Forest Land Accounting Methodology to Estimate Sediment and Phosphorus Reductions

Final Report

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V DISCLAIMER

The intent of this report is to present the final forestland best management practice (BMP) accounting methods to estimate phosphorus and sediment load reductions for suites of forestland BMPs, including reduction efficiency (percent reduction), design life, and data requirements as well as recommended next steps. This fulfills the deliverables required for the Forest Land Analysis to Support Implementation of Lake Champlain and Lake Memphremagog Restoration Plans project, Track B, Task 4.1: Final Report.

The information provided in this report reflects the best-known scientific studies to date but has not utilized field-based verification.

1 INTRODUCTION

This report provides a comprehensive summary of the proposed methods to be used by the Vermont Department of Environmental Conservation (DEC) to track and account for sediment and phosphorus reductions from forestland areas as a result of the implementation of best management practices (BMPs), also referred to as acceptable management practice (AMPs) under Title 10 VSA Chapter 47: Water Pollution Control. This report is the culmination of the collaborative work done by Watershed Consulting Associates, LLC in partnership with an interagency team of experts from the Department of Forests, Parks and Recreation (FPR), and the Department of Environmental Conservation (DEC).

In forest operations, management choices can have a significant impact on water quality, primarily as a function of heightened erosion and subsequent sediment-bound phosphorus yield. Across the United States, individual states have adopted a variety of unique BMP administrative strategies. Research has shown that state-operated BMP programs can be very successful in minimizing the effects of forestry operations on water quality, reducing impacts by 80-90% when compared to historic practices (Ice, 2004; McBroom et al., 2008; NCASI, 2012; Sugden et al., 2012). Guidelines for the proper implementation of forestland BMPs in Vermont can be found in the “Vermont Water Quality, Acceptable Management Practices Manual for Logging Professionals August 2019” guidebook (hereafter referred to as the AMP Manual) provided by the Vermont Department of Forests, Parks, and Recreation.

The methods for BMP verification and accounting are variable across states. In Maine, for example, where forestry BMPs are a combination of regulatory and voluntary measures, the state generates a bi-annual report on the overall effectiveness of a suite of BMPs. The methods of this approach follow the “Best Management Practices Implementation Monitoring Protocol,” an original project of the Northeastern Area Association of State Foresters’ (NAASF) Water Resources Committee (Ferrare, 2007). Effectiveness, in this methodology, is a qualitative determination based on an audit of management practices. This is similar to methods used in neighboring states

2 BMP DESIGN LIFE

To best inform the accounting methods outlined in this report, Watershed Consulting Associates, LLC (Watershed Consulting) conducted a survey of key experts on the longevity and effectiveness of forestland BMPs in the state of Vermont. An initial summary of findings can be found in the submitted deliverable for Track B - Task 1.6 - Collate survey results and summarize findings. Since that submission, 17 new responses have been recorded, bringing the total responses to 34. New respondents to the survey primarily consisted of consulting foresters as they were targeted in the second round of survey requests.

In the survey, respondents were asked to approximate the effective lifespan of a forestland BMP both with and without regular maintenance. The consensus amongst experts on effective life span varied by practice, suggesting that site-specific characteristics, installation techniques, and/or BMP design can influence the effective lifespan. Of those practices that receive regular maintenance, most experts did indicate that vegetated and non-vegetated erosion controls and water bars stand out as practices with an indefinite effective lifespan.

For practices that do not receive regular maintenance, most of the practice types had survey responses strongly weighted to one timespan. Of those practices, it was clear that many experts believe the effective lifespan of practices such as water bars, check dams, water diversion structures, and sediment traps is 1-5 years. In general, the responses indicated shorter effective lifespans for practices without maintenance. This reinforces the knowledge that regular maintenance is key for continued effectiveness for certain practice types.

The recommended maintenance schedule for certain practices was also surveyed. In general, survey respondents indicated that structural practices such as check dams and water bars need regular maintenance annually or even more frequently (2x/ year or more). Vegetated and non-vegetated erosion control practices primarily require no maintenance. This was to be expected as these practices are usually utilized for post-harvest site decommissioning. Responses were more varied on other BMP types. A graphical summary of the results of this survey can be found here: Forest Best Management Practice Survey (google.com)

As discussed further in this methodology, we recommend that phosphorus and sediment load reduction credits should coincide, not with the design life of individual practices, but with the overall utilization and function of multiple practices on a given road segment or parcel. The key limiting factor in determining the frequency with which credits can be applied during active silviculture operations will be the capacity of the regulatory body to perform BMP auditing. After active harvest operations, the frequency of auditing can be lowered as the primary post-harvest management practices such as vegetated erosion control do not require regular maintenance.

3 ACCOUNTING METHODS OVERVIEW

There are two accounting methodologies proposed in this report, one that assesses individual forest road segments and one that is to be used with Vermont's Use Value Appraisal (UVA) parcels. Both follow a similar approach as outlined in Figure 1, with explicit details on these two methodologies found in the following sections of this report. The focus category of forestland usage in these accounting methodologies is forest roads, including both truck roads and skid trails. Phosphorus loads derived from forestland are primarily sediment-bound and a result of practices that trigger erosion and sediment transport. Haul roads and skids trails account for 90-99% of sediment yield, which is why they are the focus area of these accounting methods (Rothwell, 1983). It should be made clear that this is not intended to undermine the value of proper BMP implementation on log landings and in harvest areas, which can provide necessary protection from further erosion and sediment transport. We highly recommend proper BMP implementation on log landings and in harvest areas as outlined in the AMP Manual.

The accounting method for 100-meter(m) forest **road segments,** as shown in Figure 1, is comprised of three steps:

1. Quantifying the phosphorus and sediment production from a road segment.
2. Determining the percentage of that load that will reach a nearby waterbody.
3. Assigning an overall BMP reduction efficiency to determine the total phosphorus and sediment load reduction associated with the full suite of BMPs utilized.

The accounting method for **UVA parcels** as shown in Figure 1, is comprised of two steps:

1. Quantifying the total phosphorus and sediment yield from a parcel.
2. Assigning an overall BMP reduction efficiency to determine the total phosphorus and sediment load reduction associated with the full suite of BMPs utilized.

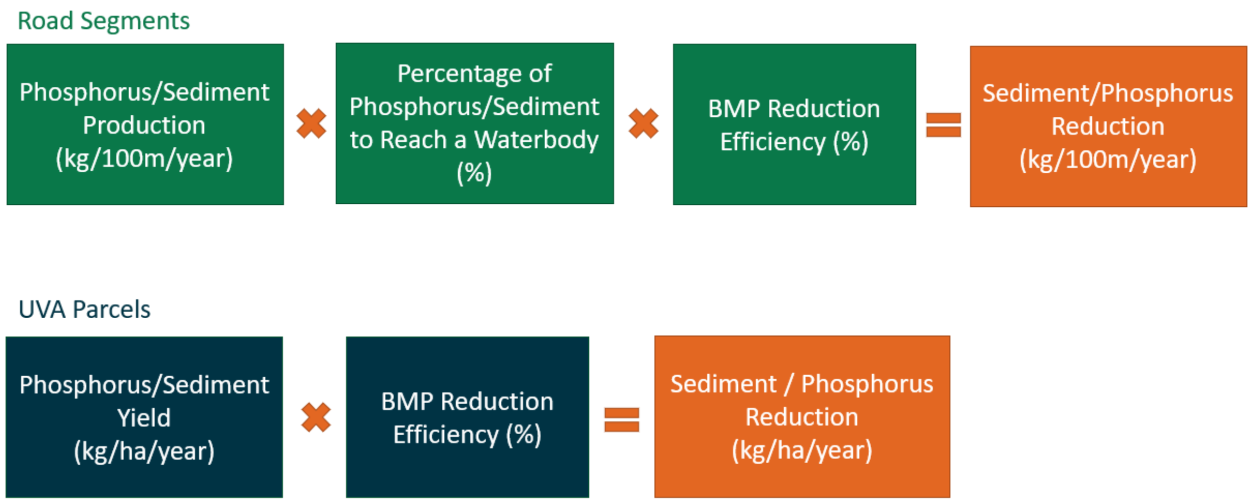

Figure 1. Overview of BMP accounting methods for road segments (upper) and UVA parcels (lower).

4 Definitions and Standards

4.1 Road Segments

We define road segments as forest roads in Vermont, including truck roads, skid trails, and stream crossings included in the road erosion inventory (REI). These roads are divided into 100-m (328-ft) segments and are categorized as hydrologically-connected if they are located within 110-ft of an existing waterbody. This method of distinction is aligned with the current method for municipal road segments being assessed under the Municipal Roads General Permit (MRGP) program. It is important to note that a large proportion of forest roads, especially skid trails, are not mapped at this time.

4.2 UVA Parcels

Qualification for the utilization of the forestland BMP monitoring program should be integrated into the existing methodology used by the Vermont UVA program. Vermont's UVA Program enables eligible private landowners who practice long-term forestry to have their land appraised based on the property's value of production of wood rather than its residential or commercial development value. To qualify, parcels must contain at least 25 acres that will be enrolled and be managed according to a forest plan approved by the Vermont Department of Forests, Parks and Recreation. House sites and land under other private or commercial developments are not eligible. To be enrolled, forestland must have an approved and signed 10-year forest management plan. This document should clearly state the landowner's long-term forest management strategy.

5 WEPP:Road Model Summary

5.1 Model Selection

Following the guidelines for soil erosion model selection outlined in Fu et al. (2010), a variety of empirical and physical models were reviewed for application in this methodology. Empirical soil erosion models are based on statistical relationships between responses and independent variables, derived from empirical observations. Conversely, physical models are based on a hydrological response model that simulates infiltration and runoff routing and mass or energy conservation equations that describe erosion and sediment delivery processes (Merritt et al., 2003). Widely known and utilized empirical models include Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1965), USLE-derived models (USLE-Forest; Dissmeyer and Foster, 1984), and the Revised USLE (RUSLE; Renard, 1997). Physical models that are well known and regularly utilized were evaluated including the Water Erosion Prediction Project (WEPP; Flannagan and Nearing, 1995) and WEPP-derived models (WEPP:Road; Elliot, 2004). For this application, we have determined WEPP:Road to be the most appropriate. We arrived at this decision due to the model's spatio-temporal suitability, ease of use, manageable data requirements, simple web-based interface, and ability to assess multiple road segments simultaneously via a batch import function.

The WEPP:Road model is a physical-based program that calculates erosion and sediment yield, primarily from roads, though it can be used to determine sediment yield from other practices as well as log landings. It was originally developed in 1995 by the USDA Agricultural Research Services to be used by federal action agencies in environmental planning and assessment (Flannagan and Nearing, 1995). As shown in Figure 2, the fundamental mechanics of the model describe a process by which the sediment produced from a road segment is routed over a fillslope and across a forest buffer before reaching nearby surface waters. The WEPP:Road model is particularly well suited for conditions common to forest management practices as it utilizes equations to describe the following processes:

- Infiltration and runoff,
- Soil detachment, transport, and deposition, and
- Plant growth, senescence, and residue decomposition.

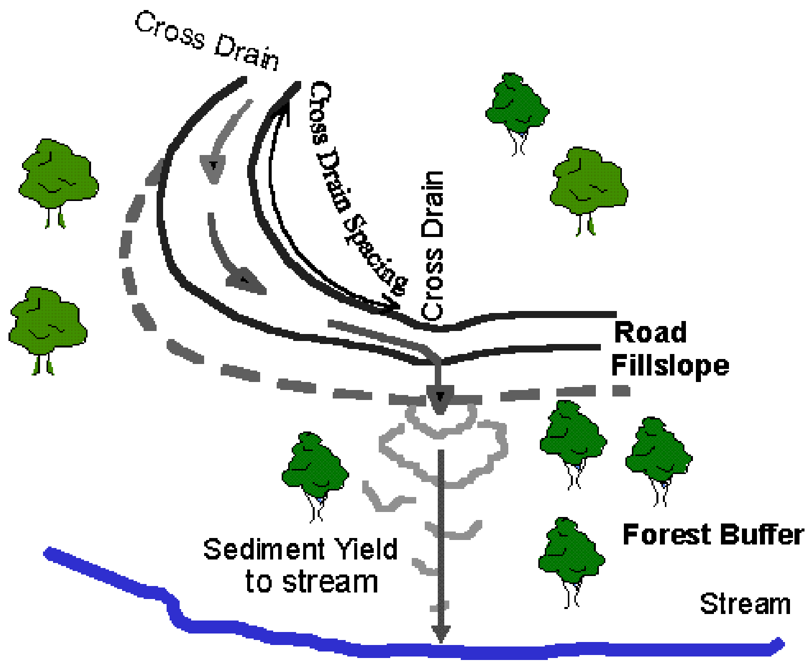

Figure 2: Template for the WEPP:Road Interface (Elliot, 2004).

5.2 WEPP:ROAD MODEL PARAMETERS

To generalize the WEPP:Road model for the purposes of this methodology, we conducted 28,801 runs of the model using a variety of unique combinations of input variables to represent truck road conditions and 15,363 runs of the model using variables that represent skid trail conditions. The values corresponding with each input variable for both truck roads and skid trails can be found in Table 1. Certain input variables were held constant due to either their relative minimal influence on sediment yield by comparison to other variables and/or because the AMP Manual has specified constraints for said inputs. In the following subsections, we discuss each input variable at length, detailing what it means, the methods used in determining the correct value to assign, what assumptions are made, and how it is utilized in our derived methodology for determining phosphorus loads for forest road segments and UVA parcels.

The key distinctions made between truck roads and skid trails include the road surface, traffic level, road width and gradient, and fill length and gradient. Unlike truck roads, whose surface can be native soil or gravel, it is assumed that the surface of a skid trail is always native soil. Similarly, “high” traffic level is reserved for truck roads only, while skid trails commonly have traffic levels of “none” or infrequently “low”. As such, the surface is assumed to be partially vegetated. It is also assumed that skid trails are narrower and steeper than truck roads. This is exemplified in the AMP Manual, which notes truck road grades should not exceed 10%, whereas skid trails should not exceed 20%. Lastly, skid trails are assumed to have no fillslope. As the WEPP:Road model requires nonzero values, a negligible fillslope length (1 ft) and grade (1%) were used.

Each of the WEPP:Road model input variables are described in Table 1 below and expounded upon in the following sections.

Table 1. WEPP:Road input variables.

Input Variable Name	Truck Road Value(s)	Skid Trail Road Value(s)
Weather Stations	Burlington Weather Station; Montpelier Weather Station; Woodstock Weather Station; Bellows Falls Weather Station; St. Johnsbury Weather Station	Burlington Weather Station; Montpelier Weather Station; Woodstock Weather Station; Bellows Falls Weather Station; St. Johnsbury Weather Station
Soil Conditions	Loam; Sandy loam; Silt loam; Clay loam	Loam; Sandy loam; Silt loam; Clay loam
Road Design	Outsloped, rutted; Outsloped, unrutted; Insloped, bare ditch; Insloped, vegetated or rocked ditch	Outsloped, rutted; Outsloped, unrutted; Insloped, bare ditch; Insloped, vegetated or rocked ditch
Road Surface	Native; Gravel	Native
Traffic Level	High; Low; None	Low; None
Road Gradient (%)	2.5, 7.5, 15	2.5, 7.5, 15, 30
Road Length (ft)	328.084 (100 meters)	328.084 (100 meters)
Road Width (ft)	12	10
Fill Gradient (%)	50	1
Fill Length (ft)	8	1
Buffer Gradient (%)	10, 20, 30, 40	10, 20, 30, 40
Buffer Length (ft)	25, 50, 70, 90, 110	25, 50, 70, 90, 110

5.2.1 Weather Stations

For the state of Vermont, there are four climate station files built directly into the WEPP:Road model to choose from representing the climates of Burlington, Bellows Falls, Montpelier, and Woodstock regions. These files include mean monthly temperature, precipitation, and number of wet days. In our adaptation of the WEPP:Road model, each of these climate stations are used to represent the climate of the county it is located within as well as adjacent counties with similar climatic regimes (Figure 3). We further expanded the representation of climatic variability in Vermont by creating a fifth climate station for St. Johnsbury and the northeast kingdom. This was done by utilizing data taken from products produced by the U.S. National Weather Service and other national and international agencies.

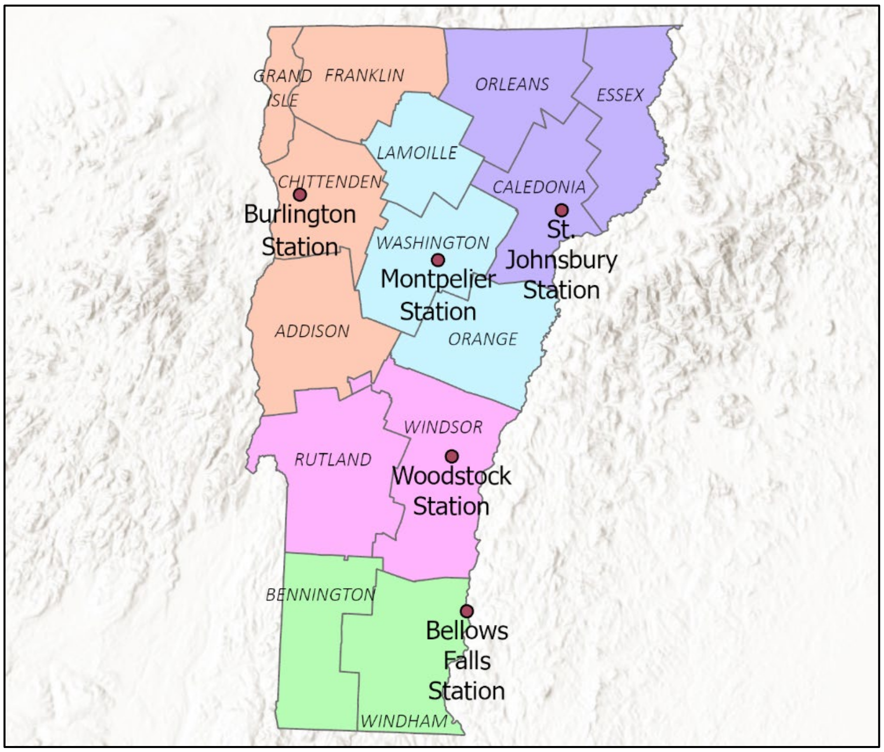

Figure 3. Distribution of five climate stations utilized in the WEPP:Road model.

5.2.2 Soil Conditions

Four soil textures (sandy loam, silt loam, clay loam, and loam) are listed as options for WEPP:Road model. The predominant soil texture on a UVA parcel, road segment, and adjacent buffer can be determined either by field investigation or through the USDA Web Soil Survey (Soil Survey Staff, 2020) or the Vermont Natural Resources Atlas. Further details describing soil parameters are available in the WEPP Technical Documentation (Flanagan and Nearing, 1995).

5.2.3 Road Design

There are four road design options in the WEPP:Road model (Figure 4). The following section discusses the details of each of these four road designs and summarizes the relevant information to assist end-users in selecting the appropriate scenario for each modeled road segment.

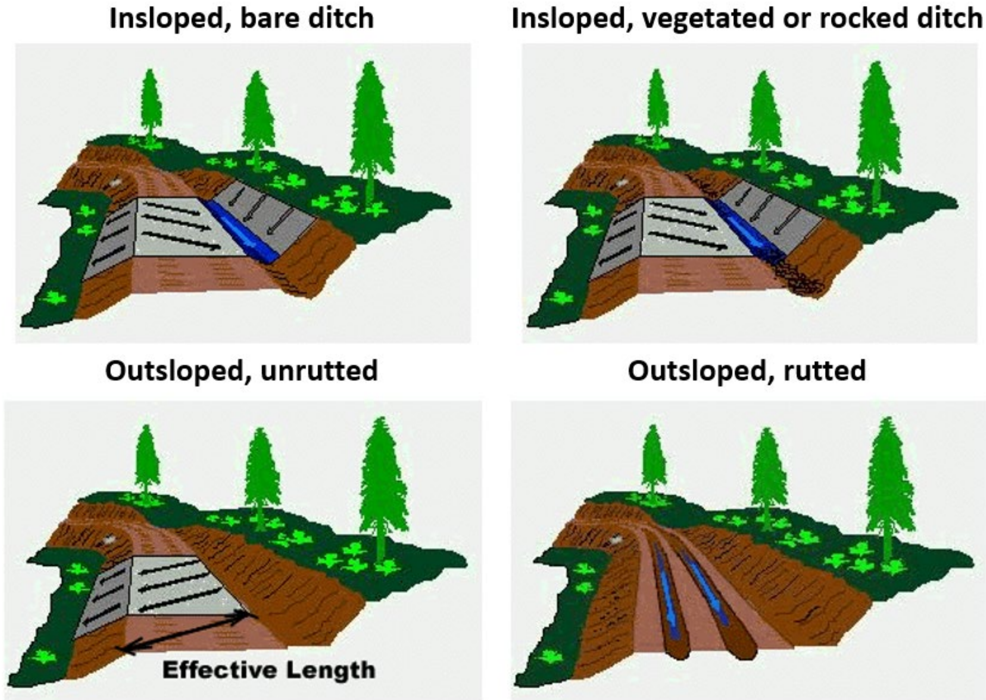

Figure 4. Diagram of flow directions for road designs in WEPP:Road program.

Insloped, bare ditch

The simplest road design is the "insloped, bare ditch" design. This template assumes that there are no ruts on the road and that all runoff is diverted to an inside road ditch. Road surface erosion is due to raindrop splash and shallow overland flow, and the road ditch is experiencing rill erosion from concentrated flow. The spacing of rills on the road in the WEPP management file is set by the interface at 4m and the soil properties are assumed to be the same as those measured by field researchers (Elliot et al., 1995; Flerchinger and Watt 1987). This design is most applicable to new roads and road systems where ditch cleaning is practiced regularly. If the insloped road has wheel ruts carrying runoff between cross drains, then the "outsloped, rutted" design is more appropriate.

Insloped, vegetated or rocked ditch

The "insloped, vegetated or rocked ditch" design option uses a critical shear for the road element of 10N-m^{-2}. The majority of erosion occurs on the road surface due to raindrop splash and shallow overland flow. Selecting this option will generally reduce road sediment production by 50% to 90%. For example, for established roads in Oregon, Luce and Black (1999) observed that road segments with vegetated ditches delivered only 10 to 20% as much sediment as did segments with freshly graded ditches. Rock lining or vegetating a ditch is particularly effective in reducing sediment delivery at stream crossings. It is less effective in reducing delivery across a forested buffer where sediment transport by runoff rather than detachment dominates the sediment delivery. This design best models an older road where the traveled way is devoid of vegetation, but the ditches are completely covered in vegetation. It is also suited to conditions where rock or gravel is used to line the ditch to limit erosion.

Outsloped, unrutted

The "outsloped, unrutted" design best describes the road condition immediately following blading. With traffic, however, wheel tracks soon begin to flatten, and runoff tends to follow wheel tracks--even if rutting is barely discernable--from one surface cross drain to the next. Only in cases where a road is outsloped, and traffic is light or restricted, is the "outsloped, unrutted" design appropriate. This may occur on a road that is closed, but prior to closure is bladed and outsloped.

Outsloped, rutted

The "outsloped, rutted" option generally is the most appropriate selection for an outsloped road. This road design option assumes a rill spacing of 2m, similar to the spacing of wheel tracks. The "outsloped, rutted" design is appropriate for an insloped road with wheel ruts which are carrying runoff between cross drains where most or all runoff is not flowing into the established ditches. As this option specifies a rill spacing of 2m, whereas the insloped design uses 4m, the predicted road erosion rates will differ.

Other Road Design

If the road is crowned with a ditch on either side, the erosion rate can be estimated by selecting either "insloped" (if there are no ruts) or "outsloped, rutted" (if ruts are generally present).

5.2.4 Road Surface

There are three options to choose from when defining the road surface in the WEPP:Road model: native, gravel, and paved. However, the methodology presented here only utilizes native and gravel material as it is unlikely that a forest road will be paved.

Native Surface

A native surface road is a road constructed from the material occurring on the site, with no added surface material (Figure 5). Note that unless native surface roads are regularly maintained or have little traffic, they will likely be rutted, and the “outsloped, rutted” option should be selected for the segment’s road design.

Gravel Surface

A gravel surface road assumes that gravel has been added to the surface. This selection alters the soil on a road segment in the WEPP:Road model by increasing the rock content and the hydraulic conductivity of the soil as well as changing the flow path length. Generally, the increase in conductivity due to the addition of gravel decreases runoff, however in areas where runoff is due to saturated conditions rather than rainfall rates, runoff from gravel roads compared to native roads may be similar. Gravel can also reduce runoff by reducing the formation of ruts which minimizes flow path length. However, under heavy traffic, a gravel road may also become rutted. Regular maintenance or reduced tire pressure on heavy vehicles can help to maintain the desired road design.

Figure 5. An example of a forested road constructed of native material with significant rutting.

5.2.5 Traffic Level

There are three road traffic level options to select from: high, low, and none. High traffic roads generally have the highest sediment loading while the rill erodibility value is reduced by 75% on roads with low or no traffic in the model. To minimize sediment generation from low use roads or roads with no traffic, the road should be outsloped and traffic restricted during wet seasons.

High Traffic

High traffic is generally associated with a timber sale, hauling numerous loads of logs over the road, or roads that receive considerable traffic during much of the year. Generally, roads with higher levels of traffic also receive regular maintenance, which may decrease rutting and erosion risk. However, high traffic can bring fines to the surface and prevent revegetation, both of which tend to increase erosion risk. High traffic roads generally have ruts or wheel tracks deep enough to assume that an "outsloped, unrutted" design is inappropriate. In most cases, a rutted design is the most appropriate for high traffic roads. The model assumes minimal vegetation on the road surface, 50% ground cover from vegetation on the fillslope, and 100% ground cover in the forest buffer.

Low Traffic

Low traffic roads are roads with administrative or light recreational use during dry weather. Low traffic roads may or may not be rutted, depending on maintenance and times of the year when the traffic occurs. The model assumes minimal vegetation on the road surface, 50% ground cover from vegetation on the fillslope, and 100% ground cover in the forest buffer.

No Traffic

No traffic roads are roads with restricted or no access. For no traffic, we assume the road has at least 50% vegetative cover, and the fillslope and forest buffer both have 100% vegetative ground cover.

5.2.6 Road Gradient

One of the most influential variables in the WEPP:Road model is road gradient. In this methodology, we break truck road gradient down into three categories, gradual (0-5%), moderate (5-10%), and steep

(>10%). For skid trails, "steep" is defined as 11-20% and "very steep" is anything greater than 20%. An upper limit of 10% for truck roads and 20% for skid trails is used as the AMP manual recommends avoiding gradients greater than these values.

As shown in Table 1, the model input value we use for each of these categories is the average slope of each category, for example sediment production from gradual roads (0-5%) are calculated using a gradient of 2.5%.

In this methodology we advise that slope is estimated using elevation data in the VT ANR Atlas or within a GIS and verified during audit inspections.

5.2.7 Road Length and Width

Of the topographical input variables for roads, both road length and width are held constant. Road length is the defining feature of how road segments are split, and road width is held constant due to specifications derived from the Vermont AMP manual.

5.2.8 Fill Gradient and Length

Fill gradient describes the percent slope of the fill slope surface. Fill length is the horizontal length of fill slope. Both values are held constant as their relative influence on loading is less than some other variables and their specifications are defined in the Vermont AMP Manual.

5.2.9 Buffer Gradient and Length.

Forest buffers, protective strips, buffer strips, filter strips, or riparian management zones are interchangeable terms for areas of forested land adjacent to streams and other bodies of water. The input variables used for buffer length and gradient in this methodology are based on those outlined in the Vermont AMP manual (Figure 7). These variables are highly critical to this analysis as they are the two variables that determine the percent of the sediment and phosphorus load that reaches a nearby body of water (Rhee, 2014). In this methodology, we advise that buffer length be determined as the smallest distance between a road segment and a stream, perpendicular to the stream beginning at the mean high watermark or the landward edge of an active flood plain or wetland (Figure 5). If the distance between a road segment and a stream is variable along the length of the segment, the shortest distance will be utilized as shown in Figure 6. Similar to road gradient, we advise that slope is estimated using elevation data in the VT ANR Atlas or within a GIS and verified during audit inspections.

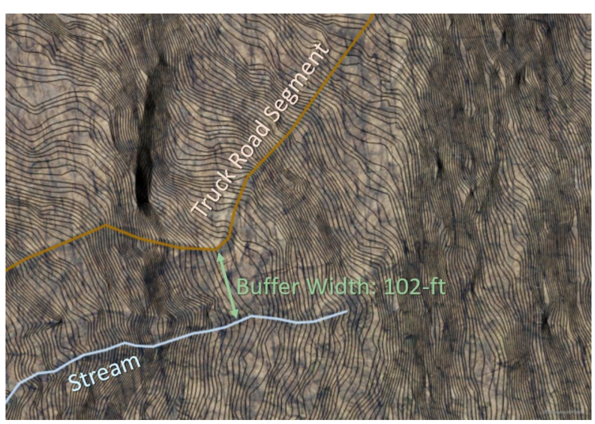

Figure 6: Buffer width example

TABLE 4
Minimum Forest Buffer Widths

Percent Slope of Land Between Skid Trails, Truck Roads or Log Landings and Streams or Other Waters	Width from Top of Bank (Feet Along Surface of Ground Measured Perpendicular to the Stream or Other Waters)
0-10	50
11-20	70
21-30	90
31-40*	110

*Add 20 feet for each additional 10 percent slope

Remember that the buffer distance is measured on each side of the stream. For example, if one side of the stream is 7% slope, the buffer distance on that side is 50 feet. If the other side is 15% slope, the buffer distance on that side is 70 feet. The total forest buffer width at location on the stream is 120 feet.

Forest Buffer

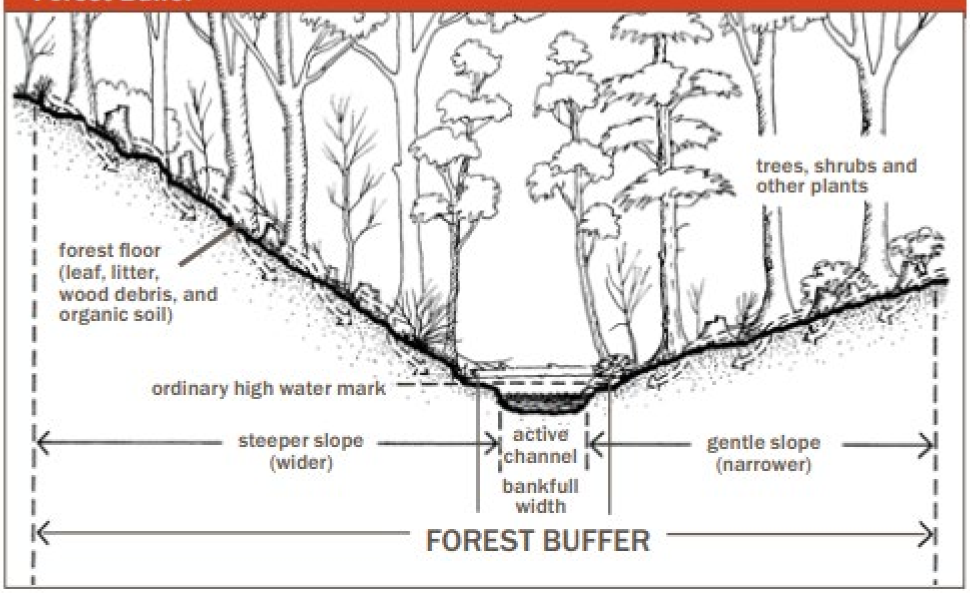

Figure 7: Vermont AMP Forest Buffer Specifications

6 WEPP:Model Adaptation

6.1 Summary of Road Segments Methodology

There are three principle components to our adaptation of the WEPP:Road model when evaluating forest road segments: phosphorus/sediment production (kg/100m/year), percentage of phosphorus/sediment to reach a nearby body of water, and BMP reduction efficiency (Figure 8). We differentiate between the phosphorus production from a forest road and the percentage to reach a nearby body of water because the WEPP:Road model contains different variables that influence each independently.

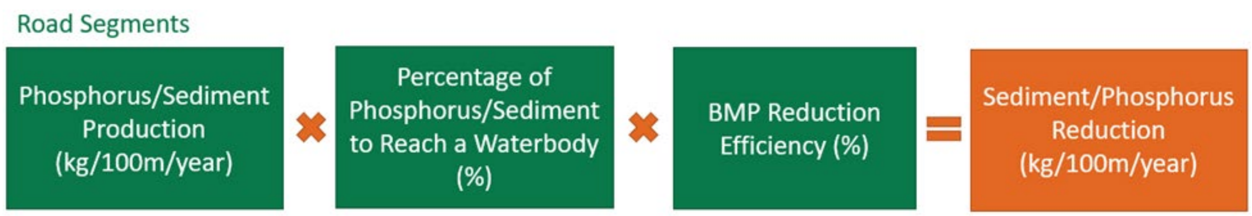

Figure 8: Road segment sediment/phosphorus reduction methodology summary.

6.2 Summary of UVA Parcels Methodology

There are two major components to our adaptation of the WEPP:Road model when evaluating UVA parcels: phosphorus/sediment yield and BMP reduction efficiency (Figure 9).

Figure 9: UVA parcel sediment/phosphorus reduction methodology summary.

On qualifying UVA parcels, it is assumed that 4.5% of the total area is made up of some type of forest road (i.e., truck roads and skid trails). This assumption was stated in Appendix B of the *Phosphorus TMDL for VT's Segments of Lake Champlain*, which is the *Crosswalk between the Vermont Phase 1 Plan and EPA's BMP scenario identifying achievable phosphorus reductions* and is based on Gucinski (2001). Of the 4.5% of forest roads, we assume truck roads make up 20% of forest roads whereas skid trails make up 80%. Determining the phosphorus or sediment yield associated with the forest roads on a UVA parcel is simply a function of parcel location (Table 3). These sediment and phosphorus yields are an average of all model simulations per weather station.

6.3 Phosphorus/Sediment Production

In the WEPP:Road model, the phosphorus and sediment production from a road segment is primarily driven by four key influential variables: road design, traffic level, weather station, and road gradient. For the sake of simplicity in this methodology for road segments, traffic level and road design are combined into a term we designate as “runoff potential”. There are four categories of runoff potential as displayed in Table 2.

Table 2. Runoff potential for road segments.

Runoff Potential	Classification
Very High	Traffic Level = “High”
High	Traffic Level = “Low” **&** Road Design = “Insloped, bare ditch” or “Outsloped, rutted”
Medium	Traffic Level = “Low” **&** Road Design = “Insloped, vegetated or rocked ditch” or “Outsloped, unrutted” ***OR…*** Traffic Level = “None” **&** Road Design = “Insloped, bare ditch” or “Outsloped, rutted”
Low	Traffic Level = “None” **&** Road Design = “Insloped, vegetated or rocked ditch” or “Outsloped, unrutted”

Either through field assessments or existing information, the appropriate road design and traffic level are assigned to each road segment, resulting in its runoff potential designation. This, when compared to the average road gradient can be then used to determine the phosphorus and sediment production (kg/100m/year) as found in the tables of Appendix B for truck roads and Appendix C for skid trails. These tables represent the mean phosphorus and sediment production calculated across all other input variables.

One key element to note is that the phosphorus production is not a direct output of the WEPP:Road model, but rather a conversion determined through an assumed direct linear relationship between sediment and phosphorus load as shown in the following equation. This conversion factor is derived from Wemple et al (2013). This same conversion factor is utilized in the Vermont DEC Road Erosion Inventory accounting methodology for unpaved roads and is similar to the Michigan Department of Transportation (MDOT) conversion factor of (0.0005 kg P / kg TSS). Additionally, this conversion factor is used for forest phosphorus loads in the SWAT model developed for the Lake Champlain TMDLs by Tetra Tech (2015). Phosphorus loads derived from a road segment per county can be found in Table 3. This is strictly the phosphorus produced from a road segment, not the load that enters a nearby body of water.

$$Phosphorus\ Load\ [kg] = Sediment\ Load\ [kg] * 0.000396$$

6.4 Percentage of Phosphorus/Sediment to Reach a Waterbody

To estimate the percent of phosphorus and sediment reaching a waterbody, the initial phosphorus and sediment production load needs to be multiplied by the percentage determined by the forest buffer length and forest buffer gradient as found in the tables of Appendix B. It is important to note that we classify all roads farther than 110-ft from a water of the state or wetland as hydrologically disconnected. This is approximate to the MRGP method which defines hydrologically connected roads as those within 100ft of a water of the state or wetland. Conversely, to estimate the sediment delivery for a road segment with a stream crossing, the user can assume that all of the road prism erosion enters the stream. This method does not include any erosion from the fill slope.

6.5 Phosphorus and Sediment Yield from UVA parcels

As previously describes, determining the phosphorus or sediment yield associated with the forest roads on a UVA parcel is simply a function of parcel location (Table 3). These phosphorus yields are an average of all model simulations, assuming a 80/20 split for skid trails and truck roads per weather station. Once the total hectares of forest roads on a parcel is determined (4.5%), the total phosphorus or sediment load in kg/year is a product of the appropriate yield and area.

Table 3: UVA parcel phosphorus/sediment yield by county.

Counties	Phosphorus Yield (kg P/ha/year)	Sediment Yield (kg/ha/year)
Grand Isle, Franklin, Chittenden, Addison	3.30	8338.34
Lamoille, Washington, Orange	4.62	11,661.02
Orleans, Essex, Caledonia	6.79	17,152.52
Rutland, Windsor	3.52	8893.91
Bennington, Windham	6.89	17,391.32

7 BMP Reduction Efficiency

7.1 Road Segment BMP Efficiency Audit

BMP reduction efficiencies are determined as a function of proper BMP implementation and maintenance. This methodology is primarily based on the Virginia Department of Forestry (VDOF) BMP implementation audit program (Lakel, 2014). In our recommended auditing methodology, a series of questions are asked of road segments and UVA parcels regarding the implementation of BMPs across six categories as noted in Table 4. These categories include harvest planning, truck roads, skid trails, stream crossings, forest buffers, and wetlands. The audit contains a total of 67 questions for road segments and 36 questions for UVA parcels (Appendix A). Audit scores are reported as the percentage of applicable audit questions that received a "Yes" on the audit. The audit score will determine the sediment and phosphorus reduction (%) creditable for the implementation of the suite of BMPs.

Table 4. BMP audit summary.

BMP Category	Number of Questions (Road Segment Audit)	Number of Questions (UVA Audit)
Harvest Planning	3	3
Truck Roads	19	9
Skid Trails	12	4
Stream Crossings	19	9
Forest buffers	10	8
Wetlands	4	3

7.2 Pollutant reductions as a function of compliance

Audit scores are calculated and an overall BMP audit score is calculated. This audit score is used to determine the level of BMP compliance for which distinct quantitative phosphorus and sediment reduction efficiencies are associated (Table 5). Here, we define the utilization of BMPs for forestry operations that receive an audit score less than 80% as "low". Forestry operations that receive an audit score of 80-90% are "standard" and operations that receive an audit score above 90% are "high". The numerical efficiency values representing each level of proper BMP utilization and implementation are conservative estimates based on existing United States Department of Agriculture (USDA) Forest Service reports and published erosion and sediment research as summarized in Cristan et al, 2019 and Nolan et a, 2015.

In the case of UVA parcels, where data is limited, the BMP utilization levels can be determined by a general assumption of standard BMP compliance (40% reduction efficiency) rather than a strict adherence to the auditing questions.

Table 5. Sediment and phosphorus efficiencies based on BMP compliance status.

Forestry Operation BMP Utilization Levels	Audit Score	Reduction Efficiency
Low	< 80%	0%
Standard	80 – 90%	40%
High	90 – 100%	80%

This form of BMP accounting methodology in which reduction efficiencies are assigned based on a suite of BMPs rather than individually is common practice among many state-organized operations. While some research has been done to assess individual forestland BMP efficiencies, replication and quantification of such studies under varying geologic, topographic, and climatic conditions has been minimal (Edwards et al., 2016). Additionally, the burden of modeling BMP practices individually exceeds the enhanced model accuracy gained from doing so.

8 FUTURE RECOMMENDATIONS

For the implementation of this methodology we recommend a web-based tool be developed for ease of use. This web-based tool would very likely resemble the existing Stormwater Treatment Practice (STP) Calculator developed by the DEC, where users enter STP data and the web-based tool calculates annual total phosphorus load reductions. For the purposes of this methodology, users should have the ability to designate their county, define the predominant soil classification within their forest roads network and enter the necessary inputs required either for road segment calculations and/or UVA parcels. The outputs of this calculator would include sediment and phosphorus loads as well as reductions.

Throughout the accounting methodology development, many data gaps were identified. In this methodology, we assume a linear relationship between sediment and phosphorus load utilizing a conversion factor derived from Wemple et al (2013). While there is merit to the usage of this conversion factor in this methodology, especially as it aligns with the conversion factor used in the estimates of the total load from the forest sector in the Lake Champlain TMDL, additional research is warranted to further develop the accuracy of phosphorus transport.

Additional field-based research is also warranted to further develop the accuracy of the BMP reduction efficiency as it pertains to the auditing questions presented. As previously discussed, many states utilize auditing methods in their evaluation of forestland BMPs. However, these audits are primarily used to gather a qualitative assessment of BMP implementation, usage, and effect rather than to designate a specific reduction efficiency. What little research that does exist on such methods were primarily conducted in the southeastern United States. The general approach is of sufficient merit for use in other regions, but additional research conducted under climatic and geographic conditions that better represent Vermont would be beneficial.

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APPENDIX A: FORESTLAND BMP AUDITING QUESTIONS

Table A1: Road Segment Audit questions by category.

Road Segment Audit Questions by Category	Yes	No	N/A
Harvest Planning			
In the case of severe site conditions (very wet or steep) was the harvesting system designed to reduce damage to soil, site and water?			
Is there any evidence that operations are timed appropriately? Harvesting under frozen, snow-covered, or dry conditions can minimize the need for additional AMPs			
Is there evidence that the logger utilized a harvesting system that is generally appropriate for the site and timber conditions?			
Truck Roads			
Are grades less than 10% except for necessary deviations?			
Are new roads located and constructed to allow for proper drainage?			
Are new roads located to avoid erodible, wet and sensitive ground?			
Are riprap and/or brush dams used where needed to slow water and trap sediment?			
Are roads built with the proper forest buffer distance? (See AMP Table 4 for specifications)			
When possible, are the majority of roads constructed during dry periods or when the ground is frozen?			
Are cut and fill slopes maintained at a natural angle of repose or less (2:1 for average soils) wherever possible?			
Are roads on the contour where practical?			
Are temporary sediment barriers to slow flowing water and trap sediment used during construction?			
Are temporary roads retired with properly constructed water bars or tank traps?			
Are turnouts directing water and/or sediment away from riparian areas?			
Are under-road culverts installed, spaced and maintained properly? (See AMP Table 1 for specifications)			
Is non-essential (i.e. recreational) access being controlled after harvest?			
Is construction of dips, bars, turnouts and traps adequate to maintain function?			
Is gravel or vegetation present to protect water bars from erosion?			
Is there rock or vegetation on slopes where needed to prevent erosion?			
Is water being “turned out” into surrounding landscape with appropriate structures?			
Is water diverted from the road surface at specified intervals using dips, bars or traps? (See AMP Table 1 for specifications)			
Was road construction and use minimized?			

Road Segment Audit Questions by Category	Yes	No	N/A
Skid Trails			
Are all skid trails free from channelized flow that is likely to cause sedimentation?			
Are all skid trails located outside the forest buffer? (See AMP Table 4 for specifications)			
Are appropriate cross drainages installed where springs or seeps crossed the trails?			
Are skid trails limited to less than 20% grade?			
Are skid trails limited to sideslopes less than 50%?			
Are water turnouts built to ensure drainage of skid trails where needed?			
Are water bars established on trails where erosion is likely at recommended intervals?			
Did the logger avoid skidding logs through intermittent or perennial streams?			
Are skid trails less than 300ft in length?			
Do trails avoid rutting that will likely cause channelized erosion near a stream?			
Is vegetation established where needed on trails to prevent erosion and sedimentation?			
Were brush mats used to stabilize trails and prevent erosion where needed?			
Stream Crossings			
Are approaches stable, have a grade less than 10% and unlikely to contribute sediment to the stream?			
Are culvert pipes installed properly in the channel to avoid undercutting and channel erosion?			
Are culverts and bridges of adequate length?			
Are culverts covered with adequate and appropriate fill material?			
Are culverts covered with gravel to reduce erosion near the stream?			
Are culverts properly sized according to the AMP manual? (See AMP Table 2A for specifications)			
Are fords used only where a natural rock base and gentle approaches allow?			
Are headwalls stabilized with vegetation, rock or fabric to minimize cutting?			
Are permanent bridge abutments adequate and stable?			
Are stream banks and approaches re–claimed with sufficient vegetation, rock or slash?			
Are stream crossings installed at or near to right angles where possible?			
Are stream crossings minimized?			
Are temporary culverts, pole bridges and bridges removed as soon as the ground conditions are stable or within 12 months of installation?			
Are water diversion structures present when needed on approaches?			
Do all ford crossings avoid restricting the natural flow of water?			

Road Segment Audit Questions by Category	Yes	No	N/A
On approaches to stream crossings, are waterbars, turn-ups or broad-based dips correctly installed as close to as 25 feet away?			
Is the soil on stream crossing approaches in the forest buffer stabilized by using slash, brush, or log corduroy?			
Is the addition of unnatural materials in the stream to facilitate the use of a ford minimized?			
Were pole bridges used only in appropriate circumstances?			
Forest Buffers			
Are all forest buffers a minimum of 25 feet wide on each side of the stream bank?			
Are forest buffer widths modified to accommodate percent slope of land?			
Did the logger avoid exposing large sections of soil in the forest buffer?			
Did the logger avoid partial or patch clear cutting in the forest buffer?			
Did the logger avoid silvicultural debris in the stream?"			
Did the logger avoid silvicultural sediment in the stream that might endanger public health, beneficial uses or aquatic life as stated in the "silvicultural water quality law?"			
Do all intermittent and perennial streams have a forest buffer?			
Is forest buffer width relatively consistent along the entire length?			
Is the forest buffers free of roads and landings where possible?			
Was exposed soil in the forest buffer revegetated or covered with organic materials?			
Wetlands			
Are landings located on appropriate ground?			
Is water movement maintained on the site?			
Did the operation avoid activities during particularly wet weather?			
Was the harvesting system appropriate for the site conditions?			

Table A2: UVA Parcel Audit questions by category.

Audit Questions by Category	Yes	No	N/A
Harvest Planning			
In the case of severe site conditions (very wet or steep) was the harvesting system designed to reduce damage to soil, site and water?			
Is there any evidence that operations are timed appropriately? Harvesting under frozen, snow-covered, or dry conditions can minimize the need for additional AMPs			
Is there evidence that the logger utilized a harvesting system that is generally appropriate for the site and timber conditions?			
Truck Roads			
Is there evidence to suggest that the majority of truck roads are designed in compliance with the standards put forward in the Vermont Acceptable Practices Manual?			
Are roads built with the proper forest buffer distance? (See AMP Table 4 for specifications)			
Are roads on the contour where practical?			
Are the majority of temporary roads retired with properly constructed water bars or tank traps?			
Is non-essential (i.e. recreational) access being controlled after harvest?			
Is gravel or vegetation present to protect water bars from erosion?			
Is there rock or vegetation on slopes where needed to prevent erosion?			
Is water being “turned out” into surrounding landscape with appropriate structures?			
Is water diverted from the road surface at specified intervals using dips, bars or traps? (See AMP Table 1 for specifications)			
Skid Trails			
Is there evidence to suggest the majority of skid trails are designed in compliance with the standards put forward in the Vermont Acceptable Practices Manual?			
Are all skid trails located outside the forest buffer? (See AMP Table 4 for specifications)			
Did the logger avoid skidding logs through intermittent or perennial streams?			
Are skid trails less than 300ft in length?			
Stream Crossings			
Is there evidence to suggest that the majority of stream crossings are designed in compliance with the standards put forward in the Vermont Acceptable Practices Manual?			
Are stream banks and approaches re–claimed with sufficient vegetation, rock or slash?			
Are stream crossings installed at or near to right angles where possible?			
Are stream crossings minimized?			

Audit Questions by Category	Yes	No	N/A
Are temporary culverts, pole bridges and bridges removed as soon as the ground conditions are stable or within 12 months of installation?			
Are water diversion structures present when needed on approaches?			
On approaches to stream crossings, are waterbars, turn-ups or broad-based dips correctly installed as close to as 25 feet away?			
Is the soil on stream crossing approaches in the forest buffer stabilized by using slash, brush, or log corduroy?			
Is the addition of unnatural materials in the stream to facilitate the use of a ford minimized?			
Forest Buffers			
Are the majority of forest buffers a minimum of 25 feet wide on each side of the stream bank?			
Did the logger avoid exposing large sections of soil in the forest buffer?			
Did the logger avoid partial or patch clear cutting in the forest buffer?			
Did the logger avoid silvicultural debris in the stream?			
Did the logger avoid silvicultural sediment in the stream that might endanger public health, beneficial uses or aquatic life as stated in the "silvicultural water quality law?"			
Do all intermittent and perennial streams have a forest buffer?			
Is the forest buffers free of roads and landings where possible?			
Was exposed soil in the forest buffer revegetated or covered with organic materials?			
Wetlands			
Are landings located on appropriate ground?			
Is water movement maintained on the site?			
Did the operation avoid activities during particularly wet weather?			

APPENDIX B: TRUCK ROADS SEDIMENT AND PHOSPHORUS TABLES

B.1 Grand Isle, Franklin, Chittenden, and Addison County

Table B1: Estimated sediment production leaving the road (kg/100m/year).

Grand Isle, Franklin, Chittenden, and Addison County			
	Predominant Soil Type	Loam	
Runoff Potential		*Road Segment Gradient*	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	336.35	855.20	2384.64
High	178.26	422.51	1068.75
Moderate	98.87	233.28	621.63
Low	66.24	103.25	278.36
	Predominant Soil Type	Sandy Loam	
Runoff Potential		*Road Segment Gradient*	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	136.76	344.16	1036.28
High	80.63	186.46	485.38
Moderate	63.52	125.30	340.42
Low	53.72	84.52	193.32
	Predominant Soil Type	Silt Loam	
Runoff Potential		*Road Segment Gradient*	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	322.80	809.44	2067.40
High	156.84	361.61	812.30
Moderate	88.10	198.07	512.22
Low	62.88	99.28	249.50
	Predominant Soil Type	Clay Loam	
Runoff Potential		*Road Segment Gradient*	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	302.74	733.64	1961.35
High	143.10	339.35	867.32
Moderate	78.67	172.84	467.89
Low	53.72	82.93	202.46

Table B2: Estimated phosphorus production leaving the road (kg/100m/year).

Grand Isle, Franklin, Chittenden, and Addison County			
Runoff Potential	*Predominant Soil Type*	Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.133	0.339	0.944
High	0.071	0.167	0.423
Moderate	0.039	0.092	0.246
Low	0.026	0.041	0.110
Runoff Potential	Predominant Soil Type	Sandy Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.054	0.136	0.410
High	0.032	0.074	0.192
Moderate	0.025	0.050	0.135
Low	0.021	0.033	0.077
Runoff Potential	Predominant Soil Type	Silt Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.128	0.321	0.819
High	0.062	0.143	0.322
Moderate	0.035	0.078	0.203
Low	0.025	0.039	0.099
Runoff Potential	Predominant Soil Type	Clay Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.120	0.291	0.777
High	0.057	0.134	0.343
Moderate	0.031	0.068	0.185
Low	0.021	0.033	0.080

Table B3: Percent of phosphorus and sediment from road segments that reaches a nearby waterbody.

Grand Isle, Franklin, Chittenden, and Addison County						
Forest Buffer Gradient	*Predominant Soil:*	Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	55%	34%	29%	27%	0%
11-20%	100%	67%	42%	32%	28%	0%
21-30%	100%	71%	57%	40%	36%	0%
31-40%	100%	74%	62%	52%	47%	0%
Forest Buffer Gradient	*Predominant Soil:*	Sandy Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	48%	40%	35%	30%	0%
11-20%	100%	61%	49%	45%	44%	0%
21-30%	100%	73%	64%	58%	54%	0%
31-40%	100%	79%	71%	68%	70%	0%
Forest Buffer Gradient	*Predominant Soil:*	Silt Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	63%	41%	36%	34%	0%
11-20%	100%	71%	48%	39%	37%	0%
21-30%	100%	78%	54%	45%	37%	0%
31-40%	100%	80%	67%	59%	53%	0%
Forest Buffer Gradient	*Predominant Soil:*	Clay Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	67%	46%	35%	30%	0%
11-20%	100%	74%	52%	40%	33%	0%
21-30%	100%	76%	62%	50%	44%	0%
31-40%	100%	79%	67%	57%	50%	0%

B.2 Lamoille, Washington, and Orange County

Table B4: Estimated sediment production leaving the road (kg/100m/year).

Lamoille, Washington, and Orange County			
Runoff Potential	*Predominant Soil Type*	Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	446.06	1060.63	2591.30
High	235.50	512.76	1093.20
Moderate	126.79	289.11	718.98
Low	83.10	130.32	345.27
Runoff Potential	*Predominant Soil Type*	Sandy Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	274.97	625.82	1563.60
High	177.38	348.01	717.80
Moderate	105.06	222.87	524.62
Low	78.78	123.72	285.28
Runoff Potential	*Predominant Soil Type*	Silt Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	471.11	1053.23	2685.39
High	223.53	458.60	1041.87
Moderate	119.32	255.34	641.89
Low	80.54	123.73	314.50
Runoff Potential	*Predominant Soil Type*	Clay Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	399.86	883.06	2054.61
High	175.71	384.67	842.35
Moderate	96.65	209.34	524.74
Low	67.62	102.63	246.79

Table B5: Estimated phosphorus production leaving the road (kg/100m/year).

Lamoille, Washington, and Orange County			
Runoff Potential	*Predominant Soil Type*	Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.177	0.420	1.026
High	0.093	0.203	0.433
Moderate	0.050	0.114	0.285
Low	0.033	0.052	0.137
Runoff Potential	Predominant Soil Type	Sandy Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.109	0.248	0.619
High	0.070	0.138	0.284
Moderate	0.042	0.088	0.208
Low	0.031	0.049	0.113
Runoff Potential	Predominant Soil Type	Silt Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.187	0.417	1.063
High	0.089	0.182	0.413
Moderate	0.047	0.101	0.254
Low	0.032	0.049	0.125
Runoff Potential	Predominant Soil Type	Clay Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.158	0.350	0.814
High	0.070	0.152	0.334
Moderate	0.038	0.083	0.208
Low	0.027	0.041	0.098

Table B6: Percent of phosphorus and sediment from road segments that reaches a nearby waterbody.

Lamoille, Washington, and Orange County						
Forest Buffer Gradient	*Predominant Soil:*	Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	69%	46%	37%	33%	0%
11-20%	100%	76%	56%	44%	38%	0%
21-30%	100%	79%	66%	57%	50%	0%
31-40%	100%	83%	71%	65%	59%	0%
Forest Buffer Gradient	*Predominant Soil:*	Sandy Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	52%	40%	32%	28%	0%
11-20%	100%	68%	54%	47%	40%	0%
21-30%	100%	76%	66%	66%	63%	0%
31-40%	100%	80%	72%	69%	67%	0%
Forest Buffer Gradient	*Predominant Soil:*	Silt Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	72%	54%	44%	38%	0%
11-20%	100%	80%	60%	50%	43%	0%
21-30%	100%	83%	71%	62%	51%	0%
31-40%	100%	85%	76%	70%	63%	0%
Forest Buffer Gradient	*Predominant Soil:*	Clay Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	78%	62%	51%	46%	0%
11-20%	100%	82%	70%	59%	52%	0%
21-30%	100%	83%	73%	66%	62%	0%
31-40%	100%	86%	78%	70%	67%	0%

B.3 Orleans, Essex and Caledonia County

Table B7: Estimated sediment production leaving the road (kg/100m/year).

Orleans, Essex and Caledonia County			
	Predominant Soil Type	Loam	
Runoff Potential	*Road Segment Gradient*		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	529.78	1283.78	3442.09
High	287.79	642.07	1532.04
Moderate	153.80	337.04	852.59
Low	97.84	154.08	393.61
	Predominant Soil Type	Sandy Loam	
Runoff Potential	*Road Segment Gradient*		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	293.05	717.74	1924.51
High	197.94	405.82	904.75
Moderate	127.75	260.03	630.65
Low	98.28	155.49	354.11
	Predominant Soil Type	Silt Loam	
Runoff Potential	*Road Segment Gradient*		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	554.42	1294.83	3608.50
High	268.32	580.78	1455.17
Moderate	144.73	312.07	787.31
Low	95.59	147.91	366.70
	Predominant Soil Type	Clay Loam	
Runoff Potential	*Road Segment Gradient*		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	494.57	1097.02	2832.44
High	216.54	491.08	1207.54
Moderate	119.79	258.54	662.20
Low	80.13	121.71	299.48

Table B8: Estimated phosphorus production leaving the road (kg/100m/year)

Orleans, Essex and Caledonia County			
Runoff Potential	*Predominant Soil Type*	Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.210	0.508	1.363
High	0.114	0.254	0.607
Moderate	0.061	0.133	0.338
Low	0.039	0.061	0.156
Runoff Potential	Predominant Soil Type	Sandy Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.116	0.284	0.762
High	0.078	0.161	0.358
Moderate	0.051	0.103	0.250
Low	0.039	0.062	0.140
Runoff Potential	Predominant Soil Type	Silt Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.220	0.513	1.429
High	0.106	0.230	0.576
Moderate	0.057	0.124	0.312
Low	0.038	0.059	0.145
Runoff Potential	Predominant Soil Type	Clay Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.196	0.434	1.122
High	0.086	0.194	0.478
Moderate	0.047	0.102	0.262
Low	0.032	0.048	0.119

Table B9: Percent of phosphorus and sediment from road segments that reaches a nearby waterbody.

Orleans, Essex and Caledonia County						
Forest Buffer Gradient	*Predominant Soil:* Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	74%	52%	43%	37%	0%
11-20%	100%	78%	62%	54%	51%	0%
21-30%	100%	83%	70%	62%	57%	0%
31-40%	100%	88%	77%	71%	66%	0%
Forest Buffer Gradient	*Predominant Soil:* Sandy Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	63%	47%	38%	32%	0%
11-20%	100%	75%	65%	62%	54%	0%
21-30%	100%	81%	73%	67%	67%	0%
31-40%	100%	87%	79%	74%	72%	0%
Forest Buffer Gradient	*Predominant Soil:* Silt Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	76%	60%	49%	43%	0%
11-20%	100%	81%	68%	57%	50%	0%
21-30%	100%	83%	72%	65%	60%	0%
31-40%	100%	88%	78%	71%	69%	0%
Forest Buffer Gradient	*Predominant Soil:* Clay Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	79%	69%	61%	54%	0%
11-20%	100%	81%	73%	67%	58%	0%
21-30%	100%	84%	77%	71%	64%	0%
31-40%	100%	87%	81%	77%	72%	0%

B.4 Rutland and Windsor County

Table B10: Estimated sediment production leaving the road (kg/100m/year).

Rutland and Windsor County			
Runoff Potential	*Predominant Soil Type*	Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	273.24	745.21	2248.52
High	156.42	383.10	1030.66
Moderate	67.77	187.34	572.87
Low	41.62	59.02	191.93
Runoff Potential	*Predominant Soil Type*	Sandy Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	96.16	318.29	988.94
High	79.55	192.74	465.33
Moderate	34.49	94.18	282.48
Low	25.24	36.69	102.00
Runoff Potential	*Predominant Soil Type*	Silt Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	268.08	736.95	2274.86
High	142.67	338.85	928.45
Moderate	60.32	151.66	491.55
Low	38.36	52.21	161.44
Runoff Potential	*Predominant Soil Type*	Clay Loam	
	Road Segment Gradient		
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	252.67	647.05	1797.02
High	118.39	309.56	814.13
Moderate	53.20	142.50	430.42
Low	34.63	46.96	137.30

Table B11: Estimated phosphorus production leaving the road (kg/100m/year).

Rutland and Windsor County			
Runoff Potential	*Predominant Soil Type*	Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.108	0.295	0.890
High	0.062	0.152	0.408
Moderate	0.027	0.074	0.227
Low	0.016	0.023	0.076
Runoff Potential	Predominant Soil Type	Sandy Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.038	0.126	0.392
High	0.032	0.076	0.184
Moderate	0.014	0.037	0.112
Low	0.010	0.015	0.040
Runoff Potential	Predominant Soil Type	Silt Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.106	0.292	0.901
High	0.056	0.134	0.368
Moderate	0.024	0.060	0.195
Low	0.015	0.021	0.064
Runoff Potential	Predominant Soil Type	Clay Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.100	0.256	0.712
High	0.047	0.123	0.322
Moderate	0.021	0.056	0.170
Low	0.014	0.019	0.054

Table B12: Percent of phosphorus and sediment from road segments that reaches a nearby waterbody.

Rutland and Windsor County						
Forest Buffer Gradient	*Predominant Soil:*		Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	58%	41%	27%	20%	0%
11-20%	100%	64%	47%	34%	27%	0%
21-30%	100%	68%	55%	45%	36%	0%
31-40%	100%	77%	63%	56%	49%	0%
Forest Buffer Gradient	*Predominant Soil:*		Sandy Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	41%	26%	17%	5%	0%
11-20%	100%	53%	40%	31%	25%	0%
21-30%	100%	64%	51%	43%	38%	0%
31-40%	100%	72%	61%	54%	49%	0%
Forest Buffer Gradient	*Predominant Soil:*		Silt Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	64%	51%	42%	30%	0%
11-20%	100%	70%	57%	49%	39%	0%
21-30%	100%	74%	61%	54%	45%	0%
31-40%	100%	79%	66%	59%	53%	0%
Forest Buffer Gradient	*Predominant Soil:*		Clay Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	66%	52%	43%	36%	0%
11-20%	100%	70%	56%	49%	41%	0%
21-30%	100%	76%	60%	52%	46%	0%
31-40%	100%	82%	67%	60%	53%	0%

B.5 Bennington and Windham County

Table B13: Estimated sediment production leaving the road (kg/100m/year).

Bennington and Windham County			
	Predominant Soil Type	Loam	
Runoff Potential	*Road Segment Gradient* Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	518.54	1254.66	3440.30
High	288.76	638.43	1578.51
Moderate	155.47	331.37	837.99
Low	98.44	148.99	377.83
	Predominant Soil Type	Sandy Loam	
Runoff Potential	*Road Segment Gradient* Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	284.03	716.90	1872.89
High	189.23	399.75	884.63
Moderate	124.81	264.80	612.22
Low	95.58	151.78	342.43
	Predominant Soil Type	Silt Loam	
Runoff Potential	*Road Segment Gradient* Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	540.80	1283.93	3625.92
High	268.87	584.44	1478.17
Moderate	140.49	295.87	772.25
Low	91.28	143.84	354.45
	Predominant Soil Type	Clay Loam	
Runoff Potential	*Road Segment Gradient* Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	473.40	1059.42	2776.52
High	212.82	483.64	1201.47
Moderate	115.56	250.25	643.18
Low	76.00	115.95	280.97

Table B14: Estimated phosphorus production leaving the road (kg/100m/year).

Bennington and Windham County			
Runoff Potential	*Predominant Soil Type*	Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.205	0.497	1.362
High	0.114	0.253	0.625
Moderate	0.062	0.131	0.332
Low	0.039	0.059	0.150
Runoff Potential	Predominant Soil Type	Sandy Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.112	0.284	0.742
High	0.075	0.158	0.350
Moderate	0.049	0.105	0.242
Low	0.038	0.060	0.136
Runoff Potential	Predominant Soil Type	Silt Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.214	0.508	1.436
High	0.106	0.231	0.585
Moderate	0.056	0.117	0.306
Low	0.036	0.057	0.140
Runoff Potential	Predominant Soil Type	Clay Loam	
		Road Segment Gradient	
	Gradual Slope (<%5)	Moderate Slope (5-10%)	Steep Slope (>10%)
Very High	0.187	0.420	1.100
High	0.084	0.192	0.476
Moderate	0.046	0.099	0.255
Low	0.030	0.046	0.111

Table B15: Percent of phosphorus and sediment from road segments that reaches a nearby waterbody.

Bennington and Windham County						
Forest Buffer Gradient	*Predominant Soil:*	Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	74%	53%	43%	38%	0%
11-20%	100%	79%	62%	55%	50%	0%
21-30%	100%	83%	70%	63%	58%	0%
31-40%	100%	88%	77%	71%	68%	0%
Forest Buffer Gradient	*Predominant Soil:*	Sandy Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	63%	48%	40%	33%	0%
11-20%	100%	73%	66%	63%	55%	0%
21-30%	100%	81%	73%	69%	69%	0%
31-40%	100%	86%	78%	75%	74%	0%
Forest Buffer Gradient	*Predominant Soil:*	Silt Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	77%	61%	50%	46%	0%
11-20%	100%	81%	70%	57%	52%	0%
21-30%	100%	86%	75%	68%	64%	0%
31-40%	100%	91%	80%	75%	72%	0%
Forest Buffer Gradient	*Predominant Soil:*	Clay Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	80%	69%	60%	54%	0%
11-20%	100%	83%	75%	65%	59%	0%
21-30%	100%	86%	78%	71%	64%	0%
31-40%	100%	89%	83%	78%	72%	0%

APPENDIX C: SKID TRAILS SEDIMENT AND PHOSPHORUS TABLES

C.1 Grand Isle, Franklin, Chittenden, and Addison County

Table C1: Estimated sediment production leaving the skid trail (kg/100m/year).

Grand Isle, Franklin, Chittenden, and Addison County				
	Predominant Soil Type	Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	121.76	408.30	1100.44	2242.28
Moderate	72.80	199.90	544.54	1241.55
Low	52.09	83.25	194.25	520.85
	Predominant Soil Type	Sandy Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	48.36	113.58	317.44	633.53
Moderate	43.69	81.70	190.62	407.94
Low	43.35	63.16	116.69	223.82
	Predominant Soil Type	Silt Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	107.36	343.74	791.43	1583.32
Moderate	68.01	169.57	441.54	1030.91
Low	55.41	81.18	173.97	453.22
	Predominant Soil Type	Clay Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	99.18	339.24	877.20	1761.78
Moderate	55.92	146.94	403.65	948.25
Low	40.65	62.45	129.91	352.30

Table C2: Estimated phosphorus production leaving the skid trail (kg/100m/year).

Grand Isle, Franklin, Chittenden, and Addison County				
	Predominant Soil Type	Loam		
Runoff Potential	*Road Segment Gradient* Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.048	0.162	0.436	0.888
Moderate	0.029	0.079	0.216	0.492
Low	0.021	0.033	0.077	0.206
	Predominant Soil Type	Sandy Loam		
Runoff Potential	*Road Segment Gradient* Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.019	0.045	0.126	0.251
Moderate	0.017	0.032	0.075	0.162
Low	0.017	0.025	0.046	0.089
	Predominant Soil Type	Silt Loam		
Runoff Potential	*Road Segment Gradient* Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.043	0.136	0.313	0.627
Moderate	0.027	0.067	0.175	0.408
Low	0.022	0.032	0.069	0.179
	Predominant Soil Type	Clay Loam		
Runoff Potential	*Road Segment Gradient* Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.039	0.134	0.347	0.698
Moderate	0.022	0.058	0.160	0.376
Low	0.016	0.025	0.051	0.140

Table C3: Percent of phosphorus and sediment from skid trail segments that reaches a nearby waterbody.

Grand Isle, Franklin, Chittenden, and Addison County						
Forest Buffer Gradient	*Predominant Soil:*	Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	55%	29%	19%	17%	0%
11-20%	100%	63%	38%	23%	19%	0%
21-30%	100%	66%	45%	28%	25%	0%
31-40%	100%	68%	51%	38%	28%	0%
Forest Buffer Gradient	*Predominant Soil:*	Sandy Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	34%	18%	8%	1%	0%
11-20%	100%	45%	32%	21%	9%	0%
21-30%	100%	52%	41%	30%	23%	0%
31-40%	100%	59%	55%	46%	41%	0%
Forest Buffer Gradient	*Predominant Soil:*	Silt Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	55%	31%	23%	18%	0%
11-20%	100%	62%	39%	27%	20%	0%
21-30%	100%	67%	42%	34%	22%	0%
31-40%	100%	69%	52%	41%	29%	0%
Forest Buffer Gradient	*Predominant Soil:*	Clay Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	62%	47%	31%	25%	0%
11-20%	100%	68%	55%	35%	29%	0%
21-30%	100%	70%	60%	41%	34%	0%
31-40%	100%	71%	65%	49%	40%	0%

C.2 Lamoille, Washington, and Orange County

Table C4: Estimated sediment production leaving the skid trail (kg/100m/year).

Lamoille, Washington, and Orange County				
	Predominant Soil Type	Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	165.32	444.32	1025.53	1905.98
Moderate	89.93	233.12	581.00	1251.52
Low	58.53	92.90	224.02	578.02
	Predominant Soil Type	Sandy Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	88.15	216.60	484.66	869.31
Moderate	71.94	139.25	318.00	636.78
Low	63.53	97.76	183.07	363.19
	Predominant Soil Type	Silt Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	141.04	389.24	948.15	1823.01
Moderate	79.95	205.94	513.76	1144.00
Low	58.44	89.90	206.75	530.73
	Predominant Soil Type	Clay Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	122.21	337.12	733.00	1396.82
Moderate	68.44	171.57	413.39	901.90
Low	45.60	72.50	150.95	394.82

Table C5: Estimated phosphorus production leaving the skid trail (kg/100m/year).

Lamoille, Washington, and Orange County				
	Predominant Soil Type	Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.065	0.176	0.406	0.755
Moderate	0.036	0.092	0.230	0.496
Low	0.023	0.037	0.089	0.229
	Predominant Soil Type	Sandy Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.035	0.086	0.192	0.344
Moderate	0.028	0.055	0.126	0.252
Low	0.025	0.039	0.072	0.144
	Predominant Soil Type	Silt Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.056	0.154	0.375	0.722
Moderate	0.032	0.082	0.203	0.453
Low	0.023	0.036	0.082	0.210
	Predominant Soil Type	Clay Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.048	0.133	0.290	0.553
Moderate	0.027	0.068	0.164	0.357
Low	0.018	0.029	0.060	0.156

Table C6: Percent of phosphorus and sediment from skid trail segments that reaches a nearby waterbody.

Lamoille, Washington, and Orange County						
Forest Buffer Gradient	*Predominant Soil:*		Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	60%	43%	31%	26%	0%
11-20%	100%	69%	50%	37%	28%	0%
21-30%	100%	72%	56%	42%	33%	0%
31-40%	100%	73%	62%	48%	39%	0%
Forest Buffer Gradient	*Predominant Soil:*		Sandy Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	43%	28%	20%	15%	0%
11-20%	100%	53%	41%	32%	26%	0%
21-30%	100%	65%	54%	47%	39%	0%
31-40%	100%	65%	59%	59%	50%	0%
Forest Buffer Gradient	*Predominant Soil:*		Silt Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	63%	48%	40%	32%	0%
11-20%	100%	70%	56%	49%	36%	0%
21-30%	100%	74%	61%	53%	42%	0%
31-40%	100%	76%	65%	59%	47%	0%
Forest Buffer Gradient	*Predominant Soil:*		Clay Loam			
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	66%	54%	43%	38%	0%
11-20%	100%	72%	61%	50%	44%	0%
21-30%	100%	74%	66%	54%	51%	0%
31-40%	100%	75%	69%	59%	54%	0%

C.3 Orleans, Essex, and Caledonia County

Table C7: Estimated sediment production leaving the skid trail (kg/100m/year).

Orleans, Essex, and Caledonia County				
	Predominant Soil Type	Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	187.14	575.69	1477.82	3004.20
Moderate	100.43	269.10	707.99	1541.39
Low	63.49	106.32	253.63	662.46
	Predominant Soil Type	Sandy Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	109.73	245.18	553.16	1068.88
Moderate	88.15	172.84	371.46	714.19
Low	76.12	118.34	224.94	440.81
	Predominant Soil Type	Silt Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	158.54	496.29	1346.66	2770.23
Moderate	90.40	231.47	640.09	1425.64
Low	63.02	100.67	238.41	621.92
	Predominant Soil Type	Clay Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	148.23	458.85	1146.57	2258.19
Moderate	76.34	208.06	548.32	1195.42
Low	45.27	75.96	186.99	496.10

Table C8: Estimated phosphorus production leaving the skid trail (kg/100m/year).

Orleans, Essex, and Caledonia County				
	Predominant Soil Type	Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.074	0.228	0.585	1.190
Moderate	0.040	0.107	0.280	0.610
Low	0.025	0.042	0.100	0.262
	Predominant Soil Type	Sandy Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.043	0.097	0.219	0.423
Moderate	0.035	0.068	0.147	0.283
Low	0.030	0.047	0.089	0.175
	Predominant Soil Type	Silt Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.063	0.197	0.533	1.097
Moderate	0.036	0.092	0.253	0.565
Low	0.025	0.040	0.094	0.246
	Predominant Soil Type	Clay Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.059	0.182	0.454	0.894
Moderate	0.030	0.082	0.217	0.473
Low	0.018	0.030	0.074	0.196

Table C9: Percent of phosphorus and sediment from skid trail segments that reaches a nearby waterbody.

Orleans, Essex, and Caledonia County						
Forest Buffer Gradient	*Predominant Soil:*	Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	64%	47%	37%	31%	0%
11-20%	100%	71%	53%	42%	36%	0%
21-30%	100%	74%	55%	46%	42%	0%
31-40%	100%	77%	61%	52%	45%	0%
Forest Buffer Gradient	*Predominant Soil:*	Sandy Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	43%	33%	24%	20%	0%
11-20%	100%	55%	49%	38%	31%	0%
21-30%	100%	62%	61%	52%	47%	0%
31-40%	100%	67%	57%	58%	53%	0%
Forest Buffer Gradient	*Predominant Soil:*	Silt Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	67%	52%	43%	37%	0%
11-20%	100%	73%	61%	50%	45%	0%
21-30%	100%	76%	65%	55%	49%	0%
31-40%	100%	79%	70%	58%	52%	0%
Forest Buffer Gradient	*Predominant Soil:*	Clay Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	70%	58%	49%	44%	0%
11-20%	100%	74%	65%	56%	50%	0%
21-30%	100%	76%	68%	59%	55%	0%
31-40%	100%	78%	71%	65%	59%	0%

C.4 Rutland and Windsor County

Table C10: Estimated sediment production leaving the skid trail (kg/100m/year).

Rutland and Windsor County				
	Predominant Soil Type	Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	125.91	392.27	1066.38	2220.96
Moderate	59.28	177.80	525.01	1276.84
Low	42.14	56.00	141.59	480.58
	Predominant Soil Type	Sandy Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	36.12	101.32	283.08	607.83
Moderate	22.16	52.82	158.15	374.89
Low	20.26	28.46	56.29	159.24
	Predominant Soil Type	Silt Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	103.50	329.59	929.67	1978.58
Moderate	50.20	154.86	456.67	1122.10
Low	40.60	52.96	131.47	429.38
	Predominant Soil Type	Clay Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	106.25	327.15	824.22	1666.62
Moderate	49.60	150.54	417.50	980.89
Low	32.21	44.27	105.08	347.65

Table C11: Estimated phosphorus production leaving the skid trail (kg/100m/year).

Rutland and Windsor County				
	Predominant Soil Type	Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.050	0.155	0.422	0.879
Moderate	0.023	0.070	0.208	0.506
Low	0.017	0.022	0.056	0.190
	Predominant Soil Type	Sandy Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.014	0.040	0.112	0.241
Moderate	0.009	0.021	0.063	0.148
Low	0.008	0.011	0.022	0.063
	Predominant Soil Type	Silt Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.041	0.131	0.368	0.784
Moderate	0.020	0.061	0.181	0.444
Low	0.016	0.021	0.052	0.170
	Predominant Soil Type	Clay Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.042	0.130	0.326	0.660
Moderate	0.020	0.060	0.165	0.388
Low	0.013	0.018	0.042	0.138

Table C12: Percent of phosphorus and sediment from skid trail segments that reaches a nearby waterbody.

Rutland and Windsor County						
Forest Buffer Gradient	*Predominant Soil:*	Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	56%	37%	24%	17%	0%
11-20%	100%	63%	43%	31%	21%	0%
21-30%	100%	66%	49%	34%	25%	0%
31-40%	100%	70%	52%	43%	35%	0%
Forest Buffer Gradient	*Predominant Soil:*	Sandy Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	19%	12%	3%	6%	0%
11-20%	100%	27%	20%	8%	3%	0%
21-30%	100%	37%	27%	15%	15%	0%
31-40%	100%	43%	28%	26%	22%	0%
Forest Buffer Gradient	*Predominant Soil:*	Silt Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	59%	43%	30%	25%	0%
11-20%	100%	66%	50%	35%	28%	0%
21-30%	100%	69%	55%	42%	33%	0%
31-40%	100%	72%	58%	49%	37%	0%
Forest Buffer Gradient	*Predominant Soil:*	Clay Loam				
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	62%	51%	38%	29%	0%
11-20%	100%	67%	58%	47%	33%	0%
21-30%	100%	69%	61%	51%	38%	0%
31-40%	100%	71%	63%	54%	46%	0%

C.5 Bennington and Windham County

Table C13: Estimated sediment production leaving the skid trail (kg/100m/year).

Bennington and Windham County				
	Predominant Soil Type	Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	181.73	569.41	1487.47	3053.71
Moderate	96.88	256.82	678.87	1502.00
Low	62.04	101.02	236.63	634.14
	Predominant Soil Type	Sandy Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	105.25	238.79	573.71	1099.80
Moderate	86.59	167.64	365.59	702.68
Low	74.49	116.28	217.99	430.12
	Predominant Soil Type	Silt Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	150.96	489.21	1341.14	2802.77
Moderate	86.55	222.40	611.17	1400.58
Low	61.86	96.57	223.73	589.91
	Predominant Soil Type	Clay Loam		
	Road Segment Gradient			
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	146.14	456.88	1159.00	2317.37
Moderate	73.09	202.13	545.40	1187.23
Low	44.07	73.10	181.48	479.49

Table C14: Estimated phosphorus production leaving the skid trail (kg/100m/year).

Bennington and Windham County				
	Predominant Soil Type	Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.072	0.225	0.589	1.209
Moderate	0.038	0.102	0.269	0.595
Low	0.025	0.040	0.094	0.251
	Predominant Soil Type	Sandy Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.042	0.095	0.227	0.436
Moderate	0.034	0.066	0.145	0.278
Low	0.029	0.046	0.086	0.170
	Predominant Soil Type	Silt Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.060	0.194	0.531	1.110
Moderate	0.034	0.088	0.242	0.555
Low	0.024	0.038	0.089	0.234
	Predominant Soil Type	Clay Loam		
		Road Segment Gradient		
Runoff Potential	Gradual Slope (<5%)	Moderate Slope (5-10%)	Steep Slope (11-20%)	Very Steep Slope (>20%)
High	0.058	0.181	0.459	0.918
Moderate	0.029	0.080	0.216	0.470
Low	0.017	0.029	0.072	0.190

Table C15: Percent of phosphorus and sediment from skid trail segments that reaches a nearby waterbody.

Bennington and Windham County						
Forest Buffer Gradient	*Predominant Soil:* Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	65%	47%	37%	31%	0%
11-20%	100%	70%	53%	42%	36%	0%
21-30%	100%	72%	57%	48%	41%	0%
31-40%	100%	77%	63%	55%	47%	0%
Forest Buffer Gradient	*Predominant Soil:* Sandy Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	45%	34%	25%	20%	0%
11-20%	100%	57%	47%	38%	32%	0%
21-30%	100%	61%	58%	54%	49%	0%
31-40%	100%	65%	60%	59%	56%	0%
Forest Buffer Gradient	*Predominant Soil:* Silt Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	66%	52%	44%	38%	0%
11-20%	100%	72%	60%	51%	45%	0%
21-30%	100%	75%	67%	56%	49%	0%
31-40%	100%	78%	71%	595	54%	0%
Forest Buffer Gradient	*Predominant Soil:* Clay Loam					
	Stream Crossing	25 – 49ft	50 – 69ft	70 – 89ft	90 – 110ft	>110ft
0-10%	100%	70%	60%	50%	45%	0%
11-20%	100%	74%	66%	57%	51%	0%
21-30%	100%	75%	68%	62%	55%	0%
31-40%	100%	78%	71%	65%	59%	0%