



FINAL REPORT

Design of a Decision Support Tool for Nutrient Credit Exchange Feasibility in Stormwater Regulatory Compliance

Date: June 2015

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Acknowledgements

The authors would like to thank Roy Mills and John Olenik of VDOT.

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Problem

Virginia Stormwater Management Program (VSMP) regulations require transportation projects to account for stormwater runoff impacts from increased impervious surfaces in order to prevent water quality reduction, erosion, and flooding.¹ Organizations like the Virginia Department of Transportation (VDOT) have traditionally constructed onsite Best Management Practices (BMPs) to mitigate these stormwater effects. Structural BMPs are designed to hold and treat the runoff temporarily in order to improve water quality and reduce flood risks.² However, structural BMPs are becoming more expensive due in part to the lack of open area caused by urbanization and also to the increasingly robust BMPs required to meet stormwater requirements.³ Consequently, there is a need for alternative strategies to meet stormwater regulations.⁴

A relatively new alternative to onsite BMP construction, nutrient credit exchanges, are becoming a popular option with agencies like VDOT for stormwater compliance.⁵ Nutrient credit exchanges allow agencies to meet stormwater requirements by purchasing pollutant reduction credits from off-site sources that are equivalent to or more than what would be treated onsite.⁵ Nutrient exchange was established by legislation passed in 2005 that created the Chesapeake Bay Nutrient Credit Exchange Program.⁶ Expansion of nutrient exchange followed the establishment of a Total Maximum Daily Load (TMDL) for nitrogen, phosphorus, and sediments entering the Chesapeake Bay in 2010 by the Environmental Protection Agency.⁴ A TMDL is the maximum amount of pollutant that a waterbody can receive while still meeting regulatory standards.⁵ Originally, point-source nutrient polluters, like a wastewater treatment facility, had the option to implement onsite pollution control or purchase load reductions from other sources that reduce loads more than the site's requirement.⁴ More recent expansion to nutrient exchange by the Virginia Department of Environmental Quality (DEQ) allowed for non-point source polluters to participate in nutrient exchange.⁷ Research has suggested that participating in WQT in lieu of constructing onsite BMPs could offer organizations like VDOT cost savings of 50% on average, although the savings are highly variable for each site and BMP.⁸

There are several steps that VDOT project managers must take before applying to use nutrient credits. Site eligibility requirements, which include factors like total site area, disturbed area, and loading reductions required, must be met. The pollutant loading generated onsite depends on annual rainfall, soil types, and impervious acreage. If the site does meet eligibility criteria, project managers must obtain cost estimates for the purchase of nutrient credits. These nutrient credit purchases are restricted to banks within certain areas and each bank may have different prices. All of this information needs to be gathered in the planning phase so that cost estimates are accurate and designers know which option will be chosen. Currently, the information is found in separate places like Excel spreadsheets, GIS datasets, and various websites. Given that nutrient credit exchanges is an economically viable option in many situations, a tool that gathers all necessary information for nutrient credit options in the early planning stages for a new project would be beneficial to project managers at VDOT.

Therefore, the objective of this research is to design a decision support tool for nutrient credit exchange feasibility. This document is limited to describing only the design of such a system because implementation of the tool would ideally require assistance from VDOT's information technology division. However, future work by researchers could further advance on this design work by building a proof of concept prototype tool for demonstration and testing purposes.

Approach

Basic Tool Design Requirements

Project managers require data from various sources to estimate nutrient credit viability. Because the information is scattered, a tool that has the data gathered into a single place and provides a simple user interface for inputting a project location and a site description would be beneficial. The tool could perform basic calculations using the gathered data to streamline the nutrient credit eligibility decision process. Because this tool would be used by planners and designers, it should be readily available and user-friendly. Finally, the results from the tool should follow current best practices in order to be defensible and transparent.

Information Needed

In order to estimate costs of participating in WQT, a project manager must first determine whether the project qualifies for the use of nutrient credits. To qualify for the use of nutrient credits a project must meet *one* of the following criteria determined by the Code of Virginia § 62.1-44.15-35:

1. The project area must contain less than 5 acres of disturbed land
2. The post-construction phosphorus control requirement is less than 10 pounds per year
3. Given that criteria 1 and 2 were not met, if the applicant can demonstrate onsite control of at least 75%, the remaining required reductions can be met through the purchase of nutrient credits.¹

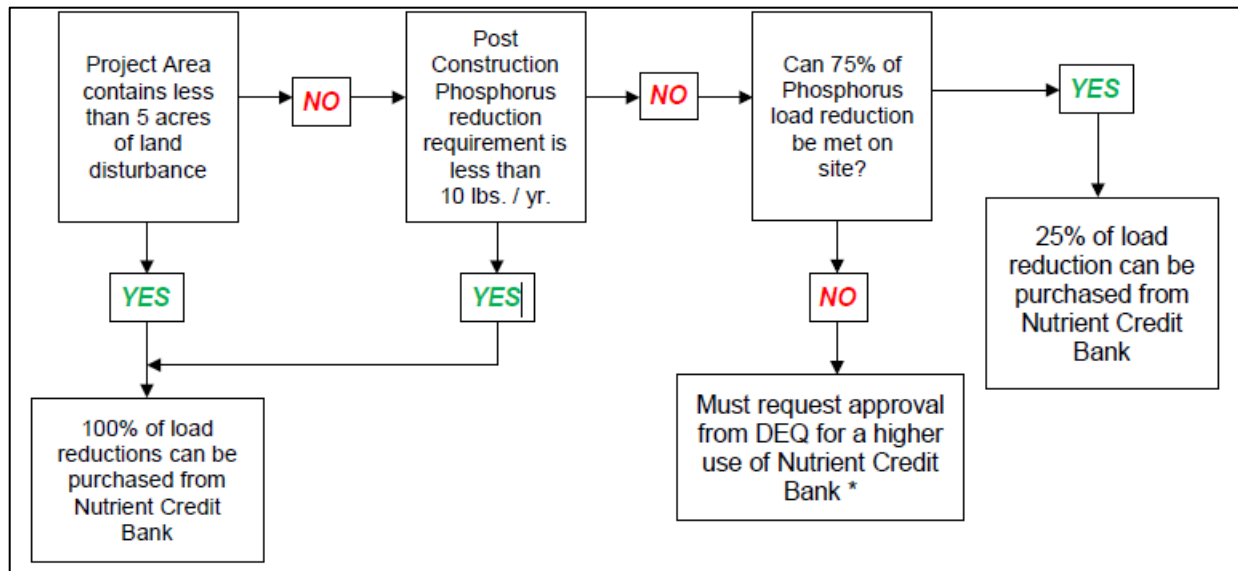


Figure 1. This flowchart is found in VDOT's IIM251.⁵ It details how to determine whether the use of nutrient credits is applicable.

However, on an individual project basis, if no criteria are met, additional load reduction via nutrient credit purchase may be attained with written approval from the DEQ. Supplementary documentation would be required in order to do so. Other considerations that project managers should account for include:

- Nutrient credits cannot be used to meet quantity control requirements
- Water quality requirements can be met with the same BMPs used to meet water quantity requirements
- If the project discharges into a local watershed with an established nutrient TMDL, nutrient credits may still be purchased provided that the use of the credits does not prevent compliance with the local limitation⁵

There are several methods to check whether or not a project meets the eligibility criteria. General site information, like total acreage, soil types, and land cover, from early surveys and the load reduction requirements procedure outlined by the Virginia Runoff Reduction Method (VRRM) provide results that would determine eligibility.

If the project meets the criteria defined above or is granted an exception by DEQ, nutrient credits may be purchased from any certified bank provided:

1. The bank is located in the same or adjacent 8-digit HUC as the project. If the adjacent HUC is used, it must be in the same basin/tributary as the project.
2. If no banks are within or adjacent to the 8-digit HUC, nutrient credits may be purchased from any bank within the same basin/tributary as the project.⁵

Eligible bank locations can be determined using services like the ones provided by EPA's Watershed Assessment, Tracking, and Environmental Results (WATERS) tools. These tools

include Web services that can link spatial points to the NHD hydrology network; can navigate upstream or downstream of a water body; and during that navigation, can find water bodies with established TMDLs or that are included on the 303(d) list. The 303(d) list is a list of impaired or threatened waters as defined by EPA regulations.⁹

Per the Instructional and Informational Memorandum (IIM) 251 for VDOT, the following information should be provided once nutrient credits are determined to be the method used to achieve water quality compliance:

- Project Number
- UPC Number
- Project Location (County/City)
- Project Latitude and Longitude
- Project 4th Order HUC
- Land Disturbance (acres)
- Amount of Nutrient Load Reduction Achieved Onsite (pounds/acre/year)
- Amount of Nutrient Credits Needed to be Purchased⁵

In addition to required information, a need for a simple, local hydrological summary near the project site would also be useful. Currently, using nutrient credits to meet stormwater requirements is economically based. This is an understandable assumption as the benefit to nutrient exchange is that the phosphorus gets removed somewhere along the line and the loading to the Chesapeake Bay is reduced. However, there may be cases where a project site discharges into an impaired water that does not have a TMDL, but is at risk at being overloaded. Having a local, hydrologic summary early in the planning phase along with the information needed to apply for nutrient credits, would be useful for VDOT project managers.

Methodology

The following section details the basic design of a tool that would be beneficial to project managers making decisions on nutrient exchange. Examples of how parts of the design might be implemented within a software tool are provided for illustrative purposes and should not be considered as the only viable options.

Required User Inputs

Table 1 provides the information required as user input. This information can be derived from early site surveys and should be available in the planning phase. Other methods that can be used to obtain the information are discussed in **Future Work**. The latitude and longitude of the project's center should be in decimal degrees. The total project area and the disturbed area are both measured in acres. Disturbed area is the area that is cleared, excavated, graded, or otherwise affected during construction activities. The annual rainfall value for the site is measured in inches and is found in **Figure 2**. For Virginia, the typical annual average rainfall

used is 43 inches. An option for whether the project is new development or re-development should be provided. Land cover summaries for pre and post-development (pre-development not required for new development) will consist of areas for forest/open space, managed turf, impervious cover and the respective soil type percentages for each of the land cover options. The onsite phosphorus removal percentage is the amount of phosphorus that can be controlled onsite.

Table 1. Required user input

Input Name	Input Description	Units	Range
Latitude	Latitude of project site centroid	Decimal degrees	-90 - 90
Longitude	Longitude of project site centroid	Decimal degrees	0 – 180
Project Area	Total area of the project	Acres	> 0
Disturbed Area	Area that is cleared, excavated, graded, or otherwise affected during construction	Acres	> 0
Annual Rainfall	Average yearly rainfall for the site. Values shown in Figure 2	Inches	> 0
Development Type	Choice between newly developed sites and previously developed sites	n/a	
Site Summary	Areas of land cover types separated by the hydrologic soil group	Acres	0 or greater
Onsite Phosphorus Removal Fraction	How much phosphorus can be controlled onsite using structural BMPs	% removal	0 - 100

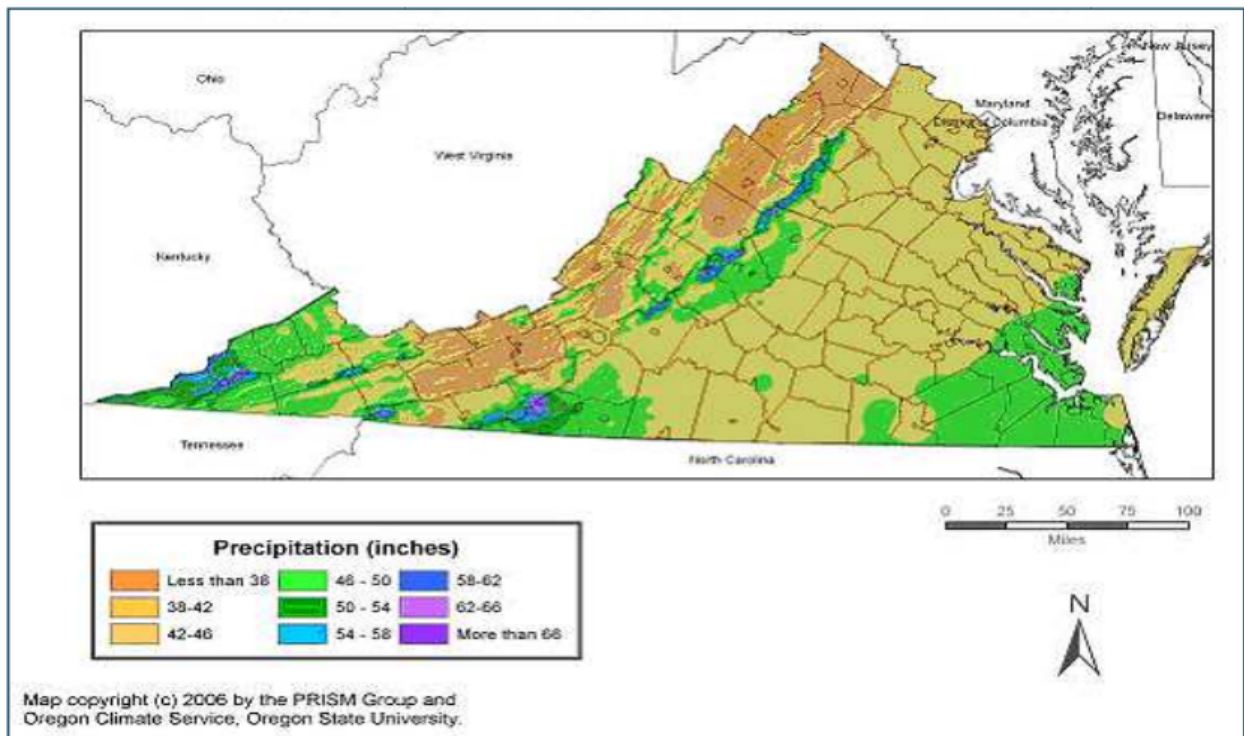


Figure 2. Average Virginia Precipitation, 1970 – 2000 (Oregon Climate Service)¹⁰

Calculations and Tool Organization

The tool should complete calculations based on the user input to determine nutrient credit eligibility, a rough cost estimate, and a local hydrological summary. These calculations should ideally be organized as separate entities within the tool (e.g., different sections or tabs within an application).

Nutrient Credit Eligibility

The first section of the results should determine whether the project is eligible to participate in nutrient credit exchange based on the three criteria defined in the approach. Criteria 1 is checked using the disturbed area from the user input section. If the value is less than 5 acres, the project is eligible for nutrient exchange.

The phosphorus control requirement can be calculated using the same procedure as the Virginia Runoff Reduction Method (VRRM), as recommended by the Virginia Stormwater Management Handbook. The VRRM uses the Simple Method to calculate the total phosphorus load post-development. The Simple Method takes into account pre and post-development land cover, soil types, annual rainfall, and average pollutant load to calculate the total phosphorus load that will be generated by the new development. That value is compared to the target phosphorus load, which is a load limit established by the Virginia Stormwater Management Program for the Chesapeake Bay on a lb/acre/year basis, to determine how much phosphorus

needs to be removed to achieve compliance. The steps to obtain these values are detailed in the following paragraphs.

The first step when calculating the required Total Phosphorus Reduction is to calculate the site's Rv coefficient. Rv coefficients are unitless, volumetric runoff coefficients that represent the percentage of runoff from different land cover and soil types. Using the user input land cover summary and individual Rv coefficients, a composite Rv coefficient (Site Rv) is calculated. The equations for calculating just the Forest/Open Space Rv and forest percentage are shown below. A(fA) represents total forest and open space area on soil type A in acres. Total site area (A_{site}) is the sum of all areas in the user input land cover summary.

$$Rv_{forest} = \frac{A(fA) * 0.02 + A(fB) * 0.03 + A(fC) * 0.04 + A(fD) * 0.05}{A_{forest}} \quad (1)$$

$$\%F = \frac{A(fA) + A(fB) + A(fC) + A(fD)}{A_{site}} * 100 \quad (2)$$

Equations 1 and 2 would be repeated for Turf (Rv_{turf} and %T) and Impervious (Rv_{imperv} and %I) areas. Equation 3 calculates the composite Site Rv.

$$Rv_{site} = Rv_{forest} * \%F + Rv_{turf} * \%T + Rv_{imperv} * \%I \quad (3)$$

The volume of runoff to be treated in acre-ft generated by the site is calculated using Equation 4. The target rainfall event (Rd) is defined to be 1" for a water quality storm.

$$TV_{site} \text{ (acre-ft)} = \frac{Rd * Rv_{site} * A_{site}}{12} \quad (4)$$

The total phosphorus load (L) in pounds per year generated by the site is calculated using Equation 5. The annual rainfall depth (P) is the user input value. The fraction of rainfall events that will produce runoff (P_j) is constant at 0.9. The pollutant concentration (C) equals 0.26 mg/L, a concentration defined by VSMH 2nd Edition. The 2.72 is a unit conversion factor.

$$L \left(\frac{lb}{yr} \right) = P * P_j * \left[\frac{TV_{site}}{Rd} \right] * C * 2.72 \quad (5)$$

Finally, to calculate the required site phosphorus load reduction (L_{red}), Equation 6 is used. The target phosphorus load (P_{target}) is a load limit established by VSMP regulations at 0.41 lb/ac/yr.

$$L_{red_{req}} \left(\frac{lb}{yr} \right) = L - P_{target} * A_{site} \quad (6)$$

L_{red} is used to check eligibility criteria 2. If L_{red} is less than 10 pounds per year, criteria 2 is satisfied. Finally, eligibility criteria 3 is checked with the user input value for onsite phosphorus control. If the value is 75% or greater, criteria 3 is satisfied. The tool should output whether or not the project is eligible for nutrient exchange and which criteria was met to obtain eligibility. If no criteria is met, the tool should state that the project manager will need to be granted a waiver by the DEQ in order to use nutrient exchange. The additional results sections should still be provided as DEQ has on occasion been lenient in granting waivers for projects that don't meet the eligibility requirements.

Supporting Information

The second section of the results should provide additional information that would be useful for project managers when applying to purchase nutrient credits. Some of the departmental specific information, like the project numbers, would need to be provided by the user. The project latitude, longitude, and land disturbance would also be input by the user. The tool should use the latitude and longitude to output the city or county that the project is located within using a geocoding service. Examples for how to find the 4th-order HUC, nutrient load reduction, and the nutrient credits required using a web-based tool are specifically shown below.

Project 4th-order HUC

The latitude and longitude from user input and several of EPA's Watershed Assessment, Tracking, and Environmental Results (WATERS) Web Services are used to find the project location. The Point Indexing Service is used to link a spatial point to the NHD hydrology network via a shortest distance snap or a raindrop indexing. The service returns information about the traversal and more importantly, information about the endpoint. The travel type is recommended to be via raindrop indexing in order to insure the water is flowing downhill. Per EPA recommendations, the search distance would be limited to 10 km and the snap distance limited to 2 km. The service returns the 12-digit identifier for the 6th-order HUC where the project is located. The first eight numbers of the identifier represent the 4th order HUC that the project is within.

Nutrient Load Reduction Achieved Onsite

The phosphorus load reduction that is achieved onsite will be based on the value the user provides. That percentage will be multiplied by the total phosphorus load generated by the site from Equation 5. The result is the amount of phosphorus load reduced onsite.

$$L_{red_{onsite}} \left(\frac{lb}{yr} \right) = \%_{onsite} * L \quad (7)$$

Cost of Nutrient Credits

The amount of nutrient credits to be purchased is based on results for Equations 6 and 7. The amount of nutrient credits is equivalent to the required nutrient load reduction (Equation 6) minus what is reduced onsite.

$$L_{credits}(\frac{lb}{yr}) = L_{red_{req}} - L_{red_{onsite}} \quad (8)$$

To provide a rough estimate of the cost associated with those nutrient credits, IIM 251 recommends that \$15,000 per pound of phosphorus be used. The \$15,000 is a one-time charge. The final cost estimate can be calculated using Equation 9.

$$Cost (\$) = L_{credits} * 15,000 \quad (9)$$

Hydrological Summary

The hydrological summary section details local watershed information. Some of the information, such as receiving waters, is required to fill out permits for land disturbing activities. Other information is useful for determining local hydrological health. While economics is the main driver behind the decision to use nutrient credits, sustainable approaches must also consider environmental and social considerations. By assessing nearby watershed health, the tool would provide environmental information on the receiving water that could assist the decision maker.

Receiving Waters

The receiving water is the first body of water that the project drains into. The EPA WATERS Point Indexing Service is called again using the same input parameters as above. The service returns the common name and reachcode for the body of water. Many streams do not have common names, in which case only the reachcode will be returned with a note that a common name was not found.

Nearby TMDLs

To check for nearby TMDLs, EPA WATERS Upstream/Downstream (USDS) Navigation Service can be used. The USDS service takes an initial reachcode, a search distance, search direction, and event summaries type as inputs. It returns a summary of the rivers traversed which can include whether the stream had an established TMDL. For the tool, “nearby” would be defined to be within 5 km downstream. Therefore the service search distance would be 5 km, the direction would be downstream-mainstream, and the TMDL events summary would be queried.

Nearby 303(d) listed waters

To check for nearby 303(d) listed waters, EPA WATERS Upstream/Downstream (USDS) Navigation Service can be used again. The same input parameters as the TMDL search would be used, however the summary would be for 303(d) events instead of TMDL events.

Software

The approach chosen for implementing the software tool based on this design should take into consideration the needs outlined in the **Basic Tool Design Requirements**. Three types of software/programs were considered for the backbone of the tool design: a GIS program like ArcGIS or ArcGIS Online, a spreadsheet program like Microsoft Excel, or a website based application. The web-based application is perhaps the most viable option. Spreadsheet programs do not deal with spatially based information well. Given that most of the required information has a spatial component, the spreadsheet method may not be optional. A robust GIS program is the best option for working with spatial data, however, the tool should also be readily available for a project manager. Desktop GIS software may not be user friendly for those unfamiliar with the tool. ArcGIS Online is one viable option if a software license for the tool is available. A web-based application that does not make direct use of ArcGIS Online could also be used to build a simple, readily available, and effective tool. Using services like WATERS works around the need for a robust GIS program because it provides access to many of the GIS-based operations required by the application. An effective tool could be built using a combination of HTML, JavaScript, and CSS languages that are popular and robust for building web applications that operate with any web browser. For this reason, the following section presents a basic mockup of a web-based tool implementing the steps described in this section.

Findings

The following section shows a basic mockup of a website-based application showing how it could look and be used. Only the nutrient credit eligibility section is shown. Other recommended sections would look similar the eligibility results.

User Input

User Input

Latitude (decimal deg):

Longitude (decimal deg):

Project Area (acres):

Disturbed Area (acres):

Annual Rainfall (in):

Development Type:

Site Soil Summary

	Soil Group A	Soil Group B	Soil Group C	Soil Group D
Forest	<input type="text" value="2"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Managed Turf	<input type="text" value="2"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Impervious	<input type="text" value="2"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Onsite Phosphorus Removal Fraction (%):

Figure 3. A sample of what the user input section of the website could look like just before the user hits the button.

Nutrient Credit Eligibility

Nutrient Credit Eligibility

Criteria 1: Disturbed acreage less than 5 acres? **6 ac**

Criteria 2: Required phosphorus control less than 10 pounds per year? **4.11 lb/yr**

Criteria 3: 75% or more Phosphorus Control met onsite? **0 %**

PROJECT MEETS REQUIREMENTS TO PARTICIPATE IN NUTRIENT TRADING

Note: Use the following sections to determine how many credits will be needed and for other necessary information.

Figure 4. A sample of what the eligibility results of the website could look like.

After clicking the “Check Eligibility” button, the website would complete the calculations and output the results shown in **Figure 4** above. In this particular example, the disturbed acreage is more than 5 acres so the project does not meet the first criteria. The second criteria is checked using the procedure outlined in methodology. The user stated that the site was a new development. The individual R_v for each land type was calculated using Equation 1. **A1** in the Appendix lists the R_v values for each soil and land type.

$$Rv_{forest} = \frac{2 * .02 + 1 * .03}{3} = .023$$

$$Rv_{turf} = \frac{2 * .15 + 1 * .2}{3} = .167$$

$$Rv_{imperv} = \frac{2 * .95 + 1 * .95}{3} = .95$$

Equation 3 yielded the site R_v .

$$Rv_{site} = .023 * .33 + .167 * .33 + .95 * .33 = .38$$

Based on Equation 4, the post development treatment volume was found as shown below.

$$TV_{site} = \frac{1 * .38 * 9}{12} = .285 \text{ acre-feet or } 12,415 \text{ ft}^3$$

Equation 5 gave the site phosphorus loading.

$$L = 43 * .9 * \left(\frac{.285}{1} \right) * .26 * 2.72 = 7.8 \text{ lb/year}$$

Given the site phosphorus loading, the control requirement is:

$$L_{red_{req}} = 7.8 - .41 * 9 = 4.11 \text{ lb/year}$$

4.11 pounds per year is lower than 10 pounds per year, thus satisfying the second criteria. The user input 0% onsite phosphorus reduction, which does not meet standards for the third criteria. Since the second criteria was satisfied, the project does meet eligibility requirements to participate in nutrient exchange.

Discussion

Currently, the tool design focuses on assisting a user with filling out VDOT’s IIM251, providing a rough cost estimate and a local hydrology summary. The advantage to this design is that all of the information is now in one place instead of a compliance spreadsheet, the Virginia

Stormwater Management handbook, and websites. While this is a useful advancement in itself, the true potential of the proposed approach of a web-based decision support tool would stem from the gathering and use of real-time, up-to-date data. Much of the data in the user-input section could be automatically populated given the location of the project. The National Resources Conservation Services (NRCS) provides web soil surveys that could be used to build the site summary table. The annual rainfall values are currently gotten from the map in **Figure 2**, but could also be obtained given an initial location via Web services provide by federal agencies. Another option for inputting the project location, instead of providing just the latitude and longitude of the centroid, would be to allow the user to draw the site boundaries onto a We-based map. Several popular services use these boundary boxes like the USGS and the NRCS. By drawing the boundaries, the tool could also calculate total area and disturbed area on its own. These options typically feasible and currently used by various services, so an experienced web programmer could combine these options and the basic methodology described above to create a very powerful and useful decision support tool.

Conclusions

- *A decision support tool to assist with nutrient credit eligibility would be useful for answering the key questions early in the planning phase of a project.* Is the project eligible for nutrient credits? How much would the credits cost? What banks will be available for use? What is the health of the nearby, downstream rivers?
- *Designing the tool to be used as a web-based application would make it easily accessible while still providing the necessary data to make an informed decision.* Only a web browser open to a website would be needed to the information that currently requires the use of several different resources.
- *A key long-term benefit of such a tool would be the ability to automatically gather supporting data minimizing the number of input required from the user.* Users would not have to look at maps to find annual rainfall, use other websites for soils data, or fill out the spreadsheets for the VRRM.

Recommendation

It is recommended that a prototype web-based tool be built based on the design presented in this report in order to evaluate nutrient credit use early in a project's planning phases. The prototype should emphasize automating the obtaining basic calculations using user inputs at first, while later efforts should concentrate on reducing the need for user inputs by automating data gathering steps when possible.

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Appendix

Table 4-1. Land Cover Runoff Coefficients (Rv)				
Cover	HSG A	HSG B	HSG C	HSG D
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf / Disturbed Soil	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

A1. This table is from the DEQ module for completing the VRRM.¹¹ HSG is the Hydrologic Soil Group.

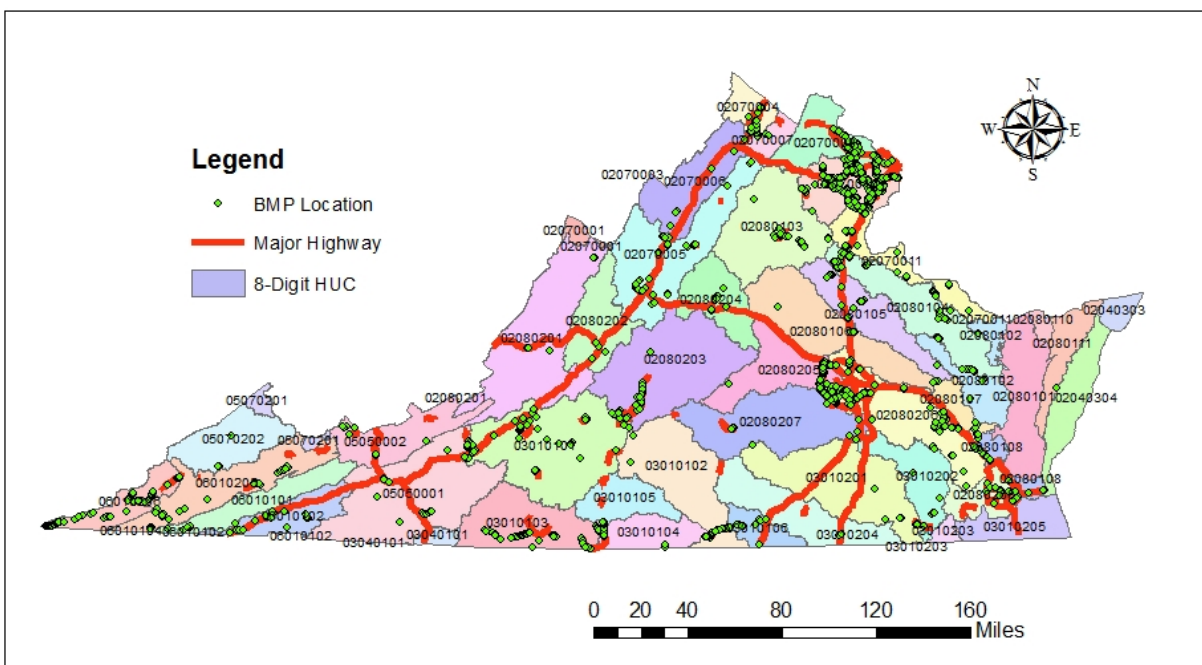
A2. This table contains a sample of 100 BMPs maintained by VDOT with the nearest downstream river.

#	Project Number	Installation Date	BMP Type	Latitude	Longitude	6 th HUC	ReachCode	Common Name
196	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.26617	-78.38119	JA10	2080207000316	Briery Creek
197	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.266338	-78.383577	JA10	2080207000316	Briery Creek
198	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.26683	-78.37836	JA10	2080207000315	Briery Creek
199	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.26798	-78.38531	JA10	2080207001371	
200	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.26985	-78.37375	JA10	2080207000315	Briery Creek
201	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.27191	-78.37118	JA10	2080207000315	Briery Creek
202	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.27317	-78.36972	JA10	2080207000314	Briery Creek
203	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.27456	-78.36799	JA10	2080207000314	Briery Creek
204	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.27684	-78.36478	JA10	2080207000313	Briery Creek
205	6460-073-F12, C501	13-Jan-94	Extended Detention Basin	37.27754	-78.36401	JA10	2080207000313	Briery Creek
206	U000-123-155, C-501	01-Jul-99	Extended Detention Basin	37.18867	-77.422466	JA40	2080207001909	
207	0601-026-262, C501	01-Jun-09	Extended Detention Basin	37.217686	-77.47328	JA40	2080207001901	
208	0001-106-F07, C501	01-Jun-00	Grassed Swale	37.23738	-77.40801	JA40	2080207000049	Appomattox River
209	0001-106-F07, C501	01-Jun-00	Extended Detention Basin	37.24115	-77.40801	JA40	2080207000875	Fleets Branch
210	0288-020-105, C502	01-Feb-95	Extended Detention Basin	37.468895	-77.657125	JA41	2080207002038	
211	0288-020-105, C504	01-Jan-01	Extended Detention Basin	37.47133	-77.65423	JA41	2080207002038	
212	0288-020-105, C502	01-Feb-95	Extended Detention Basin	37.47251	-77.66176	JA41	2080207002038	
213	0288-020-105, C504	16-Feb-00	Extended Detention Basin	37.47659	-77.65922	JA41	2080207002036	Little Tomahawk Creek
214	0288-020-105, C502	01-Feb-95	Extended	37.476711	-77.665997	JA41	2080207002036	Little Tomahawk Creek

			Detention Basin					
215	0288-020-105, C508	01-Jan-01	Extended Detention Basin	37.47901	-77.66197	JA41	2080207002036	Little Tomahawk Creek
216	0288-020-105, C508	01-Jan-00	Extended Detention Basin	37.48493	-77.66662	JA41	2080207002039	
217	0288-020-105, C502	01-Feb-95	Extended Detention Basin	37.486268	-77.662774	JA41	2080207002039	
218	0288-020-105, C508	10-Sep-00	Extended Detention Basin	37.48693	-77.67039	JA41	2080207002144	Little Tomahawk Creek
219	0288-020-105, C508	01-Jan-00	Extended Detention Basin	37.48796	-77.67077	JA41	2080207002144	Little Tomahawk Creek
220	0288-020-105, C502	01-Feb-95	Extended Detention Basin	37.488343	-77.661996	JA41	2080207002039	
221	0288-020-PPTA,C508		Extended Detention Basin	37.489616	-77.677436	JA41	2080207002140	Tomahawk Creek
222	0288-020-105, C508	01-Jan-05	Extended Detention Basin	37.49139	-77.67802	JA41	2080207002140	Tomahawk Creek
223	0288-020-105, C508	01-Jan-02	Extended Detention Basin	37.49151	-77.66629	JA41	2080207002144	Little Tomahawk Creek
224	0288-020-105, C508	01-Jan-05	Extended Detention Basin	37.49172	-77.66942	JA41	2080207002144	Little Tomahawk Creek
225	0288-020-105, C508	01-Jan-05	Extended Detention Basin	37.49323	-77.67949	JA41	2080207002140	Tomahawk Creek
226	0288-020-105, C508	11-Apr-02	Extended Detention Basin	37.49604	-77.68499	JA41	2080207002140	Tomahawk Creek
227	0288-020-105, C508	01-Jan-01	Extended Detention Basin	37.49838	-77.68751	JA41	2080207002140	Tomahawk Creek
228	0288-020-105, C508	01-Jan-02	Retention Basin	37.50223	-77.6929	JA41	2080207002140	Tomahawk Creek
229	0288-020-105, C508	01-Jan-02	Extended Detention Basin	37.50337	-77.69473	JA41	2080207002140	Tomahawk Creek
230	0288-020-105, C508	01-Jan-00	Extended Detention Basin	37.51119	-77.69451	JA41	2080207002140	Tomahawk Creek
231	6360-020-F26, C501	01-Jan-94	Extended Detention Basin	37.41672	-77.6418	JA42	2080207000030	Swift Creek
232	0653-020-274, C501	01-Jan-99	Extended Detention Basin	37.42081	-77.57767	JA42	2080207001977	
233	6360-020-F26, C501	01-Jan-95	Extended Detention Basin	37.42293	-77.63197	JA42	2080207000686	Nuttree Branch
234	6360-020-F26, C501	01-Jan-95	Extended Detention Basin	37.42421	-77.62844	JA42	2080207000686	Nuttree Branch
235	0653-020-274, C501	01-Jan-99	Extended Detention Basin	37.4317	-77.58945	JA42	2080207001978	
236	0360-020-121, C502	01-Jan-93	Extended Detention Basin	37.43528	-77.59863	JA42	2080207001978	
237	0604-020-158, C501		Extended Detention Basin	37.44079	-77.60811	JA42	2080207001979	
238	0288-020-105, C504	01-Jan-98	Extended Detention Basin	37.46769	-77.65043	JA42	2080207000688	Nuttree Branch
239	U000-116-V04, C-501	01-Nov-95	Extended Detention Basin	37.309753	-77.29653	JA45	2080207011249	
240	7095-020-F08, C501	01-Jan-99	Extended Detention Basin	37.31071	-77.39802	JA45	2080207002086	Ashton Creek
241	7095-020-F08, C501	01-Jul-97	Extended Detention Basin	37.31194	-77.3962	JA45	2080207002086	Ashton Creek
242	7095-020-F08, C501	16-Aug-99	Extended Detention Basin	37.31338	-77.39566	JA45	2080207002086	Ashton Creek
243	0288-020-PPTA,C508		Extended Detention Basin	37.48652	-77.67646	JA45	2080207002140	Tomahawk Creek
244	0895-020-F01, C501		Extended Detention Basin	37.43932	-77.42801	JL01	2080206000160	James River
245	0895-020-F01, C501	01-Jan-98	Extended Detention Basin	37.44332	-77.42482	JL01	2080206000894	
246	0895-020-F01, C501	01-Jan-98	Extended Detention Basin	37.44365	-77.42443	JL01	2080206000894	
247	U000-127-114, C501	08-May-97	Extended Detention Basin	37.49002	-77.48432	JL01	2080206000901	Broad Rock Creek
248	U000-127-114, C501	08-May-97	Extended Detention Basin	37.49168	-77.48698	JL01	2080206000901	Broad Rock Creek
249	0653-020-274, C501	01-Jan-99	Extended Detention Basin	37.41193	-77.56596	JL02	2080206000871	

Methodology for A2

A database containing 1,783 BMPs constructed by VDOT up to 2014 was provided by VDOT's Location and Design Division. The database contained BMP characteristics like location, type, installation date, and project number. The database was queried to identify BMPs with a latitude and longitude provided which returned 1,517 BMPs. The spatial information, along with the project number, installation date, BMP type, and the 6th order HUC were exported to a CSV file. The Point Navigation Service from EPA WATERS was queried using the latitudes and longitudes from the CSV file as initial points. The reachcode and common name for each location was attached to the respective row in the CSV file. Several water bodies did not have a common name and were left empty. A2 shows a sample of 100 BMPs found in the James River basin.



A3. Map showing all BMPs maintained by VDOT in Virginia. Note that the BMP must have contained a latitude and longitude to be included.