GreenPlan Modeling Tool User Guidance

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1. INTRODUCTION

The modeling tool of the GreenPlan-IT toolkit is a spatially distributed hydrologic and water quality model that simulates runoff quantity and quality from primarily urban areas as well as hydrologic performance of Green Infrastructure (GI). The tool is built upon the publicly available EPA Storm Water Management Model (SWMM) (Rossman, 2010), a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality and is used for planning, analysis and design related to stormwater runoff management, combined and sanitary sewers, and other drainage systems in urban areas. Within the toolkit, this tool is used to establish the baseline hydrology and water quality conditions through the characterization of the modeled watershed before any new management activities are implemented; identify high-yield runoff and pollution areas; and evaluate relative effectiveness of implementing GIs across different areas within a watershed, based on their potential for reducing runoff volume or contaminant loads.

The modeling tool currently utilizes three modules of SWMM: (1) the hydrological module; (2) the pollutant module; and (3) the GI module. The hydrologic and pollutant modules are used to simulate the generation, transport, and fate of stormwater runoff and associated pollutants from the landscape. The GI module utilizes stormwater runoff from the hydrologic module as the forcing function for GI simulation to estimate any reduction made from GI implementation by performing without and then with the GI scenarios simulation.

Since SWMM is an established public domain model, users of GreenPlan-IT can obtain existing SWMM documentation from the EPA SWMM website (briefly discussed in next section) for guidance on how to set up and run the model. As such, this manual will not provide a detailed description of SWMM, its strengths and weaknesses, or software and hardware requirements, nor step by step instructions on model setup as a regular user manual would do. Rather, it will focus on providing guidance on model development and application. Before running GreenPlan-IT, users should familiarize themselves with the SWMM user guidance.

The Green Plan-IT modeling tool is intended for knowledgeable users familiar with technical aspects of watershed modeling more generally and SWMM ideally.

2. DOWNLOAD AND SET UP SWMM

The SWMM installation program, user's manual, as well as source code are available at the EPA SWMM website: http://www2.epa.gov/water-research/storm-water-management-model-swmm. Users can follow the instructions provided at this link to download and install SWMM on a PC. In particular, users will need to download:

- Self-extracting installation program for SWMM5.0. Run this .exe file will install SWMM on a PC. The detailed instruction on model installation and pertinent software/hardware requirements are provided in the SWMM user manual.

- SWMM5.0 User's Manual. This is the main SWMM document that provides step-by-step instructions on how to set up and get started with SWMM, as well as detailed description on SWMM structure and various functionalities and options (graphical user interface, the project files, and how to build a network model of a drainage system, use the study area map, run a simulation, and the various ways to view model results).

In addition, users are strongly encouraged to download and go through the 'SWMM Applications Manual' to help expedite their use of SWMM. It contains nine worked-out examples that illustrate how to use SWMM to model some of the most common types of stormwater management and design problems. In some cases, advanced users may also want to download and manipulate the SWMM source code to meet their specific needs.

3. MODEL DEVELOPMENT

The model development for a SWMM application is similar to most watershed modeling projects and usually begins with collecting and reviewing input data, followed by setting up the model, and calibrating the model to match local data. Once the model development is completed, the model can then be used to answer management questions by simulating various management scenarios. In the case of this project, the developed modeling tool is used to drive GI simulation.

3.1 Input Data

The development of a hydrologic model requires all water sources and sinks to be included in the model. The data collection process involves a thorough compilation and review of information available for the study area. It generally includes gathering applicable regional and site-scale GIS data layers, digital elevation model (DEM) data, stream networks, soil, land use, critical source information, and monitoring data for calibration and validation. A summary of typical data needs for SWMM development is provided in Table 3-1.

Table 3-1. Typical Data Needs for SWMM Application

Data	Data Type	Need	Sources
Digital Elevation Data (DEM)	GIS Grid	Delineate study area into smaller subbasins	(http://seamless.usgs.gov/website/seamless/vie wer.php) or local sources
Stream Network	GIS shape file	Delineate study area into smaller subbasins	National Hydrography Dataset (NHD) from http://nhd.usgs.gov/data.html
Land Use	GIS Grid	Define land use distribution	National Land Cover Dataset (NLCD) (http://seamless.usgs.gov/website/seamless/vie wer.php) or locally derived
Soil Type	ASCII Text File	Determine the distribution of hydrologic soil group	STATSGO from http://water.usgs.gov/GIS/metadata/usgswrd/XML/muid.xml
Precipitation	ASCII Text File	Drive runoff simulation	Local rain gages or National Climatic Data Center (NCDC)
Meteorological Data	ASCII Text File	Required if snow melt is simulated	Local weather stations or NCDC (temperature, wind speed, snow melt)
Evaporation	ASCII Text File	Support runoff computation	Local weather stations or Californina Irrigation Management Information System (CIMIS) Reference Evapotraspiration
Pipes	Data Entry	Develop study area geometry for hydraulic simulation	Local planning agencies or public works (Shape and dimensions)
Flow	ASCII Text File	Calibrate and verify hydrologic simulation	USGS real time data (http://waterdata.usgs.gov/nwis/rt) or local sampling
Water Quality	ASCII Text File	Calibrate and verify water quality simulation	USGS surface water data (http://waterdata.usgs.gov/nwis/sw) or local sampling

3.2 Watershed Delineation

Watershed delineation is a process that divides a watershed into smaller sub-basins to analyze watershed behavior. Consistent with the lumped nature of the model, each sub-basin is modeled as a homogeneous unit with spatially averaged descriptive properties. Watershed delineation is normally done by GIS analysis using topographical data. The watershed delineation will establish a representation of the study area, and ideally, locally derived higher-resolution site scale data should be used. The proper spatial scale of a modeling project is usually determined through professional judgment and needs to take into account important factors such as the project goals, size of the study area, spatial scale of crucial input data, and model run time. For a stormwater management project, watershed delineation should strike a balance between a meaningful size of sub-basins for guiding GI implementation and demand on computer run time.

3.3 Hydrology Calibration

Similar to other modeling efforts, a critical first step for SWMM development is to calibrate the model using local data, before it is used by municipalities to simulate GI scenarios for their local watersheds. A hydrologic calibration is typically done by means of an iterative process of trial and error, by adjusting the parameters within the established range until modeled flow rates match the timing, magnitude, and total volume of the field-observed streamflow data. The model calibration is necessary to ensure that a representative baseline condition is established with a high degree of confidence in its applicability to form the basis for comparative assessment of various management scenarios.

SWMM is associated with a large number of spatially variable parameters that describe the characteristics of individual sub-basins. A subset of the model parameters associated with frequent storm events (impervious percentage, subcatchment width, Manning's roughness, depression storage, and soil infiltration parameters) are most sensitive and typically used as hydrologic calibration parameters. A brief discussion of each parameter follows.

- **Imperviousness**

The percentage of impervious area is often the most sensitive parameter, strongly influencing both total runoff volume and peak flows. The initial estimate of imperviousness is usually determined by GIS analysis of land use/land cover data. During calibration, the percentage of imperviousness is adjusted up/ down as necessary to be consistent with known conditions in the study area and to obtain a good adjustment of the hydrograph.

- **Subcatchment width**

The subcatchment width is computed by dividing the subcatchment area by the travel length. This is an abstract basin parameter and is commonly used as a "tuning parameter" for model calibration because of the uncertainty associated with determining the travel length of stormwater runoff. Increasing the travel length decreases the subcatchment width which creates a more attenuated response to storm events.

- **Manning's (surface) roughness**

Manning's roughness coefficient is used in SWMM for the routing of overland flows and has an influence on the timing of peak flows. Separate roughness coefficients are applied to pervious versus impervious surfaces. Typical values are as follows:
- *Impervious:* 0.015 (dimensionless)
- *Pervious:* 0.250 (dimensionless) or higher in heavily vegetated areas

Manning's n values are often assigned a default value (from typical value suggested in SWMM User Manual, GIS analysis of land cover type and/or literature review), and then adjusted within the range of the established values in the literature to ensure they are representative of current basin conditions.

- **Depression storage**

Depression storage refers to the storage depth associated with surface depressions that are filled prior to runoff. The potential depression storage is related to the surface roughness coefficient; thus, separate values are required for pervious and impervious surfaces. Typical values are as follows:
- *Impervious*: 0.1 inch
- *Pervious*: 0.2 inch

Depression storage affects sensitivity of runoff to precipitation and is negatively and weakly correlated to surface runoff. Adjusting this parameter could improve model performance, but the improvement is often limited.

- **Soil infiltration parameters**

SWMM offers three choices for modeling infiltration: the Horton's Equation, the Green-Ampt Method, and the Curve Number Method, each requiring a different set of input parameters. Regardless of the method used, the infiltration parameters are closely correlated to hydrologic characteristics of the soil groups. Regional data available from the NRCS in the State Soil Geographic Database (STATSGO) is commonly used in lieu of local soil information to determine the default values and allowable ranges for each parameter. The calibration process then involves varying the parameters within their defined bounds in an effort to optimize the model.

Other less sensitive parameters required by SWMM such as subcatchment slope and percent of impervious area with no depression storage can be assigned a default value based on recommendation from the SWMM User Manual, GIS analysis and/or literature review.

3.4 Water Quality Calibration

SWMM can simulate the production of pollutant concentrations and loads associated with stormwater runoff. The model is capable of analyzing the buildup, washoff, transport and treatment of a variety of water quality constituents such as sediment, heavy metals, and nutrient. Because the SWMM uses the buildup-washoff formulation that assumes urban runoff quality constituents behaving in some manner similar to "sediment" of sediment transport theory, it works well for constituents that are transported in solid form, either as particulates or by adsorption onto soil particles, but not for constituents that are transported primarily in a dissolved state, e.g., NO3. Water quality parameters are defined for buildup and washoff of each pollutant and include maximum surface build-up, surface build-up rate and wash-off coefficients. These parameters are land use specific and are primary parameters used for water quality calibration.

The water quality calibration is also made by means of an iterative process of trial and error, by adjusting the parameters within the established range, and comparing (numerically and graphically) the modeled results (usually pollutant concentrations) with the measured data, until a good fit is obtained. The water quality calibration has often proved more difficult than the hydrology calibration, due largely to the lack of high resolution calibration data, both temporally and spatially. Therefore, the calibration procedure should also incorporate the comparison of the outcomes with a reasonable conceptual understanding of the likely variation of pollutant sources, erosion, and transport processes in the landscape that is water quality parameter specific. The outcome of the water quality simulation should at least compare closely with this conceptual

model and follow the reasonable likelihood that pollutant production should vary more between each sub-basin than flow production. For example, flow production between sub-basins normally varies by 2-4-fold between the least to the most imperious sub-basins whereas it is not uncommon for pollutant loads to vary by any magnitude between sub-basins by 5-100-fold.

3.5 GI Simulation

SWMM can simulate the hydrologic performance of seven GI types: Permeable Pavement, Rain gardens, Green roofs, Street planters, Rain barrels, Infiltration trenches, and Vegetative swales (Rossman, 2010). The GI simulation is usually performed after SWMM is developed for a watershed using local data, to quantify any runoff reduction associated with GI implementation.

For SWMM to simulate a GI, users need to specify GI design, location, and treatment area within a watershed. The types of GI compartments are: storage, underdrain, surface, pavement and soil. GI controls are represented by a combination of these vertical layers whose properties are defined on a per-unit-area basis. These compartments are GI specific and the SWMM5 user manual (Rossman, 2010) provides a detailed description on the configuration of each GI type.

4. MODEL LIMITATIONS

Despite its capacities for addressing many stormwater problems, SWMM has a number of limitations that users need to be cognizant of before using the model.

- Although it has been widely used elsewhere, the model is not directly applicable to large-scale, non-urban watersheds, and performs best in urbanized areas with mainly impervious cover within drainage area of interest.
- The model is not applicable to forested areas or irrigated cropland because of lack of parameterization for evapotranspiration in the model.
- Water quality simulations follows a simple buildup-washoff process, as such, the model is best suitable for modeling pollutants in particle form or closely associated with sediment, and less applicable to pollutants in dissolved forms (i.e. nitrogen species).
- The model only computes sediment delivery from overland flow. The model does not contain mechanisms for sediment deposition and transport within a river channel.
- The model is currently only capable of simulating hydrologic performance of selected GI types. The mechanistic simulation of pollution reduction is not built into the model. Additional programing by the user is required for simulating load reduction within the GI types.

5. REFERENCES

Rossman, L. A (2010). Storm Water Management Model User's Manual, Version 5.0, U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/R-05/040.

USEPA (2011). Report on Enhanced Framework (SUSTAIN) and Field Applications for Placement of BMPs in Urban Watersheds, EPA 600/R-11/144. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.