Module 6.0: Advanced Topics in LID Design: Hydrologic Modeling
General instructions: You may model facility dimensions to the nearest half foot.

Exercise #1: Modeling Bioretention and Permeable Pavement

Site: WSU Extension in Everett
2000 Tower St. Everett, WA 98201

Site Design Assumptions:
- Predominant Soil: Till
- Pre-developed Land Cover: Forest

Exercise #1a: Bioretention (Water Quality)

Site: Post-developed Land Cover: Impervious
Design Standard: Water Quality Treatment (91% Infiltration)

Project: New construction of 5,000 square foot moderately sloped parking lot. Design a bioretention system to provide water quality treatment for all 5,000 sf of parking area.

Facility Design Assumptions:
- Sideslopes: 3:1
- Ponding Depth: 6 inches
- Freeboard: 6 inches
- BSM Thickness: 18 inches
- BSM Porosity: 40% effective porosity (“porosity” - “wilting”) (46% porosity in WWHM)
- BSM Infiltration Rate: 6 inches/hour
- Native Soil Infiltration Rate: 0.5 inches/hour
- Overflow pipe diameter: 12 inches

Assume:
- No underdrain permitted
- Square facility geometry
- Neglect facility footprint in post-developed area
- 15 minute computational timestep

Results:

**WWHM Everett gage**
- Facility Bottom Area: 49 square feet (7x7)
- Facility Footprint: 169 square feet (13x13)
- Percent of Development: 3.38% (top area) (169sf / 5000sf)

**MGSFlood Puget East 36**
- Facility Bottom Area: 104 square feet (10.2x10.2)
- Facility Footprint: 262.44 square feet (16.2x16.2)
- Percent of Development: 5.25% (top area) (262sf / 5000sf)
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[Diagram of a bioretention cell with input parameters and output calculations]

[Diagram showing the geometry and structure of a bioretention system]

[Input data for bioretention including elevation, slopes, and infiltration rates]
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Exercise #1b: Bioretention (Flow Control)

Site: Post-developed Land Cover: Impervious
Design Standard: Flow Control (match predeveloped flows and durations from 50% 2-year to full 50-year recurrence interval flow)

Project: New construction of 5,000 square foot moderately sloped parking lot. Design a bioretention system to provide flow control for all 5,000 sf of parking area. Use same facility assumptions as Exercise 1a.

Use a 15 minute computational timestep.

Results: MGSFlood Puget East 36
Facility Bottom Area: 615 square feet (24.8x24.8)
Facility Footprint: 949 square feet (30.8x30.8)
Percent of Development: 18.97% (949sf / 5000sf)
**Exercise #1c: Permeable Pavement**

**Site:** Post-developed Land Cover: Impervious/Permeable Pavement  
Design Standard: Flow Control (match predeveloped flows and durations from 50% 2-year to full 50-year recurrence interval flow)

**Project:** New construction of 5,000 square foot parking lot. Design a *moderately sloped permeable pavement* facility to provide *flow control* for 2,000 square feet of permeable pavement (parking stalls) and *run-on* from 3,000 square feet of adjacent impervious parking area (driving lanes).

**Facility Design Assumptions:**
- **Pavement Area:** 2,000 square feet  
- **Pavement Slope:** 2 % (model as flat without check dams - assume design will incorporate check dams to provide required average ponding depth)  
- **Pavement Infiltration Rate:** 50 inches/hour  
- **Gravel Porosity:** 30%  
- **Native Soil Infiltration Rate:** 0.5 inches/hour

Use a 15 minute computational timestep.

**Results:**
- **WWHM Everett gage**  
  Average Ponding Depth: 0.2 feet
- **MGSFlood Puget East 36**  
  Average Ponding Depth: 0.6 feet
Exercise #2: Modeling Green Roofs and Dispersion

Site: WSU Extension in Everett
2000 Tower St. Everett, WA 98201

Site Design Assumptions:
- Predominant Soil: Till
- Pre-developed Land Cover: Forest

Exercise #2a: Green Roof

Project: New construction of 5,000 square foot green roof. Evaluate performance of Green Roof in MGS Flood and WWHM. Determine how WWHM Green Roof parameters impact 2-year and 25-year flows from the baseline configuration.

Use a 15-minute computational timestep.

Baseline Green Roof Design Assumptions:
- Green Area: 0.115 acres
- Depth of Material: 4 inch
- Slope of Rooftop: 0.001 (ft/ft)
- Vegetative Cover: Ground Cover
- Length of Rooftop: 50 ft

Results: MGS Flood Recurrence Interval Flows Puget East 36
- 2-year: 0.02452 cfs
- 25-year: 0.05028 cfs

WWHM Recurrence Interval Flows Everett gage
- 2-year: 0.027445 cfs
- 25-year: 0.059058 cfs

<table>
<thead>
<tr>
<th>WWHM Green Roof Parameter</th>
<th>2-year (cfs)</th>
<th>25-year (cfs)</th>
<th>Δ from Baseline Green Roof in WWHM</th>
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<tr>
<td>Vegetative Cover</td>
<td>0.026567</td>
<td>0.057039</td>
<td>Lower</td>
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<tr>
<td>Slope of Roof</td>
<td>0.041783</td>
<td>0.084699</td>
<td>Higher</td>
</tr>
<tr>
<td>Depth of Material</td>
<td>0.025201</td>
<td>0.050343</td>
<td>Lower</td>
</tr>
<tr>
<td>Length of Rooftop</td>
<td>0.02222</td>
<td>0.044509</td>
<td>Lower</td>
</tr>
</tbody>
</table>
Exercise #2b: Green Roof to Bioretention

Site: Post-developed Land Cover: Green Roof
Design Standard: Flow Control

Project: New construction of 5,000 square foot green roof. Design a bioretention system downstream of the green roof to provide flow control for the site.

Bioretention Design Assumptions:
- Sideslopes: 3:1
- Ponding Depth: 6 inches
- Freeboard: 6 inches
- BSM Thickness: 18 inches
- BSM Porosity: 40%
- BSM Infiltration Rate: 6 inches/hour
- Native Soil Infiltration Rate: 0.5 inches/hour
- Overflow Diameter: 12 inch

Assume:
- No underdrain permitted
- Square facility geometry
- Neglect facility footprint in post-developed area
- 15 minute computational timestep

Results: MGSFlood Puget East 36
Facility Bottom Area: 547.56 square feet (23.4x23.4)

How does this facility compare to the facility sized in exercise 1b?

Smaller / Larger By how much? 10.97%
Exercise #2c: Dispersion

Site: Post-developed Land Cover: Impervious  
Design Standard: NA

Project: New construction of 5,000 square foot moderately sloped parking area. Determine the performance of sheet flow dispersion in the adjacent lawn area (5,000 square feet) next to the parking lot.

Dispersion Design Assumptions:
Option 1: Model parking lot as lateral flow impervious basin routed to a lateral flow soil basin (only available in WWHM).
Option 2: Model impervious area as grass.

Results:

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>WWHM Everett gage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmanaged Surface(s)</td>
<td>10,000sf total -- 5,000 sf lawn,</td>
<td>5,000sf impervious</td>
</tr>
<tr>
<td></td>
<td>5,000 sf impervious</td>
<td></td>
</tr>
<tr>
<td>2-year:</td>
<td>0.1192 cfs</td>
<td>0.0597 cfs</td>
</tr>
<tr>
<td>25-year:</td>
<td>0.2310 cfs</td>
<td>0.1157 cfs</td>
</tr>
<tr>
<td>Dispersed Surface</td>
<td>2-year: 0.0561 cfs</td>
<td>2-year: 0.0116 cfs</td>
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<tr>
<td></td>
<td>25-year: 0.1488 cfs</td>
<td>25-year: 0.0438 cfs</td>
</tr>
<tr>
<td>Reduction in Recurrence Interval Flows (from unmanaged):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-year:</td>
<td>53.0%</td>
<td>80.6%</td>
</tr>
<tr>
<td>25-year:</td>
<td>35.6%</td>
<td>62.1%</td>
</tr>
</tbody>
</table>

MGSFlood Recurrence Interval Flow Puget East 36

|                      |                                |                                 |
| Unmanaged Surface(s) |                                |                                 |
|                      | 2-year: 0.04072 cfs            | 25-year: 0.07678 cfs            |
| Dispersed Surface    | 2-year: 0.00878 cfs            | 25-year: 0.03570 cfs            |
| Reduction in Recurrence Interval Flows (from unmanaged): |                     |                                 |
| 2-year:             | 78.4%                           |                                 |
| 25-year:            | 53.5%                           |                                 |

Which technique (green roof or dispersion) better manages low flows (2-year)?

- MGS Flood: Dispersion
- WWHM: Option 2 Dispersion > Green Roof > Option 1 Dispersion

Which technique (green roof or dispersion) better manages high flows (25-year)?

- MGS Flood: Dispersion
- WWHM: Green Roof > Option 2 Dispersion > Option 1 Dispersion

Why? _________________________________________________________________
Module 6.0: Advanced Topics in LID Design: Hydrologic Modeling
Exercise #3: Modeling a Residential Development

Site: Hawks Prairie Gold Course
8383 Vicwood Lane Lacey, WA 98516

Site Design Assumptions:
- Predominant Soil: Till
- Pre-developed Land Cover: Forest  Puget West 48

Exercise #3a:

Site: Post-developed Land Cover: See Development Plan (attached).
Design Standard: Flow Control

Project: New construction of single residential lot. Design a bioretention system at the downstream end of the property to provide flow control for the lot.

Facility Design Assumptions:
- Sideslopes: 3:1
- Ponding Depth: 6 inches
- Freeboard: 6 inches
- BSM Thickness: 18 inches
- BSM Porosity: 40%
- BSM Infiltration Rate: 6 inches/hour
- Native Soil Infiltration Rate: 0.5 inches/hour
- Overflow Structure Diameter: 12 inches

Assume:
- No underdrain permitted
- Square facility geometry
- Subtract bioretention bottom area from lawn area
- 5 minute computational timestep

Results: MGSFlood
Facility Bottom Area: 870 square feet (29.5x29.5)

Parcel
Driveway and Walkway _____ sf
Roof _____ sf

Pre: Forest: 0.179 ac
Post: Grass: 0.086 ac
Imp: 0.073 ac

Lawn on Till _____ sf

Bioretention (BMP T7.30) (MR7)
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Exercise #3b:

Site: Post-developed Land Cover: See Development Plan (attached).
Design Standard: NA

Project: Determine performance of List #2 BMPs (see Figure 2) for a single lot. Assume roof area managed by bioretention facility, at-grade impervious managed by permeable pavement, and lawn area flows to the POC unmanaged.

Bioretention Design Assumptions:
- Bioretention Facility Sizing Factor: 5%
- Sideslopes: 3:1
- Ponding Depth: 6 inches
- Freeboard: 6 inches
- BSM Thickness: 18 inches
- BSM Porosity: 40%
- BSM Infiltration Rate: 6 inches/hour
- Native Soil Infiltration Rate: 0.5 inches/hour
- Overflow Structure Diameter: 12 inches

Assume:
- No underdrain permitted
- Square facility geometry
- Subtract bioretention bottom area from lawn area
- 5 minute computational timestep

Permeable Pavement Design Assumptions:
- Pavement Slope (ft/ft): 0.05
- Trench Slope (ft/ft): 0.0
- Pavement Infiltration Rate (in/hr): 20
- Native Infiltration (in/hr): 0.5
- Gravel Porosity (%): 30
- Trench Depth (ft): 0.25

Soil Quality and Depth Assumptions: Modeled as Pasture on Till

Results:

- Bioretention Bottom Area: 63.2 square feet (7.95x7.95)
- Lawn Area (less bio bottom area): 4,536 square feet
- 2-year peak flow: 0.02167 cfs LID Standard: Pass / Fail
- 25-year peak flow: 0.06693 cfs Flow Control Standard: Pass / Fail

Parcel:

- Driveway and Walkway
- Permeable Pavement (BMP T5.15) (Concrete)
- Roof
  - Pre: Forest: 0.179 ac
  - Post: Grass: 0.104 ac
  - Roof: 0.055 ac
  - Drive: 28.3’x 28.3’

- Bioretention (BMP T7.30) (MR5)

- Lawn
  - Soil Quality and Depth (BMP T5.13)

- POC

Pre:  Forest: 0.179 ac
Post: Grass: 0.104 ac
Roof: 0.055 ac
Drive: 28.3’x 28.3’
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Exercise #3c:

Site: Post-developed Land Cover: See Development Plan (attached).
Design Standard: NA

Project: Determine performance of List #2 BMPs (see Figure 3) for the right-of-way adjacent to two lots.
Right-of-Way Design Assumptions:
- Lot Width (ft): 75
- Number of Lots: 2
- Right-of-way Width (ft): 48
- Roadway Width (ft): 28
- Sidewalk Width (ft): 10 (5 ft both sides of road)
- Planter Strip Width (ft): 10

Permeable Pavement Roadway and Sidewalk Design Assumptions:
- Pavement Slope (ft/ft): 0.01
- Trench Slope (ft/ft): 0.0
- Pavement Infiltration Rate (in/hr): 20
- Native Infiltration (in/hr): 0.5
- Gravel Porosity (%): 30
- Trench Depth (ft): 0.25

Soil Quality and Depth Assumptions:
Modeled as Pasture on Till (for planter strip area)

Results: MGSFlood

2-year peak flow: 0 cfs; LID Standard: Pass / Fail
25-year peak flow: 0 cfs; Flow Control Standard: Pass / Fail
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Exercise #3d:

Site: Post-developed Land Cover: See Development Plan (attached).
Design Standard: NA

Project: Size a regional detention pond to meet the flow control standard for two lots and the right-of-way assuming the facilities used in Exercise 3b and 3c.

Regional Detention Pond Design Assumptions:
- Sideslopes: 3:1
- Ponding Depth: 2 feet
- Freeboard: 12 inches
- Infiltration: none

Assume: Single orifice configuration (0.5 inch min. diameter)

<table>
<thead>
<tr>
<th>Area Name</th>
<th>Area (sf)</th>
<th>Area (acres)</th>
<th>Modeled Land Cover/BMP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lot 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driveway</td>
<td>600</td>
<td>0.014</td>
<td>Permeable Pavement</td>
</tr>
<tr>
<td>Roof</td>
<td>2,400</td>
<td>0.055</td>
<td>Impervious</td>
</tr>
<tr>
<td>Lawn</td>
<td>4,537</td>
<td>0.104</td>
<td>Till Pasture</td>
</tr>
<tr>
<td>Walkway</td>
<td>200</td>
<td>0.005</td>
<td>Permeable Pavement</td>
</tr>
<tr>
<td>Bioretention</td>
<td>120 (WSE)</td>
<td>0.003</td>
<td>Bioretention</td>
</tr>
<tr>
<td><strong>Lot 2</strong></td>
<td></td>
<td></td>
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<tr>
<td>Driveway</td>
<td>600</td>
<td>0.014</td>
<td>Permeable Pavement</td>
</tr>
<tr>
<td>Roof</td>
<td>2,400</td>
<td>0.055</td>
<td>Impervious</td>
</tr>
<tr>
<td>Lawn</td>
<td>4,537</td>
<td>0.104</td>
<td>Till Pasture</td>
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<td>Walkway</td>
<td>200</td>
<td>0.005</td>
<td>Permeable Pavement</td>
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<tr>
<td>Bioretention</td>
<td>120 (WSE)</td>
<td>0.003</td>
<td>Bioretention</td>
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<td><strong>Right-of-Way</strong></td>
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<tr>
<td>Roadway</td>
<td>4,200</td>
<td>0.096</td>
<td>Permeable Pavement</td>
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<tr>
<td>Lawn</td>
<td>1,500</td>
<td>0.034</td>
<td>Till Pasture</td>
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<tr>
<td>Sidewalk</td>
<td>1,500</td>
<td>0.034</td>
<td>Permeable Pavement</td>
</tr>
<tr>
<td><strong>Total Area</strong></td>
<td>0.523</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results: MGSFlood

Facility Bottom Area: 25 square feet (5’ x 5’)
(with 1” diameter Orifice)
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Pre:
- Forest: 0.523 ac
- Roof (2x): 0.055 ac
- Drive + Walk (2x): 28.3’ x 28.3’
- Lawn (2x): 0.104 ac
- Sidewalk: 150’ x 10’
- Street: 150’ x 28’
- Grass: 0.034 ac

Post:
- Lawn
**Exercise #4:**

**Site:** Site: WSU Extension  
600 128th Street SE  
Everett, WA

**Instructions:** Review example hydrologic modeling memo and attached WWHM model output report. Identify discrepancies between the memo and the output report and errors in model inputs and/or calculations.

<table>
<thead>
<tr>
<th>Results</th>
<th>Description of Error/Discrepancy</th>
<th>Location of Error/Discrepancy</th>
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