Hydrologic Modeling for Green Roofs, Rainwater Harvesting and LID Foundations

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Presentation Outline

- Overview of Hydrologic Modeling
- Performance Standards
- Modeling Guidelines
  - Green Roofs
  - Pin Foundations
  - Detention Cisterns
  - Harvesting Cisterns
- Resources
Q: What is hydrologic modeling?

A: Use of mathematical equations to estimate runoff based on:

- weather patterns
- landuse
- soil
- topography

Source: http://www.und.nodak.edu/
Hydrologic Modeling

Q: Why do we use hydrologic models?

A1: Characterize hydrologic conditions
- Predeveloped
- Current
- Post-project

A2: Design mitigation

A3: It’s fun!
Hydrologic Modeling

Q: When does hydrologic modeling enter into your project?

A: Start to finish
  - preliminary design (sizing)
  - final design (optimization)
  - demonstrate requirements met (permit submittals)

Source: http://www.und.nodak.edu/
Flow Control
- Non Exempt Receiving Water-
  Ecology requirement to match flow duration to predeveloped condition
- Combined Sewer or Capacity Constrained Basins-
  Local requirements are typically peak-control based

Water Quality
- Ecology requirement to treat the 91st percentile of the 24-hour runoff volume
- Green roofs, LID foundations and cisterns DO NOT receive treatment credit

Wetland Protection
- Ecology guideline to maintain wetland hydroperiod
Performance Standards

- LID (Draft 2012 Ecology Manual)
  - Match 8% 2-yr to 50% 2-yr pre-developed durations

Hydrologic Modeling Methods

- **Single-event models**
  - Appropriate for conveyance sizing

- **Continuous models**
  - Required for sizing flow control (MR7) and treatment (MR6) BMPs

- **Simplified sizing tools**
  - Represent BMP footprint area as % imp. Area (“sizing factor”)
  - Prescribed design criteria
  - Engineer not needed for small projects (e.g., <10,000sf imp.)
  - GSI-Calc available for western WA Lowlands
  - Jurisdiction-specific sizing tools also available (e.g., Seattle, Bellevue, Edmonds, Kitsap County, Pierce County)
Hydrologic Modeling
Single-Event Methods

- Input single storm event
- Output peak flow rates
- Typical methods
  - SCS
  - SBUH
  - StormShed
  - SWMM
  - HEC-HMS
Hydrologic Modeling
Continuous Models

- Input long-term rain and evaporation
- Output continuous runoff, peak flow, & duration
- Typical programs
  - HSPF
  - WWHM
  - MGSFlood
  - KCRTS
  - SWMM
  - SUSTAIN
Modeling Tools
HSPF Basics – Model Inputs

- Meteorological Data
  - Rainfall (5-min, 15-min, hourly)
  - Evaporation (daily)

- Land Cover Types
  - Impervious areas (IMPLNDS)
    - Slope
  - Pervious areas (PERLNDS)
    - Vegetation
    - Soil type (A, B, C/D)
    - Slope
  - Regional calibrated parameters (Dinicola 1990)

- BMP Configurations
Green Roofs
Current Modeling Guidelines

 Implicit Method

- 2005 LID Manual Method
  - Option 1: 3-8” growing media → model as lawn on till
  - Option 2: >8” growing media → model as pasture on till
Explicit Methods

- WWHM3Pro & WWHM4
  - Modified PERLND parameters
  - Based on Hamilton Building in Portland
  - Considers material depth and vegetated cover

- MGSFlood4
  - Modified PERLND parameters (similar to WWHM)
Green Roof Example
Flow Control (WWMH4)

- 1 acre Green Roof
- In Seattle
- Performance relative to Ecology pre developed forest standard

[Image of green roof example]
Green Roof Example
Select Precipitation

MGSFlood - [Green Roof Example.fld]

Project Information
Project Name: Green Roof Example
Analysis Title: 
Comments: 

Precipitation Data for Analysis
Select Precipitation Data Set Type to Use in Analysis
- Extended Timeseries (Produces Most Accurate Results)
- Station Data - Uses Ecology Scaling Method

Select Climate Region
26. Seattle 38 in MAP
(No Scaling Factor Req'd)

Precipitation Station
Seattle 38 in 5min
Evaporation Station:
Seattle 38 in MAP

Period of Record
10/01/1939-10/01/2037

Puget East
Puget West
Vancouver
Green Roof Example
Define Predeveloped Condition

[Diagram of software interface with options for predeveloped and postdeveloped scenarios, and icons for various objects like subbasin, structure, open channel, infilt trench, user rating, splitter, CAVFS, filter strip, bioretention, porous pavement, etc.].

[Options to set point of compliance at outflow and link water surface elevation stats].
Green Roof Example
Define Predeveloped Condition
Green Roof Example
Define Developed Mitigated Condition
Green Roof Example
Define Developed Mitigated Condition
Green Roof Example
Define Developed Mitigated Condition
Green Roof Example
Run Model

Selected Precipitation and Evaporation for Simulation:
Input: MGSRegions.mdb
Precipitation: Seattle 38 in_5min
Evaporation: Seattle 38 in MAP

Simulation Time Span
Start Date: 10/01/1939 00:00
End Date: 10/01/2097 00:00
(158 Years)
(For Preliminary or Test Runs, Shorten the End Date to Reduce the Computation Time, e.g. 10/1/1996)

Computational Timestep
15 Min

Time Step Guidance
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<td>CAVFS Sizing</td>
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<td>Conveyance Sizing</td>
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Predevelopment/Post Development Area Summary

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<td>Total (ac)</td>
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Green Roof Example

Duration Plot
Green Roof Performance
Duration Plot

BMP Performance in Seattle

Green roof reduces downstream BMP size
Roof runoff dispersed on **up gradient** side of structure

- Dispersion per BMP T5.10 (downspout dispersion)
- Model roof as **pasture on native soil**
- Highest credit available
- (area receiving credit reduced when step-forming is used on a slope)

Roof runoff dispersed on **down gradient** side of structure

- Dispersion per BMP T5.10 (downspout dispersion) AND at least 50 ft of vegetated flow path that meets BMP T5.13
- Model roof as **landscaped on native soil**
LID Foundations Performance
Duration Plot

Modeled as pasture on till - Same as implicit representation for green roofs (>8”)
Modeled as lawn on till - Same as implicit representation for partial dispersion, and green roofs (3-8”)

BMP Performance in Seattle

Percent Time Exceeding

Flow (cfs)
Detention Cisterns
Current Modeling Guidelines

Explicit Method
- Model as vault/tank with low flow orifice and overflow

Orifice Limitations
- Minimum orifice size typically will not achieve creek protection flow duration standards
- Useful tool for CSO control

Note: No recommendations in 2005 LID Manual
Harvesting Cisterns
Current Modeling Guidelines

- **2005 LID Manual**
  - Estimate average annual runoff volume (V) using continuous model
  - Size cisterns to provide storage, V
  - For interior reuse, perform monthly water balance
  - Subtract roof area from site-wide model if sizing flow control or water quality treatment

- **Recommendation**
  - Perform daily (or sub-daily if rainfall data available) water balance model
  - Factor results into site-wide model for flow control sizing
Detention Cisterns
Model Representation

- Downspout Connection
- High Water Level
- Low Water Level
- Freeboard
- Detention Volume
- Sediment Storage
- Overflow
- To Approved Discharge Point
- Low Flow Orifice

* Can add faucet for rainwater reuse upstream of low flow orifice
Detention Cisterns
Model Representation

- Precipitation
- Evaporation
- Runoff/Interflow
- Contributing area
- Vault/Tank Module
- Overflow
- Detained flow

Where flow control standard must be met

Dead storage below low flow orifice invert can be neglected in model
## Detention Cisterns
### Routing

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Harvesting Cisterns
Model Representation

- Downspout Connection
- High Water Level
- Low Water Level
- Freeboard
- Detention Volume
- Sediment Storage
- Overflow
- To Approved Discharge Point
- To Reuse Point
- Pump

* Can add faucet for rainwater reuse and/or low flow orifice
Eastsound, WA (Orcas Island)

7-acre site, 34 new homes, average roof size = 995 sq. ft.

3,000 gallon underground cisterns with indoor reuse

Daily water balance model in EXCEL

Size residual detention and WQ for remainder of site (e.g., roadways, driveways, lawns) → 2005 DOE
Flow Control
OPAL - Site Plan
Flow Control

OPAL – Design of Cisterns for Reuse

CISTERN NOTES:
1. PIPE SUPPORTS NOT REQUIRED
2. CONTRACTOR TO TIE EL. TO EVERYTHING
3. ADDITIONAL FITTINGS TO BE ORDERED SEPARATELY
4. BOLTS TO BE SUPPLIED BY CONTRACTOR
5. PIPE SUPPORTS TO BE ORDERED SEPARATELY
6. PIPE SUPPORTS TO BE ORDERED SEPARATELY
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19. PIPE SUPPORTS TO BE ORDERED SEPARATELY
20. PIPE SUPPORTS TO BE ORDERED SEPARATELY

FLOW CONTROL

OPAL COMMUNITY LAND TRUST
862 MOUNT BAKER ROAD - SINGLE FAMILY HOUSING
LOW IMPACT DEVELOPMENT

DRAINAGE DETAILS

NOT IN SCALE.
Flow Control
OPAL – Evaluation of Cisterns for Reuse

Notes:
1. Large home (1,050 sq. ft. roof)
2. Assume 4 people per house
3. Assume (2) 1,500-gal underground cisterns with indoor plumbing for toilet flushing, cold water for laundry, and irrigation
4. Total daily water demand for reuse assumed to be 90 gal/day
5. Using daily rainfall data from OLGA station (Orcas Island)
Flow Control
OPAL – Evaluation of Cisterns for Reuse

Notes:
1. Average home size (995 sq. ft. roof)
2. Assume 4 people per house
3. Assume (2) 1,500-gal underground cisterns with indoor plumbing for toilet flushing, cold water for laundry, and irrigation
4. Total daily water demand for reuse assumed to be 58 gal/day
5. Using daily rainfall data from OLGA station (Orcas Island)
Flow Control
OPAL – Evaluation of Cisterns for Reuse

Notes:
1. Average home size (995 sq. ft. roof)
2. Assume 2 people per house
3. Assume (2) 1,500-gal underground cisterns with indoor plumbing for toilet flushing, cold water for laundry, and irrigation
4. Total daily water demand for reuse assumed to be 29 gal/day
5. Using daily rainfall data from OLGA station (Orcas Island)
Flow Control
OPAL – Residual Flow Control and WQ Treatment

- Modeling Approach
  - Continuous hydrologic model
  - Larger sites → can lump total roof area and route through equivalent lumped cistern
  - Smaller sites → can explicitly model individual cistern performance within site-wide model
Detention Cistern Example
Peak Reduction/ Flow Control

Lakewood RainCatchers, Seattle
Lakewood RainCatchers Project

SPU pilot project to reduce CSOs

75-acre residential neighborhood

300 homes

BMPs
  • Cisterns
  • Rain gardens
Peak Reduction

- Partially combined system
  - Roofs to combined
  - Streets to separated

- Combined system modeled in InfoWorks CS
Peak Reduction

Cistern areas

Rain garden areas
Peak Reduction

Cistern modeling method

- Typical rooftop / cistern scenario for individual home modeled in WWHM3
  - Half roof (870 sf) routed to cistern (500 gallon)
- Detained runoff timeseries exported and multiplied by the number of homes in the basin
- Imported into InfoWorks CS to evaluate performance
Peak Reduction

- Precipitation/Evap. Data \(\rightarrow\) Import timeseries from InfoWorks model
- Computational Time Step \(\rightarrow\) 15 minutes, 5 minutes preferred
Peak Reduction

Predeveloped Basin → Select area, soil type, land cover and slope
Peak Reduction

Developed Mitigated Basin → Impervious with same area and slope....
Peak Reduction

Developed Mitigated Basin Continued: Route to vault module
# Peak Reduction

## Stage Storage Discharge Table

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**Overflow**
Figure 17. Comparison of roof runoff detention benefits for cisterns with varying orifice sizes.
Peak Reduction

Figure 10. Performance of a cistern for a typical parcel

Flow to Combined Sewer (cfs)

Rainfall (inches)

Unmitigated Rooftop Runoff
Detained by Cistern
Precipitation
Peak Reduction

Time Series Export
Peak Reduction

Time Series Import to InfoWorks
Peak Reduction
Time Series Import to InfoWorks
Peak Reduction

Preliminary Results, Basin-Wide InfoWorks Model

The graph shows the relationship between the percent of rooftop area detained using cisterns and the modeled reduction in in-sewer peak flow and average annual CSO volume. The blue line represents the modeled 10% reduction in average annual CSO volume, while the green line represents the modeled 50% reduction. The x-axis represents the percent rooftop area detained, and the y-axes show the average annual CSO volume (Mgal/year) and in-sewer peak flow (MGD).
Resources

- **LID Technical Guidance Manual**
  (Draft 2012 Manual does not yet have modeling section developed)

- **WWHM**

- **MGSFlood**

- **HSPF**

- **WDMUtils**
  [http://www.epa.gov/waterscience/basins/b3webdw.htm](http://www.epa.gov/waterscience/basins/b3webdw.htm)
Questions and Answers

???
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