SWMM
(Storm Water Management Model)
Simulation of Watershed Hydrology and Hydraulics

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Agenda

- Basics of SWMM
- Data Requirements
- Model and Version Selection Considerations
- SWMM Project Applications
Storm Water Management Model

- Originally built to analyze urban drainage and sewer networks - 1971
- Enhancements have broadened applicability
- Integrated hydrology, hydraulics and water quality
- Version 4.4h (FORTRAN; OSU) and Version 5.0 (C/C++; EPA) both currently supported – more on this later
Hydrologic Capabilities

- Time-varying rainfall
- Evaporation of standing surface water
- Snow accumulation and melting
- Rainfall interception from depression storage
- Infiltration of rainfall into unsaturated soil layers
- Percolation of infiltrated water into groundwater layers
- Interflow between groundwater and the drainage system
- Nonlinear reservoir routing of overland flow.

Source: SWMM 5.0 User’s Manual
Hydraulic Capabilities

- Handle drainage networks of unlimited size
- Use a wide variety of conduit shaped, including user-defined
- Model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- Apply external flows and water quality inputs from a variety of sources
- Utilize either kinematic wave or full dynamic wave flow routing
- Model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- Apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels

Source: SWMM 5.0 User’s Manual
**Built-in WQ Capabilities**

- Dry-weather pollutant buildup over different land uses
- Pollutant washoff from specific land uses during storm events
- Direct contribution of rainfall deposition
- Reduction in dry-weather buildup due to street cleaning
- Reduction in washoff load due to BMPs
- Entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system
- Routing of water quality constituents through the drainage system
- Reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels

Source: SWMM 5.0 User’s Manual
Data Requirements

- Consider available data, scale of model, desired results

Are we here? Or here?
**Data Requirements**

**Always need** (developed watershed example):
- Climatic data – rainfall and ET
- Catchment data
  - Topography – at least conceptual – gives slope, drainage pattern, etc
  - Impervious surfaces,
  - Roughness, depression storage, infiltration, internal routing
- Routing data – at least qualitative
- BMP data – at least qualitative – use to form generic representation
- Run Controls – time step, recording interval, output interval
- Basic validation data
Data Requirements

Can utilize (developed watershed example):
- Climatic data – add snowfall/temperature if snow is a factor
- Catchment data
  - Scale – as small as you need to go
  - Impervious surfaces – define as separate catchments if necessary
  - Infiltration incorporating groundwater simulation
  - Water quality simulation
- Routing data – detailed definition of drainage system, open channels, river systems (SWMM 5 certified for FEMA NFIP Studies), water quality routing data
- BMP data – incorporate BMP shape, detailed routing schematics, BMPs in series or parallel, water quality changes in BMPs
Key SWMM Features

- Nonlinear reservoir surface routing
  - Catchments to catchments
  - Catchments as BMPs
- Horton or Green-Ampt Infiltration (Curve Number for SWMM 5)
- Discrete particle settling (SWMM 4.4h) – densities or settling velocities
- Fully dynamic routing – more uses than just pipe networks

Nonlinear Reservoir
Continuity Equation coupled with Manning’s Equation

Model Selection

- What is your scope?
  - Is there potential for it to expand?
  - What type of output do you need?
- What data do you have to build/calibrate/verify?
  - Spatial/Temporal Resolution
- What conditions do you want to model?
  - Arid/Humid; Perennial Flow/Intermittent Flow; Urban/Disturbed/Natural
Advantages of SWMM

- Designed for continuous simulation (encompasses any single-event simulation)
- Accommodates most levels of available data – can obtain meaningful results with very rough to very refined inputs
- Hydraulics are robust for collection, treatment, channel impacts
- Catchment hydrology well-suited to aggregation; linked catchments
- Hortonian overland flow - volumes of published data; applicable for arid to semi-arid areas – much of CA.
- Open source code – both versions
Quick Notes on Versions

- Set-up and Interfacing – biggest difference
  - SWMM 4.4h and earlier – Blocks
  - SWMM 5.0 and future - Integrated
- SWMM 5 comes with GUI
- SWMM 5 allows fractional routing of overland flow (possible but more difficult in 4.4h)
- SWMM 5 does not support particle settling (yet)
- EXTRAN in SWMM 4 does not support WQ routing
- Data input and computation methodology are nearly the same
Quick Notes on Versions
Quick Notes on Versions
Project Applications

- Planning Level Design Tools
  - WQ BMP Sizing
  - FDC Basin Sizing/In-stream Controls
- Hydrologic and Hydraulic Design of Drainage/Treatment
  - New Development
  - Redevelopment
  - Retrofits
- Support for Water Quality Impact Analysis
- Support for Hydromodification Analysis
Planning Level Design Tools

- Need to be usable by planners/designers
- What do planners need to know?
  - What design requirements make sense
  - Area requirements for treatment/flow control
  - Impact of distributed BMP implementation
  - Parameter sensitivity
  - Costs
- How can SWMM help?
  - BMP sizing nomographs – when designing to percent capture criteria
  - LID effect nomographs
  - Sensitivity analyses
  - Build look-up tables
  - Packaged tools – run SWMM “on the fly”
Planning Level Design Tools

BMP Sizing Nomographs

- Set catchment properties
- Vary sensitive parameters (imperviousness, infiltration rate)
- Set BMP design standards
- Vary sensitive parameters (allowable ponding depth, filtration rate)
- Batch process using Excel, VBA, and SWMM
Planning Level Design Tools

Nomograph Applications

- WERF Critical Assessment of Stormwater Treatment and Control Selection Issues –
  - Swales, basins
  - 30 rain gauges around the country
  - Nomograph results for volumetric capture and particle removal
  - Greater than 10,000 SWMM runs
- Development/Retrofit WQ Planning
  - Swales, basins, bioretention
  - Give flexibility to designers, preserve integrity of design
  - Assess feasibility w.r.t area constraint
- LID Effectiveness Nomographs
  - How does disconnected imperviousness correspond to volume reductions, downstream BMP size
  - How can cisterns be best applied to reduce downstream BMP size, protect receiving water

Source: Critical Assessment of Stormwater Treatment and Control Selection Issues, WERF, 2005
Planning Level Design Tools

Hydromodification Planning

- Develop nomographs for FDC basin size (all “uphill” control)
- Analyze various intermediate levels of control down to minimum WQ requirements
- Couple continuous sim hydrographs from SWMM with Ep analysis to determine “instream” controls needed
- Help decide how to direct future design
Project Design Applications

Hydrologic and Hydraulic Design

- Design drainage system
  - Pipe sizes, splitter/diversion structures
- Design BMPs
  - Shapes, volumes, areas, outlet structures
- Evaluate drainage system performance
- Evaluate BMP hydraulic performance
  - BMPs in series, off-site drainage systems
- Evaluate pollutant loads and reductions (possible)
Project Design Applications

Drainage and BMP design examples

- Flow-splitter, outlet structure design
- Treatment trains; separating basins into parts
- Inundation frequency in multi-use basins
Project Design Applications

Drainage and BMP Design Examples

- Inundation frequency in multi-use basin

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For illustration purposes only – please do not duplicate
Drainage and BMP Design Examples

- Integrated treatment-train design

Diagram:
- Urban Runoff
- Bioinfiltration Swale
- F.D./W.Q. Basin
- Infiltration Basin
- Storage Non-Potable
- Export out of Sub-basin

Flow:
- Urban Runoff to F.D./W.Q. Basin
- F.D./W.Q. Basin to Bioinfiltration Swale
- Bioinfiltration Swale to Storage Non-Potable
- Infiltration Basin
- Export out of Sub-basin
Project Design Applications

Drainage and BMP Design Examples

- Integrated treatment-train design
Project Design Applications

Hydromod Analysis and Channel Design

- Use SWMM to predict channel discharge in existing and proposed conditions
  - Provides long-term statistical description of channel flowrates – may be used to estimate higher frequency events (2-yr or 5-yr peak flows)
  - Accounts for effect of “uphill” hydromod controls (infiltration basins, distributed BMPs), routing of BMP discharge
  - Dynamic wave routing in channel
  - Provides continuous flow record for use in Erosion Potential analysis and/or hydraulics models (HEC-RAS, etc)
WQ Analysis Applications

Built-In Water Quality Functions

- Define build-up/wash-off relationships by land use
- Route pollutographs in pipes, channels, BMPs
- Define treatment in pipes, channels and BMPs
  - Percent removal
  - Effluent concentration
- Discrete particle settling
Critical Support for Empirical WQ models

- Empirical WQ models utilize measured runoff concentrations and BMP performance.
- Proposed condition hydrology and hydraulics can’t be measured. Thus SWMM is used to:
  - Refine estimates of runoff volumes and quantify variability in hydrology.
  - Estimate hydraulic performance of BMPs - Capture efficiency, volume reduction.
Modifications

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- Account for infiltration in channels and BMPs
- Account for irrigation input
- Track and record residence time in BMPs, compute averages
- Output processing
  - Flow Duration Curves
  - Others in the works
Summary

- SWMM is a model for many applications
- Model selection should consider available data and required output
- Models should be used as tools, not hindrances
- Many models provide great utility, SWMM is one

Thanks for your time!
Questions?

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