Fines should not be above 5 percent for a proper functioning specification.

• Also important: coefficient of Uniformity (Cu) ≥ 4. Cu is the measure of variation in particle sizes of mineral aggregate (D_{60}/D_{10}).

• Small variations in grain size distributions and uniformity can result in large variations in K values.
Monitor carefully if topsoil used for mineral component.

Sandy soil mixes are very well drained...select plants carefully.

Question of best soil mixes for bio-available P retention unresolved. Increasing depth likely improves nutrient removal.

Saturated zone improves nitrate removal.

More work needed on Cu capture and retention.

Likely that current compost guidelines in WAC did not consider use in stormwater filters. More research needed.
Bioretention Plants
PLANTS: Selection

- Soil moisture conditions
- Sun exposure
- Above and below ground infrastructure
- Site distances and setbacks along roadways
PLANTS: Selection

- Pedestrian use
- Adjacent plant communities and potential invasive species control
- Visual buffering
- Aesthetics
**PLANTS: Siting**

**Bioretention Planting Zones**

*zone 1:* periodic or frequent standing or flowing water

*zone 2:* dry soils, infrequently subject to inundation or saturation - transition area into existing landscape
PLANTS: Siting

Region 1
East-Slope Cascades

Region 2
Central Basin

Region 3
Okanogan-Spokane Palouse

Region 4
Northeastern and Blue Mountains

Statewide LID Training Program

DEPARTMENT OF ECOLOGY
State of Washington

177 3.2 BIORETENTION

INTERMEDIATE LID DESIGN
## TABLE D.2 SHRUBS

<table>
<thead>
<tr>
<th>SCIENTIFIC NAME</th>
<th>COMMON NAME</th>
<th>NATIVE</th>
<th>CLIMATE REGION</th>
<th>BIORETENTION ZONE</th>
<th>EXPOSURE</th>
<th>MATURE SIZE (H X W)</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Amelanchier alnifolia</em></td>
<td>Serviceberry</td>
<td>Y</td>
<td>☒ Region 1</td>
<td>☐ Zone 1</td>
<td>Sun</td>
<td>10'-20'</td>
<td>Very hardy, drought tolerant, will need some supplemental watering during dry months. White flowers in early spring.</td>
</tr>
<tr>
<td><em>Artemisia sp.</em></td>
<td>Sagebrush</td>
<td>Y</td>
<td>☒ Region 1</td>
<td>☐ Zone 1</td>
<td>Sun</td>
<td>18&quot;</td>
<td>Sprawling woody shrub with finely divided silver leaves. Some drought-tolerant varieties include: <em>A. frigida</em>, <em>A. tripartita</em>, <em>A. ludoviciana</em>.</td>
</tr>
<tr>
<td><em>Atriplex canescens</em></td>
<td>Four-wing saltbush</td>
<td>☐</td>
<td>☐ Region 1</td>
<td>☐ Zone 1</td>
<td>Sun</td>
<td>1-6' h x 4-8' w</td>
<td>Extremely tolerant of all conditions.</td>
</tr>
<tr>
<td><em>Berberis thunbergii</em></td>
<td>Japanese barberry</td>
<td>☒</td>
<td>☒ Region 1</td>
<td>☐ Zone 1</td>
<td>Sun · Part Shade</td>
<td>2-6' h</td>
<td>Leaves turn scarlet in autumn. Bright red berries. Insignificant blooms.</td>
</tr>
<tr>
<td><em>Chrysothamnus nauseosum</em></td>
<td>Rabbitbrush</td>
<td>Y</td>
<td>☐ Region 1</td>
<td>☐ Zone 1</td>
<td>Sun</td>
<td>3-4'</td>
<td>Bright yellow blooms in fall. Upright foliage. Thin narrow grey leaves make attractive foliage. Green rabbitbrush is also an option. Recommend 'Tall Blue' cultivar.</td>
</tr>
</tbody>
</table>
PLANTS: Rhizosphere & Soil Structure

- Agricultural literature documents well the role of plants for building soil structure (Buckman and Brady 1969, Angers and Caron 1998)

- City of Portland OR documents increasing infiltration rates in 12-year old commercial parking bioretention areas. 1995~8”/hr, 2005~13”/hr (BES 2006)

- Lucas observes increased phosphate removal in vegetated vs non-vegetated bioretention... removal more than plant uptake
Mulch reduces weed establishment, regulates soil temperature and moisture, and adds OM to soil.

Mulch should be:

- 2-3 inches thick
- Chipped or shredded softwood or hardwood
- Coarse compost for bottom of facility
- Fine beauty bark not preferable
## BIORETENTION COST: Components

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Estimated Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>CY</td>
<td>$8 – 10</td>
</tr>
<tr>
<td>Bioretention media</td>
<td>CY</td>
<td>$40 – 60</td>
</tr>
<tr>
<td>Filter fabric</td>
<td>SY</td>
<td>$1 – 5</td>
</tr>
<tr>
<td>Gravel</td>
<td>CY</td>
<td>$30 – 35</td>
</tr>
<tr>
<td>4-inch perforated underdrain pipe</td>
<td>LF</td>
<td>$8 – 15</td>
</tr>
<tr>
<td>Plants</td>
<td>each</td>
<td>$5 – 20</td>
</tr>
</tbody>
</table>

Source: [http://www.lowimpactdevelopment.org/fairfax.htm](http://www.lowimpactdevelopment.org/fairfax.htm)
## Cost Comparison – bioretention vs. filters for treatment only

### CONVENTIONAL:
1. 4’ wide landscape island between rows of stalls
2. Catch basins @ 150’o/c
3. 8” CPEP storm pipe continuous
4. Stormwater treatment provided by filter vaults sized @ 10 cartridges per acre

### LID:
1. 4’ wide bioretention cell between rows of stalls, bioretention cells sized @ +/- 5% of tributary area for treatment only)
2. Standpipe overflow with beehive grate in each bioretention cell 1 @ 150’

<table>
<thead>
<tr>
<th></th>
<th>CONVENTIONAL</th>
<th>LID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$5/ SF x 4’ = $20/LF</td>
<td>$30/SF x 4’ = $120/LF</td>
</tr>
<tr>
<td>2.</td>
<td>$1,000 / 150’ = $6.67/LF</td>
<td>$1,000/150’ = $6.67/LF</td>
</tr>
<tr>
<td>3.</td>
<td>$50/LF</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>$1.25/SF x (18’x2 +22’)= $72.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL: ~ $149.17 / LF</td>
<td>TOTAL: ~ $126.67 / LF</td>
</tr>
</tbody>
</table>

**Notes**
- Reduced detention benefit in addition to the 15% savings shown for treatment only
Cost Comparison – conventional vs. LID project

No formal cost comparison, but contractor found LID project approximately 20% less than conventional.
• Inspection and verification timing and processes fall into three general phases of project:
  • Pre-construction reviews
  • Construction
  • Verification/repair and final permit
CONSTRUCTION OVERSIGHT: Pre-Construction Reviews

- Set guidelines, expectations and timing for inspections
- Discuss construction sequencing
- Review checklists
- Determine training needs
INSPECTION & VERIFICATION
CONSTRUCTION OVERSIGHT: Pre-Construction Reviews

• Include developer, builder, utilities, plan review, inspectors in pre-construction

• Make sure everyone knows where and what the requirements are...for an LID project, there may be stormwater requirements in landscaping guidelines
CONSTRUCTION OVERSIGHT: Construction

First Visit: Pre-bioretention soil media (BSM) placement

- Certify native/existing soils comparable to design specs
- Temporary erosion and sediment control (TESC) correctly installed
- Rough grading to plans
- Under-drain(s) and overflow
- Field changes...process should have been covered at pre-construction
- Photo documentation?
Second Visit: Pre-mulch or planting

- Verify that BSM meets composition guidelines and depth
- For BSM composition: current lab report from physical submittal, truck ticket (no longer adequate), visual/texture. If questions on depth, expose to subgrade
- TESC still installed correctly and upslope areas managed properly
CONSTRUCTION OVERSIGHT: Post-Construction

Third Visit: Post-construction

• Verify final grade

• Verify contributing area as designed and stabilized

• Verify BSM not clogged and infiltration rate adequate

• Verify ponding depths, overflow, bottom swale area

• Verify plants (type and density)

• Verify mulch (type and depth)
INSPECTION & VERIFICATION

CONSTRUCTION OVERSIGHT: Post-Construction

Third Visit: Post-construction (whole site)

• Final grades

• 30-45 day follow up to remove TESC

• Verify O&M plan in place
• Site flat or sloping away from facility likely ok to:
  • Complete bioretention area with roads, utilities and storm infrastructure
  • Install conventional TESC and barriers
INSPECTION & VERIFICATION
CONSTRUCTION SEQUENCING

• Construction activity sloping to bioretention facility
  • Divert flows around facility and treat during construction
  • Partially complete and allow storm flows through facility
• Construction activity sloping to bioretention facility (w/o underdrain)
  • Delineate or partially grade to define facility. Keep construction traffic off area
  • Install TESC and stabilize upslope construction area as best as possible
  • Divert flows around facilities
  • If flows allowed through facility, leave at least 6” above final grade. Line or mulch?
  • Keep construction traffic off area
• Construction activity sloping to bioretention facility (w/underdrain)
  • Place infrastructure
  • If possible leave rest of facility at least 6” above grade
  • Install TESC and stabilize upslope construction area
  • If flows allowed through facility, leave or backfill at least 6” above final grade
  • Cover underdrain with plastic and fabric
  • Line or mulch whole facility?
  • Keep construction traffic off area
Partial excavation and completion of facility after homes are finished and landscaping stabilized requires clear agreement among developer, homebuilder and jurisdiction.
REMEDIES FOR FAILING SITES

- Poor TESC and sediment to facility
  - Excavate to depth that sediment deposits and potential clogging not present (usually 6”)
  - Replace BSM, mulch, and plants
- Compaction of existing soils
  - Does the facility still infiltrate at design rate?
  - Perform infiltration test or verify pre-construction density
  - Remedy procedures if necessary
Statewide LID Training Program

1. Introduction to course and bioretention
2. Flow control and water quality treatment
3. Bioretention siting, design and construction
4. Inspection & verification
5. Wrap-up
Statewide LID Training Program

OTHER COURSE OFFERINGS

INTRODUCTORY

1.0 Introduction to LID for Eastern Washington

2.1 Introduction to LID for Inspection & Maintenance Staff

2.2 Introduction to LID for Developers & Contractors: Make Money be Green

INTERMEDIATE

3.1 Intermediate LID Topics: NPDES Phase I & II Requirements

3.2 Intermediate LID Design: Bioretention

3.3 Intermediate LID Design: Permeable Pavement

3.4 Intermediate LID Design: Site Assessment, Planning & Layout

4.1 Intermediate LID Design: Rainwater Collection Systems & Vegetated Roofs

4.2 Intermediate LID Design: Hydrologic Modelling

ADVANCED

5.1 Advanced Topics in LID Design: Bioretention

5.2 Advanced Topics in LID Design: Permeable Pavement

5.3 Advanced Topics for LID Operations: Bioretention

5.4 Advanced Topics for LID Operations: Permeable Pavement

6.0 Advanced Topics in LID Design: Hydrologic Modeling

7.0 Advanced Topics in LID Design: Site Assessment, Planning & Layout

8.1 Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs

8.2 Advanced Topics in LID Design: Bioretention Media

TRAIN THE TRAINERS

9.1 Service Providers

9.2 LID Topic Experts
Statewide LID Training Program

ONLINE EVALUATION

• An on-line evaluation will be sent to you within 5 days following this training
Two certificates:

• LID Design certificate
• Long-term LID Operations certificate
• Stay tuned for development of certificate policy details

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

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