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

AGENDA

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

LOGISTICS

SCHEDULE
- Classroom training: 9:00-12:00
- Lunch (provided): 12:00-12:45
- 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

Statewide LID Training Program

PROGRAM OVERVIEW

- 2012: Public and private partners engage state legislature to fund program.
- June 2012: LID Training Steering Committee convened.
- 2012-2013: Washington State LID Training Plan developed: www.wastormwatercenter.org/lid-background
- 2014: Training program built from state LID Training Plan.
Statewide LID Training Program

PROGRAM OVERVIEW

• 49 trainings in western and eastern WA in 2014-2015.
• 42 trainings in western and eastern WA in 2015-2016.
• 39 trainings offered in western and eastern WA in 2017.
• Three levels: Introductory, Intermediate, and Advanced.
• Statewide LID Certificate now available.

PROJECT LEAD

INTRODUCTION TO LID FOR INSPECTION & MAINTENANCE STAFF

2.1

INTERMEDIATE

3.1 Intermediate LID Design: Site Assessment, Planning & Layout

3.2 Intermediate LID Design: Vegetation Systems & Vegetated Roofs

3.3 Intermediate LID Design: Hydrologic Modeling

3.4 Intermediate LID Design: Site Assessment, Planning & Layout

3.5 Intermediate LID Design: Hydrologic Modeling

ADVANCED

5.0 Advanced Topics in LID Design: Vegetation Systems & Vegetated Roofs

5.1 Advanced Topics in LID Design: Hydrologic Modeling

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

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

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

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

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

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

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

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

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

OVERVIEW OF PROGRAM

ADDITIONAL TRAINING SUPPORT

OVERVIEW OF PROGRAM

CORE TEAM

HERRERA

CASCADIA

CH2M

MENG

DRR

KINDRED HYDRO

MITHUN
Introduction to LID for Inspection & Maintenance Staff

INTRODUCTORY INTERMEDIATE ADVANCED

Intermediate LID Design:
- Rainwater Collection Systems
- Vegetated Roofs

Intermediate LID Topics:
- NPDES Phase I & II Requirements

Intermediate LID Design:
- Permeable Pavement
- Hydrologic Modeling

Advanced Topics in LID Design:
- Bioretention Media and Compost Amended Soils

Advanced Topics for Long-term LID Operations:
- Bioretention

Advanced Topics in LID Operations:
- Permeable Pavement

Advanced Topics for Long-term LID Operations:
- Permeable Pavement

Training Program Statewide LID

ADVANCED TOPICS FOR LONG-TERM LID OPERATIONS: PERMEABLE PAVEMENT

Introduction
- Permeable pavement O&M
- O&M costs
- Administrative tools
- Wrap up & field exercises
INTRODUCTION

TOPICS

Intro to LID  NPDES Permit  LID O&M Guidance Document

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

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

Traditional | LID

**LID: Site Design and Planning Techniques**

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

**LID: Small-Scale Engineering Controls**

- Infiltration
- Filtration
- Storage
- Evaporation
- Transpiration

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

Conserve or regain pre-developed hydrologic functions
INTRODUCTION

**LID: Best Management Practices (BMPs)**
- Rain Gardens (BMP T5.14A)
- Bioretention (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)

**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 Permittees in Washington State

<table>
<thead>
<tr>
<th>Phase I Permittees</th>
<th>Western Washington Phase II Permittees</th>
<th>Eastern Washington Phase II Permittees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle, Tacoma, Clark County, King County, Pierce County, Snohomish County</td>
<td>82 Cities</td>
<td>18 Cities</td>
</tr>
<tr>
<td>WSDOT</td>
<td>5 Counties</td>
<td>5 Counties</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>June 2014</td>
<td>June 30, 2015</td>
</tr>
<tr>
<td>Dec. 31, 2016</td>
<td>June 30, 2017</td>
</tr>
<tr>
<td>June 30, 2018</td>
<td></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
**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”
### INTRODUCTION

**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>

#### 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>

#### 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 50% 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></td>
<td>X</td>
</tr>
</tbody>
</table>

#### 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>

#### 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>
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 shows 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></td>
</tr>
<tr>
<td>*Phase I Only</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INTRODUCTION

TOPICS

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

INTRODUCTION

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

INTRODUCTION

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

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

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

Photos provided by MIG SvR
**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.

**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.

**TYPES:** Permeable Interlocking Pavers

- Hexdie, 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.
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-builts
  - 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.
  - Weed burners

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
- Monitor
- Remove if observed to affect drainage and impacts safety
- Some is okay
- Perception on Aesthetics can vary

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.

Installed ~10 years ago
12516 NE 90th Street

Photos provided by MIG SvR
Photos taken w/in 1 year of installation

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


Photos provided by MIG SvR

PERMEABLE PAVEMENT O&M

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.

Photos provided by MIG SvR

PERMEABLE PAVEMENT O&M

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.

Photos provided by MIG SvR
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.

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

Permeable Concrete
Conventional Asphalt

PHOTO CREDITS:
- 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

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.
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.
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?

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.
PERMEABLE PAVEMENT O&M

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 Pervious 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

ROUTINE: Porous Asphalt & Pervious Concrete

- No overlay
- No black topping/sealing
- May need to re-stripe parking lot more frequently
PERMEABLE PAVEMENT O&M

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

- **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)

- **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.

### 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

### 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).

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.
4/5/2017

PERMEABLE PAVEMENT O&M
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
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
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.

Photo provided by MIG SvR
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

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

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

**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
PERMEABLE PAVEMENT O&M

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)

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)

EQUIPMENT & MATERIALS: Routine Maintenance

Snow removal equipment, such as:
- Plow with skids to prevent damage to permeable pavement
- Snow blower
PERMEABLE PAVEMENT O&M

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

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
- Total Pervious Solutions (formerly Paragon Industries)
- Stay tuned … supply and demand affect technology

Timm Sowders with Paragon Industries
PERMEABLE PAVEMENT O&M EQUIPMENT & MATERIALS:

Corrective Maintenance

PERMEABLE PAVEMENT O&M EQUIPMENT & MATERIALS: Corrective Maintenance
Erosion control equipment:
- Erosion control matting
- Rocks
- Mulch
- Plants
- Landscaping tools
- Tarp (to protect pavement)

**EQUIPMENT & MATERIALS:** Corrective Maintenance

**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.

**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

Photo provided by MIG SvR
**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</td>
<td></td>
<td>Unplug wearing course</td>
</tr>
<tr>
<td>damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typically Streets</td>
<td></td>
<td>Unplug drain and inspect for damage</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maintains roadways</td>
<td></td>
<td>Run-off from adjacent landscaping</td>
</tr>
</tbody>
</table>

**O&M FREQUENCIES**

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Previous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacoma Residential</td>
<td>2 x/year</td>
<td>2 x/year</td>
</tr>
<tr>
<td>Streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tacoma Arterials</td>
<td>Every 6 weeks</td>
<td>Every 6 weeks</td>
</tr>
<tr>
<td>Puyallup Streets</td>
<td>Monthly</td>
<td>Monthly</td>
</tr>
<tr>
<td>Puyallup Sidewalks</td>
<td></td>
<td>Annually sweep with walk behind</td>
</tr>
<tr>
<td>Monroe Streets</td>
<td>Varies (Daily in fall)</td>
<td>Same as conventional + additional sweeping by cyclone</td>
</tr>
</tbody>
</table>

Source: Jessica Krienerbocker, City of Tacoma
Mark Palmer, City of Puyallup
Vince Bertrand, City of Monroe, 360-863-4552
O&M COST FACTORS

• Current street sweeping practices for conventional
• Site location and surrounding conditions
• Amount of run-on and source of run-on
• Equipment
• Level of service for aesthetics
• Quality of the initial installation
• Other

O&M LOCAL INFORMATION SHARING

• ROADMAP - Luanne Coachman
e-mail: luanne.coachman@kingcounty.gov
• APWA Stormwater Managers Committee
  Bruce Wulkan and Paul Fendt chairs, Google group:
  https://groups.google.com/forum/#!forum/apwa-stormwater
• Permeable Pavements for Puget Sound, Google group:
  https://groups.google.com/forum/#!forum/permeable-pavements-for-puget-sound
  • Industry reps
  • Other agencies

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

TOPICS

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

INSPECTION CHECKLIST EXAMPLES

Maintenance Checklist

<table>
<thead>
<tr>
<th>Maintenance Component</th>
<th>Guidelines When Maintenance Is Needed</th>
<th>Action Needed</th>
<th>Checkmark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Statewide LID Training Program  PERMEABLE PAVEMENT

ADDITIONAL TOPICS FOR LOW-IMPACT DEVELOPMENT
ADMINISTRATIVE TOOLS
INSPECTION CHECKLIST EXAMPLES

NAME(S) of Inspector:
Date of Inspection:
Location of the permeable pavement facility:
Surface/lining course type:
Approach 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 curb, islands, trees, north arrow, etc.)

ADMINISTRATIVE TOOLS
INSPECTION CHECKLIST EXAMPLES

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

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
   - Muck growth
   - Gravel, tile, or concrete: Aperture spalling
   - Tree 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 causes for ponded water below (leaf or debris build-up, non-functional underdrain, ground water inputs,iritation connection, inadequate capacity in facility, etc.)

45
**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)

**INTERPRETING PLANS & AS-BUILTS**

- How to interpret construction plans, installation photos, and as-builts.
ADMINISTRATIVE TOOLS

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 in new residential developments - identify maintenance needs and enforce maintenance standards.

Q&A

introduction

permeable pavement O&M

O&M costs

administrative tools

wrap up & field exercises
**Statewide LID Training Program**

**COURSE CATALOG**

Introduction to LID for Inspection & Maintenance Staff

Intermediate:
- Intermediate LID Topics: BMP Design & I & R Requirements
- Intermediate LID Design: Bioretention
- Intermediate LID Design: Permeable Pavement
- Intermediate LID Design: Site Assessment, Planning & Layout
- Intermediate LID: Rainwater Collection Systems & Vegetated Roofs
- Intermediate LID: Hydrologic Modeling

Advanced:
- Advanced Topics for Long-term LID Operations: Bioretention
- Advanced Topics in LID Design: Bioretention
- Advanced Topics in LID Design: Permeable Pavement
- Advanced Topics in LID Design: Site Assessment, Planning & Layout
- Advanced Topics in LID Design: Rainwater Collection Systems & Vegetated Roofs
- Advanced Topics in LID Design: Hydrologic Modeling

**OVERVIEW OF PROGRAM**

- Online Evaluation:
  - An online evaluation will be sent to you within 5 days following this training.
  - Feedback will help to refine future trainings.
Two certificates:

- LID Design certificate.
- LID Operations and Maintenance certificate.

You will receive an e-mail with login information following relevant courses.

LID Certificate Program Policies Page:
www.wastormwatercenter.org/lid-certificate-policies

Remember to sign in and sign out!

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

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

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