Pollutant Removal Credits for Restored or Constructed Buffers in MS4 Permits

Technical Memorandum

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1. Introduction

This technical memorandum is intended to help municipalities, engineers, and regulatory officials to quantify pollutant removal rates for restored or constructed buffers, whether in development, redevelopment, or restoration projects, or any time there is a change in land use. These rates can be used to allocate credits for regulatory permits issued under the NPDES Stormwater Permit Program and other efforts to manage stormwater.

Issued in January 2017, New Hampshire's Small Municipal Separate Storm Sewer System (MS4) General Permit describes tracking and accounting metrics to quantify nutrient and sediment pollutant loading for different land uses. It also includes removal efficiency curves for a range of non-proprietary best management practices (BMPs). The performance curves in this memo will allow restored or constructed buffers to be credited like other BMPs by using a method that applies a quantitative value to their capacity for pollutant removal. To date, this capacity has only been valued in a qualitative way. Specifically, these curves may be used to calculate the removal efficiency for total nitrogen (TN), total suspended solids (TSS), and total phosphorus (TP) for restored or constructed buffers ranging from 20 to 100 feet in width. This calculation is based on four performance curves formed around hydrologic soil groups A, B, C, and D.

This memorandum was generated by the Credit for Going Green Project, which used an expert panel process to develop consensus-based recommendations to help New Hampshire stakeholders use buffers to meet in-stream pollution reduction targets. The project was modeled after a similar initiative in the Chesapeake Bay region. Credit for Going Green was sponsored by the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to Reserves and their communities. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.

2. Definition of Terms

This memorandum uses the following definitions for key terms.

- ***Removal efficiency*** (RE): the restored buffer's capacity to remove total nitrogen (TN), total suspended solids (TSS), and total phosphorus (TP), calculated as the difference between the mass entering the buffer and the mass leaving, divided by the mass entering

- ***Performance*****:** the restored or constructed buffer's ability to remove TN, TSS, and/or TP

- ***Credit:*** the estimated pollutant load reduction given for the use of restored or constructed buffers under the NPDES Stormwater Permit Program and other efforts to manage stormwater

- ***Penalty:*** the reduction in credit from the total possible—reflects the impact of less optimal conditions on a restored buffer's ability to remove TN, TSS, and/or TP

3. About the Expert Panel and Its Process

Going Green's expert panel process synthesized the opinions of a group of authorities on a subject around which there had been uncertainty due to data that was insufficient and/or unattainable because of physical constraints or lack of resources. The panel included state and regional regulators and experts in watershed hydrology, stormwater management, soil science, fish and stream ecology, and spatial understanding of nutrient attenuation. Their charge was to develop nutrient and sediment removal rate percentages for upland buffers based on the best available science for New Hampshire landscapes.

In support of this, panelists conducted an extensive literature review. They determined that while numerous data sources for New Hampshire exist, these were not sufficient to depart from removal efficiencies used by the Chesapeake Bay initiative on which this process was modeled (Table 1). Likewise, they decided the range of geological areas used in the Chesapeake region would be applicable in New Hampshire if hydrologic soil groups (HSGs) were used to differentiate pollutant load reduction.

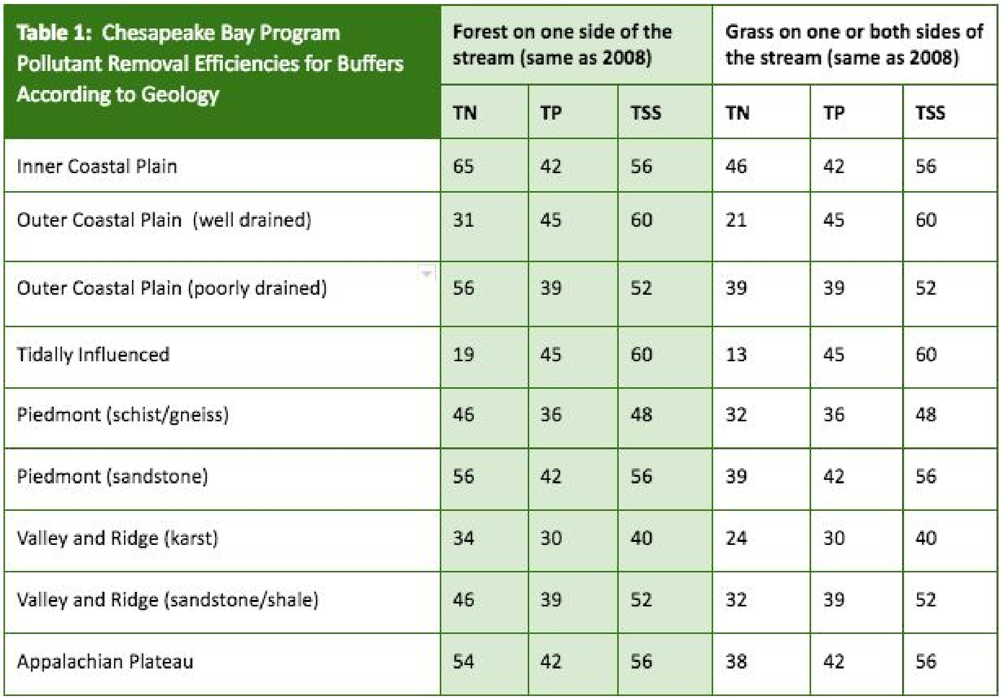


Table 1: Chesapeake Bay Program Pollutant Removal Efficiencies for Buffers According to Geology	Forest on one side of the stream (same as 2008)			Grass on one or both sides of the stream (same as 2008)		
	TN	TP	TSS	TN	TP	TSS
Inner Coastal Plain	65	42	56	46	42	56
Outer Coastal Plain (well drained)	31	45	60	21	45	60
Outer Coastal Plain (poorly drained)	56	39	52	39	39	52
Tidally Influenced	19	45	60	13	45	60
Piedmont (schist/gneiss)	46	36	48	32	36	48
Piedmont (sandstone)	56	42	56	39	42	56
Valley and Ridge (karst)	34	30	40	24	30	40
Valley and Ridge (sandstone/shale)	46	39	52	32	39	52
Appalachian Plateau	54	42	56	38	42	56

In addition to the literature review, the panel held six meetings to discuss key issues related to the performance expectations of upland buffers. These discussions, as well as further review of additional scientific and regulatory resources, helped them define an optimal restored or constructed buffer condition that would fulfill the upper boundaries of performance expectations and therefore be eligible for maximum credit under New Hampshire's MS4 permit.

The panel also agreed to use the maximum and minimum removal efficiency values represented in Table 1 to develop the final performance curves. To mimic the hydrological response unit modeling approach used in USEPA Region 1 performance curves, they selected buffer and data ranges that are bounded by the maximum removal efficiency (RE) percentages. The curves were then scaled to buffer width and shifted by the maximum RE for the corresponding HSG (Hydrologic Soil Group) using the minimum and maximum RE values in Table 1.

4. Key Decisions

The performance curves in this memorandum reflect panel decisions related to topics for which there was sufficient existing data, as well as others for which further research or data collection may be warranted. This section provides an overview of these decisions.

1. **Optimal Buffer Condition**: The panel selected a forested buffer with a width of 100 feet as the optimal buffer condition that could achieve the maximum removal efficiency values described in Table 1. This condition defines the upper boundary of pollutant removal credit. Deviations from this condition result in penalties that reflect lower performance expectations. As noted elsewhere, additional width may result in additional treatment, but the science does not exist to quantify that addition.

2. **Minimally Acceptable Buffer Width:** The panel selected 20 feet as the minimally acceptable buffer width and the lower boundary of pollutant removal performance. While the y-intercept (zero removal efficiency) occurs at a buffer width of 0 feet, credit begins for buffers that are 20 feet wide. Narrower buffers, while valuable in their own right, cannot receive credit under this system. Panelists felt that the primary benefit of the first 20 feet of a buffer is to ensure the long-term sustainability of the overall buffer.

3. **Grassed Buffers**: Both grassed and forested buffers have been shown to reduce nitrogen effectively. Yet while grass can provide dense protection of soil surfaces, it usually generates more runoff than forest (Belt et al. 2014). Several studies have found that grassed buffers are less effective than forested ones at removing nutrients (Lowrance 1998, Mayer et al. 2005). Therefore the panel assigned a 20% credit

reduction (penalty) based on Chesapeake values for nitrogen removal for grassed buffers (Lowrance 1998, Mayer et al. 2005).

4. **HSGs and Sediment and Phosphorus Removal:** The properties of soil impact pollutant reduction through infiltration and adsorption. The panel determined that hydrologic soil group (HSG) type 'A' soils would receive the maximum credit for total suspended solids (TSS) and total phosphorus (TP) removal.

5. **HSGs and Nitrogen Removal**: Given that total nitrogen (TN) performance is enhanced by decreased depth to groundwater and increased water residence time in the soil, the panel assumed that removal efficiencies for nitrogen would be *inversely* proportional to those for TSS and TP. In other words, while HSG A soils are optimal for TSS and TP removal, HSG D soils are best for TN removal. This assumption is corroborated by the range of performance values from the Chesapeake Bay studies (Table 1.)

6. **Contributing Area, Land Use, Impervious Cover, and Pollutant Loading:** *Contributing area* is the amount of land upgradient of a buffer that could generate runoff to the buffer. In a retrofit project, contributing area may include the buffer itself. The amount of contributing area, not including the buffer, that can be used to calculate *pollutant loading* is limited by the *land use* and *impervious cover* (IC) values in Table 2.

   This is because loading depends on distributed, rather than concentrated, flow conditions. Concentrated flows create channels across a buffer, which decrease its capacity for pollutant removal. Theoretically, the denser the IC, the more quickly concentrated flow occurs. As a result, the length of contributing area used to calculate pollutant loading decreases with increasing impervious cover. TN and TP load export rates for this project come from values developed for the 2017 NH MS4 permit.

Table 2: Land Use Categories and Associated Pollutant Load Export Rates (PLER)

Loading Ratio by Land Use			**PLER lb/ac/yr**		
Land Use	*% Density of Impervious Cover (IC)*	*Maximum Contributing Upland Distance (ft)*	*TSS*	*TN*	*TP*
Low Residential	<36	400	108	3.8	0.55
Residential	36-60	300	186	6.2	1.07
Commercial/ Transportation	>60	100	234	9.3	1.16

POLLUTANT REMOVAL EQUATION: L = R*A WHERE L (contributing pollutant load in lbs/yr) = **R** (pollutant load rate in lbs/acre/yr) *** A** (area in acres)

5. Situations These Curves Cannot Address

- **Buffers wider than 100 feet:** The panel did not have access to sufficient data or science to support recommendations for calculating removal efficiencies for restored or constructed buffers wider than 100 feet. However, there is extensive scientific support for the conclusion that wider buffers advance a variety of services beyond pollutant removal, including the provision of wildlife habitat, flood and storm surge protection, streambank stability, and nutrient cycling. The Buffer Options for the Bay Project synthesized this science in their Coastal Science Literature Review.

- **Buffers narrower than 20 feet:** While the panel decided the y-intercept (zero removal efficiency) of performance curves would occur at a buffer width of 0 feet, they determined the removal efficiency credit would begin at a minimum width of 20 feet. Narrower restored or constructed buffers, while valuable, will not receive pollutant removal credit in this framework.

- **Slopes steeper than 15%:** The performance curves are applicable to contributing areas with slopes of up to 15%. To calculate buffer removal efficiency for slopes between 5 and 15%, the panel agreed upon pollutant removal reduction multipliers outlined in Table 3. For slopes greater than 15%, there are no recommended removal efficiency curves.

Table 3: Performance Multiplier Based on Buffer Land Slopes up to 15%

Health and Longevity: consensus reached on 10-year lifespan of credit			
Slope	0–5%	5–10%	10-15%
Buffer Multiplier	1	0.75	0.5

- **Level spreader use:** Level spreaders transform concentrated flow into distributed flow. Level spreaders fall under the category of structural best management practices (BMPs). Application of these performance curves for land use change involving the use of level spreaders should be at the professional discretion of the site designer and permitting authorities.

- **Existing buffers:** While the curves are applicable to any buffer, credit is only given for development or redevelopment projects, including restoration, or any time there is a change in land use.

6. Considerations When Using the Curves

- The process used to create these curves is based on a weight-of-evidence approach that surveyed the best and most current available literature.
- The curves were established for use in New Hampshire and employed experts well versed in the state’s ecological, hydrological, and regulatory systems. Efforts to adapt these curves and the equation for other regions should engage regional experts and data in the process.
- The performance curves are based on HSGs A, B, C, or D, but sometimes a site will consist of more than one HSG. The panel recommends choosing the most conservative option, i.e. the soil type that is less effective at pollutant reduction. For example, if the site consists of HSG B and HSG C, choose C.
- Longevity and maintenance: The credit calculated through these curves is applicable to restored or constructed buffers for up to ten years. After ten years, the panel recommends that the buffer be re-evaluated. For example, if a buffer was vegetated and is now forested, the credits could increase, whereas if it was forested and is now grassed, the credit should be decreased.

7. Performance Curves

Pollutant reduction performance curves were developed for each HSG. Three points calibrate these curves, which are presented as Figures 1 through 4 on the following pages.

- Point 1: All pollutant removal curves start at the minimum buffer width of 20 feet.
- Point 2: All pollutant removal curves end at the maximum buffer width of 100 feet.
- Point 3: There is an inflexion point at a buffer width of 35 feet. Values at the 35-foot buffer width represent minimum removal efficiency values from Table 1, whereas the 100-foot buffer width represents the maximum removal efficiency values from Table 1.

Figure 1: Performance Curves for nutrients (TN, TP) and sediment (TSS) for upland buffers of various widths (forested and grassed) for hydrologic soil group A.

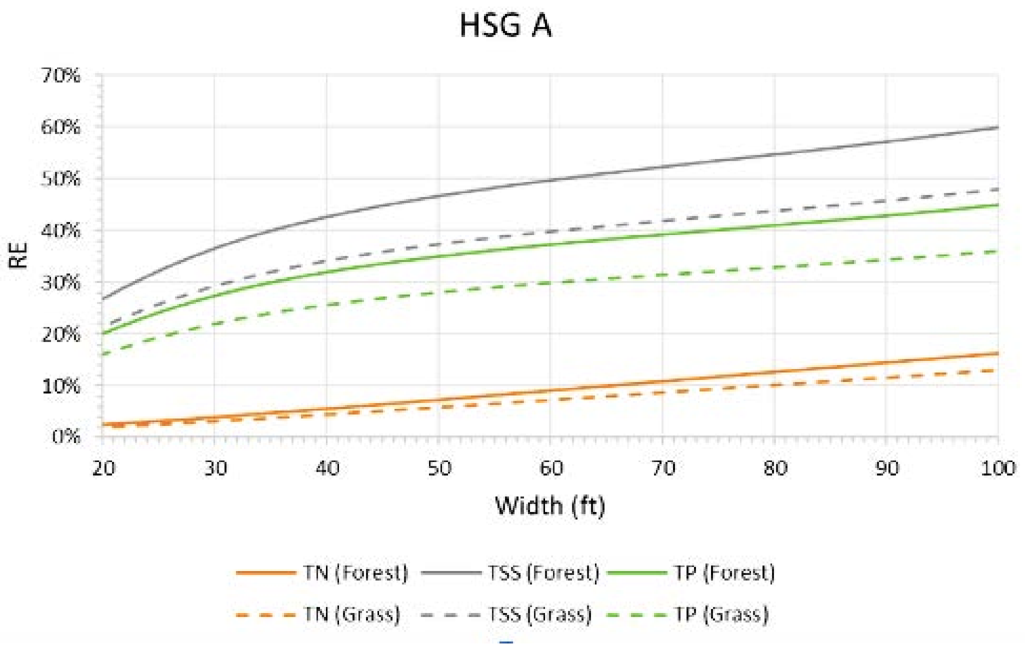


Figure 2: Performance Curves for nutrients (TN, TP) and sediment (TSS) for upland buffers of various widths (forested and grassed) for hydrologic soil group B.

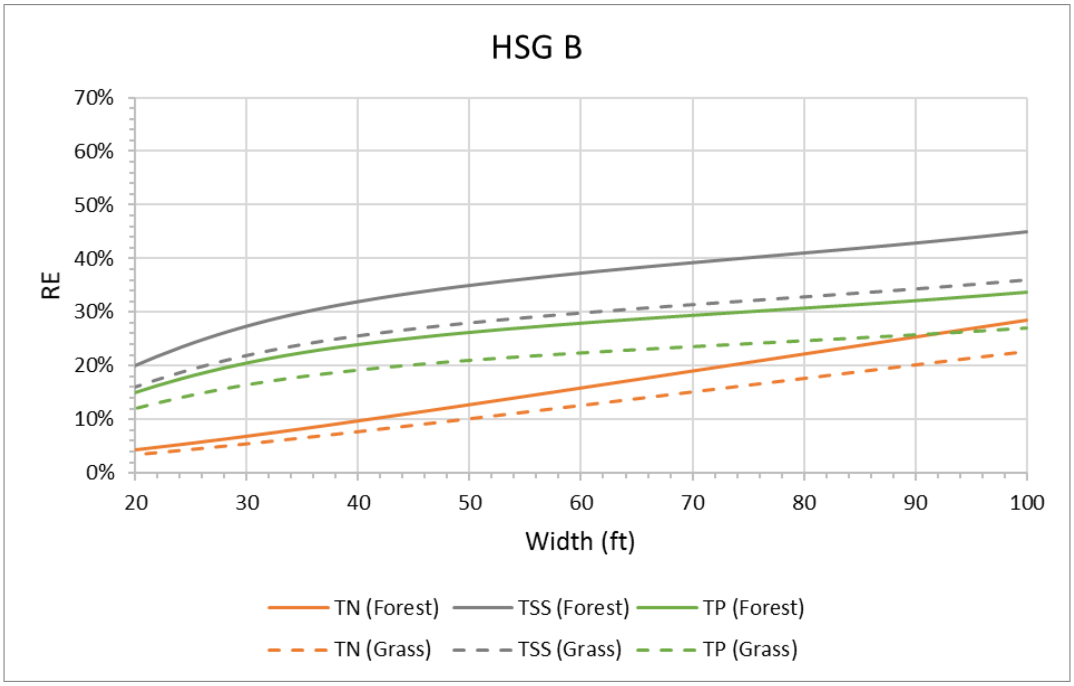


Figure 3: Performance Curves for nutrients (TN, TP) and sediment (TSS) for upland buffers of various widths (forested and grassed) for hydrologic soil group C.

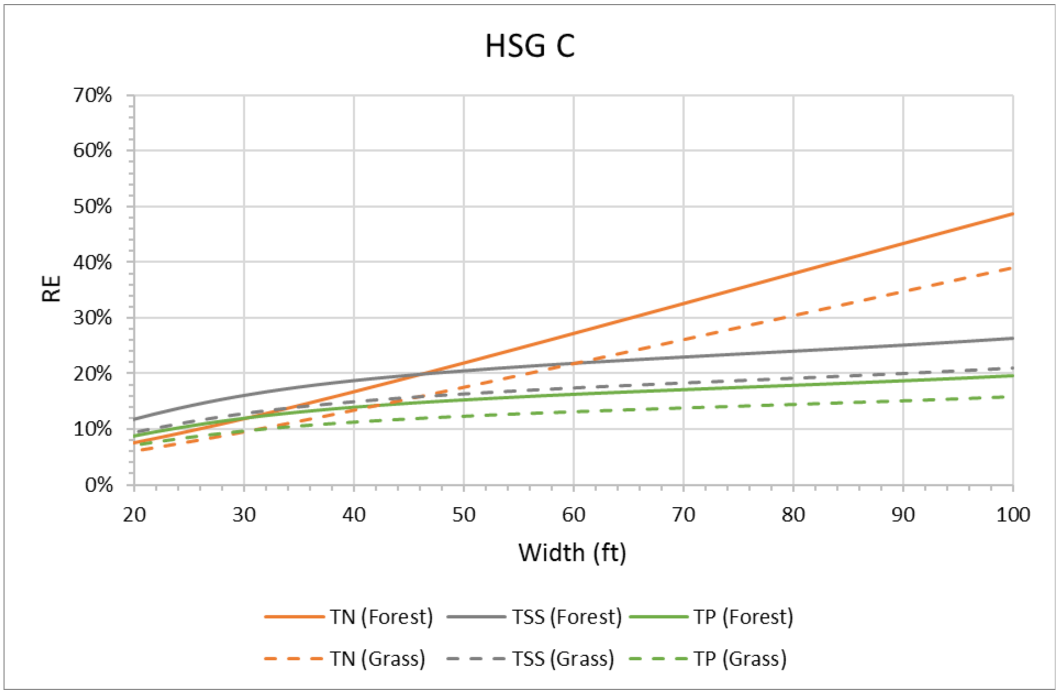
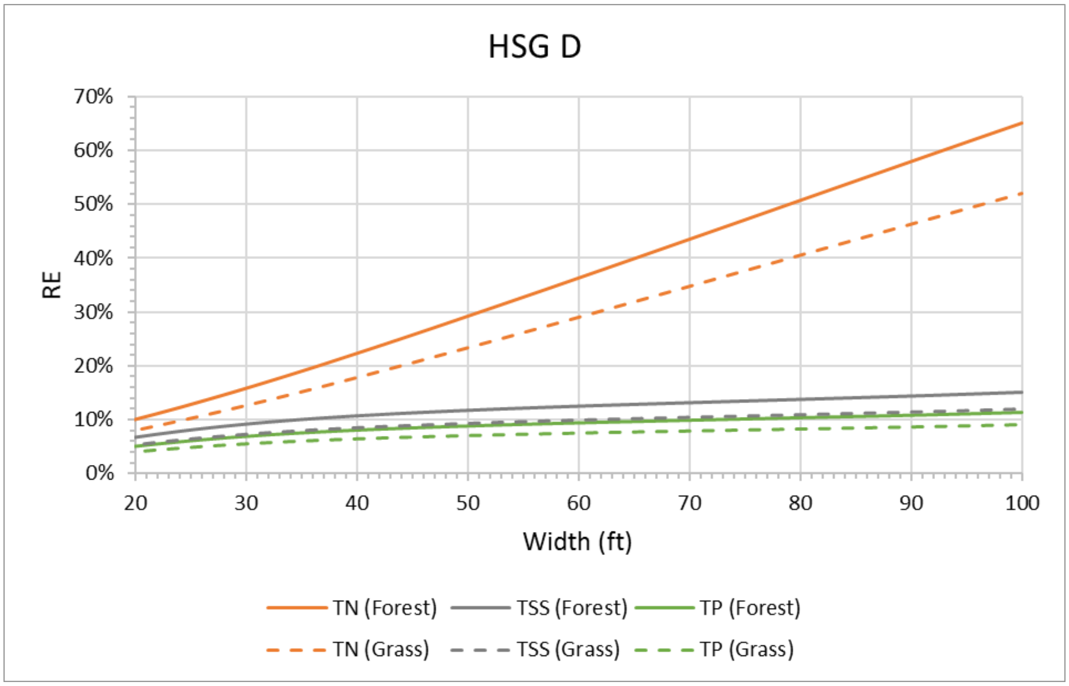


Figure 4: Performance Curves for nutrients (TN, TP) and sediment (TSS) for upland buffers of various widths (forested and grassed) for hydrologic soil group D.



The curves (Figures 1 through 4) are applicable to slopes up to a maximum of 5%. For slopes between 5–15%, use the multipliers outlined in Table 3 to calculate buffer removal efficiency.

Table 3: Performance Multiplier Based on Buffer Land Slopes up to 15%

Health and Longevity: consensus reached on 10-year lifespan of credit			
Slope	0–5%	5–10%	10–15%
Buffer Multiplier	1	0.75	0.5

8. Calculating Pollutant Load Reduction Credits

The following methods adhere to the annual phosphorus and nitrogen load export rates presented in the 2017 NH MS4 permit. The baseline pollutant load is a measure of the annual phosphorus, nitrogen, and sediment load discharging in stormwater runoff from various land uses. Land uses were adapted from the Pollutant Tracking and Accounting Pilot Project (PTAPP) and further consolidated to the land uses presented in Table 2. The actual restored or constructed buffer is treated as a land use change. In addition to land use, upslope contributing areas treated by the buffer receive a load reduction efficiency credit according to the values presented in Table 2.

There are two approaches to calculating pollutant load reductions for buffers:

1. Developed areas where buffers are being created
2. Developed areas where buffers already exist

It should be noted that only the first approach results in a net pollutant load reduction that could receive credit using these curves. *The second is useful for calculating existing buffer environmental services with respect to pollutant reduction.*

Example 1: Developed Area Enhanced by a Buffer

Situation: A new 100-ft wooded buffer is established for a commercial site with HSG B soils and a maximum slope of 2.5%. IC is anticipated to be < 60%. The site's runoff flows to the buffer and from there into a stream. The site extends 1,000 feet along the length of this stream.

1. *Calculate the contributing pollutant load to the buffer:* Determine the area (in acres) of the buffer and the land area that is contributing flow to the buffer. Then select the Pollutant Load Export Rates (PLERs) for the appropriate land use classification in Table 2.

Use the following equation to determine your existing pollutant load:

L = RxA **WHERE** **L** (contributing pollutant load in lbs/year) = **R** (pollutant load rate in lbs/acre/year) **x** **A** (area in acres)

2. *Select the appropriate performance curve from Figures 1–4:* Choose based on the site's HSGs, buffer width, and vegetation type. If slopes are greater than 5% and less than 15%, take an average of the slopes and select the appropriate multiplier from Table 3.

3. *Determine the load reduction:* Use the appropriate curve to select the removal efficiency and multiply by the contributing load you calculated in step 1. This is the load reduction; it should be expressed as pounds per year and can be used over the service life (longevity) of the buffer, in this case 10 years. For example:

   - Calculate the buffer area: 100 feet x 1,000 feet = 100,000 square feet or 2.30 acres.
   - Based on the land use type, identify the maximum contributing distance upslope of the buffer (Table 2): 100 feet.
   - Calculate the total area: contributing area {(100 feet) + buffer width (100 feet)} x (buffer length) 1,000 feet = 200,000 square feet or 4.6 acres.
   - Calculate the pollutant loads from the commercial area using values from Table 2. The results are summarized in Table 4.

Table 4: Pollutant Loading Values for the Example Problem

Pollutant	PLER (lbs/acre/year)	Acres	Load (lbs/year)
TSS	234	4.6	4930
TN	9.3	4.6	42.7
TP	1.2	4.6	5.3

4. *Identify the removal efficiencies:* In this case, we use the RE from Figure 2 (because the site is HSG B) to apply to the existing pollutant load to calculate the overall project load reduction. The results are summarized in Table 5.

L x RE = LR **WHERE** **L** (contributing pollutant load in lbs/year) X RE (Removal Efficiency) **=** **LR** (project load reduction in lbs/year)

Table 5: Overall Pollutant Load Reductions for Example Problem

Pollutant	RE %	Load (lbs/year)	Load Reduction (lbs/year)
TSS	45	4930	2219
TN	28	42.7	12.0
TP	34	5.32	1.81

These load reductions may now be used to make the case for regulatory compliance or to address other accounting metrics for environmental services associated with buffers.

Example 2: Calculation of Pollutant Load Reduction From an Existing Buffer

Situation: A land manager wishes to calculate the pollutant load reduction services of an existing 200-foot grassed buffer within a low use residential site with HSG A soils and a maximum slope of 5.1%. The site's runoff flows to the existing buffer and from there into a stream. The site extends 500 feet along the length of this stream.

1. *Calculate load to the buffer:* Given that this is an existing buffer, its area is not included as part of the contributing area. Instead, use Table 2 to determine the appropriate travel length and calculate the contributing area (in acres) to the existing buffer. Then select the Pollutant Load Export Rates (PLERs) for the appropriate land use classification in Table 2 and use the following equation to determine your existing pollutant load:

   L = RxA WHERE **L** (contributing pollutant load in lbs/yr) = **R** (pollutant load rate in lbs/acre/yr) *** A** (area in acres)

2. *Select the appropriate performance curve from* Figures 1–4: Choose based on the site's HSGs, buffer width, and vegetation type. Given that the site has slopes greater than 5% and less than 15%, identify the appropriate multiplier from Table 3.

3. *Determine the load reduction:* Use the appropriate curve to select the removal efficiency and multiply by the contributing load you calculated in step 1. This is the load removed. The load reduction should be expressed as pounds per year and can be used over the service life (longevity) of the buffer, in this case 10 years.

4. *Calculate the load reduction credit:* Determine using the established curves.
   - Based on the land use type, identify the maximum contributing distance upslope of the buffer (Table 2): 400 feet.
   - Calculate the contributing area to the buffer: contributing area {(400 feet) x (buffer length) 500ft} = 200,000 square feet or 4.6 acres.
   - Calculate the pollutant loads from the low use residential land use using values from Table 2. The results are summarized in Table 6.

Table 6: Pollutant Loading Values for the Example Problem

Pollutant	PLER (lb/acre/year)	Acres	Load (lb/year)
TSS	108	4.6	497
TN	93.8	4.6	431.5
TP	0.55	4.6	2.5

5. *Identify the removal efficiencies:* Use the RE from Figure 1 (because the site is HSG A) to apply to the existing pollutant load to calculate the overall project load reduction. The results are summarized in Table 7.

L x RE = LR WHERE L (contributing pollutant load in lbs/yr) **X RE** (Removal efficiency units?) **= LR** (project load reduction in lbs/year)

Table 7: Overall Pollutant Load Reductions For Example Problem

Pollutant	RE %	Load (lb/yr)	Load Reduction (lb/yr)
TSS	49	497	244
TN	36	431.5	155.3
TP	12	2.5	0.3

These load reductions may be used to account for load reductions for regulatory compliance or to interface with other accounting metrics for environmental services associated with buffers.

9. References

Belt, K., Groffman, P., Newbold, D., Hession, C., Noe, G., Okay, J., Weller, D. (2014). "Recommendations of the expert panel to reassess removal rates for riparian forest and grass buffers best management practices." Chesapeake Bay Program.

Environmental Protection Agency (EPA), 2017. *New Hampshire Small MS4 General Permit.* https://www.epa.gov/npdes-permits/new-hampshire-small-ms4-general-permit

Flanagan, Shea E.; Patrick, David A.; Leonard, Dolores J.; and Stacey, Paul, "Buffer Options for the Bay: Exploring the Trends, the Science, and Options of Buffer Management in the Great Bay Watershed Key Findings from Available Literature" (2017). PREP Reports & Publications. 380.

Lowrance, R., L.S. Altier, J.D. Newbold, R.R. Schnabel, P.M. Groffman, J.M. Denver, D.L. Correll, J.W. Gilliam, J.L. Robinson, R.B. Brinsfield, K.W. Staver, W. Lucas, and A.H. Todd. 1997. "Water quality functions of riparian forest buffers in the Chesapeake Bay Watershed." Environmental Management 21:687-712.

Mayer, Paul M., S. K. Reynolds, Jr., T. J. Canfield and M.D. McCutchen. 2005. "Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations." U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/118, 2005.

Soil Survey Staff. 2009. *National Engineering Handbook. Part 630 Hydrology. Chapter 7, Hydrologic Soil Groups.* United States Department of Agriculture, Natural Resources Conservation Service.

United States Environmental Protection Agency (USEPA) (2017). 2017 *Final New Hampshire Small MS4 Permit, appendix F.*