Missisquoi Bay Basin Project:
Identifying Critical Source Areas of Pollution

Second Interim Report on Modeling
March 22, 2011

Modeling Progress, Analytical Processes Applied, and Data Collected

Stone Environmental, Inc. (Stone) is the project contractor for the phosphorus critical source area modeling project, and began work in early June 2010 after workplan approval. On August 30, 2010, the EPA and NEIWPCC approved Stone's Secondary Data Quality Assurance Project Plan (QAPP), which provides a framework for data collection and analysis, via the Soil and Water Assessment Tool – Variable Source Area Model (SWAT-VSA). This second interim report describes progress on the modeling project since November 30th, when the first interim report was submitted.

To date, Stone has made significant progress on many of the tasks outlined in their project task schedule (copied below, with the current status of the task noted). Progress is described below and organized by task.

Project Objective*	Task	Date(s)	Status	Deliverable
S	Task 1: Construction and Testing of SWAT-VSA Model	6/1/2010-8/1/2010	Completed	
R	Task 2: Development of QAPP	6/1/2010 - 8/1/2010	Completed	Approved QAPP
S	Task 3: Data Collection and Evaluation	8/2010 - 10/1/2010	In progress	
S	Task 4: Model Development and Calibration	10/1/2010 - 2/1/2011	In progress	
S	Task 5: Identify P CSAs	1/1/2011 - 3/1/2011		
S	Task 6: Field Verification of CSAs	3/1/2011 - 5/1/2011		
S	Task 7: Evaluate Management Scenarios	3/1/2011 - 5/1/2011		
S	Task 8: Evaluate Climate Scenarios	3/1/2011 - 5/1/2011	In progress	
S	Task 9: Compare Simple CSA Methods	4/1/2011 - 5/1/2011	In progress	
T	Task 10: Develop Enhanced Hydrologic Network	1/1/2011 - 5/1/2011	In progress	Enhanced Hydrologic Network Layer
T	Task 11: Prioritize CSAs	5/1//2011 - 6/1/2011		
T	Task 12: Site-Specific Modeling	5/1/2011 - 7/1/2011	In progress	
R	Task 13: Quarterly Reporting	6/30/2010 - 6/30/11		
R	Task 14: Final Report, Maps, and Data Deliverables	6/1/2011 - 8/19/2011		Final Report, SWAT-VSA Model

* S = Strategic Analysis, T = Tactical Analysis, R = Reporting

Task 1: Construction and Testing of SWAT-VSA Model

Stone continued evaluation of approaches for incorporating the VSA concept into the SWAT-VSA model using the Hungerford Brook watershed as a test area. As a result of this testing, they settled on an approach for adjusting the surface runoff parameterization to account for variable source area and saturation excess runoff processes at the full watershed scale.

Task 2: Development of QAPP

The QAPP was approved on August 20, 2010.

Task 3: Data Collection and Evaluation

- Topographic Data: A seamless digital elevation model (DEM) was built from multiple sources to cover the entire study area in both Vermont and Québec. This included LiDAR data from the USGS covering the majority of the VT sector of the Missisquoi Bay Basin (MBB). After evaluating several different DEM resolutions to serve as the basis for the SWAT-VSA modeling, it was determined that a 10-m resolution DEM offered an appropriate combination of topographic data detail and computational practicality for SWAT-VSA modeling at the full MBB scale. This dataset is now finalized for the purposes of the MBB SWAT-VSA model.
- Topographic Characteristics: The topographic index component to the SWAT-VSA model was finalized in the first quarter of 2011. The Compound Topographic Index (CTI) was selected over the Soil Topographic Index (STI) as the indicator for areas of saturation excess runoff generation. An analysis of the two indices showed that the STI was heavily dependent upon the soil transmissivity, resulting in a pattern of critical areas that did not follow the conceptual understanding of the landscape. In addition, STI soil parameters are accounted for in other aspects of the SWAT-VSA model, providing further rationale for using the CTI as an indicator of topographically driven saturation excess runoff areas. The distribution of CTI was classified by the bottom 20%, middle 60% and top 20% (with the top 20% representing the area most likely to generate saturation excess runoff) as shown in Figure 1.

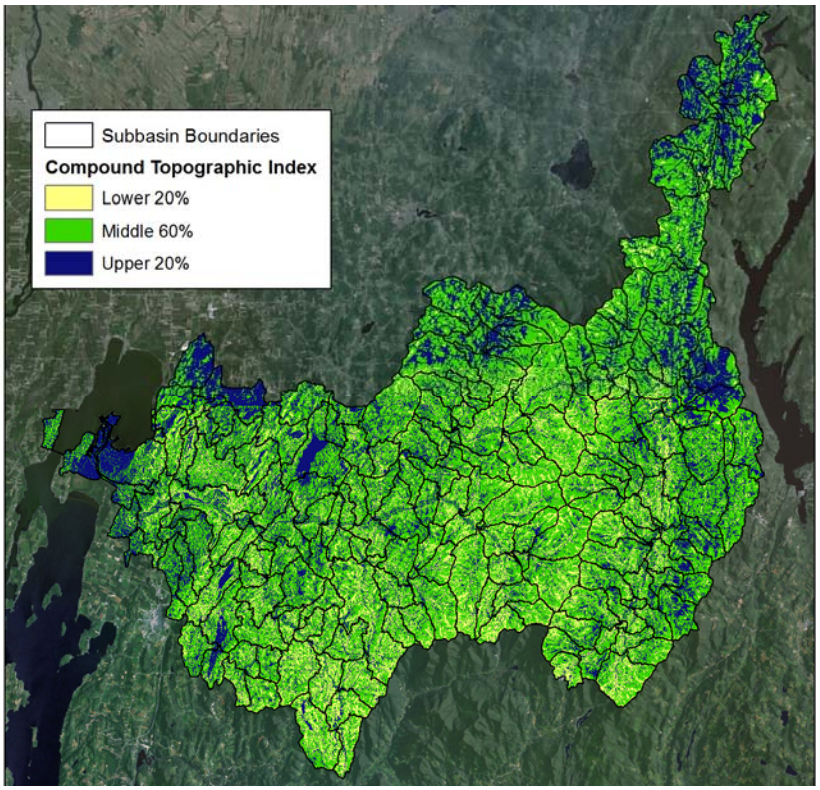

Figure 1: Basin-wide compound topographic index.

- Land Cover/Land Use Data (LCLU): A hybrid LCLU dataset for the MBB study area (both Vermont and Québec sections) was compiled for input to the SWAT-VSA model, which combines information from multiple source and scales, in order to obtain the best possible land use inputs covering the entire basin, at a scale practical for watershed scale modeling. Updates were made to this dataset after a meeting with the Project Advisory Committee (PAC) on December 7, 2010.

(1) Based on discussion with the PAC, a method for representing farmsteads within the context of the SWAT-VSA model land use component was finalized. This included differentiating between farmsteads associated with MFOs or LFOs from those associated with SFOs. This resulted in two separate land cover classes with the MBB hybrid LCLU dataset.

(2) A set of landscape-based criteria was developed to distinguish between areas of permanent corn, permanent hay, and corn-hay rotation. These criteria were then used to assign areas of corn, hay or corn-hay at the field level within the MBB hybrid LCLU dataset. A sample of this dataset is shown in Figure 2.

In addition to finalizing the hybrid LCLU for VT, Stone collaborated with *l'Institut de recherche et de développement en agroenvironnement* (IRDA) to interpret classifications of the land cover dataset for the Québec sector of the watershed. A single input data layer for LCLU has been finalized for use in the SWAT-VSA modeling.

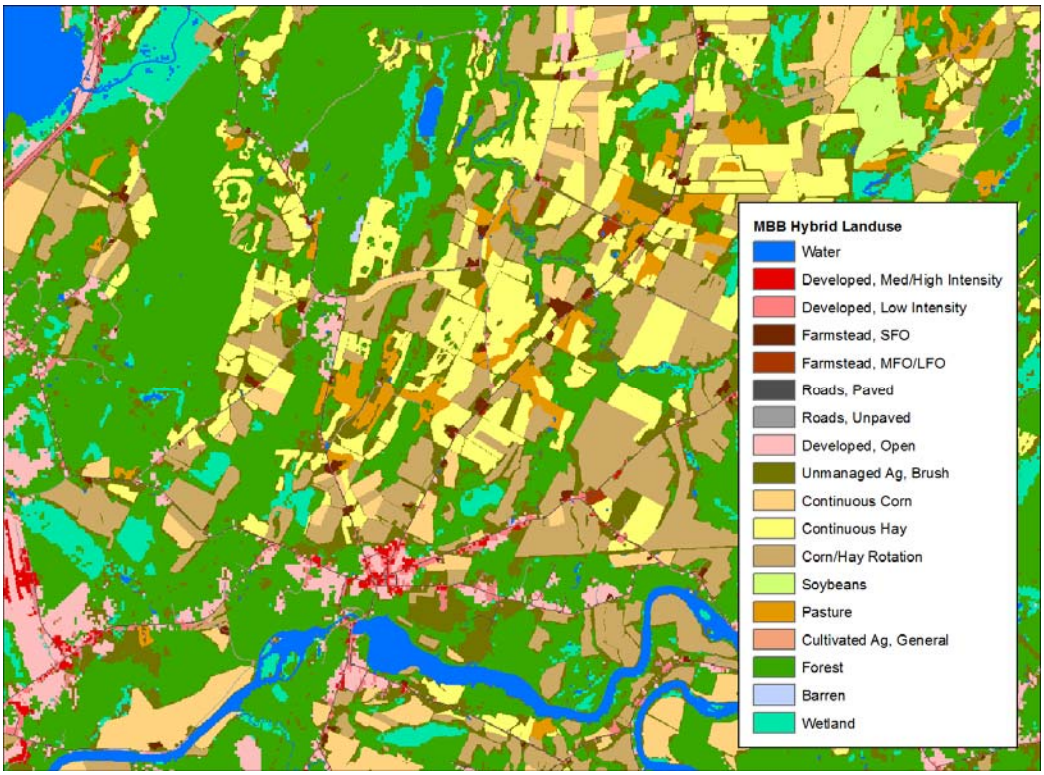

Figure 2: Hybrid land use dataset.

- Soil Data: Stone received spatial and tabular soils data for the Québec portion of the study area from IRDA; however, the tabular data were not complete for all of the soils within the study area. Therefore, Stone conducted an analysis of soil characteristics for a subset of the soils within the Québec portion of the study area, using soils descriptions from the Soil Landscapes of Canada database. Compilation of the spatial and tabular data components to the Québec soils now has been completed, thus completing soil data collection for the study area.
- Soils Data: Stone continued to work with soil phosphorus data for the VT sector of the MBB that were previously obtained from the UVM Agricultural Testing Laboratory. These data are based on a UVM Modified Morgans P extraction, but the SWAT-VSA model requires that the phosphorus inputs be from a Mehlich 3 analysis. Stone researched and identified the most appropriate conversion approach (based on a data set of both Modified Morgan and Mehlich 3 P analyses on 200 Vermont soil samples provided by the UVM Agricultural Testing Lab), and then

completed a statistical analysis of the data with the new Mehlich 3 values. The resulting statistical distributions of soil phosphorus levels by land use, town, and several other characteristics will help guide assumptions about initial soil phosphorus for different land use categories.

- Stream Channel Characteristics: Data processing for channel physical parameters has been completed. Data have been extracted from the Vermont Geomorphic Database on the US side of the MBB. Relationships that synthesize required values to subbasins where no data exist, including much of the Québec sector, have been identified. Compilation of channel soil and sediment phosphorus conditions is underway.
- Climate Data: In addition to the precipitation and temperature data of record, more recent data available for both the Vermont and Québec stations (through September 2010) were acquired. This includes the IJC-funded short-term tributary monitoring data collected through September 2010, which will be incorporated into the SWAT-VSA model. The same missing data estimation approach used for the other records was applied where needed so that for modeling purposes, all of the Vermont and Québec station time series now have complete records through the end of September 2010. Additionally, climate data from the three weather stations that were added as part of the short-term tributary monitoring program were compiled, and missing data estimated, for the period from roughly October 2009 through September 2010.
- Climate Data: An approach to generating elevation-adjusted climate time series for the SWAT-VSA model was applied to the entire MBB study area, based on tests previously conducted in several sub-watersheds. The analysis used 11 stations in the US and 5 in Canada to estimate daily precipitation, maximum temperature and minimum temperature for each of the 223 subbasins within the MBB study area. The approach uses a kriging interpolation method that incorporates both the point measurements of precipitation or temperature at the weather stations, and a second spatial factor that helps describe the variability of the measurement. In this case, this second variable is the PRISM spatial data layer of mean annual precipitation and max/min temperature. These PRISM climatological layers were developed to represent the variability of climatic variables as a function of topography. The results of the subbasin-level precipitation time series interpolation were compared to the raw weather station data to check for consistency and an excellent agreement was found. An example of subbasin mean annual precipitation (for 1999 – 2009) compared to mean annual precipitation at the gages is shown in Figure 3.

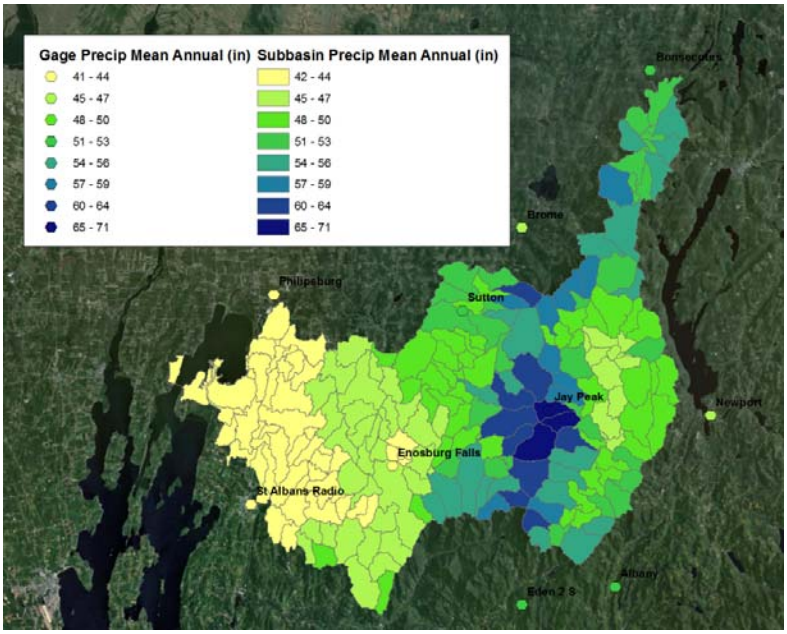

Figure 3: Sub-basin mean annual precipitation, 1999 – 2009.

- Agronomic Practices: An approach for estimating animal density and manure generation at the HUC12 watershed scale was developed. The approach incorporates county-level 2007 Census of Agriculture statistics data, locations of farmsteads, and land cover data. The approach was applied to the HUC12 watersheds covering the Vermont side of the basin and will be used to help define the inputs of manure application in the SWAT-VSA model.
- Agronomic Practices: Stone representatives attended another meeting of the Watershed Farmers' Alliance in November, and gathered data on typical agronomic practices such as planting/harvesting dates, tillage, and manure application through a group interview process. Some valuable information of typical practices was obtained at this meeting.
- Agronomic Practices: Typical management operations for continuous corn, continuous hay, and corn-hay rotations have been identified as a result of meetings with the Watershed Farmers' Alliance and several PAC members. In addition to typical management practices, criteria for estimating the locations of continuous corn, continuous hay, and corn-hay rotation based on known geospatial characteristics have been established. The resulting spatial information on agronomic practices will serve as important inputs to the SWAT-VSA model.
- Residential Sources of P: Data concerning residential practices, (fertilizer applications) and characterization of pollutant loadings from residential areas have been researched and , assumptions concerning the P inputs from these sources are in development.

Task 4: Model Development and Calibration

- Model Development: The final delineation of sub-basins and hydrologic response units (HRUs) for the entire MBB study area has been completed. The HRU delineation incorporates the final land use, soils, compound topographic index, and Common Land Unit (CLU) datasets. Application of this final HRU delineation strategy results in 112,394 unique HRUs in the study area. This HRU delineation over the Hungerford Brook watershed is shown in Figure 4. The delineation strategy provides that the HRU structure captures the variability of soils at the sub-field level and differentiates specific fields based on Common Land Unit (CLU) boundaries.

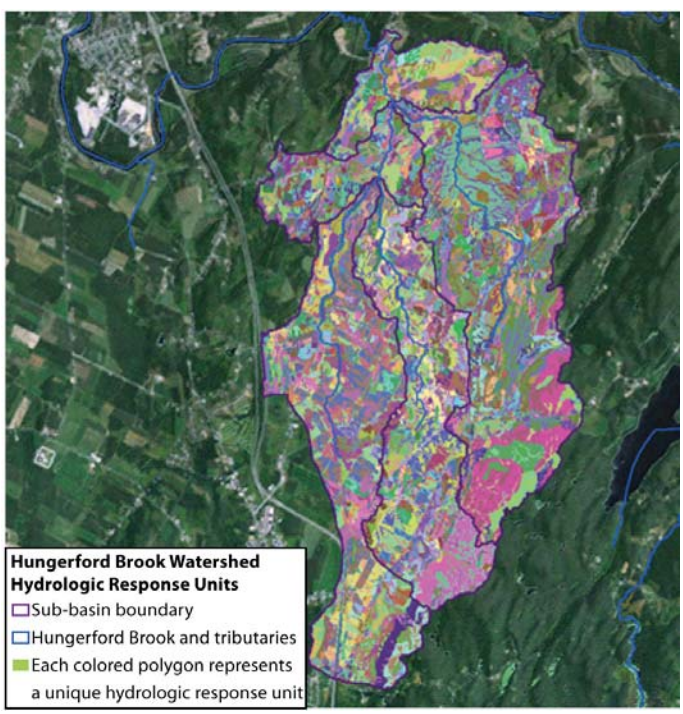

Figure 4: Hungerford Brook HRUs.

- Model Development: Based on professional experience and a review of published literature, the initial parameterization of SWAT-VSA for the full MBB study area model has been completed. This provides an appropriate and defensible set of parameters for the model from which to conduct calibration.
- Model Calibration: A strategy for using monitoring data from 18 flow, sediment, and phosphorus monitoring sites within the full MBB study area has been developed and is now underway. An image of the extent of the full MBB model including the monitoring stations being used in calibration is shown in Figure 5. Preliminary model calibrations previously conducted on the Missisquoi at North Troy, Hungerford Brook, and the Tyler Branch were used to guide the calibration of the full MBB SWAT-VSA model.

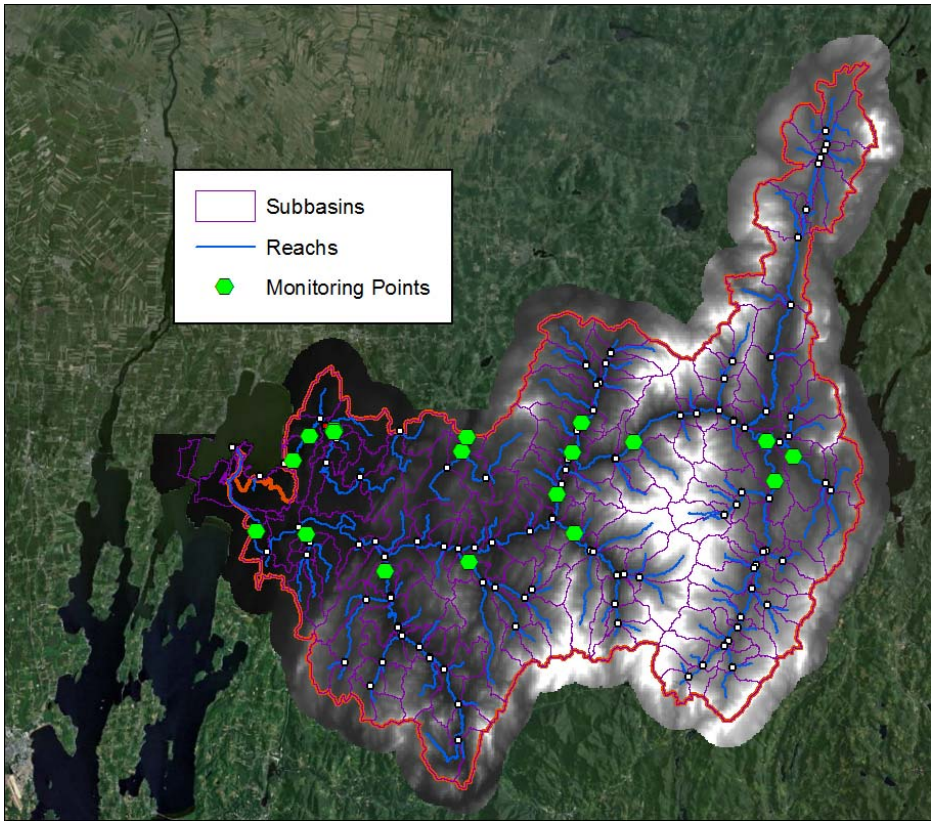

Figure 5: MBB SWAT-VSA subbasins and monitoring points.

Task 8: Assessment of Phosphorus CSAs Based on Projected Climate Conditions

- Stone has communicated with EPA regarding acquisition and processing of projected future climate time series for use as an input to the SWAT-VSA model. The data products from EPA's *"Hydrologic and water quality sensitivity to climate and land-use change in 20 U.S. watersheds"* project are currently in draft form. Stone expects to find out if these data products will be ready in time to use in the CSA project.

Task 9: Application and Testing of Simpler CSA Approaches

- Two multi-variate GIS overlay approaches to identify CSAs will be applied to the MBB: (1) the modified USLE factor map approach reported by Sivertun and Prange (2003); and (2) the topographic index weighting of export coefficients method of Endreny and Wood (2003). Stone has compiled the necessary inputs for the Silvertun and Prange method and is gathering the additional inputs required for the Endreny and Wood method. Stone has partially completed the GIS-processing model for the Sivertun and Prange approach.

Task 10: Development of Enhanced Hydrologic Network

- Stone is evaluating approaches for development of the enhanced hydrologic network derived from the 1.6-meter LiDAR DEM. An automated GIS approach to delineating the drainage network based on topographic analysis, followed by a manual evaluation to address areas of flow direction uncertainty is the current approach under evaluation. The results from this approach will be compared with a detailed manual delineation of the hydrologic network which was conducted in the Rock River watershed. Once an approach is finalized, Stone will apply it to the full area of LiDAR coverage over the MBB. Figure 6 shows an image comparing the Vermont Hydrography Dataset (VHD) network, the Rock River manually-derived enhanced hydrologic network and a network derived automatically from the LiDAR.

Figure 6: Delineation of enhanced hydrologic network.

Task 12: Site Specific Modeling to Refine Tactical Objectives

- Stone has begun a site selection process to identify suitable locations to perform the tactical analysis modeling. The process has involved identifying small clusters of fields and farmsteads that are likely to have a high density of P CSAs. The estimation of likely CSAs has been based on GIS analysis of topographic characteristics, soils, land use, and hydrography. A portion of the Rock River sub-watershed being studied for the LCBP-funded *Targeted Watershed Implementation Initiative* ("Project Rock") might be an ideal location for the CSA tactical analysis modeling. At least two micro-watersheds identified during the GIS-based site selection process are found within the 'Project Rock" study area. Stone is determining the feasibility of collaborating with the "Project Rock" team to identify a suitable site for tactical analysis modeling within their study area. Figure 7 shows one of the areas identified as a potential site for tactical analysis modeling.

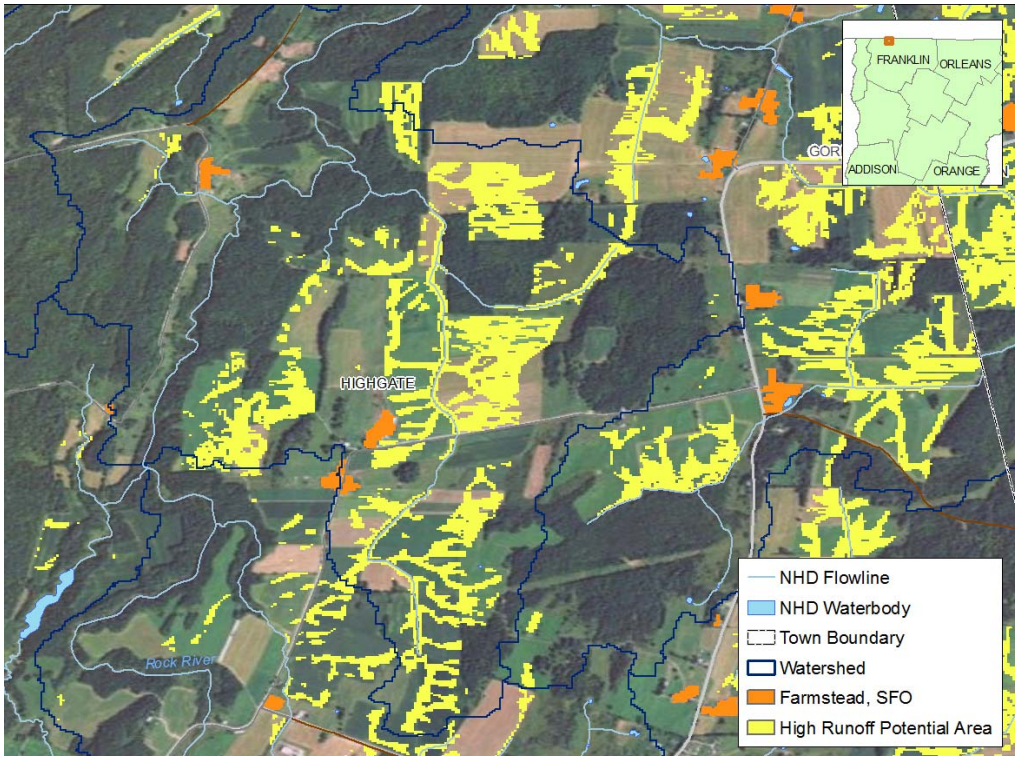

Figure 7: Site selection for tactical analysis.

Challenges Encountered

Compilation of the input datasets for the MBB SWAT model has taken longer than expected. Challenges to this work can be grouped into two principal categories: (1) delays due to receiving necessary data later than expected; (2) time required to gain acceptance of a given dataset or assumption.

Specific delays that have impacted progress are:

- Canadian Soils Data: IRDA provided spatial and tabular soils data for the Québec portion of the MBB on January 17, 2011. The data received at that time did not include soil attributes for some of the soil types. Partial soil attributes for these soils were received on February 1, 2011. Stone resolved the missing data pieces using publically available soils information from Soil Landscapes of Canada dataset; this process was completed several weeks later. The Canadian soils data are necessary to model not only the Canadian sub-watersheds but also a significant portion of the Vermont watershed that receives inflows from Canada. Correspondence with IRDA on November 3, 2010 indicated that the soils data for Québec could be delivered within days. Delayed receipt of the data has resulted in a delay in calibration efforts. Stone believes that IRDA acted in good faith to provide the requested soils data in a timely fashion; however, the time needed to provide the data was initially unclear.
- Channel Data Compilation: Gathering geomorphic data took longer than anticipated because the assessments, including the bank sediment phosphorus analyses, were in varying phases of completion. Another unexpected issue is that existing data are in very tight clusters relative to the SWAT-VSA sub-basin size, thus the data coverage is less uniform than is desirable. It has required additional time to determine appropriate ways to extrapolate the data.
- Land Cover Representations: Several classifications within the SWAT-VSA land cover dataset went through significant discussions with the PAC. These include representation of farmsteads and lands in corn, hay, and corn/hay rotations. These discussions were extremely valuable and have resulted in

a land cover dataset superior to what would have otherwise been produced. Nevertheless, the time required for these discussions resulted in a delay in the model calibration procedure.

Summary

The project is proceeding well, though it is behind schedule. The LCBP is confident that Stone Environmental, Inc. has made its best efforts toward following the schedule and accomplishing the tasks outlined in the workplan. Stone has overcome many data limitations with solid research and best professional judgment, so as to assure the best possible analysis. LCBP staff will work with Stone to ensure that the time lost due to data acquisition and acceptance does not result in a delayed delivery of the final product to the IJC. The LCBP anticipates project completion in late August with a final report to the IJC on September 30, 2011. All complete, quality-checked data acquired to-date were provided to the IJC with the first interim report, November 30, 2010. All data sets referenced in this report will be provided to the IJC in the final report.

References Cited

Endreny, T. A. and E.F. Wood. 2003. Watershed weighting of export coefficients to map critical phosphorus loading areas. Journal of the American Water Resources Association, 39: 165-181.

Sivertun, Ake and Lars Prange. 2003. Non-point source critical area analysis in the Gisselo watershed using GIS, Environmental Modelling and Software, 18: 887-898.