10/28/2014

**Statewide LID Training Program**

**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

---

**OVERVIEW OF PROGRAM**

**PROJECT LEAD** | **CORE TEAM**
---|---
HERRERA | [CASCADIA](http://example.com) [Veda](http://example.com)

**ADDITIONAL TRAINING SUPPORT**

- [CH2M HILL](http://example.com)
- [KINDERDE HYDRO](http://example.com)
- [WORKING PROSPLANS](http://example.com)
- [LAUREL SPRING COMPANY](http://example.com)
- [AMAZON](http://example.com)
- [RENEWABLE BLOCKS](http://example.com)
• 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
ADVANCED TOPICS FOR LONG-TERM LID OPERATIONS: PERMEABLE PAVEMENT

INSTRUCTORS

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

CURTIS HINMAN
Senior Scientist
Key project experience: Research specialist in the performance and design of LID applications

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

introduction
permeable pavement O&M
O&M costs
administrative tools
wrap up & field exercises
INTRODUCTION
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

INTRODUCTION
LID: Introduction to Principles: Pre-developed Forest Hydrology
**LID: Introduction to Principles: Developed Condition Hydrology**

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**

**LID: Small-Scale Engineering Controls**

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

Conservation or regain pre-developed hydrologic functions

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

- Rain Gardens (BMP T5.14A)
- Biotreatment (BMP T5.14B)
- 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
LID: Permeable Pavement

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

INTRODUCTION
TOPICS

Intro to LID  NPDES Permit  LID O&M Guidance Document
NPDES PERMIT LID O&M REQUIREMENTS:
Western WA NPDES Permit

National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permits

Municipal Stormwater Permits in Washington State

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

INTRODUCTION

NPDES PERMIT LID O&M REQUIREMENTS:
Requirements Vary By Permittee

• Phase II requirements are somewhat less extensive
• Secondary permittee requirements vary

Timeline for updating maintenance standards

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Section S5.C.5.a of the Phase I Permit</td>
<td>Per Section S5.C.5.a of the Phase II Permit</td>
</tr>
<tr>
<td>June 2014</td>
<td>June 30, 2015</td>
</tr>
<tr>
<td>June 30, 2016</td>
<td>June 30, 2017</td>
</tr>
<tr>
<td>June 30, 2018</td>
<td>June 30, 2018</td>
</tr>
</tbody>
</table>

INTRODUCTION

NPDES PERMIT LID O&M REQUIREMENTS:
Requirements Vary By BMP Classification

• On-site Stormwater Management BMPs
• Stormwater Treatment and Flow Control BMPs/Facilities
**INTRODUCTION**

**NPDES MUNICIPAL STORMWATER PERMIT:**
Minimum Requirements (MRs)

1. Preparation of Stormwater Site Plans
2. Construction SWPPP
3. Source Control
4. Preserve natural Drainage
5. On-Site Stormwater management
6. Run-off Treatment
7. Flow Control
8. Wetlands Protection
9. O&M

**INTRODUCTION**

**NPDES PERMIT LID O&M 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

**INTRODUCTION**

**NPDES PERMIT LID O&M 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
**INTRODUCTION**

NPDES PERMIT LID O&M REQUIREMENTS:
On-site Stormwater Management BMPs

- Used to help meet MR #5
- May be used to help meet MR #6 and/or MR #7
- "On-site Stormwater Management BMPs" = LID BMPs

**DEFINITIONS**

On-site SW Management BMPs (LID BMP)

- "Distributed stormwater management practices, integrated into a project design, that emphasize pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration. LID BMPs include, but are not limited to, bioretention/rain gardens, permeable pavements, roof downspout controls, dispersion, soil quality and depth, vegetated roofs, minimum excavation foundations, and water re-use."
DEFINITIONS

- SW Treatment & Flow Control BMPs/Facilities (MR #6 and/or MR #7)
  - "Detention facilities, treatment BMPs/facilities, bioretention, vegetated roofs, and permeable pavements that help meet Appendix 1 Minimum Requirements #6 (treatment), #7 (flow control), or both"
**NPDES PERMIT LID O&M REQUIREMENTS: Plan Review**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify maintenance plan completed &amp; O&amp;M responsibility assigned</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Verify submission of maintenance instructions</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Verify that O&amp;M manual is complete</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Review and approve declaration of covenant (including design details, figures and maintenance instructions) and grant of easement</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal authority to inspect private stormwater facilities and enforce maintenance standards</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Conduct post-construction inspections to ensure proper installation</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**NPDES PERMIT LID O&M REQUIREMENTS: Inspection (continued)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct inspections during construction in new residential developments*</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Conduct ongoing annual inspections</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Perform spot checks for potentially damaged BMPs owned/operated by Permittee after major storm events</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Every 6 months until 90% of the lots are constructed or when construction is stopped and the site is fully stabilized.
### NPDES PERMIT LID O&M REQUIREMENTS: Enforcement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enforce compliance with maintenance standards as needed based on inspection</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train staff involved in plan review, permitting, construction site inspections, &amp; enforcement</td>
<td>X</td>
<td>X</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>X</td>
<td>X</td>
</tr>
</tbody>
</table>

### NPDES PERMIT LID O&M REQUIREMENTS: Record Keeping

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep records of inspections and enforcement actions (e.g., inspection reports, notices of violations)</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
**INTRODUCTION**

NPDES PERMIT LID O&M REQUIREMENTS:

Mapping

<table>
<thead>
<tr>
<th>Requirement</th>
<th>On-site SW Management BMPs</th>
<th>SW Treatment &amp; Flow Control BMPs/Facilities (MR #6 and/or MR #7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale drawing of the lot(s) and public ROW that show BMP locations</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Map BMPs owned/operated by Permittee</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Map connections between BMPs and tributary conveyances*</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Phase I Only

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**INTRODUCTION**

TOPICS

Intro to LID  NPDES Permit  LID O&M Guidance Document

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**INTRODUCTION**

LID O&M GUIDANCE DOCUMENT: Objective

- 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

- 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

INTRODUCTION
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)
TOPICS

• Types
• How the system works
• Maintenance considerations for facility function
• General maintenance for all
• Routine maintenance activities specific to each type
• Corrective maintenance activities
• Equipment and material recommendations
• Skills

TYPES & TERMS

Permeable Interlocking Concrete Pavers

Open Celled Systems (Flexible & Rigid)
**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

**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

**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
**Permeable Pavement O&M**

**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

**How the Facility Works**

- Sections vary – check as-built
  - 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)
INTRODUCTION TO MAINTENANCE

• “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.............

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
**GENERAL: Protection of Surface**
Inform crews about protecting permeable pavements
Use tarps/cover under stockpiles

**GENERAL: Adjacent Stabilization**
Maintain stabilization of adjacent areas to protect from sediment transport

- Proactive vs. reactive
- Address the source

**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
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 observed to affect drainage
- Some is okay
- Perception

Pervious concrete sidewalk with moss

- 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

- Installed ~10 years ago
- Photo taken w/-1 year of installation
**GENERAL: Moss Growth**

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

**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

**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
GENERAL: Snow Removal

- Adjust snow plow height to avoid scratching
- 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

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.

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

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

VIDEO IN THE RAIN

PERMEABLE PAVEMENT O&M

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?
PERMEABLE PAVEMENT O&M

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

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 daylight, check for erosion damage at discharge point:
  - Identify source of problem
  - Repair erosion and stabilize surface

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
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.

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

ROUTINE AND CORRECTIVE MAINTENANCE BY COMPONENT

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

**PERMEABLE PAVEMENT O&M**

- No Overlay
- No black topping/sealing
- May need to re stripe parking lot more frequently

**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?
**NON-ROUTINE: Raveling at Construction Joints**

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

**NON-ROUTINE: Drainage Function Rehabilitation**

- Consult with industry, engineer
- Significant decline in infiltration when system is not routinely maintained

**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
PERMEABLE PAVEMENT O&M

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)

CORRECTIVE: 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)

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
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)

NON-ROUTINE: PICP & Pavers

- 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

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
PERMEABLE PAVEMENT O&M

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

PERMEABLE PAVEMENT O&M

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

PERMEABLE PAVEMENT O&M

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)
**PERMEABLE PAVEMENT O&M**

**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)

**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

**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
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:
    • Mulum mower
    • Top dress with 0.5 inches of compost if nutrient deficient (do not use fertilizer)
  - Surface settling: May require resetting

• 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

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
PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS

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

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
PERMEABLE PAVEMENT O&M

EQUIPMENT & MATERIALS: Routine Maintenance

Weed/vegetation removal equipment, such as:

- Weeding tools
- Weed burner
- Edging and trimming equipment control groundcover and other vegetation)

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

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)
Additional equipment for permeable paver systems, such as:

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

Snow removal equipment, such as:

- Plow with skids to prevent damage to permeable pavement
- Snow blower

Pipe/structure inspection and maintenance equipment:

- Hand tools
- Wrench or manhole opener
- Flashlight
- Mirror
- Garden hose
- Plumbing snake
- Measuring tape or ruler
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
PERMEABLE PAVEMENT O&M
EQUIPMENT & MATERIALS: Corrective Maintenance

Erosion control equipment:
• Erosion control matting
• Rocks
• Mulch
• Plants
• Landscaping tools
• Tarps (to protect pavement)

PERMEABLE PAVEMENT O&M
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
PERMEABLE PAVEMENT O&M
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)

PERMEABLE PAVEMENT O&M
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

Q&A
O&M COSTS

CONVENTIONAL VS LID O&M ACTIVITIES

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

O&M COSTS

PERMEABLE PAVEMENT

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Maintenance Frequency Low</th>
<th>Maintenance Frequency Medium</th>
<th>Maintenance Frequency 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>Every 3 years</td>
<td>1/year</td>
<td>$47</td>
<td>$0.01</td>
</tr>
<tr>
<td>Litter &amp; minor debris removal</td>
<td>Every 3 years</td>
<td>Every 3 years</td>
<td>1/year</td>
<td>$120</td>
<td>$0.03</td>
</tr>
<tr>
<td>Sweeping</td>
<td>Every 3 years</td>
<td>1/year</td>
<td>12/year</td>
<td>$80</td>
<td>$0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</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>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 unblock the upper layer and restore porosity) is estimated at $1/SF

O&M COSTS PER BMP

<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
introduction
permeable pavement O&M
O&M costs
administrative tools
wrap up & field exercises

ADMINISTRATIVE TOOLS

TOPICS

• Inspection checklist
• Record keeping and tracking
• Interpreting plans and as-buils
• Inspection programs

ADMINISTRATIVE TOOLS

INSPECTION CHECKLIST
## INSPECTION CHECKLIST

**Name(s) of Inspection:**
**Date of Inspection:**
**Location of the permeable pavement facility:**
**Surface sealing course type:**
**Address or Intersection:**
**Age of permeable pavement facility:**
**Permeable pavement area (ft² or m²):**
**Time since last mow(s) (hr):**
**Quantity of lost rainfall (in):**

**Site Sketch (include curbs, islands, trees, existing arrows, etc.):**

---

### ADMINISTRATIVE TOOLS

**INSPECTION CHECKLIST**

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

**Surface/Washing 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, slip hazards, or concrete / asphalt spalling
   - Trash 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 underrains, groundwater input, illicit connection, inadequate capacity in facility, etc.)

### ADMINISTRATIVE TOOLS

**INSPECTION CHECKLIST**

**Inlets/Outlet Pipes**
3. How many inlet pipes are present?  0  1  2  3  4  5
4. Are any of the inlet pipes clogged? (If yes, mark the location on your site sketch and fill in the boxes below with the cause of the clogging (e.g., debris, sediment, vegetation, etc.))
   - Yes
   - No
   - Partially
   - Completely
   - Other

5. Are any of the inlet pipes altered from the original design or otherwise in need of maintenance? (If yes, write in reasons: fasteners, vandalism, undermining, etc.)

<table>
<thead>
<tr>
<th>Partially clogged</th>
<th>Completely clogged</th>
<th>Reason for maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td></td>
</tr>
</tbody>
</table>
1. Are any overflows, underdrains, related subsurface overflow pipes, or outlet structures clogged?  
   - Yes ☐  Partially ☐  Completely ☐  No ☐  
   - If yes, mark the location on your site sketch and fill in the boxes below with the cause of the clogging (e.g., debris, sediment, vegetation, roots, etc.) 
   - 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 m</th>
<th>Outlet m</th>
<th>Outlet m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partially clogged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completely clogged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reason for maintenance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

---

**Administrative Tools: Inspection Checklist**

**Summary**

6. 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.

<table>
<thead>
<tr>
<th>Summary and other observations</th>
</tr>
</thead>
</table>

---

**Administrative Tools: 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)
ADMINISTRATIVE TOOLS

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

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)
• 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

Statewide LID Training Program
COURSE CATALOG

http://www.wastormwatercenter.org/lidswtrainingprogram/
## Statewide LID Training Program

### OTHER COURSE OFFERINGS

<table>
<thead>
<tr>
<th>Level</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTRODUCTORY</strong></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>Introduction to LID for Service Providers</td>
</tr>
<tr>
<td>2.1</td>
<td>Intermediate LID Topics: NID/ID &amp; Requirements</td>
</tr>
<tr>
<td>2.2</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>3.4</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td><strong>INTERMEDIATE</strong></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>3.6</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>4.2</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>4.1</td>
<td>Intermediate LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td><strong>ADVANCED</strong></td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>5.2</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>5.3</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
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<tr>
<td>5.4</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
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<td>8.1</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td>8.2</td>
<td>Advanced Topics in LID Design: Site Assessment, Planning &amp; Layout</td>
</tr>
<tr>
<td><strong>TRAIN THE TRAINERS</strong></td>
<td></td>
</tr>
<tr>
<td>9.1</td>
<td>Train the Trainers: Service Providers</td>
</tr>
<tr>
<td>9.2</td>
<td>Train the Trainers: Site Assessment, Planning &amp; Layout</td>
</tr>
</tbody>
</table>

### ONLINE EVALUATION

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

### CERTIFICATE

Two certificates:
- Stay tuned for decisions on certificate
- LID Design certificate
- Long-term LID Operations certificate

Sign out!
ONLINE RESOURCES

For information on training and other resources, visit the Washington Stormwater Center website:
http://www.wastormwatercenter.org

Stay connected through Social Media
- Come “Like” our Page
- Sign up to follow and get Tweets

PROJECT LEAD

QUESTIONS

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

Field Exercises
Site Inspection
Infiltration Tests
Equipment Demos