PROGRAM OVERVIEW

• 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

CORE TEAM

HERRERA
CASCADIA
Veda

ADDITIONAL TRAINING SUPPORT
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

**OVERVIEW OF PROGRAM**

<table>
<thead>
<tr>
<th>INTRODUCTORY</th>
<th>INTERMEDIATE</th>
<th>ADVANCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introductory LID Topics: NWAPA Phase 5E Requirements</td>
<td>Advanced Topics in LID Design-Bioretention</td>
</tr>
<tr>
<td>2.1</td>
<td>Introductory LID Design-Maintenance</td>
<td>Advanced Topics in LID Design-Hydrologic Modeling</td>
</tr>
<tr>
<td>2.2</td>
<td>Introductory LID Permeable Pavement</td>
<td>Advanced Topics in LID Design-Pervious Pavement</td>
</tr>
<tr>
<td>3.3</td>
<td>Intermediate LID Design-Pervious Pavement</td>
<td>Intermediate Topics in LID Design-Planning &amp; Layout</td>
</tr>
<tr>
<td>3.4</td>
<td>Intermediate LID Design-Vegetated Roofs &amp; Stormwater Quality</td>
<td>Intermediate Topics in LID Design-Rainwater Systems</td>
</tr>
<tr>
<td>4.2</td>
<td>Intermediate LID Design-Planning, &amp; Vegetated Roofs</td>
<td>Intermediate Topics in LID Design-Stormwater Management Models</td>
</tr>
</tbody>
</table>

**TRAIN THE TRAINERS**

- Introductory: Train the Trainers: Trainings for Introductory Providers
- Intermediate: Train the Trainers: Trainings for Intermediate Providers
- Advanced: Train the Trainers: Trainings for Advanced Providers

**TODAY’S TRAINING**

- Introductory: Train the Trainers: Trainings for Introductory Providers
- Intermediate: Train the Trainers: Trainings for Intermediate Providers
- Advanced: Train the Trainers: Trainings for Advanced Providers
INSTRUCTORS

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

KATHY GWILYM, PE
Principal Civil Engineer
Key project experience: Complete street design, LID and permeable pavements for public works and private projects

LOGISTICS

SCHEDULE
• Classroom training (8:30-11:45)
• 1-hour lunch break (11:45-12:45)
• Classroom training (12:45-1:30)
• Field exercises (1:30-3:30)

OTHER LOGISTICS
• Restroom location
• Food
• Turn off cell phones
• Sign in and sign out
LEARNING OBJECTIVES

1. Understand the structure and function of permeable pavement components.
2. Gain an in-depth understanding of the primary inspection activities and tools to maintain permeable pavement function over time.
3. Know the primary maintenance requirements for permeable pavement.
4. Identify maintenance problems and associated solutions necessary for long-term function of permeable pavement areas.

AGENDA

1. Introduction
2. Permeable pavement O&M
3. O&M costs
4. Tools for success
5. Wrap up & field exercises
INTRODUCTION

TOPICS

- Intro to LID
- NPDES Permit
- LID O&M Guidance Document

LOW IMPACT DEVELOPMENT (LID): Introduction to Principles

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

LID: Introduction to Principles: Pre-developed Forest Hydrology

- Yakima Regional LID Stormwater Design Manual (April 2011)
**INTRODUCTION**

**LID: Introduction to Principles: Developed Condition Hydrology**

[Diagram of hydrological processes]

**Yakima Regional LID Stormwater Design Manual (April 2011)**

---

**INTRODUCTION**

**LID: Site Design and Planning Techniques**

- Minimize disturbance
- Reduce impervious surface
- Protect and restore native soils and vegetation
- Manage stormwater close to the source

**Traditional**

**LID**

---

**INTRODUCTION**

**LID: 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

---
INTRODUCTION

LID: Permeable Pavement

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

TOPICS

Intro to LID  NPOES Permit  LID O&M Guidance Document
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>Selah</td>
</tr>
<tr>
<td>Clarkston</td>
<td>Spokane</td>
</tr>
<tr>
<td>East Wenatchee</td>
<td>Spokane Valley</td>
</tr>
<tr>
<td>Ellensburg</td>
<td>Sunnyside</td>
</tr>
<tr>
<td>Kennewick</td>
<td>Union Gap</td>
</tr>
<tr>
<td>Moses Lake</td>
<td>Walla Walla</td>
</tr>
<tr>
<td>Pasco</td>
<td>Wenatchee</td>
</tr>
<tr>
<td>Pullman</td>
<td>West Richland</td>
</tr>
<tr>
<td>Richland</td>
<td>Yakima</td>
</tr>
</tbody>
</table>

**NPDES PERMIT REQUIREMENTS:**

**Core Elements**

1. Preparation of Stormwater Site Plans
2. Construction/Stormwater Pollution Prevention
3. Source Control of Pollution
4. Preservation of Natural Drainage Systems
5. Runoff Treatment
6. Flow Control
7. Operation and Maintenance
8. Local Requirements
INTRODUCTION & REGULATIONS
NPDES PERMIT REQUIREMENTS:
Core Elements (CE)

• CE #5 – Runoff Treatment
  • Water quality treatment for pollution-generating areas

• CE #6 – Flow Control
  • Control of flow peaks and flow durations

NPDES PERMIT LID O&M REQUIREMENTS:
O&M Standards

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Permit Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adopt or update ordinance or other enforceable documents that includes O&amp;M standards</td>
<td>Post-construction Stormwater Management for New Development and Redevelopment ([S.B.S.a.ii])</td>
</tr>
<tr>
<td>Include in municipal O&amp;M Plan (stormwater collection and conveyance system component):</td>
<td>Municipal Operations and Maintenance ([S.B.6.a.i.(ii)])</td>
</tr>
<tr>
<td>• Catch basin cleaning</td>
<td></td>
</tr>
<tr>
<td>• Stormwater system maintenance</td>
<td></td>
</tr>
<tr>
<td>• Scheduled structural BMP inspections and maintenance</td>
<td></td>
</tr>
<tr>
<td>• Pollution prevention and good housekeeping practices</td>
<td></td>
</tr>
</tbody>
</table>

NPDES PERMIT LID O&M REQUIREMENTS:
Plan Review

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Permit Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify that O&amp;M plan is completed and includes the following:</td>
<td>Appendix 1 – Core Element #7</td>
</tr>
<tr>
<td>• Addresses all proposed stormwater facilities and BMPs</td>
<td></td>
</tr>
<tr>
<td>• Identifies the party (or parties) responsible for maintenance and operation</td>
<td></td>
</tr>
<tr>
<td>• Addresses the long-term funding mechanism to support O&amp;M</td>
<td></td>
</tr>
</tbody>
</table>

INTRODUCTION
**NPDES PERMIT LID O&M REQUIREMENTS: Inspection**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Permit Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinance providing legal authority to inspect private stormwater facilities</td>
<td>Post-construction Stormwater Management (S5.B.5.a.ii)</td>
</tr>
<tr>
<td>Inspect structural BMPs at least once during installation</td>
<td>Post-construction Stormwater Management (S5.B.5.c.ii)</td>
</tr>
<tr>
<td>Inspect structural BMPs at least once every 5 years after installation</td>
<td>Post-construction Stormwater Management (S5.B.5.c.iii)</td>
</tr>
<tr>
<td>Perform spot checks for potentially damaged BMPs owned/operated by Permittee after major storm events</td>
<td>Municipal O&amp;M (S5.B.6.a.4.c(ii))</td>
</tr>
</tbody>
</table>

**NPDES PERMIT LID O&M REQUIREMENTS: Enforcement**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Permit Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enforce compliance with maintenance standards as needed based on inspection</td>
<td>Post-construction Stormwater Management (S5.B.5.a.iv-v)</td>
</tr>
</tbody>
</table>

**NPDES PERMIT LID O&M REQUIREMENTS: Training**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Permit Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train staff involved in permitting, planning, plan review, field inspection, &amp; enforcement</td>
<td>Construction Site Stormwater Runoff (S5.B.4.b.i) and Post-construction Stormwater Management (S5.B.5.d)</td>
</tr>
<tr>
<td>Implement an ongoing training program for employees who have primary O&amp;M job functions that may impact SW quality</td>
<td>Post-construction Stormwater Management (S5.B.6.b)</td>
</tr>
</tbody>
</table>
### Record Keeping

**Requirement** | **Permit Reference**  
--- | ---  
Keep records of inspections and enforcement actions (e.g., inspection reports, warning letters, notices of violations) | Post-construction Stormwater Management (55.8.S.c.i)  
Private facilities – retain a copy of the O&M Plan on site or within reasonable access to the site | Appendix 1 – Core Element #7  
Public facilities – retain a copy of the O&M Plan within the appropriate department | Appendix 1 – Core Element #7

### Mapping

**Requirement** | **SWMMEW Reference**  
--- | ---  
Footprint of proposed drainage features (ponds, vegetated or other infiltration facilities, pipe routes, ditches) | SWMMEW, Appendix 3B
INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Objective

• Developed for Western WA, but is also applicable to Eastern WA
• Support permittees in implementing LID maintenance programs
• Provide specific O&M guidance so permittees can create maintenance standards that preserve facility function
• Note: Jurisdictions may want to tailor the tables in the O&M guidance document to address varying levels-of-service

LID O&M GUIDANCE DOCUMENT: Development

• Two advisory committees
  • LID Maintenance Advisory Committee
  • LID Maintenance Administrative Issues Advisory Committee
• Best available information
  • Advisory committee input
  • Literature review
  • Targeted surveys sent to jurisdictions, contractors/landscapers, and vendors
• Guidance will evolve over time

LID O&M GUIDANCE DOCUMENT: Content

• Summary of NPDES Permit Requirements
• Maintaining LID BMPs
  • Bioretention facilities
  • Rain gardens
  • Permeable pavement
  • Vegetated roofs
• Programmatic & Administrative Guidance
  • Downspout infiltration systems
  • Downspout, sheet flow, and conc. dispersion systems
  • Compost amended soils
LID O&M GUIDANCE DOCUMENT: Content

- BMP description
  - How water moves through facility
- Key maintenance considerations to ensure facility function
  - Function by BMP component
  - Key maintenance by BMP component
- Key operations to preserve facility function

INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Maintenance Standard and Procedures

INTRODUCTION

LID O&M GUIDANCE DOCUMENT: Equipment and Materials List
**LID O&M GUIDANCE DOCUMENT: Skills and Staffing**

- List of general skills required
- List of additional specialized skills
- Staffing survey estimates (e.g., crew hours per facility, per linear foot, or per square foot)

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**TOPICS**

1. Types & terms
2. How the facility works
3. Maintenance considerations for facility function
4. General maintenance for all types
5. Routine maintenance activities specific to each type
6. Corrective maintenance activities
7. Equipment and material recommendations
8. Skills
1. TYPES & TERMS

- Pervious Concrete
- Porous Asphalt
- Permeable Interlocking Concrete Pavers
- Open Celled Systems (Flexible & Rigid)

1. TYPES: Porous Asphalt

- Flexible, non-proprietary
- Placement is similar to conventional asphalt but need large quantity
- Typically used for parking and light traffic loads; however, has been used for medium and heavy applications
- Initial Infiltration rate: 200+ inches/hour

1. TYPES: Pervious Concrete

- Rigid, non-proprietary
- Placement differs from conventional. Small batches feasible.
- 3/8" typical (round or crushed) aggregate w/o to minimal fines. Admixtures (optional) to increase workability and strength.
- Initial Infiltration rate 200+ inches/hour
1. TYPES: Permeable Interlocking Pavers

- Flexible, proprietary
- Capable of high vehicle loads. Used for lower speeds
- High-density concrete that interlock and transfer vertical loads to surrounding pavers
- Clean aggregate (w/o fines) filled within the openings/gaps
- Initial infiltration rates can vary depending upon paver type

1. TYPES: Plastic Grids

- Flexible, proprietary
- Plastic grid filled with clean gravel (w/o fines) or soil and planted with grass
- Trails, paths, maintenance access in a park, parking
- Highest percent voids

2. HOW THE FACILITY WORKS
2. HOW THE FACILITY WORKS

- Sections vary – check as-buils
  - Top Wearing Course
  - Leveling Course?
  - Sub-base (storage)
  - Water quality treatment layer?
  - Geotextile?
  - Native soil
  - Storage within Sub-base
  - Slope conditions – check dams
  - Overflow (pipe or structure)

3. MAINTENANCE CONSIDERATIONS

- “The maintenance of LID facilities is essential to ensure that design stormwater management and other benefits continue over the full lifecycle of the installation.”
- What to look for?
  - Drainage Function
  - Safety
  - Aesthetics
- Is it different?
  - Long term infiltration capacity can remain high however……………
3. O&M TRANSITION

- O&M starts at the Planning phase
- Transitioning from Construction to O&M
  - Purpose?
  - What are the regulatory reporting requirements?
  - Record/As-built?
  - Training new staff
  - Mapping

4. GENERAL: Protection of Surface

Inform crews about protecting permeable pavements

Use tarps/cover under stockpiles

4. GENERAL: Adjacent Stabilization

Maintain stabilization of adjacent areas to protect from sediment transport

- Proactive vs. reactive
- Address the source
4. GENERAL: Vegetation Migration & Rooting

- Ground Cover Migration
- Cover if Hydroseeding
- Options for Maintenance
  - Modify planting plan and remove invasive plants
  - Maintain adjacent landscaping

Ground cover migration happens even with conventional pavement

4. GENERAL: Moss Growth

- Be careful with expectations
- Moss is present regardless of pavement type in PNW
- More prevalent in shady areas and under trees
- Remove if it's observed to affect drainage
- Some is okay
- Perception

Previous concrete sidewalk with moss

4. GENERAL: Moss Growth

- If severe, options for removal:
  - Pressure washing (concrete)
  - Weed burner
  - Sweeping (during dry periods)
  - Vacuuming (effectiveness varies)
- During planning & design, consider impacts of shade to maintenance frequency

Non-Pervious Concrete urban sidewalk with moss
4. GENERAL: Moss Growth

- Installed ~10 years ago, 12516 NE 90th Street
- Photo taken within 1 year of installation

4. GENERAL: Moss Growth

- Installed in 2010 – no routine maintenance, Photo July 2014
- Installed in 2005 – no routine maintenance, Photo May 2014

4. GENERAL: Protection From Staining

- Applies to pavers, asphalt, cement concrete. Same as conventional pavements
- During construction, keeping pervious concrete covered for curing & protection can lead to some discoloration but fades with time
- Avoid placement of organic/compost material on pavement

Staining from compost spilling onto pervious concrete
4. GENERAL: Snow Removal

- Modify snow management procedures
- Avoid sanding since it will clog the system, except in cases of emergencies/safety issues (vacuum sediment as soon as possible after melt)
- Avoid sanding adjacent streets since tires will track it onto the porous pavement
- Avoid stockpiling snow on porous pavement

4. GENERAL: Snow Removal

- Adjust snow plow height to avoid scratching when feasible
- UNH reported up to 75% decrease in salt use but it will depend on site conditions (shade, location etc)
- Permeable sub-base provides drainage
- Voids in wearing course provides space for freeze thaw
- Installed in cold climates such as Iowa, Pennsylvania, Colorado, Ohio, Lake Tahoe

Parking Lot, Denver, CO – Next AM Following 12” Snow

Photos courtesy of National Ready Mixed Concrete Association and slide courtesy of Center for Portland Cement Concrete Pavement Technology, 2005 via John Kevern at National Concrete Pavement Technology, Iowa State University
PERMEABLE PAVEMENT O&M

4. GENERAL: Drainage Function Inspection

• Inspect drainage function in the rain and identify areas for maintenance
  • Is there runoff from the surface?
  • Is water still ponding on the surface 1 hour after rain has stopped?
  • Is there ponding water in the observation port 24 hours after the rain has stopped?
  • If ponding, then corrective action required for cleaning surface.

4. GENERAL: Drainage Function Inspection

• Video/photos of overall area during rain event
  • If no ponding on the surface then its flowing through top wearing course

4. VIDEO IN THE RAIN
4. **GENERAL: Drainage Function Inspection**

- Inspect drainage function in dry weather
  - Cylinder test: ASTM C1701 results indicate an infiltration rate of 10 inches per hour or less then corrective action required.
  - Test the surface infiltration rate using ASTM C1701 (perform 1 test/installation but not < 1 test/2,500 sf)
  - Run cylinder tests over multiple areas
  - Turn on sprinklers/garden hose to test larger area?
  - Does water pool or drain out?

4. **GENERAL: Corrective Action for Drainage**

- If not draining through top wearing course then corrective maintenance options include:
  - Pressure wash and/or vacuum system
  - Hand held pressure wash or power wash with rotating brushes
  - Pure vacuum sweeper (calibrated to not dislodge wearing course aggregate)
  - Gravel grid and pavers – removing and replacing aggregate

4. **GENERAL: Under- and Elevated-Drains**

- Under-drain/Elevated drain is clogged:
  - Jet clean or rotary cut debris/roots from under-drain
  - Clean flow restrictor/orifice
  - Identify the source of the blockage and take actions to prevent future blockages
- If pipe daylights, check for erosion damage at discharge point:
  - Identify source of problem
  - Repair erosion and stabilize surface
4. GENERAL: Under- and Elevated- Drains

- Water remains in storage aggregate longer than anticipated:
  - Inspect standpipes for under-drain
  - Inspect drains
  - If structural problems possible schedule investigation of subsurface materials or other potential causes of extended ponding

4. GENERAL: Inspect Overflow/Backup System

- Check overflow drainage path
  - What is the flow path if water does not infiltrate?
  - If has under-drain pipes, verify they are draining
  - Verify that the overflow structure is not plugged.

4. GENERAL NON-ROUTINE: Utility Cuts

- Temporary Patch
- Protect adjacent porous to remain
- Permanent Panel replacement
- Permanent Restoration: Use same material as original, except use conventional asphalt for porous asphalt
5. ROUTINE AND CORRECTIVE MAINTENANCE BY COMPONENT

- Pavement surface
  - Porous Asphalt and Pervious Concrete
  - Permeable Interlocking Concrete Pavers
  - Open Celled Gravel grid
  - Open Celled Grass grid

5. ROUTINE: Porous Asphalt & Pervious Concrete

- Cleaning surface debris
  - Large areas: vacuum sweep (regenerative air or high efficiency vacuum)
  - Small areas: walk behind vacuums, shop vacs, hand held pressure washer or power washer with rotating brushes
  - Frequency: 1-2 times annually or as determined by site conditions
  - Consult with equipment manufacturer/rep for optimum operation

5. ROUTINE: Porous Asphalt & Pervious Concrete

- No Overlay
- No black topping/sealing
- May need to re stripe parking lot more frequently
5. NON-ROUTINE: Pervious Concrete Structural

- Major cracks or trip hazards and concrete spalling and raveling
- Determine cause
- Replace panel with porous material if feasible
- Modify operations?

5. NON-ROUTINE: Raveling at Construction Joints

- Consult with industry, engineer
- Patch?
- Cut out and replace with new panel (pervious concrete)
- Replace with conventional asphalt?

5. NON-ROUTINE: Drainage Function Rehabilitation

- Consult with industry, engineer
- Significant decline in infiltration when system is not routinely maintained
5. ROUTINE: PICP & Pavers

- Routine maintenance (cleaning surface debris)
  - Large areas: vacuum sweep (regenerative air or high efficiency vacuum)
  - Small areas: walk behind vacuums, shop vacs
  - Frequency: 1-2 times annually or as determined by site conditions
  - Consult with equipment manufacturer/rep for optimum operation
  - Vacuum settings may have to be adjusted to prevent excess uptake of aggregate from paver openings or joints
  - Vacuum surface openings in dry weather to remove dry, encrusted sediment

5. ROUTINE: PICP & Pavers

- Routine maintenance (vegetation)
  - Remove weeds if they start to affect drainage performance
  - Aesthetics
  - Do not use herbicides (this is a stormwater facility)
  - Weed burner
  - Vinegar? (small applications)
  - Larger gaps between pavers easier for removal of weeds (shovel)

5. ROUTINE: PICP & Pavers

- Clogged wearing course
  - Review overall performance of the facility
  - If water ponds or flows off pavement surface during rain event, corrective maintenance or testing is needed
  - Dry Weather: Test the surface infiltration rate using ASTM C1781 (perform 1 test/installation but not < 1 test/2,500 sf)
PERMEABLE PAVEMENT O&M

6. CORRECTIVE: PICP & Pavers

• Clogged wearing course
  • Corrective maintenance options include:
    • Pure vacuum sweeper
    • Pressure wash and vacuum system calibrated to remove all visible sediment (likely 2-3 cm of aggregate) in the joints or infiltration cells
    • Replace aggregate in joints or infiltration cells per manufacturer specifications

5. NON-ROUTINE: PICP & Pavers

• Utility work
  • Pavers can be removed individually and replaced after work is complete
  • Clean sub-base material (no to minimal fines)

• Structural integrity
  • Loss of aggregate material between paver blocks: Refill per manufacturer’s recommendations
  • Paver block missing or damaged: Remove individual damaged paver blocks by hand and replace or repair per manufacturer’s recommendations
  • Surface settling: May require resetting
5. NON-ROUTINE: PICP & Pavers

- Structural integrity and snow
  - The structure of the top edge of the paver blocks reduces chipping from snowplows
  - Skids on the corner of plow blades are recommended

5. ROUTINE: Gravel Grid

- Cleaning surface debris
  - Large areas: vacuum sweep? (regenerative air or high efficiency vacuum)
  - Small areas: walk behind vacuums, shop vacs, rake, leaf blower
  - Frequency: 1-2 times annually or as determined by site conditions
  - Consult with equipment manufacturer/rep for optimum operation
  - Vacuum settings may have to be adjusted to prevent excess uptake of aggregate from paver openings or joints
  - Vacuum surface openings in dry weather to remove dry, encrusted sediment
  - Maintain aggregate 0.25 inches above grid structure

6. CORRECTIVE: Gravel Grid

- Clogged wearing course
  - Observe the pavement system after a rain event (testing infiltration rate using ASTM C1701 likely not applicable)
  - Corrective action needed, if ponding on surface or water flows off aggregate surface during rain event
6. CORRECTIVE: Gravel Grid

- Clogged wearing course
  - Use vacuum system calibrated to remove all visible sediment (likely 2-3 cm of aggregate)
  - Replace aggregate per manufacturer specifications (usually 0.25 inches above grid structure)

5. NON-ROUTINE: Gravel Grid

- Structural integrity
  - Grid damaged:
    - Remove pins (if present), pry up grid segments, and replace grid, pins and gravel
    - Replace grid segments where three or more adjacent rings are broken or damaged
  - Loss of aggregate material: Refill per manufacturer’s recommendations (usually 0.25 inches above grid structure)

5. ROUTINE: Grass Grid

- Cleaning surface debris
  - Large and small areas: rakes, leaf blowers
  - Consult manufacturer guidelines
  - Frequency: 1-2 times annually or as determined by site conditions
  - Maintain soil/sand slightly below grid structure
**PERMEABLE PAVEMENT O&M**

6. CORRECTIVE: Grass Grid

- Clogged wearing course
  - Observe the grass pavement system after a rain event (testing infiltration rate using ASTM C1701 likely not applicable)
  - Corrective action needed if ponding on surface or water flows off grass surface during rain event
  - Follow manufacturer’s guidelines for repairing surface

---

**PERMEABLE PAVEMENT O&M**

5. NON-ROUTINE: Grass Grid

- Structural integrity
  - Grid damaged:
    - Remove pins (if present), pry up grid segments, and replace grid, pins and grass.
    - Replace grid segments where 3 or more adjacent rings are broken or damaged
  - Grass growth:
    - Mulch mower
    - Top dress with 0.5 inches of compost if nutrient deficient (do not use fertilizer)
  - Surface settling: May require resetting

---

**PERMEABLE PAVEMENT O&M**

5. NON-ROUTINE: Grass Grid

- Structural integrity
  - Poor grass coverage:
    - Restore growing medium, reseed or plant and/or amend vegetated area as needed
    - Traffic loading may be inhibiting grass growth; reconsider traffic loading if feasible
    - Growing media elevation should be maintained slightly below grid structure
    - Consult manufacturer/sales representative
    - May need occasional reseeding
5. NON-ROUTINE: Grid Systems

- Structural integrity and snow
  - Snow plows should use skids to elevate the blades to prevent loss of aggregate and damage to the grid

7. EQUIPMENT & MATERIALS: Routine Maintenance

Equipment to address clogging of wearing course, such as:
- Hand held pressure washer or power washer with rotating brushes
- Walk-behind vacuum
- Pure vacuum sweeper
- Brush broom
- Combined higher pressure wash and vacuum system
PERMEABLE PAVEMENT O&M
7. EQUIPMENT & MATERIALS: Routine Maintenance

Equipment to remove sediment, debris, and leaf litter, such as:
- High efficiency regenerative air or vacuum sweeper
- Push broom
- Brush broom
- Leaf blower

7. EQUIPMENT & MATERIALS: Routine Maintenance

Weed/vegetation removal equipment, such as:
- Weeding tools
- Weed burner
- Edging and trimming equipment control groundcover and other vegetation

7. EQUIPMENT & MATERIALS: Routine Maintenance

Additional equipment for grass-filled open-celled grid systems, such as:
- Mower or mulch mower
- Topdress grass seed
- Compost
- Replacement grid segments
7. EQUIPMENT & MATERIALS: Routine Maintenance

Additional equipment for gravel-filled open-celled grid systems, such as:

- Rakes and shovels
- Replacement grid segments
- Replacement aggregate
- Wheelbarrow (for transporting replacement aggregate)

7. EQUIPMENT & MATERIALS: Routine Maintenance

Additional equipment for permeable paver systems, such as:

- Rakes and shovels
- Extra pavers and bedding material
- Replacement aggregate
- Wheelbarrow (for transporting replacement aggregate)

7. EQUIPMENT & MATERIALS: Routine Maintenance

Snow removal equipment, such as:

- Plow with skids to prevent damage to permeable pavement
- Snow blower
PERMEABLE PAVEMENT O&M

7. EQUIPMENT & MATERIALS: Routine Maintenance

Pipe/structure inspection and maintenance equipment:
- Hand tools
- Wrench or manhole opener
- Flashlight
- Mirror
- Garden hose
- Plumbing snake
- Measuring tape or ruler

7. EQUIPMENT & MATERIALS: Corrective Maintenance

- Elgin’s Whirlwind (pure vacuum sweeper)
- Bunyan B.I.R.D. vacuum attached to vactor truck (10 gpm): $7,800 +
  power if not on vactor
- Paragon Industries
- Stay tuned — supply and demand affect technology

Timm Sowders with Paragon Industries
7. EQUIPMENT & MATERIALS: Corrective Maintenance

Erosion control equipment:
- Erosion control matting
- Rocks
- Mulch
- Plants
- Landscaping tools
- Tarps (to protect pavement)
7. EQUIPMENT & MATERIALS: City of Olympia

2006 Study Findings:
• Leaf/Litter vacuums are more effective than sweepers with dust control vacuum systems
• Vacuum machines had difficulty removing leaf piles when they were more than 2 to 3 inches thick

7. EQUIPMENT & MATERIALS: City of Portland

N Gay Avenue & Westmoreland Projects:
• Pavers, porous asphalt and pervious concrete public streets
• 1X to 2X/year - Vacuum sweepers used to collect fines:
  • Tymco’s 500x, Schwarze’s A7000, Elgin’s Crosswind J-Plus
• Infiltration testing with flusher truck
• “Vegetation growth in pavers did not appear to hinder infiltration on Rex St.” (~63 in/hr)

8. SKILLS
• Sweeper and equipment operation
• Commercial driver’s license (CDL)
• Landscaping skills (e.g., general plant care) for grass-filled open-celled grid systems
• Engineer and/or landscape architect for major maintenance
introduction  
permeable pavement O&M  
O&M costs  
tools for success  
wrap up & field exercises

**O&M COSTS**  
**CONVENTIONAL VS LID O&M ACTIVITIES**

<table>
<thead>
<tr>
<th>Conventional</th>
<th>LID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweeping</td>
<td>Sweeping/clean surface debris</td>
</tr>
<tr>
<td>Repair structural damage</td>
<td>Unclog wearing course</td>
</tr>
<tr>
<td>Typically Streets Department maintains roadways</td>
<td>Unclog drain and inspect for damage</td>
</tr>
<tr>
<td></td>
<td>Run-on from adjacent landscaping</td>
</tr>
</tbody>
</table>

Q&A
## PERMEABLE PAVEMENT

### O&M COSTS

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Maintenance Frequency</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 1/year</td>
<td>$47</td>
<td>$0.01</td>
</tr>
<tr>
<td>Litter &amp; minor debris removal</td>
<td>Every 3 years 1/year</td>
<td>$120</td>
<td>$0.03</td>
</tr>
<tr>
<td>Sweeping</td>
<td>Every 3 years 1/year</td>
<td>$80</td>
<td>$0.02</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$247</td>
<td></td>
</tr>
</tbody>
</table>

### 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>x</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

### O&M COST PER BMP

**BMP**

- Permeable Sidewalk: $15.30 / SF
- Permeable Pavement: $1.16 / SF
- Conventional Pavement: $1.16 / SF

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

TOPICS

• Inspection checklist
• Record keeping and tracking
• Interpreting plans and as-builts
• Inspection programs
INSPECTION CHECKLIST

Name(s) of Inspector: ____________________________  
Date of Inspection: ______________________________  
Location of the permeable pavement facility: ________________________________  
Surface/finishing course type: ______________________  
Address or Intersection: ____________________________  
Age of permeable pavement facility: _____________________  
Permeable pavement facility area (ft. x ft.): _______________  
Time since last rainfall (hrs.): _______________________  
Quantity of last rainfall (in.): ________________________  

Site Sketch (include curbs, islands, trees, north arrow, etc.):

INSPECTION CHECKLIST

Based on visual assessment of the site, answer the following questions and take photographs of the site:

Surface/finishing Course:
1. Are there indications of any of the following on the surface of the permeable pavement facility? (If yes, mark on site sketch)
   - Excessive sediment
   - Moss growth
   - Cracks, trip hazards, or concrete spalling
   - Track and debris
   - Leaf accumulation
   - Settlement of surface
   - Other: ____________________________
   - None

2. Is there ponding on the surface of the permeable pavement? □ Yes □ No
   If yes, describe the potential reasons for ponded water below (leak or debris build up, non-functional underdrain, groundwater input, illicit connection, inadequate capacity in facility, etc.):

Notes: ____________________________

Statewide LID Training Program
ADVANCED TOPICS FOR LONG-TERM LID OPERATIONS
TOOLS FOR SUCCESS
INSPECTION CHECKLIST

Inlets/Outlets/Flows
3. How many inlet pipes are present? □ 1 □ 2 □ 3 □ 4 □ 5 □ NA

4. Are any of the inlet pipes clogged? (If yes, mark the location on your site sketch and add notes to the box below with the cause of the clogging (e.g., debris, sediment, vegetation, etc.).) □ No □ Partially □ Completely □ NA

5. Are any of the inlet pipes altered from the original design or otherwise in need of maintenance? (If yes, write in reason: frost heave, vandalism, unknown, etc.)

<table>
<thead>
<tr>
<th>Partially clogged</th>
<th>Completely clogged</th>
<th>Reason for maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet 1</td>
<td>Inlet 2</td>
<td>Inlet 3</td>
</tr>
</tbody>
</table>

Tools for Success
INSPECTION CHECKLIST

6. Are any overflow, underdrains, raised subsurface overflow pipes, or outlet structures clogged?
   □ No □ Partially □ Completely □ NA
   a. If yes, mark the location on your site sketch and add notes to the box below with the cause of the clogging (e.g., debris, sediment, vegetation, moss, etc.).
   b. Are any of the overflow structures altered from the original design or otherwise in need of maintenance? (If yes, write in reason: frost heave, vandalism, unknown)

<table>
<thead>
<tr>
<th>Outlet 1</th>
<th>Outlet 2</th>
<th>Outlet 3</th>
<th>Outlet 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partially clogged</td>
<td>Completely clogged</td>
<td>Reason for maintenance</td>
<td></td>
</tr>
</tbody>
</table>

Observation Port (if present)

7. Is water remaining in the storage aggregate longer than anticipated by design after the end of a storm?
   □ Yes □ No □ Unknown
   a. If yes, identify potential cause of extended ponding and mark the location of observed extended ponding on your site sketch.

Tools for Success
INSPECTION CHECKLIST

Summary

8. Inspector’s Recommendations. When is maintenance needed?
   □ Immediately
   □ Within a month or two
   □ Within a year
   □ No sign that any maintenance is required

9. Summarize the results of this inspection and write any other observations in the box below:

   Summary and other observations
RECORD KEEPING & TRACKING

- Parcel information
- City/County permit (ROW and/or building permit)
- Relevant sections of the Stormwater Site Plan
- “As-builts” or “record drawings” (individual lots and public ROW)
- Legal agreements (covenants, easements)

TOOLS FOR SUCCESS

RECORD KEEPING & TRACKING

- Location information (GPS data, digital maps)
- Project O&M manual (where applicable)
- Maintenance logs (typically included in a Project O&M Manual)
- Inspection forms
- Enforcement documents

TOOLS FOR SUCCESS

INTERPRETING PLANS & AS-BUILTS

- How to interpret construction plans, installation photos, and as-builts
INSPECTION PROGRAMS

• Immediately post-construction for all LID BMPs - installed per plan and functioning properly

• Every 6 months (until 90% of lots are constructed) for permanent Stormwater Treatment and Flow Control BMPs/Facilities in new residential developments - identify maintenance needs and enforce maintenance standards

• Ongoing annual inspections for all Stormwater Treatment and Flow Control BMPs/Facilities (MR #6 and/or MR #7)

Q&A

introduction

permeable pavement O&M

O&M costs

tools for success

wrap up & field exercises
# Statewide LID Training Program

## COURSE CATALOG

![Image](http://www.wastormwatercenter.org/lidwtrainingprogram/)

<table>
<thead>
<tr>
<th>Course</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to LID for Inspectors &amp; Maintenance Staff</td>
<td>Intro</td>
<td>Basic understanding of LID principles</td>
</tr>
<tr>
<td>Intermediate LID Design: Permeable Pavement</td>
<td>Interm</td>
<td>Designing permeable pavement for specific sites</td>
</tr>
<tr>
<td>Intermediate LID Training Program</td>
<td>Interm</td>
<td>Training in LID for professionals</td>
</tr>
<tr>
<td>Advanced Topics in LID Design: Bioretention Media</td>
<td>Adv</td>
<td>Advanced techniques for bioretention media</td>
</tr>
<tr>
<td>Advanced Topics for Long-term LID Operations: Permeable Pavement</td>
<td>Adv</td>
<td>Planning and maintenance for long-term LID</td>
</tr>
</tbody>
</table>

## OTHER COURSE OFFERINGS

- **Introductory**
  - Introduction to LID for Inspectors & Maintenance Staff
- **Intermediate**
  - Intermediate LID Design: Permeable Pavement
  - Intermediate LID Design: Rainwater Collection Systems & Vegetated Roofs
- **Advanced**
  - Advanced Topics in LID Design: Bioretention Media
  - Advanced Topics for Long-term LID Operations: Permeable Pavement

## Online Evaluation

- An online 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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• Sign up to follow and get Tweets

Further questions? Contact:
training@cascadiaconsulting.com
(206) 449-1163
Field Exercises
Site Inspection
Infiltration Tests
Equipment Demos