Article 13

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Simple and Complex Stormwater Pollutant Load Models Compared

Estimates of stormwater pollutant loadings are important to watershed managers as they grapple with costly decisions on nonpoint source control. Often, a knowledge of comparative pollutant loadings helps managers target resources to priority subwatersheds or predict the water quality response of a stream, lake, or estuary to urbanization. When choosing models to compute stormwater pollutant loads, managers seek a blend of accuracy, reliability, and timeliness, while minimizing the cost of obtaining such information. Stormwater pollutant loading models vary widely in their cost, effort, and accuracy depending on the complexity of model used, its data requirements, drainage area resolution, and need for model calibration and verification.

Stormwater pollutant load models allow managers to quantitatively assess water quality impacts from development and benefits of stormwater treatment practices. Although often used to refer specifically to computerized models, the term "model" in this article encompasses the entire range of stormwater pollutant load estimate computation techniques. Stormwater pollutant load models can range from the simple to complex, encompassing "back-of-the-envelope" methods to full-blown, multi-year computerized models (see Table 1).

Given the variety and number of models available, the key question is which model provides the required management information with the best blend of accuracy and speed.

A common simple model, the Simple Method (Schueler, 1987; Table 2), estimates stormwater pollutant loads as the product of mean pollutant concentrations and runoff depths over specified periods of time (usually annual or seasonal). Two well-known examples of computerized models include EPA's Stormwater Management Model (SWMM) and the Hydrologic Simulation Programming-FORTRAN (HSPF) model. These models simulate representative hydrologic and hydraulic conditions in the watershed, subwatershed, and stream system and estimate stormwater pollutant loads through consideration of a variety of factors including soil type, infiltration, and exponential washoff (Table 2). In general, the Simple Method is most appropriate for small watersheds (<640 acres) and when quick and reasonable stormwater pollutant load estimates are required (Table 3). Computer models, which are usually more time and funding intensive, are generally better suited for analysis of larger and more complex watersheds and management scenarios.

Chandler (1994) reviewed case studies that used either SWMM or HSPF to estimate annual urban stormwater runoff volumes and pollutant loads (Table 4). Computer model runoff and pollutant load estimates were then compared to estimates made using the Simple Method. Chandler focused on four case studies: Santa Clara Valley in California and Lake Union/Ship Canal, Covington, and Scriber Creek in Washington State. In total, 124 comparisons were made, with 96 of those comparisons occurring as part of the Santa Clara Valley case study (Table 4).

The Simple Method and computer model results were compared by computing a "maximum ratio" for various parameters. The maximum ratio represents the largest ratio between the simple and complex model pollutant load and runoff volume estimates. The maximum ratio is always greater than or equal to one; the larger of the two estimates being compared (i.e., the Simple Method or the computer model estimate) is always in the numerator. Positive values indicate that the computer model estimate was larger than the corresponding Simple Method estimate. Negative values indicate that the Simple Method estimate was larger than the computer model estimate. For example, in a given scenario the annual runoff volume estimate gen-

Table 1: Stormwater Pollutant Model Types (From Least to Most Complex) (Horner, 1994)

- Models based on established literature ranges of unit area pollutant loading factors
- Models based on simple empirical relationships such as the Simple Method (Schueler, 1987)
- Models using regression equations (Driver and Tasker, 1990)
- Models incorporating site-specific or modeled flow data and either local or published concentrations
- Continuous simulation models, such as the Storage, Treatment, Overflow, and Runoff Model (STORM); Storm Water Management Model (SWMM); and Hydrologic Simulation Program-Fortran (HSPF)

Table 2: Summary of the Simple Method (Schueler, 1987) and Factors Used in Complex Models (e.g., SWMM and HSPF) to Estimate Pollutant Loads (Chandler,1993 and 1994)

Simple Method

1. Calculation of the runoff coefficient, Rv

   $Rv = 0.05 + 0.009(I)$

2. Calculation of runoff depth (acre-feet per time interval)

   $R = [(P)(Pj)(Rv)/12](A)$

3. Calculation of annual pollutant loads (pounds/acres per time interval)

   $L = \frac{(R)(C)(2.72)}{A}$ or $L = [(P)(Pj)(Rv)/12](C)(2.72)$

where:

Rv	=	Mean runoff coefficient, expressing the fraction of rainfall converted into runoff
I	=	Percent of site imperviousness
R	=	Runoff (acre-feet per time interval)
P	=	Rainfall depth over desired time interval (inches)
Pj	=	Fraction of rainfall events that produce runoff (0.9 in the Washington, DC region)
A	=	Area of the site (acres)
L	=	Urban runoff load (pounds/acres per time interval)
C	=	Flow-weighted mean concentration of the pollutant in urban runoff (mg/L or ppm)
12	=	Conversion factor (inches/foot)
2.72	=	Conversion factor (pounds/acre-foot-ppm)

Complex Models: Considered Factors

- Rainfall
- Infiltration rates
- Evaporation rates
- Overland flow
- Depression storage
- Imperviousness
- Channel roughness
- Solar intensity
- Pollutant accumulation
- Exponential washoff of pollutants
- Interflow
- Streamflow
- Snowmelt
- Slope
- Temperature
- Soil type

erated by SWMM is 83,000 acre-ft and the Simple Method estimate is 68,000 acre-ft. The maximum ratio value (the larger computer model estimate/the smaller Simple Method estimate) is approximately 1.22. Since the computer model estimate is the higher value, the ratio is positive.

Chandler computed a total of 124 maximum ratios for runoff volume and select nutrient, chemical, and heavy metal constituents (Table 5). Seventy percent of the maximum ratio values ranged from one to two, indicating that, in general, the computer model and Simple Method results were comparable (Figure 1). Total Kjedhal nitrogen (TKN), nitrate, and BOD estimates were the most similar, ranging from positive 1.11 to negative 1.19.

Significant discrepancies, however, were noted between the Simple Method and computer model estimates for phosphorus and heavy metals, particularly lead (Table 5). This may be partly attributed to the fact that the Simple Method, unlike the computer models, does not take into account background or erosional sources of pollutants.

The use of national average "C" values could also be a source of disagreement between model results. "C" values are the flow-weighted mean concentrations of pollutants in urban stormwater runoff (mg/L or ppm). Nationwide Urban Runoff Program (NURP) data (U.S. EPA, 1983) is often used to develop "C" values used in computer models ("C" values were used in the Santa Clara Valley study). The NURP data, however, may not adequately account for regional and seasonal variations in pollutant concentrations. Furthermore, reductions in stormwater pollutant concentrations attributable to pollutant reduction measures implemented since the NURP study was conducted are not taken into account. For example, concentrations of lead in stormwater runoff have consistently declined over the past 20 years as a result of decreased use of leaded gasoline.

In other cases, the use of significantly different pollutant concentrations may explain differences between Simple Method and computer model results. In the Lake Union case study, Chandler applied the Simple Method and used a cadmium "C" value of 0.0014 mg/L,

Table 3: Conditions Making Simple and Complex Models (i.e., SWMM and HSPF) Appropriate for Estimating Urban Stormwater Pollutant Loads (Schueler, 1987; Chandler, 1993 and 1994)

	When to Use	When Not to Use
Simple	• small urban watersheds (<640 acres) • only stormwater runoff and pollutant load estimates are desired • need for quick and reasonable load estimates • only percent imperviousness and runoff pollutant concentrations are available • Only planning level estimates are needed	• baseflow runoff/pollutant loads are desired • large watersheds (>640 acres) • non-urban land uses (e.g., construction sites, industrial areas, rural development, agricultural uses), as reliable "C" values are unavailable • ambiguity about watershed's percent imperviousness
Complex	• large and complex watersheds • desire for: - a time history of runoff flow rate and pollutant concentrations - defining channel segments, bridges, culverts, etc., subject to erosion - determining maximum water elevations (for identifying floodplains) - provide hourly or daily load inputs to lake, river, or estuary water quality model	• limited by time • limited by funds • high accuracy needed for dissolved pollutant parameters • uncertain whether complex model can provide more accurate information than simple model

Table 4: Qualitative Summaries of Four Case Studies Reviewed by Chandler (1993, 1994)

	1 Santa Clara Valley	2 Lake Union & Ship Canal	3 Covington	4 Scriber Creek Watershed
Complex model	SWMM	SWMM	HSPF	HSPF
Location	CA	WA	WA	WA
Study area (acres)	441,600	2,605	1,238	4,389
Avg. annual rain (in)	13.2	39.77	36	36
Avg. imperv.	—	60%	26.7%	36%

synthesized from nine separate stormwater runoff studies. SWMM modelers, on the other hand, used a value of 0.05 mg/L, the average of three wide-ranging field samples. Consequently, the SWMM cadmium load estimate was much higher than the Simple Method estimate (see Table 5). Thus, the selection of significantly different pollutant concentrations and/or limited data can generate significantly different results.

Chandler's study suggests that the Simple Method, with some refinements of the "C" values for current,

Table 5: Maximum Ratios for Runoff and Pollutants in Four Case Studies Comparing Simple and Complex Models, as Derived From Annual Load Estimates (Chandler, 1994)

Parameter *(loads in pounds)*	Santa Clara	Lake Union	Covington	Scriber Creek *Current Land Use*	Scriber Creek *Future Land Use*
Runoff (acre-ft)	1.22	-1.04	1.93	–	–
TP	2.06	-3.57	-2.08	-1.47	-1.39
TKN	-1.01	1.11	–	–	–
NO_3	-1.19	–	–	–	–
BOD	-1.04	–	–	–	–
Copper	1.72	1.87	1.84	–	–
Zinc	1.30	1.57	-1.95	–	–
Lead	-2.35	1.75	1.05	2.45	2.62
TSS	1.92	1.32	1.16	1.51	1.56
Chromium	–	2.07	-1.38	–	–
Cadmium	–	7.00	–	–	–

local conditions and recognition of method's limitations, is a useful tool that can provide reasonable water quality and pollutant load estimates quickly and cheaply. On the other hand, the use of complex computer models is justified, indeed necessary, when more complicated issues (e.g. urban pollution versus erosional or natural background sources, TMDLs, load allocation, etc.) are of interest. The key to choosing the appropriate model lies with determining beforehand the drainage area scale, availability of water quality and hydrologic data, and availability of resources and personnel. When the appropriate model is selected, it can provide watershed managers with important guidance for targeting areas in need of protection and for predicting the magnitude and risks associated with pollutant loads.

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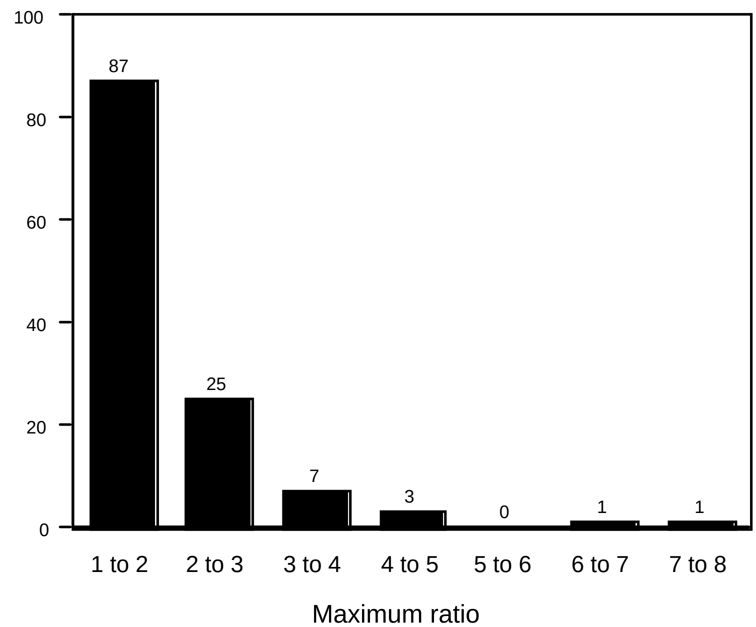

Figure 1: Ratio of Load Difference Computed by Simple Method Compared to SWMM or HSPF (124 annual comparisons) (Chandler, 1993 and 1994)

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