An Environmental Accounting System to Track Nonpoint Source Phosphorus Pollution in the Lake Champlain Basin

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Year 2 Project Work Plan

The stated goal of our project is to develop a framework and model that can be used to account for major sources and potential reductions of phosphorus across the landscape. In Phase 1, we conducted a literature review and framed the issues. We summarized the relative reductions in phosphorus that might be achieved using various BMPs in both agricultural and urban/suburban land areas.

We chose to start our project with a focus on the Missisquoi watershed. Because agriculture is estimated to be about 70% of the nonpoint source in this watershed, we also chose to begin by developing an agriculturally focused tool. In order to accumulate phosphorus across the watershed and consider the relative importance of landscape factors like slope, soil type and specific land use, contiguities and connections in the riparian corridor and stream network, we needed to use a watershed model. We selected SWAT (Soil and Water Assessment Tool) for this purpose.

In order to identify critical source areas of phosphorus, it is essential to have a way to account for phosphorus across the landscape and transport it to Lake Champlain. Critical source area identification and evaluation of the most effective ways to control and/or reduce phosphorus losses in these areas are the primary uses of an accounting system, and thus a second endpoint of our project. The development of an accounting system and use of that system to examine critical sources and potential reduction scenarios are essentially highly related tasks and both are included in our efforts.

Because of logistical challenges associated with starting with a watershed the size of the Missisquoi and data availability to calibrate the SWAT model, we have begun by focusing on the Rock River watershed. This smaller watershed will allow us to examine in detail the sources and transport of phosphorus and to develop an overall approach to accounting and targeting critical source areas that then can be applied throughout the basin.

The single greatest problem with the current TMDL implementation plan is the lack of clearly defined and measurable objectives for the nonpoint sources. Our goal is to produce a tool that can be used to account for the phosphorus reductions that might be associated with various management actions on agricultural land. In addition to telling us where we stand, these comparative values can be used to explore which management interventions, in which places, offer the greatest potential for reducing the phosphorus load to Lake Champlain.

In year two, we will focus explicitly on developing a management tool that can be used in an adaptive implementation strategy to answer four critical questions relative to agricultural land uses:

- Where do we stand right now?
- What are the critical sources and source areas we need to address?
- What interventions will provide the greatest phosphorus reductions in these areas?
- What are realistic expectations of outcomes once we do intervene (in terms of both the phosphorus balance and the timeline for response)?

The following sections outline the major tasks remaining in the project.

<u>Tasks to be accomplished in **Phase I** of the project</u>

The majority of the Year 2 work plan involves continuation of the Tasks listed in **Phase I** of the report (Year 1 report, Figures 4-2, 4-3, and 4-4). Major tasks of **Phase I** involve:

1. Data gathering (base input data, management data) and pre-processing to support the SWAT model.

Basic input data such as, land use, soils, elevation, weather data (daily precipitation, Tmax, & Tmin, and monthly Radiation) have been gathered and pre-processed to fit the format requirement by SWAT model.

The SWAT model allows a watershed to be divided into sub-basins based on topographic criteria and user defined streams. A 10 m DEM data of the Rock River Watershed was used to define stream networks, and a USGS digitized streams layer was also used to make sure the modeled streams closely matched these data. In addition, stream networks were defined to match the VT DEC planned synoptic sampling sites within the watershed. The sub-watershed and stream net-works generated in our SWAT modeling are as presented in the Year 1 report. However, stream networks representation in SWAT can be modified should there exist actual drainage networks data. We are not aware of existence of any other data related to drainage networks and we plan to work on these stream net-works and sub-watersheds defined and presented in the Year 1 report.

In the SWAT model, hydrologic response units (HRUs) within each sub-watershed are defined based on the combinations of land use, slope, and soil types. In order to simplify SWAT runs, areas of a particular land use, slope, and soil type within a sub-basin are combined together to form one HRU without any consideration to individual fields and with no significance to their spatial location. However, in this project, we are planning to minimize lumping of land areas with similar combinations of land use, slope, and soils by performing some modification of the SWAT model input data format and by uniquely coding the FSA Common Land Unit (CLU) fields. The distinct representation of fields is useful during the process of HRU formation to avoid lumping of similar land use, slope, and soil combinations of different fields within a sub-basin into one HRU. Once the field boundaries are taken into account in the process of HRU development, amounts of runoff and associated sediment and nutrient loadings for each field can then be extracted from the outputs of HRUs that are distinct to each field.

We will also gather as much information as we can on tile drainage and ditching. SWAT has a standard routine for representing tile drainage. Colleagues in Canada (IRDA) who are also working on SWAT applications in the Lake Champlain Basin have also developed a SWAT version with a modified tile drainage module that captures their study area. We plan to test the suitability of both these SWAT versions. It is possible to use SWAT to represent hydrologic modifications in the landscape due to ditches. Hence, if the data can be acquired, we will examine the impacts of both tile drainage and ditching using SWAT.

Input data concerning management are not completely acquired and hence we will continue to gather these data as part of the Year 2 work plan. Management input data required include: 1) inventory of livestock, which will be used to estimate the amount of manure production, 2) data related to crop planting, tillage, and harvesting, grazing dates, 3) typical manure application rates and scheduling, 4) fertilizer application, and scheduling, and 4) management practices (such as crop rotation, cover crops, and others) that are currently implemented. These data are required by the model in order to appropriately simulate sediment and phosphorus losses. Other input data that may help in improving data representation and validating model predictions include, among others, soil phosphorus test, manure analysis results (% of phosphorus in manure).

So far, data related to the number of livestock have been obtained for the 1 large farm (LFO) and 3 medium farms (MFOs) in the Rock River watershed. Similar data for the small farms still must be gathered. Details of input data, their sources and level of specificity and importance are presented in the table below.

Table showing details of input data for Phase I of the project
(information will continue to be updated and refined as the project proceeds)

Data Item	Source of Data	Data Status	Level of Specificity	Level of importance and purpose
		(a) already obtained by investigators, or (b) promised by agency (specify), or (c) will be obtained by investigators (d) other	(a) farm or field-specific, or (b) generalized for watershed (c) other (specific)	
Measured data Stream flow, sediment, & Phosphorus	Canada: Québec Ministère du Développement durable, de l'Environment et des Parcs (MDDEP)	(a)	(c) Data at the outlet of the Rock River Watershed	Required for model calibration/validation
Synoptic sampling data within the Rock River watershed.	VT DEC	(b)	(c) Data within the subwatersheds of the Rock River Watershed	Optional data, if available, important for validating SWAT predictions across the subwatersheds

DEM	1) Vermont Center for Geographic Information VCGI 2) Canadian Digital Elevation Data)	(a)	(b)	Required input for SWAT model: used to generate stream networks, slope calculations, and other watershed characteristics.
Land use General land cover data (2001) FSA Common Land Unit (CLU) fields Active farmstead areas	University of Vermont (UVM) spatial analysis lab USDA/NRCS GIS lab	(a)	(a) and (b)	Required input for SWAT model: used to represent land cover characteristics of crop and animal production area.
Soils map & Soil characteristics	USDA/NRCS	(a)	(a)	Required input for SWAT model: used to represent soil- water movement
Climate data: Precipitation, temperature	NOAA/ NCDC stations (Enosburg, South Hero, & Saint Albans) Canada (Philipsburg) - Banque de données climatologiques - données préliminaires et approuvées, Québec, Ministère du Développement durable, de l'Environnement et des Parcs, Direction du suivi de l'état de l'environnement.	(a)	(c) Station-specific daily data	Required input for SWAT model: used to represent water balances and initiate water-soil movement
Crop planting, tillage, harvesting, grazing	NRCS, Nutrient management planners, VT AAFM, Farmers Watershed Alliance, USDA-NASSS data	(d) We will set a meeting with these agencies to figure out from where exactly to find this data	(a) -Best will be to find field specific data If not, (c) crop-specific typical data	Required input data for SWAT model in representing crop production
Inventory of Large and Medium Farm operations	*Vermont* Agency of Natural Resources	(a)		Required to estimate manure production input to SWAT model.
Inventory of Small Farm operations	UVM extension, NRCS, Nutrient Management planners, VT AAFM, Farmers Watershed Alliance, USDA-NASSS data	(d) We will set a meeting with these agencies to figure out from where exactly to find this data	(c) preferred to find, # of small farms, and # livestock of each farm	Required to estimate manure production input to SWAT model.
Manure application rates and scheduling	NRCS, Nutrient management planners, VT AAFM, Farmers Watershed Alliance, USDA-NASSS data	(c)	(a) Best will be to find field specific data; If not, (c) crop-specific typical data	Required input data for SWAT model: used to estimate input sources of phosphorus in manure
Type of manure produced (liquid, sold, mixed	Nutrient management planners	(c)	(b)	Input data for SWAT model.
Manure analysis	Nutrient management planners, or	(c)	(b)	Input data for SWAT model.
Fertilizer application, and scheduling	NRCS, Nutrient management planners, VT AAFM,	(c)	(a) Best will be to find field specific data;	Required input data for SWAT model: used to estimate input sources of

	Farmers Watershed Alliance, USDA-NASSS data		If not, (c) crop-specific typical data	phosphorus in fertilizer
Management practices (such as crop rotation, cover crops, and others)	NRCS, Nutrient management planners, VT AAFM, Farmers Watershed Alliance, USDA-NASSS data	(c)	(a) Best will be to find field specific data; If not, (c) crop-specific typical data	Required input data for SWAT model: used to represent existing management efforts
Soil Phosphorus test	NRCS, Nutrient management planners	(c)	(a) Best will be to find field specific data; If not, (c) crop-specific typical data	Optional data, if available, important for validating SWAT predictions of soil phosphorus
Tile drained fields (and ditches)	UVM extension, NRCS, Nutrient Management planners, VT AAFM, Farmers Watershed Alliance, USDA-NASSS data	(c)		Required input data for SWAT model: used to represent the hydrological modifications due to tile (ditches) drainage.

2. Model calibrating and validation for hydrology, sediment and phosphorus.

Observed flow and water quality data required for calibration and validation the SWAT model is being acquired from the Québec Ministère du Développement durable, de l'Environment et des Parcs (MDDEP). Stream flow data obtained is from the station # MDDEP 030425, located at Rivière de la Roche à Saint Armand in Canada (with 45.0217 Latitude ºN; 73.0161 Longitude ºW**).** Sediment and phosphorus data gathered are from the station # MDDEP 03040112, located at Rivière de la Roche, north of border in Canada (with 45.0177 Latitude ºN; 73.0519 Longitude ºW**).**

So far, preliminary calibration of hydrology is completed. As part of the Year 2 work plan, we plan to improve hydrologic predictions by calibrating sensitive hydrologic model parameters, such as Curve Numbers and Snow-melt factors and also by improving actual hydrologic response areas such as representing the existing tile drained fields.

In addition, in Year 2 we will calibrate and validate the sediment and phosphorus loss predictions. As a result, critical source areas will be identified within the Rock River Watershed for runoff, sediment, and phosphorus losses.

3. Application of the model for representing and evaluating best management practices.

The effectiveness of potential best management practices within the Rock River Watershed will be quantitatively evaluated.

<u>Tasks to be accomplished in **Phase II** of the project.</u>

1. Select two (or three) representative farms and gather data required for IFSM model simulation.

Though detailed soil phosphorus test data for Rock River Watershed fields are not available, considerable agricultural fields in Lake Champlain Basin were reported in the "*State of the Lake 2008*" to have high and very high soil phosphorus levels that are above the crop's phosphorus requirements. Similar soil phosphorus levels may be presumed in the Rock River Watershed in which the phosphorus loss per unit area is high. There may be many contribution factors to these higher soil phosphorus levels. Excess feeding of phosphorus to animals may enrich livestock manure with excess phosphorus. Application of manure with higher phosphorus content to cropland has the potential to cause phosphorus accumulation in the soil. In addition, application of manure to agricultural crops, with manure application rates based on field-specific nitrogen (N) requirements, increases soil phosphorus build-up and the risk for runoff phosphorus loss.

As stated previously, we are using a modeling approach to account for and track P (for its sources and movements) across the landscape. In Phase I of the project presented previously, we plan to use SWAT model in accounting and tracking P sources and transport factors in the landscape. SWAT model representation of P sources and transport mechanisms and management strategies for remediation is the major part of the project, and it is expected to take the major part of the time in the Year 2. However, for comprehensive P accounting system, there is a need of P accounting in the animal production part of the agricultural production, which won't be accounted using the SWAT model. SWAT model doesn't have components, such as an animal model, that represents P processes in cows and farm phosphorus inflows (in feed concentrates, minerals, and forage) and outflows (in milk, and crops and animals sold). Also, the SWAT model does not have a model component for predicting the amount of manure produced, manure P contents, P imports and exports and other important farm factors for specific farm strategies. Hence, using the IFSM model becomes helpful in order to account for this P in animal production that would not otherwise be included in the SWAT model. Hence IFSM model is expected to provide information that can't be acquired by using the watershed scale model, the SWAT model. Conjunctive use of both SWAT and IFSM models is helpful in order to perform comprehensive accounting of the P sources and transport processes. However, by integrating the use of both models, information acquired from one model can also be used to instruct the other model in testing management strategies that address P problem issues in both animal and agriculture production areas.

The IFSM has model components that can be used to examine farm dietary P and farm P balances among others. Accounting for dietary P and farm P balances (or imbalances) will help to estimate surplus P in resulting from the existing set of farm strategies. As part of the accounting system and using this system to target management practices to these practices, we feel that it is important to identify potential root causes of the phosphorus imbalance at the farm level.

Best management practices, which are typically structural or management based, are designed to control off-field P transport to streams, but they do not address long-term, on-farm P imbalances. Over time, the effectiveness of such BMPs may be limited as soil-P build-up continues. Hence, identifying and targeting the root cause of the P imbalance is critical to the long-term health and quality of the Lake Champlain.

Because of Lula's experience on successful use of IFSM in New York farms in identifying and targeting the root cause of the P imbalance, we know what set of input data need and how to robustly run the model to represent farm strategies. We are also planning to bring a student to facilitate data collection and model data entry.

The 2002 CENSUS OF AGRICULTURE - USDA, National Agricultural Statistics Service (presented in table below) shows that about 42% of the cows in Franklin county are owned by small farm operations; 26% of the cows are owned by medium farm operations (MFO), and 31% of the cows are owned by large farm operations (LFO). Based on the Vermont's farm size categorization, a farm having cows that are less than 199 is considered to be small farm; farms with number of cows greater than 200 but less than 499 are categorized as MFO; and farms with number of cows greater than 500 are categorized as LFO.

Table showing Cattle Inventory of 2002 in Franklin County, VT
(source USDA, National Agricultural Statistics Service)

Farms by inventory	# cows	# of farms	Percent of farm sizes in the county
1-9	216	41	0.3%
10-19	596	44	1%
20-49	2,154	69	3%
50-99	6,221	83	9%
100-199	19,332	139	29%
200-499	17,832	59	26%
>500	21,020	24	31%

In Rock River Watershed, there are 3 MFO, with 380 cows (plus 200 youngstock), 250 cows, and 206 cows (135 youngstock). Also there is one farm categorized as a large farm operation (LFO) with 95,000-100,000 chickens. The majority of the farms in the Rock River Watershed fall under small farm operations category.

Therefore, for our study, we plan to select 1 MFO farm and another 2 farms from small farm operations with 100-199 cows as representative farms. Though these are our criteria for selecting representative farms, the numbers of farms and actual farms to be studied are dependent upon finding volunteer farmers. We plan to consult with a variety of agricultural professionals to help find willing farmers.

We will also use meetings with farm practitioners and advisors to help guide our farm input scenarios. In addition to nutrient management planners and UVM extension faculty and staff, we will also consult with the Farmer's Watershed Alliance, NRCS, and VT AAFM. We are also aware that farm data is being acquired through Heather Darby's oilseed demonstration project. We will assess the possibilities of involving this farm as one of our pilot (representative) farms in assessing P inflows and outflows and in testing benefits of potential farm strategies in balancing farm P.

Model Input data: IFSM model requires three input data files, such as farm, machinery, and weather input data to represent the farm system. The farm data consist of detailed information that describes a farm enterprise. These are crop types and their area, generalized soil type and slope, type of animal (Holstein, Jersey, and others), number of cows of different ages, typical feed rations, manure handling strategies, equipment and structures used, and prices of farm commodities produced, purchased feeds, and farm products sold off-farm.

The machinery file contains data for machinery used, including parameters related to machine type, size and associated costs. Finally, the weather file consists of weather data required by the IFSM model. These data include daily values of total precipitation, maximum and minimum temperatures, and solar radiation.

Data sources: most of the data related to farm and machinery use will be collected from the specific farms. However, data related to weather data, slope, and soils that have already been gathered in Year 1 will be used as input to the IFSM model.

2. Once these farm inputs are gathered and entered in the IFSM model, the model will be used, among others, to assess feed production and utilization, determine phosphorus mass balance and the economic status of the farms, and determine dietary phosphorus in the ration.

3. Using the model outputs, the need for a change in farm system strategies, such as on-farm feed production and feeding strategies will be evaluated for farms with surplus phosphorus.

4. Finally, benefits of various potential changes in farm strategies will be evaluated for reducing surplus phosphorus.

<u>Tasks to be accomplished in **Phase III** of the project</u>

This section of the project involves integrating findings of modeling systems developed in Phase I and II, the watershed-scale and farm-scale models and accounting systems. This is essential for incorporating farm-based planning into watershed-scale management programs. Details of this task will depend on the results of Phases I and II. However, based on these analyses, we will:

- Identify critical areas of runoff and phosphorus losses in the Rock River Watershed.
- Group critical areas of runoff and phosphorus loss by characteristics such as common land use, soil, slope, distance to streams, and management activities.
- Identify potential management practices appropriate to these specific combinations of land uses and assess management practices for their effectiveness in the Rock River Watershed.

We will also extend the study farm results to selected watershed-scale scenarios designed to assess varying degrees of adoption of farm management systems by the dairy community and their potential impacts on the watershed phosphorus mass balance.

We recognize the particular interest in determining whether high soil P concentration is a critical source factor. Continued addition of fertilizer and manure in excess of crop nutrient requirements leads to a build-up of soil phosphorus levels in soils, which is a critical source factor in increasing the risk of adverse environmental effects from P loss to water. In addition to soil P, the load of P loss, however, depends on the runoff volume and erosion potential, which in turn, are related to climatic, agronomic, and tillage factors. By using SWAT, we expect to find out how different sets of situations, sources and transport factors contribute to high P loss. In short terms, using SWAT we expect to find where high build-up of soil P levels are occurring, and where the P losses to the water bodies are coming from.

Once the runoff, sediment and phosphorus losses are simulated using a SWAT model, we envision a great potential for using the field-by-field based P runoff losses from Rock River Watershed predicted by the SWAT model for validating the P transport component of VT P-index. However, such a full validation of the phosphorus transport component of VT P-index is beyond the scope of the Year 2 work plan. The processes of representing runoff, sediment, and phosphorus losses and management scenarios in the SWAT model will take the major part of the time in the Year 2.

Because there is basic uncertainty and some disagreement among the basin technical community about the relative importance of farm production areas and cropping areas as critical sources of phosphorus loading, we will examine this question using the combination of IFSM and SWAT modeling. In particular, data related to the location and size of the farm production areas will be collected in order to simulate P losses from active barn areas.

At the end of the project, we will develop overall guidance for a basin-wide system of phosphorus critical source area identification and accounting that can be scaled up for use in agricultural watersheds throughout the Lake Champlain Basin. We will use the lessons learned from the modeling to inform the development of this guidance.   We hope to be able to generalize predictions from this process about the effectiveness of various potential management practices at a larger scale and over longer time frames.

Deliverables

The following deliverables will be produced as part of this project:

- A QAPP for secondary data
- A modeling system consisting of SWAT that will identify critical sources areas for phosphorus loss and that will quantify environmental impacts of variety of management practices by Rock River Watershed dairy farms.
- A modeling system consisting of IFSM that will identify points of farm phosphorus imbalances and that can quantify economic and environmental impacts of variety of management practices, with an application to Rock River Watershed dairy farms.
- Quarterly reports as required by the agreement.
- A comprehensive final report that includes methodologies and findings on the potential for reduction in phosphorus losses from the Rock River Watershed, a discussion of how the modeling system can be extrapolated to other similar watersheds throughout the Lake Champlain Basin, making clear the limits of extrapolation, and a discussion of how this approach might be integrated with a similar approach for urban/suburban land uses and to consider stream restoration for phosphorus reductions.
- Modeling results will also be analyzed, interpreted, and summarized for publication in the peer-reviewed literature although the submissions may occur after the end of the second year of the project.
- Presentations to the Lake Champlain Basin Program; the Vermont Agency of Natural Resources and Agency of Agriculture, Food, and Markets; and other interested parties.

Schedule

Complete QAPP for secondary data:	January 2009
Conduct and Complete Phase 1 tasks:	December 2008 – June 2009
Conduct and Complete Phase 2 tasks:	January 2008 – April 2009
Conduct and Complete Phase 3 tasks:	June 2009 – October 2009
Submit draft final report to VT ANR and LCBP:	October 31, 2009
Submit final report to VT ANR and LCBP	December 31, 2009