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Appendix L

Simple Method for Estimating Phosphorus Export

1. The Simple Method

The Simple Method is a technique used for estimating storm pollutant export delivered from urban development sites. The method was developed to provide an easy yet reasonably accurate means of predicting the change in pollutant loadings in response to development. This information is needed by planners and engineers to make rational non-point source pollution decisions at the site level.

The Simple Method Calculation is intended for use on development sites less than a square mile in area. As with any simple model, the method to some degree sacrifices precision for the sake of simplicity and generality. Even so, the Simple Method is still reliable enough to use as a basis for making non-point pollution management decisions at the site level.

Phosphorus pollutant loading (L, in pounds per year) from a development site can be determined by solving the equation displayed in Table L.1.

1.1. Depth of Rainfall (P)

The value of P represents the number of inches of precipitation that falls during the course of a normal year of rainfall. Long-term weather records around the state of Minnesota suggest that the average annual rainfall depth is about 26 inches. This can be used to estimate P or a user can substitute the average annual rainfall depth from the closest National Weather Service long-term weather station or other suitable locations for which a reliable record can be demonstrated (> 10 years).

1.2. Correction Factor (P_j)

The P_j factor is used to account for the fraction of the annual rainfall that does not produce any measurable runoff. Many of the storms that occur during the year are so minor that all of the rainfall is stored in surface depressions and eventually evaporates. As a consequence, no runoff is produced. An analysis of regional rainfall/runoff patterns indicates that only 90% of the annual rainfall volume produces any runoff at all. Therefore, P_j should be set at 0.9.

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1.3. Runoff Coefficient (R_v)

The R_v is a measure of the site response to rainfall events, and in theory is calculated as:

$R_v = r/p$, where r and p are the volume of storm runoff and storm rainfall, respectively, expressed as inches.

The R_v for the site depends on the nature of the soils, topography, and cover. However, the primary influence on the R_v in urban areas is the amount of imperviousness of the site. Impervious area is defined as those surfaces in the landscape that cannot infiltrate rainfall consisting of building rooftops, pavement, sidewalks, driveways, etc. In the equation:

$$R_v = 0.05 + 0.009(I)$$

"I" represents the percentage of impervious cover expressed as a whole number. A site that is 75% impervious would use I = 75 for the purposes of calculating R_v.

1.4. Site Area (A)

The total area of the site (in acres) can be directly obtained from site plans. If the total area of the site is greater than one square mile (640 acres), the Simple Method may not be appropriate and applicants should consider utilizing other approaches, such as modeling or monitoring.

1.5. Pollutant Concentration (C)

Statistical analysis of several urban runoff monitoring datasets has shown that the average storm concentrations for total phosphorus do not significantly differ between new and existing development sites. Therefore, a pollutant concentration, C, of 0.30 mg/l should be used in this equation as a default. However, if good local data are available or an adjustment is needed, this factor can be customized for local condition.

Chapter 8 contains a range of C values for those interested in conducting a more detailed analysis of phosphorus export.

The Simple Method equation listed in Table L.1 can be simplified to the equation shown in Table L.2. Applicants with verified data indicating alternative values may choose to use the original Simple Method equation as represented in Table 1; otherwise, Table L.2 represents the revised Simple Method equation and associated values.

2. Calculating Pre-Development and Post-Development Phosphorus Load

The methodology for comparing annual pre-development pollutant loads to post-development pollutant loads is a six-step process (Table L.3).

Step 1: Calculate Site Imperviousness

In this step, the applicant calculates the impervious cover of the pre-development (existing) and post-development (proposed) site conditions.

Impervious cover is defined as those surfaces in the landscape that impede the infiltration of rainfall and result in an increased volume of surface runoff. As a simple rule, human-made surfaces that are not vegetated will be considered impervious. Impervious surfaces include roofs,

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buildings, paved streets and parking areas and any concrete, asphalt, compacted dirt or compacted gravel surface.

Step 2: Calculate Pre-Development Phosphorus Load

In this step, the applicant calculates stormwater phosphorus loadings from the site prior to development. Depending on the development classification, the applicant will use one of two equations (Table L.4). The equation to determine phosphorus loading in a redevelopment situation is based on the Simple Method. The equation to determine phosphorus loading in a new development situation utilizes a benchmark load for undeveloped areas, which is based on average phosphorus loadings for a typical mix of undeveloped land uses.

Step 3: Calculate Post-Development Pollutant Load

In this step, the applicant calculates stormwater phosphorus loadings from the post-development, or proposed, site. Again, an abbreviated version of the Simple Method is used for the calculations, and the equation is the same for both new development and redevelopment sites (Table L.5).

Table L.1 Phosphorus Pollutant Export Calculation

$$L = [(P)(P_j)(R_v)/12]\ (C)\ (A)\ (2.72)^*$$

Where:

- L = Load of a pollutant in pounds per year
- P = Rainfall depth per year (inches)
- P_j = Fraction of rainfall events that produce runoff
- R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff. $R_v = 0.05 + 0.009(I)$
- C = Flow-weighted mean concentration of the pollutant in urban runoff (mg/l)
- A = Area of the development site (acres)

*12 and 2.72 are unit conversion factors

Table L.2 Simplified Pollutant Loading Calculation

$$L = (P)\ (R_v)\ (C)\ (A)\ (0.20)^*$$

Where:

- L = Load of a pollutant in pounds per year
- P = Rainfall depth per year (inches)
- R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff = 0.05 + 0.009(I)
- I = Site imperviousness (i.e., I = 75 if site is 75% impervious)
- C = Flow-weighted mean concentration of the pollutant (total phosphorus) in urban runoff (mg/l) = 0.30 mg/l**
- A = Area of the development site (acres)

*0.20 is a regional constant and unit conversion factor

** The C factor can be customized if good local water quality data exist or if an adjustment in the 0.30 mg/l term is needed.

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Step 4: Calculate the Pollutant Removal Requirement

The phosphorus load generated from the post-development site must be reduced so that it is 90% or less of the load generated prior to development, In this example, a 10% reduction in phosphorus loading from pre-development conditions is used. This should not be construed as a recommended reduction for the State of Minnesota. Applicants should check with local stormwater authorities to determine if specific pre- to post-development phosphorus reduction requirements exist. The amount of phosphorus that must be removed through the use of stormwater BMPs is called the Pollutant Removal Requirement (RR). The equation in Table L.6 expresses this term numerically.

Table L.3 Process For Calculating Pre- and Post-Development Pollutant Loads

Step No.	Task
1	Calculate Site Imperviousness
2	Calculate the Pre-Development Phosphorus Load
3	Calculate Post-Development Pollutant Load
4	Calculate the Pollutant Removal Requirement
5	Identify Feasible BMPs
6	Select Off-Site Mitigation Option

Table L.4 Method For Calculating Pre-development Phosphorus Loading

New Development Phosphorus Loading, $L_{pre} = 0.5\ (A)$

Where:

- L_{pre} = Average annual load of total phosphorus exported from the site prior to development (lbs/year)
- 0.5 = Annual total phosphorus load from undeveloped lands (lbs/acre/year)
- A = Area of the site (acres)

Redevelopment Phosphorus Loading, $L_{pre} = (P)\ (R_v)\ (C)\ (A)\ (0.20)$

Where:

- L_{pre} = Average annual load of total phosphorus exported from the site prior to development (lbs/year)
- P = Rainfall depth over the desired time interval (inches)
- R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff = $0.05 + 0.009(I_{pre})$
- I_{pre} = Pre-development (existing) site imperviousness (i.e., I = 75 if site is 75% impervious)
- C = Flow-weighted mean concentration of the pollutant (total phosphorus) in urban runoff (mg/l) = 0.30 mg/l
- A = Area of the development site (acres)

*0.20 is a regional constant and unit conversion factor

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Step 5: Identify Feasible BMPs

Step 5 looks at the ability of the chosen BMP to meet the site's pollutant removal requirements. The pollutant load removed by each BMP (Table L.7) is calculated using the average BMP removal rate (Table L.8), the computed post-development load, and the drainage area served.

If the load removed is equal to or greater than the pollutant removal requirement computed in Step 4, then the on-site BMP complies. If not, the designer must evaluate alternative BMP designs to achieve higher removal efficiencies, add additional BMPs, design the project so that more of the site is treated by the proposed BMPs, or design the BMP to treat runoff from an off-site area.

Table L.5 Method For Calculating Post-Development Phosphorus Loading

$$L_{post} = (P)\ (R_v)\ (C)\ (A)\ (0.20)$$

Where:

L_{post} = Average annual load of total phosphorus exported from the post-development site (lbs/year)
P = Rainfall depth over the desired time interval (inches)
R_v = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff = $0.05 + 0.009(I_{post})$
I_{post} = Post-development (proposed) site imperviousness (i.e., I = 75 if site is 75% impervious)
C = Flow-weighted mean concentration of the pollutant (total phosphorus) in urban runoff (mg/l) = 0.30 mg/l
A = Area of the development site (acres)

*0.20 is a regional constant and unit conversion factor

Table L.6 Computing Pollutant Removal Requirements

$$RR = L_{post} - 0.9(L_{pre})$$

Where:
RR* = Pollutant removal requirement (lbs/year)
L_{post} = Average annual load of total phosphorus exported from the post-development site (lbs/year)
L_{pre} = Average annual load of total phosphorus exported from the site prior to development (lbs/year)

*0.90 is suggested post-development phosphorus load reduction. Local requirements may vary.

Table L.7 Estimate of Pollutant Load Removed by Each BMP

$$LR = (L_{post})\ (BMP_{RE})\ (\%\ DA\ Served)$$

Where:

LR = Annual total phosphorus load removed by the proposed BMP (lbs/year)
L_{post} = Average annual load of total phosphorus exported from the post-development site prior to development (lbs/year)
BMP_{RE} = BMP removal efficiency for total phosphorus, Table 8 (%)
% DA Served = Fraction of the drainage area served by the BMP (%)

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Step 6: Select Off-Site Mitigation Option

If the pollutant removal requirement has been met through the application of on-site stormwater BMPs, the process is complete.

In the event that on-site BMPs cannot fully meet the pollutant removal requirement and on-site design cannot be changed, an offset fee should be charge (e.g. $X per pound of phosphorus).

Table L.8 Comparative BMP Phosphorus Removal Performance [a, e, f]

BMP Group	BMP Design Variation	Average TP Removal Rate[b]	Maximum TP Removal Rate[c]	Average Soluble P Removal Rate [d, g]
Bioretention	Underdrain	50%	65%	60%
	Infiltration	100	100	100
Filtration	Sand Filter	50	55	0
	Dry Swale	0	55	0
	Wet Swale	0	40	0
Infiltration [f,i]	Infiltration Trench	100	100	100
	Infiltration Basin	100	100	100
Stormwater Ponds	Wet Pond	50	75	70
	Multiple Pond	60	75	75
Stormwater Wetlands	Shallow Wetland	40	55	50
	Pond/Wetland	55	75	65

[a] Removal rates shown in table are a composite of five sources: ASCE/EPA International BMP Database (www.bmpdatabase.org); Caraco (CWP), 2001; MDE, 2000; Winer (CWP), 2000; and Issue Paper D P8 (William Walker, http://wwwalker.net/p8/) modeling

[b] Average removal efficiency expected under MPCA CGP Sizing Rules 1 and 3 (see Chapter 10)

[c] Upper limit on phosphorus removal with increased sizing and design features, based on national review

d Average rate of soluble phosphorus removal in literature

[e] See also Appendix N (link) and Chapter 12 for details.

[f] Note that the performance numbers apply only to that portion of total flow actually being treated; it does not include any runoff that by-passes the BMP

[g] Note that soluble P can transfer from surface water to ground water, but this column refers only to surface water

[h] Note that 100% is assumed for all infiltration, but only for that portion of the flow fully treated in the infiltration facility; by-passed runoff or runoff diverted via underdrain does not receive this level of treatment

IMPORTANT NOTE: Removal rates shown here are composite averages intended solely for use in comparing performance between BMP designs and for use in calculating load reduction in site-based TP models. They have been adapted, rounded and slightly discounted from statistical values published in BMP performance databases.

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3. References

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Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition. Center for Watershed Protection. Ellicott City, MD.