Lake Champlain Phosphorus TMDL

Watershed Modeling Approach Recommendation

Prepared for:

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Introduction

This report was prepared for the U.S. Environmental Protection Agency (EPA) Region 1, in support of activities pursuant to the revision of the Lake Champlain Phosphorus total maximum daily load (TMDL). Multiple objectives are being addressed under the scope of the overall project, including revising and recalibrating the lake model used to develop the original TMDL and linking it to a watershed model to characterize loading conditions and sources in the watershed and estimate potential for loading reductions in the Vermont and New York portions of the basin.

This report is intended to inform the selection of an appropriate watershed modeling application. Project-specific criteria for model selection are identified, several potentially applicable modeling applications are discussed in context of the criteria, and a modeling approach that best addresses the multiple management objectives is recommended.

Background

Lake Champlain is one of the largest lakes in North America and is shared by Vermont and New York and the province of Quebec. The lake is 120 miles long, with a surface area of 435 square miles and a maximum depth of 400 feet. The 8,234-square-mile watershed drains nearly half the land area of Vermont and portions of northeastern New York and southern Quebec (Figure 1).

The original TMDL was developed jointly by Vermont and New York in 2002. EPA is revising the Vermont portion of the TMDL in response to a 2008 lawsuit by the Conservation Law Foundation. One of EPA's goals for the revised TMDL is to ensure that there is adequate Reasonable Assurance that identified nonpoint source reductions are feasible. To support this and other technical needs, EPA intends to develop and apply a watershed model to support the source loading estimation and reduction analysis for the TMDL. The model will be used for providing more detailed loading estimates/allocations for individual source categories (relative to the original TMDL), evaluating results of different load reduction/best management practice (BMP) implementation strategies, evaluating effects on loading from potential changes in climate, and helping to understand the impacts of watershed loading scenarios on lake water quality and in-lake modeling results.
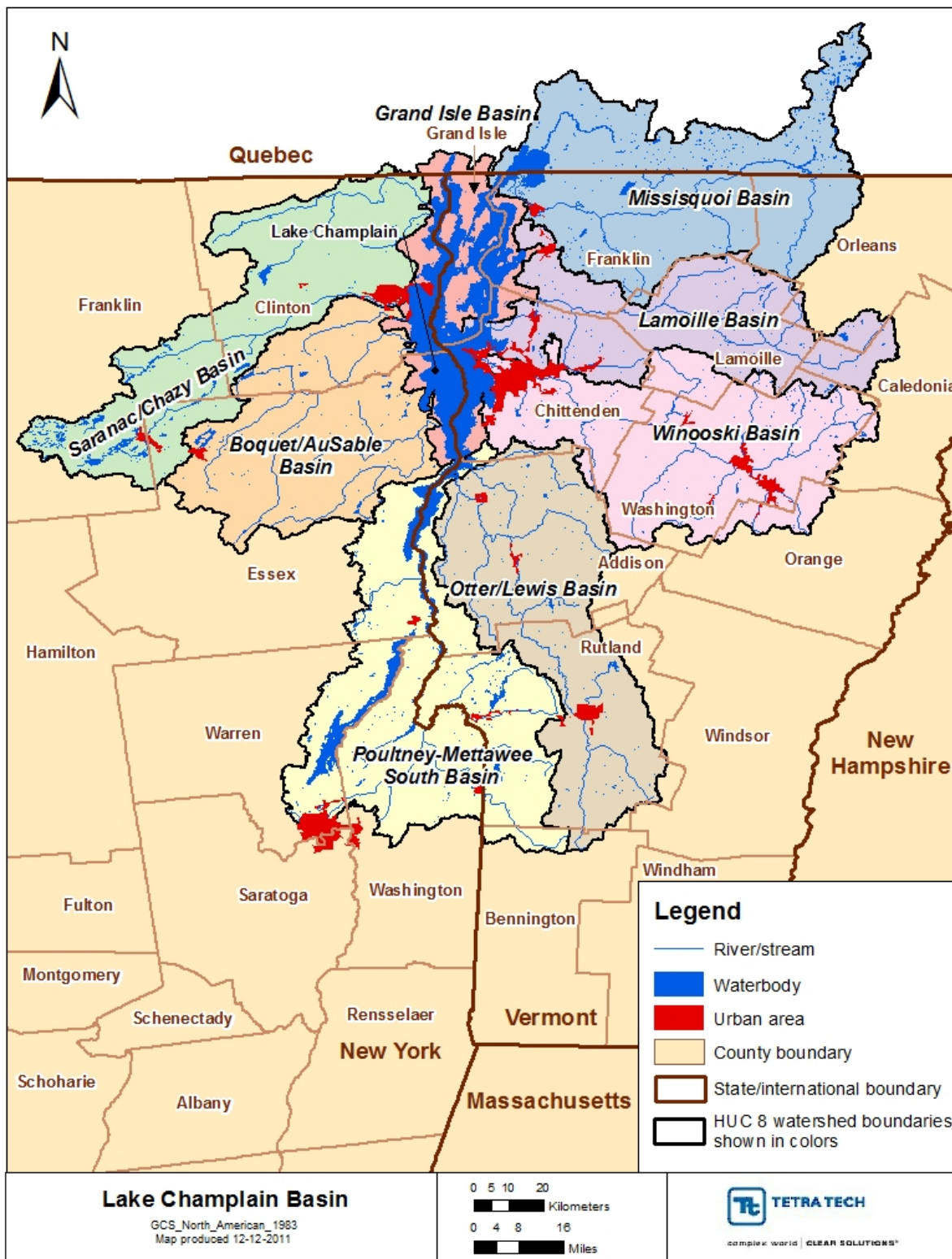
Figure 1. Lake Champlain Basin.

Types of Models

Models used to simulate the water quality effects of watershed processes range in complexity and can be classified into three basic types: data-driven, mid-range, and complex models. Data-driven models can be very general, for example using a simple empirical relationship to estimate the amount of runoff produced by a certain level of precipitation. Data-driven models are represented by techniques that are based on monitoring data or literature values and apply simple equations to describe pollutant behavior. Examples include export coefficients and load duration curves. The mid-range and complex models differ from data-driven approaches in that they apply a set or sets of equations to analyze key components of a watershed system. Models can use different techniques to analyze the same component. More complex models generally provide for an increased number of processes and parameters that can be represented.

The key processes that are represented by watershed models include the following:
- Rainfall/runoff: calculates the amount and timing of runoff from a land area.
- Erosion and sediment transport: simulates soil detachment, erosion, and sediment movement from a land area.
- Pollutant loading: simulates wash-off of pollutants from a land area.
- Stream transport: represents the stream portion of watershed models, which is needed, at a minimum, to collect the runoff/sediment/pollutants from the various land areas (the watershed) and to route it through to the mouth of the basin.
- Management practices: represents management measures and expected impacts to water quality, including land-based (e.g., tillage or fertilizer application), structural (e.g., stormwater ponds), or input/output to a stream (e.g., wastewater treatment). Land-based management can be generalized (e.g., number of acres treated) or specific (e.g., field-specific practices).

The mid-range category of models includes models such as the Generalized Watershed Loading Functions model (GWLF) or the Program for Predicting Polluting Particles Passage through Pits, Puddles, and Ponds, Urban Catchment Model (P8). The complex category includes models such as the Hydrologic Simulation Program Fortran (HSPF), the Loading Simulation Program C++ (LSPC), the Soil and Water Assessment Tool (SWAT), and the Stormwater Management Model (SWMM), which simulate many dynamic processes and their inter-relationships. By separately addressing each physical process, those latter category models can be adapted to local conditions, and the simulation can be made more sensitive to land use activities and management changes.

It is important to note that models that represent certain processes in a more simplified manner than other models are not necessarily less appropriate for use in a given situation. For example, a one-dimensional receiving water model might be appropriate for situations where a waterbody is reasonably well mixed in the lateral direction as opposed to a two- or three-dimensional model. In such a case, the one-dimensional model will have the advantage of easier setup and, most likely, lower cost. As a result, selecting an appropriate model application must always be evaluated against the unique characteristics of the system to which it will be applied, and, given the particular issues that might or might not be critical to simulate, certain representational trade-offs could be deemed acceptable.

Criteria for Model Selection

To select an appropriate model for the Lake Champlain Basin, EPA conducted a review process in which the applicability of several candidate approaches was evaluated against specific project needs, listed as follows:

- The model should enable prediction of contributions from different sources in each major tributary watershed, including phosphorus loads from forested and agricultural land sources, developed land sources, and loads from within the stream channel system.
- The model should be able to provide output using the concept of a hydrologic response unit (HRU) to facilitate management and implementation. An HRU is defined as an area of land having unique soil, slope, and land use characteristics.
- The model should enable prediction of potential phosphorus reductions from sources associated with potential future BMP implementation in each tributary watershed
- The model should facilitate assigning wasteload allocations (WLAs) to Vermont-permitted sources (e.g., municipal separate storm sewer systems [MS4s] and wastewater treatment plants [WWTPs].
- The calibrated model will be used to perform loading evaluations related to source reduction scenarios and whether the Lake TMDL conditions are being met.
- The calibrated model should facilitate identification of critical loading areas for targeting priority implementation activities and providing Reasonable Assurance for the TMDL.
- The model should facilitate assessing the impacts of temporally variable drivers such as precipitation and should allow for evaluation of climate change and landuse change scenarios.

Related to the specific project needs listed above, other technical, regulatory, and management criteria are also relevant to the model selection process. Technical criteria refer to the selected model's ability to simulate the physical system in question, including physical characteristics or processes and constituents of interest. A variety of technical issues and how they will be addressed must be considered during model selection. Regulatory criteria make up the constraints imposed by regulations, such as water quality standards or procedural protocol. Management criteria comprise the operational or economic constraints imposed by the end user and include factors such as financial and technical resources and intended model application. Several specific concepts related to modeling the Lake Champlain Basin for this project are noted below. EPA believes the selection of the modeling approach should be based in part on how well all purposes are met.

Snow Hydrology—Elevation and associated precipitation phenomena (e.g., rain/snowfall, snowpack accumulation and snowmelt) can have a significant influence on the hydrology in the Lake Champlain Basin. The snowfall/snowmelt process acts like a reservoir of stored precipitation during the winter, which is ultimately released during the spring. Therefore, those processes will be important considerations.

Stream Bank Erosion—A significant source of sediment in the basin, it is anticipated that stream bank erosion will be the focus of significant reduction measures. An application that can be used to quantify stream bank erosion and support analysis of reduction scenarios related to implementing stream channel BMPs is desirable.

Climate Change Impacts—A major objective of the watershed model will be the analysis of the impacts of climate change to phosphorus loading in the watershed. An important, but sometimes ignored, aspect of climate change is an increase in ground level CO_2 concentrations. The Intergovernmental Panel on Climate Change predicts an increase in future CO_2 concentrations under all emissions scenarios. Plants require CO_2 from the atmosphere for photosynthesis. An important effect of CO_2 fertilization is

increased stomatal closure because plants do not need to transpire as much water to obtain the CO_2 they need for growth. That effect can counterbalance predicted increases in temperature and potential evapotranspiration and thus has a profound effect on hydrology. It could also reduce water stress on plants, resulting in greater biomass and litter production, which in turn will influence pollutant loads.

The selected model will need to facilitate running scenarios designed to evaluate the potential effects on flow and loading of phosphorus if climate/precipitation patterns are altered. That could also involve running scenarios to evaluate BMP performance under alternative climate scenarios.

HRU-Based Analysis—To allow for maximum flexibility in developing implementation plans for the revised TMDL, it is highly desirable to apply an application that will enable the evaluation of outputs for units that are similar in hydrologic response. Such units are highly amenable for use in post-TMDL tracking systems since HRU modeling results can be expressed in simple terms such annual runoff yields and pollutant export rates.

Nutrient Representation—Data and analysis suggest that it will be important to consider the distribution between particulate and dissolved forms of phosphorus. As a result, the selected model must be able to simulate appropriate nutrient and sediment parameters, including total and constituent phosphorus, nitrogen, and sediment.

Review of Candidate Watershed Models

EPA reviewed a variety of publicly available and accepted technical approaches for estimating phosphorus loading to develop the model recommendation in this report. Models selected for this review include applications that range in complexity, are applicable in mixed use watersheds, have a previous track record of use in New England or have been used to support TMDL development. For context, techniques from each category of model (data-driven, mid-range, and complex) were evaluated against the project modeling needs and criteria. The mid-range approaches include GWLF model and P8. The complex models include the HSPF, LSPC, and SWAT. Tables 1 and 2 provide an assessment of the capabilities of the technical approaches/models to address various criteria.

Table 1 was adapted from a recent EPA review of available models and summarizes basic capabilities of each of the reviewed watershed models (USEPA 2005). It illustrates differences between approaches but does not highlight differences in the way the models simulate similar pollutants. Table 2 provides a qualitative assessment of the models' abilities to address project-specific requirements.

Table 1. Comparison of reviewed watershed models

Model	Type	Level of complexity			Time step				Hydrology		Water quality		
	Stream routing included	Export coefficient	Loading curves	Physically based	Sub-daily	Daily	Monthly	Annual	Surface	Surface and ground	User-defined	Sediment	Nutrients
Data-driven			●					●				●	●
GWLF		●					●	●		●		●	●
P8	●			●	●	●	●	●		●		●	
HSPF/LSPC	●			●	●	●	●	●		●	●	●	●
SWAT	●			●		●	●	●		●		●	●

Source: Adapted from USEPA 2005

Table 2. Comparison of capability of candidate models to satisfy project objectives

Capability key: ● High ⏷ Medium • Low					
		Technical approach options			
Criteria	**Data**	**GWLF**	**P8**	**HSPF/LSPC**	**SWAT**
Technical					
Spatial Scale and Representation					
• Ability to customize segmentation	--	●	●	●	●
• Predict loads for multiple scales	--	⏷	⏷	●	●
• Ability to predict HRU-based loading	--	--	--	●	●
Temporal Scale and Representation					
• Long-term trends and averages	●	●	●	●	●
• Continuous –predict shorter time period variability	--	⏷	●	●	●
• Sub-daily concentrations	--	--	●	●	•
Sources					
• Land uses (urban and non-urban)	⏷	●	●	●	●
• WWTPs	⏷	⏷	--	●	●
Land and Water Features					
• Agricultural, urban, forest land covers	--	⏷	⏷	●	●
• Stream network/routing	--	--	⏷	●	●
• Impoundments	--	--	•	●	●
Pollutants					
• Total nutrient concentrations	⏷	●	●	●	●
• Dissolved/particulate partitioning	⏷	●	--	●	●
• Particle fate	--	--	⏷	●	●
• Sediment loading	⏷	●	●	●	●
• In-stream sediment transport	--	--	⏷	●	●
Physical Processes/Critical Basin Factors					
• Snow hydrology	--	--	•	●	⏷
• Streambank erosion	--	--	--	⏷	•
Regulatory					
• Assign VT WLAs	⏷	⏷	•	●	●
• Technically defensible (previous use/validation, thoroughly tested, results in peer-reviewed literature, previous TMDL studies)	⏷	●	●	●	●
Management Scenarios					
• Linkage to Lake TMDL model	●	⏷	⏷	●	●
• Urban BMP representation	--	--	⏷	⏷	•
• Agricultural BMP representation	--	•[a]	--	⏷	●
• Ability to represent climate change	--	--	--	●	●
• Ability to address CO2 fertilization	--	--	--	•	●

Notes:

a. GWLF-E version

● = High: detailed simulation of processes associated with land feature

⏷ = Medium: moderate level of analysis; some limitations

• = Low: simplified representation of features, significant limitations

-- = Not supported

Conclusion

Of the technical approaches reviewed, the complex models clearly provide the best ability to accomplish a majority of the analysis goals. A major advantage of utilizing a dynamic model for the basin is the ability to represent multiple critical processes and effectively analyze loads and potential reductions from a variety of sources across the watershed. While EPA is recommending one of the complex models be used (see below for discussion of each), EPA recognizes that not all sources and phosphorus reduction practices can be appropriately simulated with a watershed process model. To accommodate this concern, it is recommended that the selectedmodel be supplemented with a spreadsheet tool to account for a broader spectrum of phosphorus sources and loads, and to evaluate implementation scenarios involving reductions for practices simulated with the watershed model as well as those calculated through other means external to the model.

The differences between the complex models have largely to do with how well they address important management and application needs. Below are brief descriptions of each of the three complex models reviewed and discussion of critical advantages and disadvantages in applying them for the Lake Champlain Basin analysis.

HSPF/LSPC

HSPF is the culmination of consolidating three earlier watershed models (Stanford Watershed Model, Agricultural Runoff Model, and Nonpoint Source Loading Model), into an integrated, basin-scale model combining watershed processes with in-stream fate and transport in one-dimensional streams. It simulates watershed hydrology, land and soil contaminant runoff, and sediment-chemical interactions. For in-stream fate and transport, overland sediment is divided into three particle sizes (sand, silt, clay). The most recent release of HSPF is version 12.2. HSPF is part of EPA's Better Assessment Science Integrating point and Nonpoint Systems (BASINS). BASINS provides WinHSPF, a Windows-based interface system for HSPF through which the HSPF model can be parameterized, edited, and executed.

The model conceptualizes a subwatershed as a group of land uses that are all routed to a stream segment. The model accounts for pervious and impervious surfaces in each land use. Small subwatersheds and stream segments can be networked to represent a larger watershed drainage area. HSPF predicts loadings from different land use scenarios for nutrients, sediment, bacteria and toxics. Various modules can be activated to simulate specific processes but are not required for every application.

LSPC is a watershed model that includes selected HSPF algorithms for simulating hydrology, sediment, and general water quality on pervious and impervious land. It also includes a one-dimensional stream transport model and is available as part of EPA's Modeling Toolbox.[1] It was designed to handle very large-scale, yet complex watershed modeling applications (8-digit HUCS) and is derived from the Mining Data Analysis System (MDAS), which was developed for EPA Region 3 to address mining areas and TMDLs.

The LSPC model is organized in a slightly different way than its predecessor HSPF model. Both models are modular in nature and are based on the same underlying algorithms. For land segments, HSPF is

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[1] The TMDL Modeling Toolbox is a collection of models, modeling tools, and databases that have been used over the past decade in developing TMDLs. For more information, see http://www.epa.gov/athens/wwqtsc/Toolbox-overview.pdf.

divided into PERLND (pervious land) and IMPLND (impervious land segments), which represent the smallest modeling units, while LSPC has only one LAND module in which flagged impervious land segments have subsurface activity disabled. Both models have a simple stream segment model for flow and pollutant transport. There are also various simulation options for physical processes. The most significant difference between the two is that HSPF simulates each land segment for all time *before* routing the resulting flow and pollutants to the stream network; whereas LSPC simulates each routing network element (by subwatershed, with land and stream components) for each time step. In general, the same advantages and disadvantages apply to both so they are listed together below.

Advantages
- Able to represent the various sources and all necessary constituents.
- Able to simulate peak and low flows and a variety of time steps.
- Can provide spatially explicit representation of point sources (WWTPs) in the watershed.
- Can be set up to simulate BMPs (urban or agricultural or both).
- Can include Special Actions programming that allow a lot more flexibility in simulating BMPs.

Disadvantages
- Simulation processes for each land use type are lumped at the subwatershed level, which means that the model does not account for spatial variation between similar land use types within a subwatershed. Greater detail can be achieved by finer subwatershed delineation, but that can increase model complexity and run times.
- Representation of cropping or tillage management practices requires additional customization and can be difficult in HSPF.
- Requires substantial hydrologic and water quality calibration and generally requires a high level of expertise for application.
- For BMP simulation, Special Actions programming is time-consuming and difficult to use.
- Does not address CO_2 fertilization and is not easily built into the model because it does not simulate plant growth.

SWAT
SWAT is a watershed-scale model originally developed for the U.S. Department of Agriculture Agricultural Research Service. It is available with EPA's BASINS (the BASINS version is SWAT2000). SWAT was developed to predict impacts of land management practices on water, sediment, and agricultural chemical yields in complex watersheds with varying soils, land uses, and management practices over long periods. It is a product of combining ideas from several other models including Simulator for Water Resources in Rural Basins (SWRRB); Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS); Groundwater Loading Effects on Agricultural Management Systems (GLEAMS); and Erosion-Productivity Impact Calculator (EPIC). Originally, the model was used to predict sediment, pesticide and nutrient loadings from agricultural areas. Over the years, additional constituents have been added to the model's simulation capabilities including urban land pollutant loading using buildup/washoff or USGS regression routines.

SWAT divides a large watershed into subwatersheds, which are further subdivided into HRUs (unique combinations of soil, land cover type, and management practices in a subwatershed). SWAT simulates hydrology, vegetation growth, and management practices at the HRU level. Thus, as the number of HRUs in a watershed increases, computational demand, run times, and number of output files can increase. Water, nutrients, sediment, and other pollutants such as metals from each HRU are

summarized in each subwatershed and then routed through the stream network to the watershed outlet.

Advantages
- Ability to simulate the effects of CO_2 fertilization on plant growth and evapotranspiration.
- Ability to use U.S. soils data directly.
- Ability to directly represent agricultural tillage, fertilization, and cropping practices.
- Ability to simulate the pollutants and sources of concern.
- Underlying databases for crop growth and land management are detailed.
- Has already been applied on a smaller and more detailed scale in various subwatersheds in the basin; as a result, it is very likely that parameters established for nearby efforts can be applied to the basin modeling effort.
- Widely applied and validated for monthly and seasonal nutrient load estimates.

Disadvantages
- Not reliable for simulating sub-daily pollutant concentrations (e.g., single storm events or diurnal changes in dissolved oxygen).
- Does not provide a solid basis for evaluating hydromodification impacts on channel stability; less adept (in comparison to HSPF/LSPC) at representing in-stream processes.
- Represents hydrology using a simplified Curve Number approach (unless the Green-Ampt option is selected).
- Routines for simulating bacteria and in-stream dissolved oxygen concentrations are not reliable.
- Representation of urban sources is limited by use of composite Curve Number approach

Recommended Approach

On the basis of a preliminary review of data available for modeling the Lake Champlain Basin, the relative capabilities of the three complex models reviewed, and prior history of model application in the basin, it is recommended that the SWAT model be applied to develop loading estimates for the Lake Champlain Basin and be augmented with external techniques to address the basin-specific concerns of channel stability/instream loading sources and the potential reductions from certain other BMP categories less suitable for simulation with a watershed process model such as SWAT..

SWAT's major advantages over LSPC and HSPF are its detailed ability to represent loads and potential reductions associated with agricultural management practices and to incorporate the impacts of CO_2 fertilization during climate change simulation. Sufficient data are available to satisfy key SWAT modeling needs for the entire basin, including representative reach and water quality data for calibration, as well as soils (SSURGO), and topographic (10 m DEM for VT and NY and 20 m DEM for the Quebec portion). The National Agricultural Statistics Service Cropland Data Layer is also available for the entire basin. Several additional datasets, including impervious cover (2011), farmsteads, and areas suitable for certain agricultural BMPs, are available for the Vermont portion of the basin only – an acceptable limitation because these additional layers will primarily assist with the identification of potential reduction options, something that is especially important for the Vermont portion of the TMDL.   The use of SWAT also has the advantage of being able to incorporate much of the detailed SWAT modeling work already conducted in the basin, including in the Missisquoi watershed (Lake Champlain Basin Program, 2011), the Rock River (Ghebremichael et al., 2010), the Pike River (Michaud_et al.,2007) and the LaPlatte River (EPA, in progress)

SWAT does present certain disadvantages relative to the other options because it is not reliable for predicting sub-daily concentrations () and it does not provide a solid basis for direct evaluation of hydromodification impacts on channel stability and in-stream phosphorus loads. However, those considerations do not pose a problem in this case because: 1) sub-daily concentrations are not critical to phosphorus mass loading to the lake, 2) EPA is proposing a separate, alternative approach to estimating in-stream loads (see below) , and 3) if sub-daily data is needed for any reason, SWAT can be configured with the Green-Ampt option

Approach Overview
The analysis will be broken into two main steps: 1) estimating P loading from major sources and 2) estimating reduction potential from existing sources from likely treatment techniques and BMPs.

Load Estimation
SWAT will be utilized to estimate annual P export rates for the study period (i.e., 5yr or 10 yr, TBD) using HRUs representative of a range of land characteristics. Critical landuse source categories include pasture, cropland, forest, wetland,urban/developed land, and transportation (paved and unpaved roads). The urban and transportation categories will be further broken out into both pervious and impervious subsets. The HRUs should be specified in such a way that they distinguish between different types of land uses (especially agricultural land uses) for which different candidate management actions are likely to be considered. Urban land uses should likely distinguish between those that are subject and not subject to MS4 permit requirements because it will ease subsequent analysis of WLAs. The model will be set up with multiple meteorological stations that are suitable for model calibration and evaluation of potential climate change impacts. SWAT will also be used to simulate the transport of WWTF loads, which will be specified to the model based on discharge monitoring data.

SWAT has the ability to simulate urban land use loading and point source loads. Urban lands are assigned a percentage imperviousness and a default curve number value is assigned to the impervious fraction. While SWAT does not output loads for pervious and impervious areas, it can be configured to do so by setting up the model to treat the pervious and impervious fractions as separate HRUs.

For urban/developed land, SWAT will be customized using appropriate loading rates, to generate loads appropriate for Vermont's urban areas.Tetra Tech recommends making use of several additional tools to enhance SWAT's output for these areas. Vermont's existing Best Management Practices Decision Support System (BMPDSS) applications for the stormwater-impaired watersheds, EPA's BMP performance curves (EPA 2010), and detailed impervious cover and existing BMP assessments for Vermont's urban areas, may all be used, where available. These tools and information can be used to adjust pollutant loads predicted for urban areas through appropriate modification of the land cover data layer and the buildup-washoff coefficients used in SWAT.

Annual phosphorus loading from stream channel processes will be estimated outside of SWAT, using either 1) an analysis based on the results of the recent Bank Stability and Toe Estimation Model (BSTEM) application in the Missisquoi watershed, or 2) a stream power analysis.

The first analysis would make use of the relationships between loading rates and certain geomorphic characteristics found in the Missisquoi watershed following an intensive data collection and modeling effort using BSTEM. While additional applications of BSTEM are beyond the feasibility of the TMDL project, the results of the BSTEM work in the Missisquoi provide an opportunity for a simpler, but potentially very effective analysis. The first step would determine the correlation between phosphorus and sediment loading rates per linear kilometer and key geomorphic assessment features such as

erodability of the channel boundary materials, confinement and slope of valley, departure from reference condition, and sediment and flow regime.   These geomorphic parameters are available for many river and stream reaches throughout Vermont, and therefore the correlations established in the Missisquoi watershed may be used to estimate loading rates in the remainder of the watersheds in the Vermont portion of the basin. The Missisquoi watershed includes examples of all common stream reach types in the Vermont portion of the basin, so the relationships found in the Missisquoi are expected to be widely applicable to the other Vermont watersheds.   However, the necessary geomorphic data are not as consistently available for streams in New York, so an alternative approach, such as one of the power analyses described below, may be needed for the New York portion of the basin.

Stream power analyses (Bledsoe et al. 2007) appropriate for use with a summary of SWAT daily flow estimates can be based on the dominant discharge (Q), including Bagnold's specific stream power, ω, and Chang's mobility index, m, where $\omega = \gamma QS/w$ and $m = S [Q/d50]0.5$, γ is the specific weight of water, S is the slope, w is the width, and d50 is the median bed material size of the surface layer. At a somewhat more sophisticated level, paired series of daily flows with and without climate or land use change may also be used to calculate the erosion potential index $EP = \Sigma qs\text{-post}/\Sigma qs\text{-pre}$, where qs represents the sediment transport capacity associated with a given day's flow. SWAT is already designed to estimate the daily sediment transport capacity as $qs = csp (prf\ q/A)spexp$, in which q is the width-averaged flow, prf is an adjustment factor relating channel peak flow to channel average flow, A is the cross-sectional area, csp is a user-defined calibration coefficient, and spexp is an exponent in the range of $1 – 2$, typically set to 1.5 (Neitsch et al., 2005). To determine the flow regime, SWAT can be configured and run with Green-Ampt infiltration on a sub-daily basis—although the water quality still operates on a daily basis—to develop detailed hydrographs with more accurate estimates of daily and sub-daily flows. Following model calibration and stream channel source analysis, a master table will be used to store existing source loading estimations by major tributary system and 12 digit HUC.

Reduction Estimation

TMDL scenarios will require estimates of feasible load reductions obtained from a variety of practices. SWAT will be used to determine reduction efficiencies for certain source category and treatment technique combinations while external reduction calculations will be made for other source/BMP combinations. For example, SWAT will be used directly to estimate load reductions associated with changes in tillage, fertilization, and animal management practices, while potential reductions associated with certain urban practices, stream restoration practices, and other some other BMP programs will be calculated separately using methods referenced above. Potential reductions from all sources will be brought together in the spreadsheet tool discussed below.

Table 3 and Table 4 are *working conceptual* tables that summarize the major load estimation and reduction analysis components of the technical approach.

Table 3. Load Estimation Techniques for Source Categories

Load Estimation		
SWAT		
Source	*Inputs*	*Outputs*
Forest	landuse land practices, soils, topography, weather, point sources datareach network, etc	stream flows and pollutant loads by source by tributary
Agriculture		
Wetlands		
Transportation (Paved and unpaved Roads)		
WWTF		
Urban (using SWAT customized with supplemental BMP efficiency data)		
Channel Evolution Model*		
Source	*Inputs*	*Outputs*
Streambank Sediment	Geomorphic data; daily/subdaily flows**	pollutant loads

*Based on Missisquoi BSTEM results or stream power analysis
** Obtained from separate SWAT run with Green-Ampt infiltration

Table 4. Reduction Analysis Techniques for Source/BMP Combinations

Source	SWAT Estimation	External Calculation
	Reduction Analysis	
Forest	Forest bmp 1 Forest bmp 2 …..	
Agriculture	Vegetated buffer Cover crops No-till Reduced P manure Ag bmp 5 Ag bmp 6 …	
Wetlands	…	
Transportation (Dirt Roads)	…	Drainage ditch armoring
WWTF		Permit Limits
Urban	P fertilizer ban	Infiltration Disconnection Wet pond …..
Streambank Sediment	…	Bank slope 2:1, 5 yr vegetation Floodplain access

Scenario Evaluation, Allocations, and Demonstration of Reasonable Assurance

For transparency and to facilitate review by multiple stakeholders, load estimation and reduction analysis results (predicted loading rates and delivery factors) can be exported to a Scenario Evaluation spreadsheet tool. The spreadsheet would serve as an accounting inventory of specific phosphorus source areas in the Champlain Basin. It would be applied during the Reasonable Assurance process to facilitate evaluating the change in predicted load reductions based on application of different BMPs to appropriate source categories in different locations. EPA envisions this tool to display load estimates and predicted reductions by major tributary basin, allowing for further filtering to the HUC 12 level or below.

Linkage to BATHTUB Lake Model

The BATHTUB model will be calibrated using the existing setup, which uses monitoring data to provide inputs. Once the SWAT watershed model is calibrated, it will be used to provide inputs to the lake model on the basis of results of various scenario runs.

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