Catchment-Scale Evaluation of Stormwater Green Infrastructure Using a Flexible Surface-Subsurface Interaction Model

Mohammad Almadani  
PhD candidate CUA, King Abdulaziz University

Arash Massoudieh  
PhD Civil Engineering Department chair, CUA

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Content Layout

• Background
  - Urbanization and natural system
  - Storm water
  - GI and modeling

• Problem statement
  - Complexity of the natural system
  - GI modeling limitation

• Research Objective

• Methodology
  - Site selection: Sligo Creek details
  - Geospatial model GIS
  - Data process & preparation
  - GIFMod Model

• Conclusion
The urbanization changes the nature of the land

Negative impacts: impervious surfaces ++ (buildings, rooftops, roads, parking lots, sidewalks)

preventing water to infiltrate and recharge - high stormwater peak flows – flooding – erosion – enormous pollutant
Main impacts of urbanization on the generalized hydrograph

- Shorter time to peakflow
- Increased peakflow
- Higher peakflow
- Lower baseflow
- Baseflow or groundwater recharge
- Stormwater runoff

Flow vs. time graph showing the differences between natural and urbanized watersheds.
Earth's climate is changing

- Temperatures are rising
- Precipitation patterns are shifting
- More extreme climate events

Jeddah City

- 2nd largest
- 4m people
- Saudi Arabia's commercial capital
- 600 sq mi

More than $1 billion in last 2-3 years
For 100s km of stormwater drainage system
1 inch of rain on Jeddah
Generates more than 10 billion gallons stormwater
Conventional Drainage system

Collect & transport quickly
Connecting impervious surfaces

to address
deficits in drainage system
climate change impacts

Urbanization
Climate change

High flooding pea degrading watershed

Green Infrastructure
Green Infrastructure

- GI is a sustainable method of Best Management Practices (BMP) to manage stormwater referred to as low impact development (LID) practices.

- maintaining the site hydrology patterns close to the predevelopment condition.

- GI treats runoff close to where it is generated.

- decreasing runoff volume and peaks, reduce pollution and other impacts.

- GI is designed to promote retention of water and infiltration into the ground.

Re-connecting the pervious surfaces
Hydrological Modeling

mathematical conceptualization of a real world water system
to be similar but simpler contracture
Urbanization impervious

Precipitation

Runoff/low quality

Gray drainage system

Result in

Higher runoff pick and volume
Erosion
Deterioration of watershed quality

New approach
Need more understanding and details
For future prediction & optimum design

Evaluation by modeling

GI practices

Result in
Research Goal

Evaluation the long-term effects of GI in Catchment-scale

Subobjectives:

• Building a new comprehensive model

• Simulate GIs mechanism & interaction with different media including:
  ✷ generation of runoff;
  ✷ interaction between surface and groundwater;
  ✷ Contaminants transport and fate
Building 3 framework models

1. Pre Development Land
2. After Development Surfaces
3. Post GI Implement
Sligo Creek, MD

- Tributary of the Anacostia River
- Length: 9.1 miles
- Precipitation: 40 inches
- Water temperature: 0°C – 25°C
- Impervious area: 34%
Geospatial model (GIS)

Representing digital model parameters (raster/vector):

- topography
- vegetative
- land use/cover
- soils
- impervious areas

**DEM maps**

- Download Satellite images
- High resolution
- Unify units
- Combine different image
- Extract the targeted area
Watershed Delineation

- Fill & sink
- Flow direction
- Flow accumulation
• Delineate the watershed

• Discretize to sub-watersheds
Elevations

Streams segment length

Centroid and gages

Areas (total/ imp/perv)

Interface area
Data process: accept format – convert units – create time series
Conceptual model GIFMod

• GIFMod: flexible framework for modeling
• Multi-dimensional hydro/quality within GI practices (with level of complexity)
• Using scripts/graphical interface
• Conceptualize spatial/temporal features (hydrology/water quality)
• Using blocks to represent these features
• Connecters between blocks:
How the model work?
• Using equation that express Head relationships:
For blocks: head-storage
For connectors: head-flow
The equations:

- Van Genuchten-Maulem for unsaturated media
- Darcy for saturated porous media & storage
- Diffusive wave (DW) for surface water components including streams, ponds and overland flow

Calculating (evaporation and evapotranspiration):

- Penman model
- Priestly-Taylor model
- Aerodynamic model
- Assign new equation (function of moisture content, light intensity, temperature, wind and humidity)
Water Quality

Reaction fundamental: Chemical balance equation

Total concentration rate = Rate income – Rate outcome +/- source/sinks
Calibration

Observation Vs Observed
Validation
calibration/validation - annual flow and correlation coefficients

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<th>Mean Observed Annual Flow (inches)</th>
<th>Mean Simulated Annual Flow (inches)</th>
<th>R Average Daily</th>
<th>R Average Monthly</th>
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Evapotranspiration
Flow Catch-stream
Soil Moisture Content
PHASE 4

Running results
Results interpretation
Invers modeling

- For best parameters estimation
- Using Genetic Algorithms $\Rightarrow$ point estimate
- Using Markov Chain Monte-Carlo $\Rightarrow$ Probabilistic

Auto Calibration
Future work

- Site selection
- Geospatial model
- Data process
- Create the Model
- Calibration
- Validation
- Quality
- GI
- Evaluation
Green Infrastructures

• 1) The ones make water is diverted to/from impervious areas like, dry/wet ponds, bioretention, infiltration basin/trench; and

• 2) The ones turn impervious surface to pervious such as green roof and permeable pavement.

• 3) combination between techniques and numbers
Expected results & sensitive Interpretation

Selection of input variables that have the greatest impact on the outcomes of interest
quantify the range of likely outcomes, and likelihood of each outcome
Eliminating redundant uncertain inputs

Determination of parameters sensitivity

<table>
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<tr>
<th>% change of output</th>
<th>% change of Q</th>
<th>% change of input</th>
<th>% change of Area</th>
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</table>

aggregate measures: Comparing multi scenarios

output time series (peak, total volume, % quality, avg. concentration, loading, head ........)
Conclusion

• Enhance the understanding & predicting behavior of the GIs practices mechanisms
• Increasing the fidelity of the model by explicitly including important components
• Gaining better understanding of how GIs process interact with the watershed
• Evaluating GI performance for:
  - Hydraulic process
  - Contaminants transport and fate

First attempt of new model with noticeable features:
  - hybrid between lumped and distributed model
  - invers modeling and auto calibration

Capability to use the model for arid regions (Jeddah) depending how fast
We All live Downstream

Thank you...