Groundwater

Technology Spotlight/ Yu-Feng Forrest Lin, Technology Editor

# A New ArcGIS-Based Software of Uncertainty Analysis for Nitrate Load Estimation

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Domestic waste water treatment using Onsite Sewage Treatment and Disposal Systems (OSTDS) (also known as septic systems) is a source of nitrogen contamination in groundwater and surface water. Estimating nutrient load from septic systems as a storm water source to surface water bodies is important to reduce nutrient load in support of Total Maximum Daily Load (TMDL) programs. Software packages of nitrate load estimation using geographic information systems (GIS) have gained popularity, not only because a GIS is efficient to process and integrate spatial data but also because skills required for applying GIS-based software are widely available. Recently, Rios et al. (2013a) developed an ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) to simulate nitrate transport in groundwater and to estimate nitrate load from septic systems to surface water bodies. However, the load estimates are inherently uncertain, and impacts of the uncertainty on TMDL-related decision making have not been well studied. Uncertainty analysis for GIS-simulated results is of particular importance, because GIS is frequently used as a decision support system. Conducting uncertainty analyses within GIS environments has become popular, owing to recent development of GIS tools and technologies for coupling GIS with methods and tools of uncertainty analysis.

This paper presents a new software package, ArcNLET-MC (MC stands for Monte Carlo), developed by Rios et al. (2013b) to analyze uncertainty in nitrate load estimates given by ArcNLET. The software is implemented as an extension to ArcGIS by using the Visual Basic .NET programing language, and accessed as a tool on the toolbar of the main ArcMap window. ArcNLET-MC is structured in a modular fashion with the following four modules: (1) a *Setup* module to set up options of file management and coefficients needed to generate random parameter samples, (2) a *Random Variables* module to select random variables and their distributions functions and to input defining statistics of the distributions, (3) a *Deterministic Parameters* module to input GIS layers and parameter values of deterministic variables needed for ArcNLET simulation, and (4) an *Execution* module for three options of model execution. By running MC simulation for ArcNLET-specific random parameters, ArcNLET-MC produces multiple realizations of nitrate concentrations at user-specified locations and nitrate load estimates at all surface water bodies involved in the load estimation. On the basis of the MC results, various statistics of load estimates can be evaluated in support of TMDL development and implementation.

ArcNLET-MC is designed to be flexible for the users to select random parameters by checking the box of "*Random Variable*?" for each of seven random parameters used in ArcNLET. Among the parameters, smoothing factor, longitudinal dispersivity, horizontal transverse dispersivity, and first-order denitrification coefficient are treated as *Spatially Homogeneous Random Variables*. Hydraulic conductivity, porosity, and source nitrate concentration are handled as *Heterogeneous Random Variables*. ArcNLET-MC uses the concept of zonal heterogeneity that can be implemented using data available in the Soil Survey Geographic (SSURGO) database. For example, SSURGO delineates a domain into various soil zones, and each zone has its own representative, low, and high values for hydraulic conductivity. ArcNLET-MC can handle four kinds of probability distributions: uniform, triangular, normal, and lognormal, which are commonly used in uncertainty analysis of environmental modeling. Because of the wide use of ArcGIS, ArcNLET-MC has the potential to

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doi: 10.1111/gwat.12247

be a genuinely useful management tool that allows for the easy calculation, interpretation, and visualization of nitrogen load estimate.

The ArcNLET-MC software package, example data, and user's manual are available for free download from http://people.sc.fsu.edu/~mye/ArcNLET/index.html

## Acknowledgments

This research was supported in part by National Natural Science Foundation of China (grant 51328902), Collaborative Research Fund of the State Key Laboratory of Water Resources and Hydropower Engineering Science of the Wuhan University, and contract WM956 with the Florida Department Environmental Protection.

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