Selection of Modeling Tools for Sustainable Stormwater Management

Hosted by the Stormwater Management Committee
March 10, 2010
Introduction –
Robert Murdock (Michael Baker Jr., Inc.)

Reasons for BMP Modeling Tools Selection Track

• Stricter, more far reaching stormwater requirements are likely to come soon
  • EPA initiate national rulemaking ([EPA–HQ–OW–2009–0817; FRL–9095–3])
NRCS Finding

“the rapid conversion of land to urban and suburban areas has profoundly altered how water flows during and following storm events, putting higher volumes of water and more pollutants into the nation’s rivers, lakes, and estuaries. These changes have degraded water quality and habitat in virtually every urban stream system.”
Reasons for Modeling Tools – cont’d

EPA Stated Objectives for Rule Making:

- Expand the area subject to federal stormwater regulations.
- Establish specific requirements to control stormwater discharges from new development and redevelopment.

Green Infrastructure for Clean Water Act: IEPA to deliver report to IL General Assembly by June 30 2010:

“Findings and recommendations for adopting an urban storm water management regulatory program in Illinois which includes performance standards and encourages the use of green infrastructure”
Outline for Presentation

Co Presenters – Erin Pande (ERA), Greg Kacvinsky (Foth)

1. Overview of RECARGA, WinSLAMM, SUSTAIN, and EPA SWMM.
2. Provide 6 short scenarios on considerations for program selection.
3. Provide two in-depth examples
Introduction –
Erin Pande (Engineering Resource Associates, Inc.)

Introduction to RECARGA
- Simple tool for Hydrologic modeling of Bio/Infiltration systems
  - Quantifies Ponding
  - Infiltration
  - Overflow
  - Et
  - Recharge
- Useful tool for impact analysis
  - Flexible – user inputs
- RECARGA does not model water quality
Introduction –
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM
  - (Source Loading And Management Model)
  - Ideal for watershed-wide nonpoint source pollution controls
    - Structural BMPs (Ponds, Bioswales, Filters, etc.)
    - Non-Structural BMPs (Street sweeping, impervious area disconnection, etc.)
Introduction –
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM (KEY INPUTS)
  - Drainage area
  - Pervious/impervious surface percentages
    - Connected vs. disconnected
  - Land uses (i.e. “source areas”)
  - Existing / proposed BMPs
    - Cost data for BMPs (if available)
  - Extended period rainfall file
Introduction –
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM (KEY OUTPUTS)
  - Pollutant concentration(s) at outfall
  - Pollutant yield(s) (lbs)
  - Runoff volume
  - Before/after comparison on impacts to receiving water
    - Removal efficiencies for individual BMPs
    - Cost efficiencies of individual BMPs
Introduction –
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- **WinSLAMM**
  - Computations based on decades of field data for pollutant buildup and BMP removal efficiencies
  - Mainly a planning tool, although it can be used for site-specific BMP selection and sizing
  - Used widely in Wisconsin
Introduction –
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- SUSTAIN (EPA)
  - System for Urban Stormwater Treatment and Analysis INtegration
  - Similar to WinSLAMM
  - Planning tool for BMP selection and placement on a watershed scale
  - Cost-effectiveness analysis
  - GIS interface
Introduction –
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- **SUSTAIN (EPA)**
  - Version 1.0 available on EPA’s website
    - Includes flow routing (uses EPA SWMM engine)
    - Sediment transport
    - BMP Optimization (load reduction vs. cost)
    - Scaled use from individual sites to community-wide watersheds

*Image Source: US EPA*
Introduction –
Robert Murdock (Michael Baker Jr., Inc.)

- EPA Storm Water Management Model (SWMM) Capabilities
  - Dynamic rainfall-runoff simulation model
  - Single event or long-term (continuous) simulation of runoff quantity and quality
  - Intended for urban areas
  - Full hydrology and hydraulics capabilities
  - Models water quality, infiltration, and snow melt.
Introduction –
Robert Murdock (Michael Baker Jr., Inc.)

- EPA Storm Water Management Model (SWMM) – Uses
  - Evaluate Best Management Practices (BMPs)
  - Design and size drainage system components (including detention)
  - Analyze combined and sanitary sewer overflows (CSOs and SSOs)
  - Generate non-point source pollutant loadings for wasteload allocation studies
  - Flood plain mapping of natural channel systems
Introduction –
Robert Murdock (Michael Baker Jr., Inc.)

- Key differences between models
  - WinSLAMM, SUSTAIN
    - WinSLAMM is a **proprietary model**
    - Primarily intended for watershed-wide planning
    - Decision support systems
  - RECARGA
    - Infiltration BMP sizing and design
    - Event-based and continuous simulation
    - Underdrain function
  - EPA SWMM
    - Full hydraulics and hydrology
    - Ideal for collection system design *and* BMP sizing/design
    - Event-based and continuous simulation
    - Primarily for urban watersheds.
Application Examples–

- Site #1: 28-lot single-family residential development: design for local stormwater management requirements
  - EPA SWMM
  - Why use this model?
Factors: Detention, Wetland, Water Qual Vol Capture

Existing Stream

Wetland

Proposed Detention

Proposed Bioretention Filters

Offsite Runoff
Total Washoff of Available Buildup

Buildup and Washoff Functions for Pollutants
Application Examples–

- Site #2: 10-acre commercial redevelopment
Application Examples–

- Site #2: 10-acre commercial redevelopment: design bioretention to meet local stormwater quality requirements
- RECARGA: Why use this model / why not use others?
  - Easy to determine required area needed for BMP
  - Local MS4 Permit requires treatment of water quality storm
  - Detention basin is pre-existing
Application Examples–

- Site #3: Urbanized watershed: develop Watershed Master Plan to satisfy MS4 Notice of Intent
- WinSLAMM
- Why use this model / why not use others?
  - Local MS4 Permit requires % reduction in TSS over next 5 yrs
  - Need to evaluate City-wide BMPs (both structural and non-structural)
  - Evaluate cost-effectiveness of BMPs
  - No design-level effort necessary at this stage (planning only)
### WinSLAMM Input

- 5-year rainfall data set
- Pollutant loadings based on field research

**Current File Data**

<table>
<thead>
<tr>
<th>SLAMM Data File Name:</th>
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<tbody>
<tr>
<td>X:\GB\IE\2008\08B012\SLAMM Modeling\Bellevue MS4 Subbasin E2.22 Existing.dat</td>
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<tr>
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<table>
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<tr>
<td>End of Winter (mm/dd): 03/29</td>
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### Additional Files

- Pollutant Probability Distribution File: C:\Program Files\WinSLAMM\WI_GEO01.ppd
- Runoff Coefficient File: C:\Program Files\WinSLAMM\WI_SL06_Dec06.rsv
- Particulate Solids Concentration File: C:\Program Files\WinSLAMM\WI_AVG01.psc
- Particulate Residue Delivery File: C:\Program Files\WinSLAMM\WI_DLV01.prr

### Street Delivery File (Select LU)

- Residential LU
- Institutional LU
- Other Urban LU
- Commercial LU
- Freeways

### Drainage System:

- Data Entered
WinSLAMM Input

- Land uses and corresponding areas defined
- Each Source Area has its own pollutant buildup profile
- Each Source Area has other key characteristics:
  - Disconnected impervious areas
  - Existing BMPs

<table>
<thead>
<tr>
<th>Source Area No.</th>
<th>Source Area</th>
<th>Area (acres)</th>
<th>H</th>
<th>W</th>
<th>P</th>
<th>O</th>
<th>S</th>
<th>B</th>
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<td>Isolated/Water Body Area</td>
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<td>Other Pervious Area</td>
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<td>Other Part Cnctd Imp Area</td>
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</tbody>
</table>
WinSLAMM Output (Existing Conditions)

- Total pollutant yields (lbs)
- Can break out data per pollutant type
- Sets benchmark for future pollutant reduction
WinSLAMM Output (Future Conditions)

- 82% reduction in solids
- Controls reduce particulate concentration from 162 mg/L to 33 mg/L
- BMP cost data can be added for additional planning tool
Application Examples–

- Site #4: Small Municipal Project
Application Examples–

- Site #4: Small Municipal Project
  - RECARGA – Cosley Zoo
  - Why use this model / why not use others?
Application Examples–

Site #4: Small Municipal Project

Cosley Zoo Parking Lot Expansion
Wheaton Park District
Application Examples—

- Site #5: Municipality (10,000 pop.) with 3 separate watersheds: analyze impacts of City-wide stormwater quality BMPs on receiving streams (local TMDL issues)
  - WinSLAMM
  - Why use this model / why not use others?
    - WinSLAMM can model removal efficiencies for multiple pollutants, especially those typically found in TMDLs
Application Examples–

- Site #5: Municipality (10,000 pop.) with 3 separate watersheds (WinSLAMM):
  - Watershed 1: Heavy industrial area developed before detention regulations (TMDLs: Lead, Zinc)
  - Watershed 2: Developing area with significant ongoing construction (Potential for innovative design by coordinating with developers)
  - Watershed 3: Commercial / Residential mix (TMDL: Total Nitrogen)
Application Examples–

- Site #5: Analyze Watershed-Specific Solutions (WinSLAMM)
  - Watershed 1: Reduce heavy metals: targeted wet detention, facility pavement sweeping, targeted mechanical separation (swirl concentrators)
  - Watershed 2: Opportunity for application of newer stormwater management techniques (i.e. bioretention)
  - Watershed 3: Reduce Total Nitrogen: street sweeping, impervious area disconnection, targeted rain gardens, detention pond retrofits
Application Examples–

- Site #5: Analyze Watershed-Specific Solutions (WinSLAMM)
  - Total cost of BMPs per watershed
  - Evaluate cost effectiveness of recommended BMPs
    - Prioritize BMPs based on cost-effectiveness
  - Locate and determine preliminary size for each BMP
  - Update land development ordinances
  - Submit materials for regulatory review
Application Examples—

- Site #6: 640 acre mixed use watershed
  - EPA SWMM – Show Dynamic flood modeling combined with Pollutant reduction measures
Local Flooding

Frequent Flooding of Commercial Establishment

Frequent Roadway Overtopping

Culvert Opening Downstream Invert
Significant Storage and Dynamic Flow Situations

Base Flow Path

Flood Path

Major Road

Split Flow

Homes in Floodplain

Base Flow Path

[Image of a map with labeled areas such as Base Flow Path, Flood Path, Major Road, Split Flow, Homes in Floodplain, and Water Tank]
Proposed Stormwater Wetland

Culvert Increase
Modeling Examples—
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential development
  - Model: EPA SWMM
  - Model demonstration
    - Key data needs
    - Model structure and input data
    - Design alternative analysis using model
    - Output data and interpretation
Modeling Examples—
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
  - Data Needs:
    - Basic hydrologic variables
      - Drainage areas
      - % Impervious
      - % Disconnected Impervious
    - Bioretention storage volume
    - Soil boring data (CRITICAL FOR BIORETENTION DESIGN)
      - $K_{sat}$
Modeling Examples—
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

Runoff Calculations in EPA SWMM

<table>
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<tr>
<th>CN=74</th>
<th>CN=98</th>
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OUTLET
Modeling Examples—
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

Runoff Calculations in EPA SWMM

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<td>OUTLET</td>
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</table>

Disconnected Impervious Surfaces
Modeling Examples--
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- **EPA SWMM**
  - Hydrology relies on the *Distributed CN Approach*
  - *Composite CN Approach* is not necessarily appropriate for small storm hydrology

<table>
<thead>
<tr>
<th>Approach</th>
<th>Area (acres)</th>
<th>Curve Number</th>
<th>Description</th>
<th>Runoff Depth (in.)</th>
<th>Runoff Volume (ac-ft)</th>
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<tbody>
<tr>
<td>Composite CN</td>
<td>20</td>
<td>75</td>
<td>¼ acre lots, 38% impervious, SCS Soil Type B</td>
<td>0.1</td>
<td>0.17</td>
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<tr>
<td>Distributed CN</td>
<td>6</td>
<td>98</td>
<td>Paved roads, rooftops</td>
<td>1.08</td>
<td>0.54, 0.55</td>
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<tr>
<td></td>
<td>14</td>
<td>65</td>
<td>Green spaces with disconnected impervious area interspersed</td>
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<td>0.01</td>
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</tbody>
</table>

*Source: Stormwater Magazine, March-April 2010*
Modeling Examples—
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

Bioretention Modeling

Ideal location for infiltration BMPs?

Depends on the soil characteristics
Modeling Examples—Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- **Geotechnical data**
  - S-1: Silty loam, Ksat <0.50 in/hr
  - S-2: Clayey Silt, Ksat <0.10 in/hr
  - S-3: Clayey Silt, Ksat <0.20 in/hr
  - S-4: Silty Clay, Ksat <0.05 in/hr
  - S-5: Silty Clay, Ksat <0.1 in/hr
  - **Water table for all samples generally between 12 -20 feet below the surface**

<table>
<thead>
<tr>
<th>VISUAL SOIL CLASSIFICATION</th>
<th>Sample</th>
<th>N</th>
<th>Qs (MP)</th>
<th>Qd (MP)</th>
<th>HEC (ft)</th>
<th>Dth (ft)</th>
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<td>1-AU</td>
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<td>27</td>
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</tbody>
</table>

END OF BORING AT 21.5 FEET
Modeling Examples–
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
  - Model Structure / Input Data:
    - Distributed CN approach
      - Consider compacted soils (SCS Soil Type B → C ?)
    - Bioretention storage volume and infiltration rates
    - Rainfall data (Huff 1st and 3rd distributions, continuous data set)
    - Evaporation data
    - Hydraulic connections (bioretention overflow to detention pond)
Modeling Examples—

- Bioretention modeling:
  - Establishing infiltration criteria
    - Green-Ampt method
      - **Conductivity (in/hr):** Ksat (saturated soil conductivity)
        - MOST IMPORTANT VARIABLE
        - Should be at least 0.3-0.4 in/hr for effective infiltration
      - Suction Head (in): capillary suction
        - Higher for fine-grained soils
      - Initial deficit (fraction): lower for saturated soils
        - Typically 0.2 – 0.5 (lower for wet soils)
EPA SWMM uses $K_{\text{sat}}$ for bioretention drawdown, although amended soils (and vegetation) may increase infiltration potential.
EPA SWMM uses bottom contour to apply infiltration

BIORETENTION STORAGE

AMENDED SOILS (DEPTH 3+ FEET)

IN-SITU SOILS
Ksat
Modeling Examples–
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

• Site #1: 40-acre single-family residential (EPA SWMM)
  • BMP performance measures:
    • Water quality event (i.e. 1-yr, 2-yr)
      • Example: 1-inch, 1-hour storm (zero runoff)
    • Continuous Simulation (1 year of rainfall data)
      • Maintain % of pre-development runoff (i.e. 90%)
  • Design Alternative Analysis:
    • Vary bioretention footprint size
    • Adjust % disconnected impervious area
    • Wet / dry detention pond (infiltration / evaporation)
Modeling Examples—
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
- Output data interpretation:
  - No impervious disconnection
  - 50% of impervious area routed to pervious area
Modeling Examples–
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
Modeling Examples–
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development
Modeling Examples–
Erin Pande (Engineering Resource Associates, Inc.)

• Site #2: 10-acre commercial re-development
  • Key data needs
    • What are you designing the bio-infiltration for?
      • Specific storm event (e.g. in DuPage 2yr 24 hr, 3.04in)
      • Reduced percentage of runoff from impervious area (e.g. in Wisconsin post-development infiltration volume shall be at least 90% of the pre-development infiltration volume, based on an average annual rainfall)
Site #2: 10-acre commercial re-development

- Model structure
  - Continuous Simulation—Model-generated runoff
  - Design-Storm—SCS Type I, IA, II, III
  - Green-Ampt infiltration model for initial infiltration into the soil surface
  - Van Genuchten relationship for drainage between soil layers
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial development
- Input Data
  - Tributary Area
  - Percent Impervious
  - Pervious CN (not composite CN)
  - Precipitation Input Files (if using user specified data)
  - Saturated Hydraulic Conductivity of underlying soils
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial development
- Determine area needed for bio-infiltration facility
  - Assumes event based (2yr 24hr event)
  - Tributary area = 10 acres
  - Percent Impervious = 98%
  - Pervious CN = 78
  - Approximate depths and materials to be used in facility
  - $K_{sat}$ of underlying soils = 0.4 in/hr
Modeling Examples–
Erin Pande (Engineering Resource Associates, Inc.)

- Existing
  - 2yr 24 hr storm (3.04 in) Design-Storm–SCS Type II
  - Must input 1 ft for facility or you will get an error
  - Tributary area = 10 acres
  - Percent impervious 90%
  - Pervious CN = 78
  - Existing Infiltration = 0.3123
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

- Existing
  - Eliot Silt Loam
  - $K_{sat} = 0.2-0.6$
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

- Determine Facility Area Ratio for new developed area
- 2yr 24 hr storm (3.04 in) Type II
- Redevelopment area = 1.6 acres
- Percent impervious 100%
- $K_{sat} = 0.4$ in/hr
- Target infiltration (3.04 in + 0.3123 in) = 3.3523 in
- $FAR = 0.3123$
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

- Proposed Facility
  - 3.35 in Type II
  - Redevelopment area = 1.6 acres
  - Percent impervious 100%
  - $K_{sat} = 0.4$ in/hr
  - Infiltration = 3.35 in

RECARGA Version 2.3
Bioretention/Raingarden Sizing Program

.Files
Regional Ave. ET: 0.13 [in./acre]
Simulation Type: Single Event
Rainfall Distribution: T∽Rain
Rainfall Depth: 2.5623 [in.]
Output File Name: T∽Rain22

.Rocks
Soil Texture: Clay Loam
Hydraulic Conductivity: 0.31 [in./hr]
Thickness: 24 [in.]

.Storage Zone
Sand: 5.91 [gpm]
Diam. 48 [in.]

.Limiting Subsoil Layer
Silt Loam: 4 [in.]

.Results
Plant Survivability
[Less than 48 hours max., ponding desirable]

<table>
<thead>
<tr>
<th>Rainfall</th>
<th>Runoff</th>
<th>Infiltration</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3523</td>
<td>0.000</td>
<td>3.3523</td>
</tr>
</tbody>
</table>

Raingarden Water Balance

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<tr>
<th>Rain</th>
<th>Runoff</th>
<th>Redep</th>
<th>Evapot</th>
<th>Underdrain</th>
<th>Soilt</th>
<th>Stay-on</th>
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</thead>
<tbody>
<tr>
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<td>1.7255</td>
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<tr>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Developed by the University of Wisconsin Madison
CIV & Environmental Engineering Water Resources Group
(D. Althoff, A. Dussault, L. Savvarion)

[Button: RUN SIMULATION]
[Button: CLEAR RESULTS]
Modeling Examples–
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development
Modeling Examples—
Erin Pande (Engineering Resource Associates, Inc.)

Existing = 740,700 gallons
Proposed = 430,100 gallons

- Comparison of results of existing 10 acre development vs. proposed 1.6 acre re-development with full 10 acres tributary to bio-infiltration practices
Choose vegetation that will withstand depth and duration of proposed ponding.
Recap and Close – Q&A