Appendix A: Method of Pollutant Load Calculation for Compliance with Water Quality Standards

This appendix is included with the City of Easley's Stormwater Management Ordinance to provide additional guidance to designers and engineers considering the loading calculation approach as a requirement for large or complex projects, or projects located in sensitive areas.

For certain magnitude projects, a loading calculation analysis may be required by applicants to document compliance with water quality standards by calculating pre-development pollutant loads, calculating uncontrolled post-development pollutant loads and then applying a prescribed pollutant removal efficiency to selected practices to arrive at a net pollutant load delivery. The post-developed load must be equal to or less than the pre-developed load.

Pollutant Loading Calculation Approach for Compliance
Because of the potential for some projects to exceed pre-developed loads, even with Best Management Practices (BMPs) that are designed to meet performance standards, the City of Easley may require applicants to prepare pollutant loading calculations that are intended to keep pollutant levels to the pre-developed condition baseline. The City may require the maintenance of a "no net increase" in pollutant load; new development cannot exceed the pre-developed load based on pre-developed land cover conditions that are present at the time an applicant files for a Stormwater Permit. Loading from redevelopment projects may be required to be reduced 10% from existing levels. The City may require a pollutant loading assessment for targeted pollutants to a receiving water body, based on pollutants of concern (i.e., phosphorus for freshwater systems, nitrogen for saltwater systems, and/or sediment).

The following computational exercise may be used to ensure that above provisions are met:

1. Loadings are computed for the pre-developed condition based on pre-development pollutant loading values;
2. The load from the proposed development is computed based on the proposed level of impervious cover and the appropriate loading factor for that land use. The City shall require that the net difference between these two loads be reduced (or captured) by effective stormwater treatment practices.

This appendix presents data and a methodology for using the Simple Method (Schueler, 1987) to estimate pollutant load from a site or drainage area.

The Simple Method estimates stormwater runoff pollutant loads for urban areas. The technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. With the Simple Method, an applicant can either break up land use into specific areas, such as residential, commercial, industrial, and roadway and calculate annual pollutant loads for each type of land, or utilize more generalized pollutant values for "urban runoff." It is also important to note that these values may vary depending on other variables such as the age of development.

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$L = 0.226 * R * C * A$$

Where: L = Annual pollutant load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$L = 103 * R * C * A$$

Where: L = Annual load (billion colonies)
R = Annual runoff (inches)
C = Bacteria concentration (1,000/ ml)
A = Area (acres)
103 = Unit conversion factor

Stormwater pollutant concentrations can be estimated from local or regional data, or from national data sources. Table A.1 presents typical concentration data for pollutants in urban stormwater.

Table A.1 National Median Concentrations for Chemical Pollutants in Stormwater Runoff		
Constituent	Units	Urban Runoff
TSS	mg/l	54.51
TP	mg/l	0.261
TN	mg/l	2.001
Cu	ug/l	11.11
Pb	ug/l	50.71
Zn	ug/l	1291
F Coli	1,000 col/ ml	1.52
Sources: 1: Pooled NURP/USGS (Smullen and Cave, 1998) 2: Schueler (1999)		

In addition, some source areas appear to be particularly important for some pollutants. Table A.2 summarizes these data for several key source areas. It is important to note that, because the Simple Method computes runoff based on an impervious area fraction, it cannot be easily used to isolate pervious sources, such as lawns. In addition, a composite runoff concentration can be developed based on the fraction of lawn, driveway and roof on a residential site, for example.

Table A.2 Pollutant Concentration from Different Source Areas/Land Uses							
Constituent	TSS[1]	TP[2]	TN[3]	F Coli[1]	Cu[1]	Pb[1]	Zn[1]
Units	mg/l	mg/l	mg/l	1,000 col/ ml	ug/l	ug/l	ug/l
Residential Roof	19	0.11	1.5	0.26	20	21	312
Commercial Roof	9	0.14	2.1	1.1	7	17	256
Industrial Roof	17	-	-	5.8	62	43	1,390
Commercial/Res Parking	27	0.15	1.9	1.8	51	28	139
Industrial Parking	228	-	-	2.7	34	85	224
Residential Street	172	0.55	1.4	37	25	51	173
Commercial Street	468	-	-	12	73	170	450
Rural Highway	51	-	22	-	22	80	80
Urban Highway	142	0.32	3.0	-	54	400	329
Lawns	80	2.1	9.1	24	17	17	50
Landscaping	37	-	-	94	94	29	263
Driveway	173	0.56	2.1	17	17	-	107
Heavy Industrial	124	-	-	-	148	290	1600
Residential (general)[4]	100	0.40	2.2	-	-	18	37
Commercial (general)[4]	75	0.20	2.0	-	-	370	250
Industrial (general)[4]	120	0.40	2.5	-	-	-	-

Sources:
1: Claytor and Schueler (1996)
2: Average of Steuer et al. (1997), Bannerman (1993) and Waschbusch (2000)
3: Steuer et al. (1997)
4: Caraco (2001), default values averaged from several individual assessments

Pre-developed loads are usually estimated from specific loading rates based on pre-developed land cover. The following lists typical unit loading rates for key pollutant parameters from forest and rural land uses (Caraco, 2001).

<u>Forest:</u>
TSS: 100 lbs/acre/year
TP: 0.2 lbs/acre/year
TN: 2.0 lbs/acre/year
FC bacteria: 12 billion col/acre/year
<u>Rural:</u>
TSS: 300 lbs/acre/year
TP: 0.75 lbs/acre/year
TN: 5.0 lbs/acre/year
FC bacteria: 39 billion col/acre/year
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Figure A.1: Relationship between Watershed Imperviousness and the Stormwater Runoff Coefficient

The Simple Method calculates annual runoff as a product of annual runoff volume, and a runoff coefficient (Rv). Runoff volume is calculated as:

$$R = P * P_j * Rv$$

Where: R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on impervious cover in the drainage area. This relationship is shown in Figure A.1. Although there is some scatter in the data, watershed imperviousness does appear to be a reasonable predictor of Rv. The following equation represents the best fit line the dataset (N=47, R2=0.71).

$$Rv=0.05+0.9I_a$$

Where: I_a = Impervious fraction

Cover Data

The Simple Method uses different impervious cover values for separate land uses within a subwatershed. Representative impervious cover data, are presented in Table A.3 (Cappiella and Brown, 2001). Designers may request detailed impervious cover information from the Pickens County GIS Department, or applicants can measure impervious cover directly from site plans.

Table A.3 Land Use and Impervious Cover Estimates

Land Use Category	Mean Impervious Cover
Agriculture	2
Open Urban Land*	9
2 Acre Lot Residential	11
1 Acre Lot Residential	14
1/2 Acre Lot Residential	21
1/4Acre Lot Residential	28
1/8 Acre Lot Residential	33
Townhome Residential	41
Multifamily Residential	44
Institutional**	31-38%
Light Industrial	50-56%
Commercial	70-74%

* Open urban land includes developed park land, recreation areas, golf courses, and cemeteries.
** Institutional is defined as places of worship, schools, hospitals, government offices, and police and fire stations
Source: Cappiella and Brown, 2001

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method.

The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land use and stormwater management scenarios. The Simple Method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to overemphasize the precision of the results obtained. For example, it would be inappropriate to use the Simple Method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% Impervious cover).

The Simple Method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling may be needed to analyze larger and more complex drainage areas. In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow volume. Typically, baseflow is negligible or non-existent at the scale of a single development site, and can be safely neglected. However, catchments and subwatersheds do generate baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels (NVPDC, 1980). Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low. For example, in a large low density residential subwatershed (Imp. Cover ,5%), as much as 75% of the annual runoff volume may occur as baseflow. In such a case, the annual baseflow nutrient load may be equivalent to the annual stormflow nutrient load.

The removal efficiencies of various BMPs are also needed to determine final annual pollutant loads. Table A.4 provides estimates of the average pollutant removal efficiency of the five BMP categories.

Table A.4 Suggested Pollutant Removal Rate for Stormwater BMPs (%)

Constituent	TSS	TP	TN	Metals[1]	Bacteria
Wet Ponds	80	50 (51)	35 (33)	60 (62)	70
Stormwater Wetlands	80[2] (76)	50 (49)	30	40 (42)	80 (78)
Filtering Practices	85 (86)	60 (59)	40 (38)	70 (69)	35 (37)

Infiltration Practices[4]	90[3] (95)	70	50 (51)	90[3] (99)	90[4]
Water Quality Swales	85 (84)	40 (39)	50[5] (84)	70	0 (-25)[6]

1. Average of zinc and copper. Only zinc for infiltration
2. Many wetland practices in the database were poorly designed, and we consequently adjusted sediment removal upward.
3. It is assumed that no practice is greater than 90% efficient.
4. Data inferred from sediment removal.
5. Actual data is based on only two highly performing practices.
6. Assume 0 rather than a negative removal.

Note: Data in parentheses represent median pollutant removal data reported in the National Pollutant Removal Database - Revised Edition (Winer, 2000). (Source: CWP, 2001)

These data were adjusted for convenience and to reflect biases in the data. These efficiencies represent ideal pollutant removal rates that cannot be achieved at all sites. Of particular importance is how to account for practices applied in series (e.g., two ponds applied in sequence). If the volume within the practices adds up to the total water quality volume, they are assumed to act as a single practice with that volume. Otherwise, total pollutant removal should be determined by the following equation:

$$R = L\,[(E_1) + (1- E_1)E_2 + (1-((E_1)+(1- E_1)E_2)E_3 + \ldots]$$

Where: R = Pollutant Removal (lbs)
L = Annual Load from Simple Method (lbs.)
E_i = Efficiency of the ith practice in a series

Another adjustment can be made to these removals to account for loss of effectiveness and irreducible concentrations. Evidence suggests that, at low concentrations, BMPs can no longer remove pollutants. Table A.5 depicts typical outflow concentrations for various BMPs.

Another simplified way to account for this phenomenon is to reduce the efficiency of a second or third practice in a series. For example, the estimated removal efficiency could be cut in half to reflect inability to remove fine particles.

Table A.5 Typical BMP Effluent Concentrations

Constituent	TSS (mg/l)	TP (mg/l)	TN (mg/l)	Cu (ug/l)	Zn (ug/l)
Wet Ponds	17	0.11	1.3	5.0	30
Wetlands	22	0.20	1.7	7.0	31
Filtering Practices	11	0.10	1.12	10	21

Infiltration Practices	17[1]	0.05[1]	3.8[1]	4.8[1]	39[1]
Open Channel Practices	14	0.19	1.12	10	53

1. Data based on fewer than five data points

(Source: Winer, 2000)

Summary of The Simple Method Calculation Procedure

1. <u>Calculate Pre-Development Pollutant Load</u>

   - Use the equation L = 0.226 * R * C * A (or L = 103 * R * C * A for bacteria) to determine pre-development pollutant loading, where R = P * P_j * Rv, C is determined by values in tables A.1 or A.2, and A is the area of the site. Rv is the predeveloped volumetric runoff coefficient, usually in the range of 0.1 for woods to 0.2 for meadow.

2. <u>Calculate "Uncontrolled" Post-Development Pollutant Load</u>

   - Use the equation L = 0.226 * R * C * A (or L = 103 * R * C * A for bacteria) to determine post-development pollutant loading without BMPs, where R = P * P_j * Rv, C is determined by values in tables A.1 or A.2, and A is the area of the site. Rv is determined by Rv=0.05+0.9Ia, where values from I_a may be determined by Table A.3.

3. <u>Determine Efficiency Removal Rates of proposed BMPs</u>

   - Use Table A.4 to obtain pollutant removal rates for the proposed BMPs. If more than one BMP is to be used in series, calculate the total effective removal rate using $R = L\ [(E_1) + (1- E_1)E_2 + (1-((E_1)+(1- E_1)E_2)E_3 + \ldots]$

4. <u>Determine "Controlled" Post-Development Pollutant Load</u>

   - Multiply the uncontrolled post-development pollutant load by the total pollutant removal rate, to obtain the amount of pollutant removed.
   - Subtract the total amount of pollutant removed from the uncontrolled post-development load, to obtain the "controlled" post-development pollutant load.

5. <u>Compare Controlled Development Load versus Pre-Development Load</u>

   - If the post-development controlled load is less than or equal to the pre-development load, then the proposed design complies with the prescribed loading calculation criteria. If not, the designer must revise the project design to reduce the pollutant loadings, or revise the design to include an alternate system of BMPs.

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