**OVERVIEW OF PROGRAM**

- 2012: Public and private partners engage state legislature to fund program
- June 2012: LID Training Steering Committee convened
- 2014: Training program built from state LID Training Plan.

**PROJECT LEAD**

- Herrera

**CORE TEAM**

- Cascadia
- Veda

**ADDITIONAL TRAINING SUPPORT**

- CH2M-Hill
- Aspect
- Sublime Design
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

**INTRODUCTORY**

1.0 Introduction to LID for Decision Makers Washington

2.1 Introduction to LID for Design & Construction Staff

2.2 Introduction to LID for Developers, Inspectors, & Property Owners for Green Streets

**INTERMEDIATE**

3.1 Introduction to LID Topics - BMP Phase 1 & 2 Requirements

3.2 Intermediate LID Design - Maintenance

3.3 Intermediate LID Design - Permeable Pavement

3.4 Intermediate LID Design - Stormwater, Planning & Layout

4.1 Intermediate LID Design - Sediment & Sedimentation Basins

4.2 Intermediate LID Design - Hydrologic Modeling

**ADVANCED**

5.1 Advanced Topics in LID Design - Vegetated Roofs

5.2 Advanced Topics in LID Design - Permeable Pavement

5.3 Advanced Topics in LID Design - Vegetated Roofs, Planning & Layout

5.4 Advanced Topics in LID Design - Assessment, Design & Vegetated Roofs

5.5 Advanced Topics in LID Design - Site Hydrologic Modeling & Vegetated Roofs

6.1 Advanced Topics in LID Design - Vegetated Roofs, Sediment & Sedimentation Basins

6.2 Advanced Topics in LID Design - Stormwater, Planning & Layout

6.3 Advanced Topics in LID Design - Site Hydrologic Modeling & Vegetated Roofs

7.1 Advanced Topics in LID Design - Vegetated Roofs, Sediment & Sedimentation Basins

7.2 Advanced Topics in LID Design - Stormwater, Planning & Layout

7.3 Advanced Topics in LID Design - Site Hydrologic Modeling & Vegetated Roofs

**TRAIN THE TRAINERS**

9.1 Train the Trainer (Lead Trainers)

9.2 Train the Trainer (Supporting Trainers)

TODAY’S TRAINING

- Train the Trainer (Lead Trainers)
- Train the Trainer (Supporting Trainers)
INSTRUCTORS

CHRIS WEBB, PE
LEED FELLOW
Associate Engineer
Key project experience:
permeable pavement,
bioretention, rainwater harvesting

JASON KING, RLA
ASLA LEED AP
Senior Landscape Architect
Key project experience:
Stormwater design for
development, site design,
vegetated roofs, stormwater art, ecological planning

AGENDA

1. introduction & regulations
2. site assessment, planning, layout
3. BMP specifics
4. cost comparisons & resources
5. wrap up
LEARNING OBJECTIVES

1. Efficient application of LID BMPs.
2. New LID regulatory requirements.
3. How LID development process and cost compares with conventional stormwater practices.
4. The basic principles of site assessment, site layout and construction sequencing to improve the design and long-term, effective operation of LID best management practices (BMPs) and projects.
5. How to minimize construction impacts.
6. Minimum requirements for construction and protection of LID BMPs during construction.

Why LID?
LOW IMPACT DEVELOPMENT (LID): Stormwater Management Strategy

- Site design & planning techniques emphasizing conservation
- Use of small-scale & distributed engineered controls to closely mimic pre-development hydrologic processes
- Minimizing the concentration of stormwater
- Careful assessment of site soils and strategic site planning to best use those soils for stormwater management

LID Principles: Pre-developed forest

LID Principles: Developed condition
LID Principles: Site Design And Planning

- Minimize disturbance
- Reduce impervious surface
- Protect and restore native soils and vegetation
- Manage stormwater close to the source in a system of distributed practices
- Disconnect impervious surfaces

Traditional  LID

LID BMPs: Small-Scale Engineering Controls

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

Synonyms for LID BMPs:
- Green Stormwater Infrastructure (GSI), Integrated Management Practices (IMPs), and On-Site Stormwater Management BMPs

Washington Municipal Stormwater Permits

National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permits (2013-2018 permit cycle)

<table>
<thead>
<tr>
<th>Phase I Permits</th>
<th>Western Washington Phase II Permits</th>
<th>Eastern Washington Phase II Permits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle</td>
<td>82 Cities</td>
<td>18 Cities</td>
</tr>
<tr>
<td>Tacoma</td>
<td>5 Counties</td>
<td>5 Counties</td>
</tr>
<tr>
<td>Clark County</td>
<td></td>
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<tr>
<td>King County</td>
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<tr>
<td>Pierce County</td>
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<td></td>
</tr>
<tr>
<td>Snohomish County</td>
<td></td>
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</tr>
</tbody>
</table>

Secondary Permittees: Approximately 45; such as ports and universities

To see a listing of permittees visit [http://www.ecy.wa.gov/programs/wq/stormwater/municipal/MuniStrmWtrPermList.html](http://www.ecy.wa.gov/programs/wq/stormwater/municipal/MuniStrmWtrPermList.html)
NPDES PERMIT LID REQUIREMENTS:
Implementation Timeline Varies By Permittee

Review and revise development related codes, rules & standards (i.e. adopt the 2012 Stormwater Manual)

Western WA Phase I and II timeline for updating local codes

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Section 38C.5.A of the Phase I Permit</td>
<td>Per Section 38C.6 of the Phase II Permit</td>
</tr>
<tr>
<td>West Lewis Co. and Clark Co.</td>
<td>City of Aberdeen</td>
</tr>
<tr>
<td>June 2014</td>
<td>June 30, 2015</td>
</tr>
<tr>
<td>2016</td>
<td>Dec. 31, 2016*</td>
</tr>
<tr>
<td>2017</td>
<td>June 30, 2017</td>
</tr>
<tr>
<td>2018</td>
<td>June 30, 2018</td>
</tr>
</tbody>
</table>

* = GMA update deadline

NPDES PERMIT LID REQUIREMENTS:
Minimum Requirements

1. Preparation of Stormwater Site Plans
2. Construction SWPPP
3. Source Control of Pollution
4. Preservation of Natural Drainage Systems and Outfalls
5. On-Site Stormwater management
6. Runoff Treatment
7. Flow Control
8. Wetlands Protection
9. O&M

INTRODUCTION & REGULATIONS

NPDES PERMIT LID REQUIREMENTS:
Minimum Requirements (MRs)

- MR #2 – Construction Stormwater Pollution Prevention Plan (SWPPP)
  - Protect LID BMPs from sediment and compaction
- MR #5 – On-Site Stormwater Management
  - Infiltrate, disperse, and retain runoff on-site to the extent feasible
NPDES PERMIT LID REQUIREMENTS: Minimum Requirements (MRs)

- MR #6 – Runoff Treatment
  - Water quality treatment for pollution-generating areas

- MR #7 – Flow Control
  - Control of flow peaks and flow durations

NPDES PERMIT LID REQUIREMENTS: List #1 & 2 vs. LID Performance Standard

- List #1 (MR 1-5) and List #2 (MR 1-9)
  - For each surface, consider the BMP’s in the order listed for that type of surface. Use the first BMP that is considered feasible
    - Example: Hard surfaces other than roof
      1. Full Disruption
      2. Permeable Pavement
      3. Bioretention
      4. Sheet Flow Dispersion
  - Achieve the LID Performance Standard (Duration Flow Control)

Note: achieving LID Performance Standard will require very large ponds that may significantly reduce buildable area without incorporating LID practices.

NPDES PERMIT LID REQUIREMENTS: On-Site Stormwater Management BMPs

- Used to help meet MR #5

- May be used to help meet MR #6 (Treatment) and/or MR #7 (Flow Control)

- “On-site Stormwater Management BMPs” = LID BMPs
INTRODUCTION & REGULATIONS

NPDES PERMIT LID REQUIREMENTS:
On-Site Stormwater Management BMPs

- Includes the following LID BMPs:
  - Rain Gardens (BMP T5.14A) (Not "Engineered")
  - Bioretention (BMP T5.14B) ("Engineered")
  - Permeable Pavement (BMP T5.15)
  - Vegetated Roofs (BMP T5.17)
  - Downspout Full Infiltration (BMP T5.10A)
  - Downspout Dispersion (BMP T5.10B)
  - Concentrated Flow Dispersion (BMP T5.11)
  - Sheet Flow Dispersion (BMP T5.12)
  - Compost Amended Soils (BMP T5.13)

INTRODUCTION & REGULATIONS

NPDES PERMIT LID REQUIREMENTS: Treatment and Flow Control BMPs/Facilities

Subset of On-site Stormwater Management BMPs used to meet MR #6 or MR #7 (may also be used to meet MR #5)

<table>
<thead>
<tr>
<th>BMP</th>
<th>Flow Control</th>
<th>Treatment¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost Amended Soils (BMP T5.13)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dispersion (BMP T5.11, T5.12, T5.13)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Retaining &amp; Planting Trees (BMP T5.14)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bioretention (BMP T5.15)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bioretention Underdrain</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Permeable Pavement (BMP T5.15)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Green Roofs (BMP T5.15)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rainwater Harvesting (BMP T5.19)</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

¹ When used, bioretention and permeable pavement required site infiltration or meeting Ecology treatment requirements.

2. Bioretention and dispersion systems where underdrain is elevated within the underlying base course can have some peak flow reduction benefit.

3. Where permeable pavement is over soils meeting the suitability criteria or a treatment layer (sand or soil meeting criteria) is included, then permeable pavement can provide treatment.

Q&A
TRADITIONAL V. LID DEVELOPMENT

• Minimize disturbance
• Reduce impervious surface
• Protect and restore native soils and vegetation
• Manage stormwater close to the source in a system of distributed practices
• Disconnect impervious surfaces

Traditional LID
TRADITIONAL V. LID DEVELOPMENT

Typical grid road layout
- Impervious coverage: 27-36%
- Less adaptive to site features.
- Promotes transit and connectivity with more direct access to services.

Typical curvilinear road layout
- Impervious coverage: 15-29%
- More adaptive to site features.
- Generally discourages transit with longer, less connected system.

Hybrid or LID road layout
- Impervious coverage: similar percentage to other layouts.
- Adaptive to site features and uses site features (particularly water as an organizing theme).
- Can provide good connectivity and fire and safety access.
Hydrologic modeling comparing a conventional development and the flow reduction benefits from individual practices for a low impact development design. The 24-acre till-mantled site in southern Puget Sound has 103 lots and was modeled with Western Washington Hydrologic Model (adopted from AHBL, 2000).

### Site Layout: New Suburban Development

**General Layout Strategies**
- Cluster development to preserve vegetation and protect soils
- Grade to create small basins
- Maximize infiltration potential by locating BMPS on best soils
TRADITIONAL V. LID DEVELOPMENT

Site Layout: New Suburban Development

Roads, Driveways and Parking
• Reduce TIA by reducing overall road network cover and minimize or eliminate EIA
• Use stormwater BMPs to infiltrate, slow, and filter storm flows
• Minimize overall site disturbance
• Create connected walking, biking, vehicular, and transit services
• Create and use open space as a community amenity and stormwater management area
Preliminary Site Analysis

- Collect information from existing analyses, inventories, and historic information
- Conduct site reconnaissance and characterization
  - Info needed varies depending on which Minimum Requirements are triggered

Minimum Requirements for 1-5

- A survey prepared by a registered land surveyor
  - Contour map
  - Soils report
  - Survey of native soil and vegetation areas
  - Drainage report / Stormwater Site Plan

Minimum Requirements for 1-9 (Larger projects)

- More in-depth Geotechnical assessment than conventional project
  - Ideally in 2 phases
    1. Infiltration soils reconnaissance (similar to septic reconnaissance) for planning level design
    2. Infiltration soils testing for design level design information at the location of the BMP
- Geotechnical Report or Soils Report need to include infiltration feasibility and design discussion
SITE ASSESSMENT

Critical sub-surface assessment for BMPs
• Bioretention
  • Infiltration test at proper depth
• Permeable Pavement
  • Staging and access
  • Subgrade protection and remediation
  • Infiltration test at proper depth
• Additional testing for Design
  • PIT tests
  • Depth to groundwater
  • Mounding analysis (if required)

ECOLOGY

ECOLOGY SMALL-SCALE PIT METHOD

• PIT Timing
  • Test between December 1 and April 1

• 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 linear feet
    (unless borings indicate consistent soil characteristics)

SITING CONSIDERATIONS: Native Soils

• Important for infiltrating facilities ONLY
• Infiltrating facilities sized based on infiltration rates
• Minimum “feasible” initial infiltration rate of 0.3 in/hr
• Locate infiltrating BMPs in areas with best soils
SITING CONSIDERATIONS: Soil Variability

Site 1: Loam

Site 2: Sand
SITE ASSESSMENT, PLANNING & LAYOUT

SITING CONSIDERATIONS: Soil Variability

Site 3: Glacial till (highly compacted with high clay content)

SITE ASSESSMENT, PLANNING & LAYOUT

SITING CONSIDERATIONS

- Tree and vegetation preservation
- Site Slopes
  - Cross & Longitudinal Slopes
  - Positive Drainage from drainage area to overflow
- Setbacks (e.g., utilities & other infrastructure)
- May require pre-settling
- Public acceptance/participation (retrofits)

SITE ASSESSMENT, PLANNING & LAYOUT

Site Layout: Urban Redevelopment & Infill

Roads, Driveways and Parking

- Reduce total impervious area (TIA) and minimize effective impervious areas (EIA)
- Use stormwater BMPs to infiltrate, slow, and filter storm flows
- Incorporate trees and adequate soil into planting galleries and streetscapes
- Connect walking, biking, and vehicular access to transit services
- Create and use open space as a community amenity and stormwater management area
SITE ASSESSMENT, PLANNING & LAYOUT
RIGHT OF WAY: Seattle SEAstreets

SITE ASSESSMENT, PLANNING & LAYOUT
RIGHT OF WAY: Curb Bulbs

SITE ASSESSMENT, PLANNING & LAYOUT
MULTI-FAMILY DEVELOPMENTS
SITE ASSESSMENT, PLANNING & LAYOUT

MULTI-FAMILY DEVELOPMENTS: Block Level Design

Parking
- Conduct parking studies to establish min. and max. demand ratios
- Design parking to reduce impervious surface area
  - Diagonal parking stalls with one-way traffic lanes
  - Place parking under buildings or create multi-story parking structures
  - Use permeable surface materials
  - Utilize BMPs to capture, treat, and infiltrate stormwater
  - Design parking lots to be multi-use and serve different users at different times
**Rooftops**

- Create vegetated roofs to reduce EIA

---

**COMMERCIAL PARCELS**

Downtown CSO Demand Management, Seattle, WA
SITE ASSESSMENT, PLANNING & LAYOUT
COMMERCIAL PARCELS: Parking Lots

Combining landscape requirements with bioretention

Lewis Creek Park, Bellevue, WA

Combining conveyance with bioretention

Bagley Elementary, Seattle, WA

SITE ASSESSMENT, PLANNING & LAYOUT
COMMERCIAL PARCELS: Bioretention and Rain Gardens

Bioretention and Rain Gardens

YMCA Silverdale, WA

Villanova Campus
SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 1: Using List #2

- Forested 0.8 ac. Parcel
- 2012 Manual adopted by local jurisdiction
  - 7,000 sf building
  - 7,000 sf parking
  - 1,750 sf walks
  - 12,000 sf landscaping
- Till & perched groundwater at 1-2’ depth

SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 1: Lawn and Roofs

Lawn
- Post Construction Self-Drainage and Depth in accordance with BMP 7.5.2 in Chapter 6 of Volume IV of the SDM/MMW

Roof
- Full Dimension in accordance with BMP 7.5.3 in Chapter 5 of Volume IV of the SDM/MMW, or
- Conventional Downspout Systems in accordance with BMP 7.5.4 in Section 2.1.1 of Volume IV of the SDM/MMW.
- Infeasible (Selected)
- Infeasible
- Infeasible
- Infeasible
- Infeasible

SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 1: Other hard Surfaces

Other hard surfaces
- Infeasible
- Feasible (selected for sidewalks*)
- Infeasible for PGIS
- Infeasible
- Infeasible

* Groundwater/saturated conditions must be no more than 12” from bottom of aggregate base
SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 1: Using List #2

- Forested 0.7 ac. Parcel
- 2012 Manual adopted by local jurisdiction
  - 12,000 sf building
  - 22 parking stalls
- Outwash soils (4" per hour long term)
- Groundwater at 15’ +

SITE LAYOUT EXAMPLE 2: Lawn and Roofs

<table>
<thead>
<tr>
<th>Requirement</th>
<th>lawn</th>
<th>roof</th>
</tr>
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<tbody>
<tr>
<td>Feasible (SELECTED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infeasible due to lack of downstream flow path and site land coverages</td>
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</tr>
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<td></td>
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</tbody>
</table>

SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 2: Resulting Site Plan

- Site Area
- Detention Area
- Stormwater Management Area
- Bioswale
- Rain Garden

SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 2: Using List #2

- Forested 0.7 ac. Parcel
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SITE ASSESSMENT, PLANNING & LAYOUT

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<td>Feasible</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 2: Other hard Surfaces

1. Tablets in accordance with BMP 75.10 of Chapter 5 of Volume V of the SWMM.
2. Straw bale pavement in accordance with BMP 75.15 of Chapter 5 of Volume V of the SWMM.
3. Bioretention in accordance with Volume V of the SWMM.
4. Permeable pavement in accordance with Volume V of the SWMM.
5. Permeable pavement in accordance with Volume V of the SWMM.

Feasible
Infeasible
Feasible (SELECTED)

SITE ASSESSMENT, PLANNING & LAYOUT

SITE LAYOUT EXAMPLE 2: Resulting Site Plan

COMMERCIAL PARCELS: Stormwater Planters

Downtown CSO Demand Management, Seattle, WA
CONSTRUCTION CONSIDERATIONS: Access & Staging

- Staging Areas
- Temporary Access
- Subgrade protection and restoration procedures
- Element #13 of the SWPPP
**SITE ASSESSMENT, PLANNING & LAYOUT**

**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

**SITE ASSESSMENT, PLANNING & LAYOUT**

**CONSTRUCTION CONSIDERATIONS: Erosion & Sediment Control**

- Inadequate protection of BMPs during construction can result in expensive mitigation

**SITE ASSESSMENT, PLANNING & LAYOUT**

**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 lightweight, 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.

CONSTRUCTION CONSIDERATIONS: Subgrade Permeability

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

Smeared and sealed by bucket

Q&A

www.agriscapesoils.com
introduction & regulations
site assessment, planning, layout
BMP specifics
cost comparisons & resources
wrap up
BMP SPECIFICS

BIORETENTION

• Bioretention and Rain Gardens (30 minutes)
  • Anatomy of bioretention and rain gardens
  • NPDES protection requirements for bioretention and rain gardens (MR #2 and MR #5-7)
  • Setbacks
  • Construction sequencing and protection during construction for bioretention and rain gardens
  • Case Study with lessons learned

OVERVIEW: Definition and Types

• Shallow landscaped depressions that receive stormwater from small contributing areas
• Small scale, dispersed facilities
• Types:
  • Bioretention cells
  • Bioretention swales
  • Infiltration planters
  • Flow-through planters

COMPONENTS

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

- Water enters facility
- Ponds
- Infiltrates through bioretention soil/ gravel bed
- Infiltrates into underlying soil
- Ponded water exceeding max. depth overflows

Bioretention Cell

Bioretention Planter

- Underdrain collects water in gravel layer and routes to overflow
**BIORETENTION VS RAIN GARDENS**

<table>
<thead>
<tr>
<th>Structures/Underdrains</th>
<th>Rain Garden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Usually no</td>
</tr>
</tbody>
</table>

- **Bioretention**
  - Designed
  - Less restrictive
  - Soil mixes

- **Rain Garden**
  - Usually no

---

**BMP specifics**

- Anatomy of a facility
- NPDES protection requirements for permeable pavement (MR #2 and MR #5-7)
- Construction sequencing and protection guidelines for permeable pavement
- Case Studies with lessons learned

---

**PERMEABLE PAVEMENT**
**FACILITY ANATOMY: Porous Asphalt**

- Flexible
- Similar to conventional asphalt, but fines < No. 30 sieve reduced
- Typically used for parking and light traffic loads; however, has been used for medium and heavy applications
- ~16% voids typical (2-3% for conventional)

**FACILITY ANATOMY: Pervious Concrete**

- Rigid
- 1/4 to 5/8 round or crushed aggregate typical, portland cement, and admixtures (optional) to increase workability and strength
- 15 to 20% voids typical

**FACILITY ANATOMY: Permeable Pavers**

- Flexible
- Capable of high vehicle loads. Used for lower speeds
- High-density concrete that interlock and transfer vertical loads to surrounding pavers
- 12% voids typical
FACILITY ANATOMY: Plastic Grids

- Flexible
- Plastic grid filled with gravel or soil and planted with grass
- Capable of high vehicle loads. Used for lower speeds
- Highest percent voids

HOW THE FACILITY WORKS

- Inlets
- Outlets
- Slopes
**BMP specifics**

**DISPERSION & INFILTRATION**

- Dispersion and Infiltration (20 minutes)
  - Downspout infiltration and dispersion
  - Concentrated and sheet flow dispersion
  - Soil quality and depth (composted amended soils)
  - Local jurisdiction and homeowner requirements
  - Q&A

**COMPONENTS: Downspout Dispersion**

- Splash block
- Dispersal area

Source: City of Seattle
BMP SPECIFICS – DISPERSION AND INFILTRATION

COMPONENTS: Downspout Dispersion

- Dispersion trench
- Dispersal area

COMPONENTS: Sheet Flow and Concentrated Flow Dispersion

Sheet Flow Dispersion
- Transition zone
- Dispersal area

Concentrated Flow Dispersion
- Rock pad at discharge point
- Dispersal area

COMPONENTS: Downspout Full Infiltration

- Rock trench/well
- Inlet
- Storage sump
COMPONENTS: Compost Amended Soils

BMP SPECIFICS – DISPERSION AND INFILTRATION

BMP specifics

CONSTRUCTION CONSIDERATIONS: Tree Protection

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

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

- Dripline
  - Fence during construction

---

BMP SPECIFICS – NEWLY PLANTED AND RETAINED TREES

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

---

BMP SPECIFICS – NEWLY PLANTED AND RETAINED TREES

IMPEPARTIOUS SURFACE REDUCTION CREDITS

<table>
<thead>
<tr>
<th>Tree Type</th>
<th>Flow Control Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen</td>
<td>20% of canopy area (min of 100 sf/tree)</td>
</tr>
<tr>
<td>Deciduous</td>
<td>10% of canopy area (min of 50 sf/tree)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tree Type</th>
<th>Flow Control Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen</td>
<td>50 sf/tree</td>
</tr>
<tr>
<td>Deciduous</td>
<td>20 sf/tree</td>
</tr>
</tbody>
</table>
COST COMPARISONS & RESOURCES

CONSTRUCTION COST: Bioretention

- Cost Comparison – bioretention vs. filters for treatment only

Assumptions:
- Double loaded parking lot with perpendicular stalls & landscape strip
- 22' travel lane / 9’x18’ parking stalls
- Exclude reduced detention benefits
CONSTRUCTION COST: Bioretention

- Cost Comparison – bioretention vs. filters for treatment only

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Cost Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONVENTIONAL</td>
<td>1. 4’ wide landscaped island between rows of stalls</td>
<td>$57/3' x 4 = $228/LF</td>
</tr>
<tr>
<td></td>
<td>2. Catch basins @ 150’/ac</td>
<td>$1,000/150’ = $6.67/LF</td>
</tr>
<tr>
<td></td>
<td>3. 8” CPEP storm pipe continuous</td>
<td>$50/LF</td>
</tr>
<tr>
<td></td>
<td>4. Stormwater treatment provided by filter vaults sized @ 5 cartridges/acre</td>
<td>$1.25/SF x (18’ x 22’) = $72.50</td>
</tr>
<tr>
<td></td>
<td>TOTAL: ~ $169.17/LF</td>
<td></td>
</tr>
<tr>
<td>CONSTRUCTION COST:</td>
<td>1. 4’ wide bioretention cell between rows of stalls</td>
<td>$57/3' x 4 = $228/LF</td>
</tr>
<tr>
<td>Bioretention</td>
<td>2. Catch basins @ 150’/ac</td>
<td>$1,000/150’ = $6.67/LF</td>
</tr>
<tr>
<td></td>
<td>3. 8” CPEP storm pipe continuous</td>
<td>$50/LF</td>
</tr>
<tr>
<td></td>
<td>4. Stormwater treatment provided by filter vaults sized @ 5%</td>
<td>$1,000/150’ x 5% = $6.67/LF</td>
</tr>
<tr>
<td></td>
<td>TOTAL: ~ $126.67/LF</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- Reduced detention benefit in addition to the 15% savings shown for treatment only

CONSTRUCTION COST: Rain Gardens

<table>
<thead>
<tr>
<th>Location</th>
<th>Self Installation (cost per SF)</th>
<th>Professional Installation (cost per SF)</th>
<th>Average Size (SF)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wisconsin</td>
<td>$2.90 - 4.60</td>
<td>$12.70 - 15.00</td>
<td>NA</td>
<td>Edgewood College (2003)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>$3.50 - 5.80</td>
<td>$11.50 - 13.90</td>
<td>300</td>
<td>Kassulke (2003)</td>
</tr>
<tr>
<td>General</td>
<td>$3.00 - 4.00</td>
<td>$10.00 - 40.00</td>
<td>NA</td>
<td>EPA (2008)</td>
</tr>
<tr>
<td>Virginia</td>
<td>$0.50 - 0.75</td>
<td>$10.00</td>
<td>150</td>
<td>James City County (2008)</td>
</tr>
<tr>
<td>Lincoln</td>
<td>$2.00 - 8.00</td>
<td>$8.00 - 14.00</td>
<td>NA</td>
<td>Lincoln (2008)</td>
</tr>
<tr>
<td>Salt Lake City, UT</td>
<td>$8.83</td>
<td>$16.63</td>
<td>NA</td>
<td>RS Means 100 Estimate of Elaborate Garden EPA LID Cost Calculator</td>
</tr>
</tbody>
</table>
PERMEABLE PAVEMENT

Pervious Hot Mix Asphalt Per WSDOT Bid Tabs:
- Pervious HMA: $105-$135/TON (2014)
- Pervious Base: $25/TON (2014)

Conventional Pavement:
- Dense Graded HMA Class 3½": $85-$100/TON (2014)
- Crushed Surfacing Base Course: $20-$25/TON (2014)

Note: In many instances using pervious HMA is considered cost neutral. If soils infiltrate, permeable is much less costly than conventional.

Pervious Concrete Sidewalk Per Three City of Bellingham Bid Tabs:
- Say $5-$6/sf with base

Note: The 2013 values included some 8" thick bike lanes, bids from each same contractor basically same as solid sidewalk.

OTHER LID BMPS: Cisterns

- Approximate cistern costs per gallon stored by tank type

- $0.50
- $1
- $2.00
- $4-$6

- $1.50
- $2.00
- $4-$6
- $4-$6
### COST COMPARISON & RESOURCES

**OTHER LID BMPS: Vegetated Roof**

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Green Roof Cost (s.f.)</th>
<th>Roofing Cost (s.f.)</th>
<th>Total Cost w/ Roofing (s.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive Green Roof (3-4” soil with sedums)</td>
<td>$5-8</td>
<td>$15-20</td>
<td>$20-28</td>
</tr>
<tr>
<td>Semi-Intensive Green Roof (4-8” soil with sedums/wildflowers, perennials)</td>
<td>$10-15</td>
<td>$15-20</td>
<td>$25-35</td>
</tr>
<tr>
<td>Intensive Green Roof (8-12” with groundcover, small shrubs)</td>
<td>$18-25</td>
<td>$15-20</td>
<td>$33-45</td>
</tr>
<tr>
<td>Roof Terrace (intensive with pavers, trees, planters, shrubs)</td>
<td>$50-80+</td>
<td>$15-20</td>
<td>$65-100+</td>
</tr>
</tbody>
</table>

### COST COMPARISONS & RESOURCES

**MAINTENANCE**

<table>
<thead>
<tr>
<th>Conventional (Biofiltration swale/pond)</th>
<th>LID (Bioretention/Rain gardens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mowing</td>
<td>Weeding &amp; vegetation management</td>
</tr>
<tr>
<td>Inlet/outlet protection</td>
<td>Inlet/outlet protection</td>
</tr>
<tr>
<td>Sediment removal</td>
<td>Ponding area maintenance</td>
</tr>
<tr>
<td>Check dam/weir sediment management and erosion repair</td>
<td>Check dam/weir sediment management and erosion repair</td>
</tr>
<tr>
<td>Maintain vegetation cover</td>
<td>Protect bioretention soil from compaction</td>
</tr>
<tr>
<td>Ponding area maintenance</td>
<td>Mulching</td>
</tr>
<tr>
<td>Flow spreader</td>
<td>Underdrain clog removal</td>
</tr>
<tr>
<td>Watering</td>
<td>Watering</td>
</tr>
</tbody>
</table>

### COST COMPARISONS & RESOURCES

**MAINTENANCE: Bioretention**

WERF LID Cost Calculator (last updated 5/9/2009)

<table>
<thead>
<tr>
<th>Item</th>
<th>Maintenance Frequency</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Annual O&amp;M Cost for 400 SF (Medium)</th>
<th>Cost/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation management</td>
<td>Every 3 years</td>
<td>1/year</td>
<td>12/year</td>
<td>$134</td>
<td>$0.34</td>
<td></td>
</tr>
<tr>
<td>Replace mulch</td>
<td>Every 5 years</td>
<td>1/year</td>
<td>1/year</td>
<td>$224</td>
<td>$0.61</td>
<td></td>
</tr>
<tr>
<td>Till soil</td>
<td>Every 10 years</td>
<td>1/year</td>
<td>1/year</td>
<td>$90</td>
<td>$0.23</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>$448</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Puget Sound Stormwater BMP Cost Database Technical Memorandum (Herrera 2013)

<table>
<thead>
<tr>
<th>O&amp;M Activities</th>
<th>Unit</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watering, weeding, and mulching</td>
<td>SF</td>
<td>$0.19</td>
<td>$1.27</td>
<td>$2.78</td>
</tr>
</tbody>
</table>
MAINTENANCE: Bioretention

30-Year Cost Comparison

<table>
<thead>
<tr>
<th>BMP</th>
<th>30-year O&amp;M Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention</td>
<td>$21.84 / SF</td>
</tr>
<tr>
<td>Wet Pond</td>
<td>$9.01 / SF</td>
</tr>
<tr>
<td>Combined Detention and Wetpool</td>
<td>$9.01 / SF</td>
</tr>
<tr>
<td>Stormwater Treatment Planter Vault</td>
<td>$27,903 / PV</td>
</tr>
<tr>
<td>Infiltration Basin</td>
<td>$3.36 / SF</td>
</tr>
<tr>
<td>Catch Basin</td>
<td>$1,331 / CB</td>
</tr>
</tbody>
</table>


MAINTENANCE: Permeable Pavement

WERF LID Cost Calculator (Last updated 5/9/2009)

<table>
<thead>
<tr>
<th>Item</th>
<th>Maintenance Frequency</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Annual O&amp;M Cost for 5,000 SF (Medium)</th>
<th>Cost/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection, reporting, and data management</td>
<td>Every 3 years</td>
<td>$47</td>
<td>$0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter &amp; minor debris removal</td>
<td>Every 3 years</td>
<td>$120</td>
<td>$0.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweeping</td>
<td>Every 3 years</td>
<td>$80</td>
<td>$0.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$247</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MAINTENANCE: Permeable Pavement

Puget Sound Stormwater BMP Cost Database Technical Memorandum (Herrera 2013)

<table>
<thead>
<tr>
<th>O&amp;M Activities</th>
<th>Unit</th>
<th>n</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine sweeping (2X per year)</td>
<td>SF</td>
<td>1</td>
<td>$0.02</td>
<td>$0.02</td>
<td>$0.02</td>
</tr>
</tbody>
</table>

- Restorative maintenance (power washing followed by vactoring to unplug the upper layer and restore porosity) is estimated at $1/SF
LEARNING OBJECTIVE RECAP

1. Efficient application of LID BMPs.
2. New LID regulatory requirements.
3. How LID development process and cost compares with conventional stormwater practices.
4. The basic principles of site assessment, site layout and construction sequencing to improve the design and long-term, effective operation of LID best management practices (BMPs) and projects.
5. How to minimize construction impacts.
6. Minimum requirements for construction and protection of LID BMPs during construction.

RESOURCES

COST COMPARISONS & RESOURCES

MAINTENANCE: Permeable Pavement

<table>
<thead>
<tr>
<th>BMP</th>
<th>30-year Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeable Sidewalk</td>
<td>$15.30 / SF</td>
</tr>
<tr>
<td>Permeable Pavement</td>
<td>$1.16 / SF</td>
</tr>
<tr>
<td>Conventional Pavement</td>
<td>$1.16 / SF</td>
</tr>
</tbody>
</table>

Source: Herrera - Cost Analysis for Western Washington LID Requirements and Best Management Practices

2012 Stormwater Management Manual for Western Washington

Low Impact Development Technical Guidance Manual for Puget Sound

Western Washington Low Impact Development (LID) Operations and Maintenance (O&M) Guidance Document,
(Click on the “Maintain LID” tab)
RESOURCES

Ecology Webinar - Low Impact Development – Rain Gardens and Bioretention

WWHM 2012 Training Documents
www.ecy.wa.gov/programs/wq/stormwater/municipal/PrevWS.html

Rain Garden Handbook for Western Washington

Q&A

introduction & regulations
site assessment, planning, layout
BMP specifics
cost comparisons & resources
wrap up
Statewide LID Training Program

COURSE CATALOG

http://www.wastormwatercenter.org/lidswtrainingprogram/

OTHER COURSE OFFERINGS

INTRODUCTORY
1.0 Introduction to LID for Auditors

INTERMEDIATE
3.1 Introduction to LID for Inspectors
3.3 Introduction to LID for Designers

ADVANCED
5.1 Advanced Topics in LID Design: Vegetation
5.4 Advanced Topics in LID Design: Permeable Pavement
6.0 Advanced Topics in LID Design: Hydrologic Modeling

TRAIN THE TRAINERS
9.1 LID Training Providers
9.2 LID Training Experts

ONLINE EVALUATION

- An on-line evaluation will be sent to you within 5 days following this training
Two certificates:
• Stay tuned for decisions on certificate
• LID Design certificate
• Long-term LID Operations certificate

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