Alternative Load and Load Reduction Models

This document provides a summary of some of the more common and publicly available (non-proprietary) watershed models that can be used as an alternative to the STEPL and Region 5 models for estimating annual nitrogen, phosphorous, and sediment loads and load reductions for entry into the Grant Reporting and Tracking System (GRTS). Except for the simple models, every model included in this document has the capability to evaluate the effects of implementing a BMP. For the simple models that do not provide this capability, the user may estimate the load reduction by multiplying the estimated loads with the pollutant removal efficiency of the BMP.

The models are grouped into three categories: simple, mid-range, and complex models. These models vary in data requirements, rigor of analysis, and the required level of effort and modeling expertise of the user. STEPL and Region 5 models data and modeling requirements are comparable to the simple models and GWLF. In fact, the algorithms that were used to estimate runoff, sediment delivery, pollutant loads, and load reductions are similar to the simple model and GWLF. The rest of the mid-range models and the complex models simulate runoff, sediment delivery, and pollutant transport in more detail spatially (e.g., grid cells), temporally (e.g., continuous hourly simulation), and by considering individual process components such as infiltration, evapotranspiration, and nutrient cycling. The simulation of BMP effects is also more detailed and integrally linked with the overall process simulation but is limited to the specific types of BMPs that are handled by the models. It should be noted that the continuous models (e.g., hourly or daily simulation) provide the capability to summarize the results in an annual basis, which is what GRTS requires. When using event-based models (e.g., for simulating individual representative storms during the year), the user should ensure that the results are extrapolated into annual basis (e.g., either by summing the results of all simulated events over the year, or multiplying the results of the representative storm by the average number of times it happens over the year) for purposes of entering the results into GRTS.

The following table shows a summary of the key distinguishing features of the different alternative models. The description of each model is intended to be generic and not pertaining to a specific version or enhancement of the model. The information in the table and the subsequent description of the models were taken mainly from EPA (1997), and WERF (2001). The reader is referred back to these references for more detailed information about each model, and other models that are not included in this document. When available, the model description refers to a Web site where a specific version of the model is available for download.

Models for Estimating Loads and Load Reduction

Model	Field or Watershed	Land Use	Pollutant	Event or Continuous	BMP	Data Reqt's	Level of Effort
Simple							
Simple Method	Watershed	Urban	N, P	Event		Low	Low
FHWA	Both	Urban	N, P	Event		Low	Low

SLOSS/ PHOSPH	Both	Rural	P, Sed	Event		Low	Low
Watershed	Both	Both	P	Event	Simple	Medium	Medium
Mid Range							
AGNPS	Both	Rural	N, P, Sed	Both	Detailed	Medium to High	Medium to High
GWLF	Both	Both	N, P, Sed	Both	Simple	Low to Medium	Low to Medium
Detailed/Complex							
ANSWERS	Both	Rural	N, P, Sed	Both	Detailed	Medium to High	Medium to High
GLEAMS	Field	Rural	N, P, Sed	Both	Detailed	Medium to High	Medium to High
HSPF	Both	Both	N, P, Sed	Both	Detailed	Medium to High	Medium to High
SWAT	Both	Rural	N, P, Sed	Both	Detailed	Medium	Medium
SWMM	Both	Both	N, P, Sed	Both	Detailed	High	High
WEPP	Both	Rural	Sed	Continuous	Detailed	Low to High	Low to High

Simple Method. The Simple Method is an empirical approach developed for estimating pollutant export from urban development sites in the Washington, DC area. It is used at the site-planning level to predict pollutant loadings under a variety of development scenarios. Its application is limited to small drainage areas of less than one square mile. Pollutant concentrations of phosphorus, nitrogen, chemical oxygen demand, biochemical oxygen demand, and metals are calculated from flow-weighted concentration values for new suburban areas, older urban areas, central business districts, hardwood forests, and urban highways. The method relies on the National Urban Runoff Program (NURP) data for default values.

FHWA. The Federal Highway Administration Model (FHWA) is a screening-level statistical model to estimate nutrient loadings and the variability of loadings are estimated from runoff volume distributions and event mean concentrations for the median runoff event at highway or urban sites. Rainfall is converted to runoff, using a runoff coefficient calculated from the percentage of impervious land use. Pollutant buildup is based on traffic volumes and surrounding area characteristics. Annual loads are calculated by multiplying by the number of storms per year. The model is used to evaluate lake and stream impacts of stormwater runoff from highways and their surrounding drainage areas.

SLOSS-PHOSPH. Simplified Pollutant Yield Approach uses two simplified loading algorithms to evaluate soil erosion, sedimentation, and phosphorus transport from distributed watershed areas. The SLOSS algorithm based on USLE and sediment delivery ratio provides estimates of sediment yield, whereas the PHOSPH algorithm uses a loading function to evaluate the amount of sediment-bound phosphorus. These equations have been incorporated into the PC-VirGIS (Virginia Geographical Information System).

Watershed. Watershed is a spreadsheet model developed at the University of Wisconsin to calculate phosphorus loading from point sources, combined sewer overflows (CSOs), septic tanks, rural croplands, and other urban and rural sources. It uses an annual time step to calculate total nutrient loads and to evaluate the cost- effectiveness of pollution control practices in term of cost per unit load reduction. The program uses a series of worksheets to summarize watershed characteristics and to estimate pollutant loadings for uncontrolled and controlled conditions. Because of the simple formulation describing the various pollutant loading processes, the model can be applied using available default values with minimum calibration effort.

AGNPS. Agricultural Non-Point Source Pollution Model, developed by the USDA Agricultural Research Service, is designed to estimate loads from agricultural watersheds and to assess the relative effects of alternative management programs. The model simulates surface water runoff along with nutrient (nitrogen, phosphorus, and organic carbon) and sediment constituents associated with agricultural nonpoint sources, as well as point sources such as feedlots, wastewater treatment plants, and streambank or gully erosion. Several versions that integrate the model with GIS and Windows-based graphical user interfaces are available. For instance, the Annualized AGNPS (AnnAGNPS) is a continuous-simulation, multi-event modification of the single-event model AGNPS, which can be used to estimate annualized load and load reduction (http://www.sedlab.olemiss.edu/agnps.html).

GWLF. The Generalized Watershed Loading Functions model was developed at Cornell University to assess the point and nonpoint loadings of nitrogen and phosphorus from a relatively large, agricultural and urban watershed and to evaluate the effectiveness of certain land use management practices. One advantage of this model is that it was written with the express purpose of requiring no calibration, making extensive use of default parameters. The GWLF model includes rainfall/runoff and erosion and sediment generation components, as well as total and dissolved nitrogen and phosphorus loadings. The simulation results can be used to identify and rank pollution sources and evaluate basinwide management programs and land use changes. The model also includes several reporting and graphical representations of simulation output to aid in interpretation of the results. Several versions that integrate the model with GIS and Windows-based graphical user interfaces are available. BasinSIM 1.0 is a desktop Windows version that was developed at the Virginia Institute of Marine Science, College of William and Mary (http://www.vims.edu/bio/vimsida/bsabout.html).

ANSWERS. The Areal Nonpoint Source Watershed Environment Response Simulation Model is a comprehensive model developed to evaluate the effects of landuse, management schemes, and conservation practices or structures on the quantity and quality of water from both agricultural and non-agricultural watersheds. It is a physically based, spatially distributed model allowing better representation and more rigorous analysis of pollution sources and loads. The version, ANSWERS-2000 uses Green-Ampt infiltration equation to describe soil water movement, and an event based particle detachment and transport model to simulate the erosion processes. Nutrients (nitrogen and phosphorus) are simulated using correlation relationships between chemical concentrations, sediment yield and runoff volume.

GLEAMS. Groundwater Loading Effects of Agricultural Management Systems is a continuous simulation, field scale model, which was developed as an extension of the Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) model. GLEAMS can be used to estimate surface runoff, sediment, nutrient, and pesticide losses from the field (e.g., edge-of-field) and nutrient leaching below the root zone. GLEAMS can provide estimates of the impact management systems, such as planting dates, cropping systems, irrigation scheduling, and tillage operations, have on the potential for chemical movement. Application rates, methods, and timing can be altered to account for these systems and to reduce the possibility of root zone leaching. The model also accounts for varying soils and weather in determining leaching potential. Erosion in overland flow areas is estimated using a modified Universal Soil Loss Equation. GLEAMS Version 3 can be downloaded at http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm.

HSPF. The Hydrological Simulation Program-FORTRAN is a comprehensive package developed by EPA for simulating water quantity and quality for a wide range of organic and inorganic pollutants from complex watersheds to receiving waters. The model uses continuous simulations of water balance, pollutant generation, transformation, and transport. HSPF uses such information as the time series of rainfall, temperature, evaporation, and parameters related to land use patterns, soil characteristics, and agricultural practices to simulate watershed processes. Runoff flow rate, sediment loads, nutrients, pesticides, toxic chemicals, and other quality constituent concentrations can be predicted. The model uses these results and stream channel information to simulate instream processes. HSPF is one of the supported models of EPA BASINS system and the Window-based HSFP model (WinHSPF) can be downloaded from the B ASINS Web site at www.epa.gov/ost/basins.

SWAT. The Soil and Water Assessment Tool is a river basin or watershed scale model that can be used to predict the impact of land management practices on water, sediment and agricultural chemical yields in complex watersheds with varying soils, land use and management conditions over long periods of time. The model is continuous-time, physically based (i.e., rather than incorporating regression equations to describe the relationship between input and output variables) and requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modeled by SWAT using this input data. SWAT is one of the supported models of EPA BASINS system and can be downloaded at www.epa.gov/ost/basins.

SWMM. The U.S. EPA Storm Water Management Model is a comprehensive watershed model which is widely used for analysis of quantity and quality problems related to stormwater runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well, including floodplain hydraulics and analysis. SWMM simulates hydrographs and (optionally) pollutographs (concentration vs. time) at any point in the drainage system. Rainfall/runoff simulation is accomplished by the nonlinear reservoir approach. The lumped storage scheme is applied for soil/groundwater modeling. For impervious areas, a linear formulation is used to compute daily/hourly increases in particle accumulation. For pervious areas, a modified USLE determines sediment load. Several DOS versions of the SWMM executable and FORTRAN code can be downloaded from http://www.ccee.orst.edu/swmm. This Web site also provides links to proprietary versions of SWMM that provide Windows-based GUI and GIS capabilities.

WEPP. The Watershed Erosion Prediction Project is a process-based, continuous simulation model that can be used to estimate soil erosion and sediment delivery from hillslope profiles and small watersheds. Processes considered in hillslope profile model applications include rill and interill erosion, sediment transport and deposition, infiltration, soil consolidation, residue and canopy effects on soil decomposition, percolation, evaporation, transpiration, snow melt, frozen soil effects on infiltration and erodibility, climate, tillage effects on soil properties, effects of soil random roughness, and contour effects including potential overtopping of contour ridges. In watershed applications, the model allows linkage of hillslope profiles to channels and impoundments. The latest version of the WEPP model including a Windows version and related utilities (e.g., climate generator) can be downloaded from http://topsoil.nserl.purdue.edu/nserlweb/weppmain/. Simpler and web-based versions of the WEPP model mainly targeted for specific BMPs in forests are available also in the Web site.

References:

USEPA, 1997. *Compendium of Tools for Watershed Assessment and TMDL Development*. EPA841-B-97-006. U.S. Environmental Protection Agency. Washington, D.C.

WERF. 2001. *Water Quality Models. A Survey and Assessment*. Water Environment Research Foundation, Alexandria, VA.