Missisquoi Bay Basin Project:
Identifying Critical Source Areas of Pollution

Workshop on Approaches to Identifying Critical Source Areas in the Missisquoi Bay Basin
Wednesday and Thursday, March 12 and 13, 2009
Doubletree Hotel, Burlington, VT

Workshop Summary
Day 1

I. Welcome and Introductions

Bill Howland, manager of the Lake Champlain Basin Program (LCBP), welcomed everyone to the workshop and provided an overview of the agenda.

II. Overview of the Missisquoi Bay Basin Project

Bill Howland, LCBP, provided an overview of the Missisquoi Bay Basin Project. The goal of this project is to identify critical areas contributing nonpoint phosphorus pollution to Missisquoi Bay. Identifying the critical areas will help to target resources to manage the problem. The LCBP is convening a series of workshops to help guide the critical source area identification and the development of a request for proposals. This workshop will provide an overview of recent and ongoing research on phosphorus pollution and explore possible approaches to identifying critical source areas.

III. Key Note Address: *Identifying Critical Source Areas*
Dr. Andrew Sharpley, University of Arkansas

Dr. Sharpley discussed critical source areas and how they can be defined, identified, managed, monitored and assessed. Phosphorus and other nutrients, including nitrogen, are valuable resources, but can become a problem when they runoff the land into our waterways. Soils have a capacity to combine with phosphorus. Research on plots of soil with rainfall simulation helped develop a relationship between soil test phosphorus (STP) and the amount of dissolved phosphorus in the runoff. Breaking the curvilinear relationship with defined thresholds is one way to define soil phosphorus levels and to determine when to add phosphorus to the soil.

A critical source area occurs where there is both a source of phosphorus and a transport mechanism to move the phosphorus to the waterways. The amount of phosphorus lost is a function of both the amount of phosphorus in the soil and the runoff volume. Critical source areas can be identified at different levels of complexity. Management decisions are made at the farm level; therefore, identifying the critical source areas at this level will best help affect the amount of phosphorus runoff.

There are different tools to identify critical source areas at different scales, including phosphorus indices, simulation models and Geographic Information Systems (GIS) overlays. Phosphorus indices are a simple tool for the field scale and help farmers manage their fields. Phosphorus indices examine both the source (soil phosphorus content and added phosphorus) and the transport (runoff potential, erosion potential, leaching potential and proximity to the stream). Simulation models are complex and can be data intensive, but can work at the basin or watershed scale. GIS overlaying is a simple method for examining potential transport of phosphorus. Overall, selecting the right tool is critical to meeting the research objectives.

Critical source areas change with time and land management. Identifying critical source areas allows for Better Management Practices (BMPs) to be effectively implemented. BMP effectiveness also changes overtime. Documenting changes and adapting management is essential to ensure that the remediation of phosphorus pollution is successful. Monitoring at different levels of complexity is critical to assess change. It is also important to remember that there are legacy effects from phosphorus in soils and sediments being released slowly overtime. Due to these effects, the benefits of land management may not be seen immediately.

It will be important to select the appropriate tool to identify critical source areas for the complexity required by the management objectives, to encourage stakeholders to be involved in the process, and to remember that the research approach will have to develop black and white guidelines to represent a dynamic and variable system.

IV. Presentations on Recent and Ongoing Research

The Vermont Phosphorus Index

Joel Tilley, UVM Soil Test Lab

The Vermont version of the phosphorus index was proposed in July 1999 and is based on the original phosphorus index. It is a tool used to assess the risk or potential for phosphorus runoff from individual fields. It examines source factors including soil test phosphorus, manure and fertilizer, and transport factors (e.g. erosion, surface runoff, subsurface flow, distance to streams and buffers). The index is based on a range of soil and field characteristics and management practices. One limitation of the index is that it is applied to an individual field, and the field is defined by the farmer. Another limitation is due to the fact that transport factors (erosion rate and surface runoff volume) are based on long term averages and may not account for individual high-intensity events.

In Vermont, the phosphorus index is required for all fields with manure application on farms with a Nutrient Management Plan (NMP) under Natural Resources Conservation Service (NRCS) contract. Currently, the phosphorus index is used to estimate phosphorus reductions in a pilot program to test performance-based incentives for agricultural phosphorus reduction.

The Missisquoi Areawide Plan: a watershed approach to improving water quality in Lake Champlain

Presented by Kip Potter, NRCS

The Missisquoi Areawide Plan compiled and summarized existing information on the Missisquoi Watershed, developed new priority data layers, identified priority actions and recommended future actions. Missisquoi Bay is the most eutrophic bay in the lake. The watershed is 68% forested, 21% agriculture and 5% urban. The agricultural land is dominated by dairy operations. According to NRCS Ag Census data, the number of farms and acreage of land in farms has remained fairly constant between 1992 and 2002. However, there were changes in the acreage in pasture versus corn.

NRCS compiled data including locations of farmsteads, corn and hay fields, areas suitable for no-till practices, riparian buffer gaps, potential wetland restoration areas, slopes of cropland fields, and available stream geomorphic assessments. NRCS then evaluated potential BMP effectiveness, examining ten BMPs and combinations of BMPs using RUSLE2 (a soil loss equation) and the Vermont Phosphorus Index. The sediment and phosphorus reductions and overall costs were estimated. Based on testing different scenarios, a set of 13 recommendations were developed, including: completing farmstead identification maps and enhancing a GIS database for the entire subbasin, determining where discharges from farmsteads are occurring and their relative severity, and targeting conservation practices to specific crop fields.

Identifying Critical Source Areas (CSA) in Agricultural Areas: the role of hydrological modelling, aerial imagery, Lidar and Geomatics in general
Presented by Isabelle Beaudin, Institut de recherche et de développement en agroenvironnement inc. (IRDA)

Critical source areas are driven by their position in the landscape; the occurrence of elevated water tables; the connectivity, density and convergence of hydrologic networks; and the soil type and its properties. Land use and management – including cropping practices, addition of phosphorus, and nutrient levels in soil – also drive critical source areas. Critical source areas can be identified at two different levels, strategic and tactical. Strategic level identification is done at the territory or basin scale and is quantitative in nature. Tactical level identification is done at the farm or micro-watershed scale and is relative in nature. Tools for identifying critical source areas at each level of identification differ; hydrologic modeling, such as SWAT, could be used for strategic identification while remote sensing and indexing would be more appropriate for tactical identification. The type of information obtained also differs between the two levels. Strategic identification could yield information to support pollutant targets and the assessment of BMP scenarios. Tactical assessment could yield information to support site-specific diagnoses and custom BMP designs.

IRDA has applied SWAT to the Pike River Watershed, a 600 square-kilometer basin. SWAT was used to characterize the landscape and reproduce the transport of water. It was also used to quantify the amount of phosphorus runoff and to target and predict the effectiveness of BMP scenarios. Monitoring data from the watershed calibrated and validated the model. The results of the model show that there is a high spatial variability in the basin, with 10% of the agricultural areas contributing 50% of the total phosphorus export. BMP scenarios were tested to optimize phosphorus reductions and feasibility of implementation. While the model can determine what is feasible, it does not indicate where the BMPs should be placed at the field scale.

Remote sensing was used to determine the location of vegetation, wet areas, tile drains, and buffer strips. Multispectral imagery can also be used to develop a wetness index, which can help identify areas that are prone to runoff. Techniques that can determine microtopography, including GPS, LiDAR and Corelator 3-D, are also useful for identifying critical source areas. The Phosphorus Export Diagnostic Tool (p-edit), a quantitative phosphorus index for Quebec is currently under development and implementation using readily available information.

In conclusion, identifying critical source areas is only the beginning. Any approach to do so must generate results which can be used to convince extension workers and farmers of the benefits of changing their practices. Such an analysis must result in concerted actions.

SWAT Modeling of Critical Source Areas for Runoff Generation and Phosphorus Transport
Presented by Lula Ghebremichael, University of Vermont

The goal of the project currently underway at the University of Vermont is to identify sources of phosphorus and to explore different management strategies to reduce phosphorus loss. Two modeling approaches are being used for the Rock River Watershed: a farm-scale model (IFSM) and a watershed scale model (SWAT). The farm scale model is being used to identify farm phosphorus imbalances that have a potential to cause elevated soil phosphorus levels. The watershed model is being used to identify critical source areas of phosphorus loss.

The intersection between transport factors and phosphorus source factors create a critical source area. These factors are represented and simplified in the model to estimate or quantify phosphorus loss. For example, SWAT approaches runoff generation using the Hortonian flow (infiltration excess) theory, where the amount of water that does not infiltrate into the ground will be considered runoff. SWAT also takes flow from tile drainage into account and uses equations to represent the cycles of phosphorus.

The SWAT model is being applied to the Rock River Watershed, a small agriculturally dominated subwatershed in the Missisquoi Bay Basin. Stream flow and phosphorus concentration data from monitoring are available for calibration of the model. Preliminary results indicate that SWAT has the potential to identify different source areas for runoff and phosphorus loss. Once source areas are characterized, different management practices will be tested to determine what can be done to reduce phosphorus loss. Data are still being gathered to support the farm-scale model for the watershed.

Case Study: Identification of Runoff Contributing Areas in the Little Otter Creek Watershed Using a Topographic Index
Presented by Don Meals

A critical source area is a land area where a significant phosphorus source and a transport mechanism exist at the same place and at the same time. Phosphorus does not move from the land unless these two factors coincide. This project focused on identifying where transport mechanisms were present in the Little Otter Creek Watershed in Addison County. These areas were termed runoff contributing areas (RCAs). The project was part of a larger effort to target critical source areas for watershed phosphorus management.

The analysis of RCAs was based on the principle that runoff is generated by saturation excess for overland flow. As soil becomes saturated, additional precipitation or emerging interflows generate runoff. The variable source area principle was adopted for this study, where runoff contributing areas vary by storm magnitude and are dynamic overtime. To identify the RCAs a set of design storms and assumptions were developed. Each pixel in a digital elevation model was assigned a probability of contributing runoff based on specific criteria; however, runoff was not routed from pixel to pixel. The results indicated that almost half of the watershed rarely contributed surface runoff and a third of the watershed contributed runoff every three years.

Assessing Nutrient Runoff in the Little Chazy River, northeastern New York: A Synoptic Water Sampling Strategy in Nested Subwatersheds
Presented by David Franzi, SUNY Plattsburgh

The Chazy River is located in Clinton County, NY. The basin is 145 square kilometers and the main channel runs through the towns of Chazy and West Chazy, New York. The project includes studying geomorphology, hydrology and water quality. Preliminary geologic maps of the Little Chazy River watershed have been developed. There are two physiographic regions in the watershed: the St. Lawrence Hills and the Champlain Lowlands. Agriculture is unevenly distributed throughout the watershed.

There are several impoundments in the Little Chazy River. A gaging network determines water flow and synoptic sampling is done over several hours each time samples are taken. Samples are analyzed for nitrogen and phosphorus. Data indicates that stream flow is spatially heterogeneous and seasonally variable. In addition, the spatial variability of nutrient concentrations and loads generally follow the agricultural land use patterns in the watershed.

Nutrient Management Planning in the Missisquoi Bay Basin
Presented by Jeff Carter, University of Vermont Extension

This project was funded through the LCBP, with International Joint Commission funds. The project consists of preparing Nutrient Management Plans (NMPs) that meet the NRCS 590 standard for thirty small farm operations in the Missisquoi Bay Basin. The project encompasses 400 fields and approximately 4,500 acres. The data being gathered as part of this project will help farmers make better management decisions.

Temporal Trends of Risk of Water Contamination by Phosphorus in Agricultural Watersheds of Canada and the Great Lakes Basin: P-balance, P-source and P-transport factors from 1981 to 2006
Presented by Eric van Bochove, Agriculture and Agri-Food Canada

The objective of the National Agri-environmental Health Analysis and Reporting Program (NAHARP) is to develop and provide science-based agri-environmental information to improve decision-making. A technical report, with 25 indicators, will be available soon. Factors including climate, vegetation and soils were considered for 279 agricultural watersheds across Canada.

The Indicator of Risk of Water Contamination by Phosphorus (IROWC-P) was developed for agricultural lands and examines phosphorus source, transport and connectivity to water bodies. The indicator also includes tiles drainage flow and excessive flow factors. Data to support the IROWC-P is available through the Ag Census every five years. The project also examined phosphorus balance and phosphorus enrichment.

Phosphorus source is defined as the phosphorus desorbed from agricultural soils by storm events. Four models were developed for Canada as a function of soil test phosphorus and dominant soil surface texture. The transport hydrology component used meteorological data, crop parameters and soil characteristics. Rainfall and snowmelt runoff are also factored into the model equations. Connectivity to water bodies is also included using a topographic index, a tile drain index and a surface-drainage density index.

Results of the project indicate that the risk of phosphorus water contamination increased in half of the watersheds examined from 1981 to 2006. In addition, regulations, BMPs, and NMPs in Quebec and Ontario led to significant reductions of phosphorus balance since 1996.

V. Thank You and Adjourn

Workshop Summary
Day 2

I. Welcome and Introductions
Bill Howland, manager of the Lake Champlain Basin Program (LCBP), welcomed attendees to the second day of the workshop and provided an overview of the day's agenda.

II. Overview of the Missisquoi Bay Basin Project
Mike Winslow, Lake Champlain Committee, provided an overview of the Missisquoi Bay Basin Project and the previous workshop to determine a definition for a critical source area (CSA). A CSA is the intersection of a transport pathway and a phosphorus source; this project aims to identify these places on the landscape. A useful scale for this identification depends on the user – field-scale data would be helpful for best management practice (BMP) implementation but watershed-scale data might help focus strategic management decisions. An approach to CSA identification will need to function without farm-specific data and consider temporal variations. It must also consider ground and surface water transport and inputs from the urban landscape as well as the agricultural. It may need to differentiate between the various forms of phosphorus and consider the impact of downstream transport and storage. As models are presented in this workshop, we need to focus on which will best address all of these questions and can work within our data constraints.

III. Key Note Address: *Use of Models to Identify Critical Source Areas*
Dr. David Dilks, Vice President of Limnotech, Inc.
Dr. Dilks defined a model as a mathematical description of real world processes that converts inputs about environmental conditions and human activities into outputs about the environmental response, based on what we know or are willing to assume. Its objective is to determine the magnitude and location of nonpoint source loads and how the load might change in the future. Environmental models can be classified as empirical or mechanistic. Empirical models are based on observed data correlated from other similar sites. They are simple to use but have limited accuracy. Mechanistic models are based on mathematically replicating physical processes. They are more complex and potentially more accurate than empirical models.

In order to identify CSAs with a model, one must determine what needs to be modeled and the available model frameworks (models can account for source and/or transport). Models that link sources of P and its potential availability are Unit Area Load, the Simple Method, and the Universal Soil Loss Equation. Transport Models consider that delivery ratios (pollutant delivered: pollutant eroded) vary significantly from site to site. Delivery ratios can be estimated from direct measurements, empirically from watershed characteristics, or from process modeling. Hybrid empirical/mechanistic models that account for both source and transport are SPARROW and "inventory with scoring." Similar mechanistic models include SWAT, HSPF, and GWLF.

When selecting a model, one must consider site-specific characteristics (natural processes, sources, space and time scales, land uses), management objectives (project vision, pollutants of interest, desired precision and scale, critical threshold targets), and project constraints (available data, resources for new data, budget, schedule, modeler experience, computing capacity). One should choose the simplest model that can address management concerns while considering that the accuracy of the model will be constrained by the input data. More complexity does not necessarily mean more reliability. Reliability can decrease rapidly if complexity is not supported by data or understanding.

After the presentation, Dr. Dilks responded to questions about his example models and principles of modeling. Management needs should be clear to consultants responding to an RFP, so that they can propose an appropriate model. Clearly defined but differing management objectives (strategic vs. tactical) can be handled by a model. There will be uncertainty in the modeling, but it can be improved with the right inputs. However, management decisions can still be made despite uncertainty with the model. Interpreting the outputs of a model to inform action is a policy task. In one watershed, stakeholders were able to choose an optimum scenario based on 19 options rather than having a practice prescribed to them. A phased approach to modeling, that is refined over time based on better data or financial inputs, can be valuable. With this approach, coarse-level decisions can be made with preliminary results and more refined decisions can follow.

IV. Presentations on CSA Identification Approaches

HSPF and BASINS

Rick Baker, Numeric Environmental Services

HSPF is a deterministic model with a public domain source code that is well documented and supported by the EPA. For pervious land, the model can define hydrological response units (HRUs, defined by land uses and soil types) and connectivity to determine effective imperviousness. The model can use detailed meteorological input data, simulate surface and subsurface hydrologic processes, and simulate soil erosion processes (using the Agricultural Runoff Management Model). It can also simulate nutrient transport processes; simple methods involve nutrient transportation within water or soils and complex methods consider how nutrients transform within their chemical cycles. HSPF also simulates nutrients and their transport in rivers and lakes. In general, HSPF is not as data dependent as some other models.

BASINS, or Better Assessment Science Integrating Point and Nonpoint Sources, is an integrated GIS that supports watershed based analysis and TMDL development. It includes national datasets with the option to import local data, tools incorporating analysis techniques for watershed assessment, and models for predictive studies. BASINS, and its integrated HSPF model, are complex and use limited data, so that they can provide various levels of output information.

Mr. Baker then addressed questions about this model and program, as pertinent to this project. Soils may but do not need to be separated into different levels when considering water percolation or subsurface chemical processes. We may have difficulty accurately calibrating this model for the Basin because of inadequate data points. HSPF can take into account the diversity of stream types and systems, such as access to floodplains.

SWAT Model

Mike Winchell, Stone Environmental

SWAT was developed by the USDA. It is a widely used and well supported model and is continually updated (a new version will be released this year). The model simulates surface and in-stream process interactions and both urban and agricultural management practices. It works on a watershed scale with a daily time-step, and can simulate water, sediment, nutrient, and pesticide transport. One feature of SWAT is that it is driven by varying plant cover because of its affects on soil moisture and surface flow. Required data include topography, land use, soils, weather data, management, channel characteristics, calibration data, and initial soil P conditions.

A SWAT simulation might include subbasin delineation, HRU delineation, weather data definition, running a default model, refining the default inputs to calibrate the model, rerunning the model and beginning to simulate alternative management practices. Challenges include data collection prior to modeling as well as calibration and validation of the model (especially for flow and nutrient concentrations). SWAT can also be integrated with APEX which allows more detailed modeling for smaller areas, such as fields.

Mr. Winchell then clarified that a P load is generated by the model at the HRU level and then transported by a "virtual stream" to the reach. SWAT does not transport P between HRUs. He noted that SWAT uses a modified USLE as an event basis in its process and an intensity distribution for storm events. Cross-border data can be incorporated easily.

SPARROW
Keith Robinson, United States Geological Survey

The SPARROW model (Spatially Referenced Regression on Watershed Attributes) is a statistical approach that relates water quality data to upstream watershed characteristics in a GIS and then uses this relationship to predict water quality in unmonitored waters. The water quality load is the dependent variable and nutrient source data becomes the independent variables (point source, fertilizer use, land use, etc.). The model is empirical with mechanistic features (land and stream transport) and its regression approach uses only variables that are statistically significant. It incorporates climate, geology, soils, hydrology, and slope to simulate transport. Model predictions are in terms of mean annual loads of nutrients and are spatially referenced. Because the model is based on the hydrologic network and predicts loads in stream reaches, it is best calibrated with nested monitoring load measurements. It has generally been used regionally to determine critical watersheds and inform management actions.

The New England SPARROW model generates a total nutrient load for each watershed, estimates the proportion of the load from different sources (agricultural and urban land use, point sources, atmospheric deposition), and locates the sources within the watershed. The model can determine an in-stream nutrient loss rate. In the Basin, it would be possible to refine the existing SPARROW models with more detailed information and use it to predict loads and concentrations. Seasons and related flow conditions could be modeled, depending on available data, but storm events or flooding would be difficult.

An advantage of SPARROW is that it can extend water quality data across a spatial domain. It can help illuminate which local processes affect water quality. The model can also be objectively calibrated using observed data. Unfortunately, the model can only be run for one water quality indicator and the process can be data intensive, especially when defining the dependent variable.

AVGWLF
Becky Weidman, NEIWPCC

AVGWLF (Arc View Generalized Watershed Loading Function) was used to create a watershed scale, calibrated model for New England and New York State with EPA funds. It models the overland flow of nonpoint source pollutants and includes hydrology, landcover, soils, topography, weather, and pollutant discharges. It is possible to use a subset of the existing regional model and then recalibrate with more detailed data. AVGWLF currently comes as a prepackaged model with data and it that requires ArcView 3. The data can be updated and the model will soon be available for public domain software, and called Mapshed. The model was calibrated and verified using water quality and flow data from 22 watersheds. PRediCT is a tool associated with AVGWLF that allows the user to see the effect of different management scenarios in terms of cost-effectiveness.

Some benefits of AVGWLF are that it is data rich and user friendly, included data can be replaced with more detailed or current data, datasets are not confined to political boundaries, the model can be recalibrated, and it can be linked to an in-stream model. However, it can only model nitrogen, phosphorus, sediment, and flow. It may also need to be recalibrated for a specific area.

LiDAR and High Resolution Mapping
Keith Pelletier, UVM Spatial Analysis Lab

The Spatial Analysis Lab plans to use new high resolution imagery and LiDAR to complete an automated feature extraction, which could help with CSA modeling in part of the Basin. Both the current land cover data and digital elevation models for this region are too coarse to do local analyses. The 2008 NAIP 1-meter, 4-band imagery for the state, LiDAR data (which provides both surface elevation and feature height data), and parcel and road vector data will be combined with a set of decision-making rules to generate detailed land cover information. The Lab plans to begin this project in the summer of 2009 and complete it by early fall.

Mr. Pelletier then responded to questions. It might be possible to distinguish between hay and pasture land, depending on the data and the inclusion of additional information. The accuracy of this extraction generally ranges between 95 and 97 percent. The analysis requires a high level of computing power, which the lab is equipped to handle. The Lab will also create a digital surface model of bare ground for the area of the LiDAR data. The Lab does not currently plan to make corrections to the existing water data based on the LiDAR, but it would be possible.

Spatial Analysis
Bill Hegman, Middlebury College

Spatial analysis tools and functions can aide in CSA identification without requiring separate models. Data can be stored in either vector or raster layers; the conversion between these is subject to consideration because of resolution errors. Usually, raster models are used for watersheds because of the continuous nature of data across the landscape. A GIS can apply local functions, in which calculations are independently performed on each cell of a grid; zonal functions, in which a value is determined for a grouping of cells (such as within an administrative boundary); global functions, in which the value of a cell is a combination of cell values from multiple input grids; or neighborhood functions, in which a cell value is a function of the input cells within its specified neighborhood. A majority filter can be used to smooth the boundaries of nominal or ordinal zones and reduce errors.

A GIS program can be used to calculate stream order, runoff accumulation, or flow direction. The resolution of input data will affect the detail of outputs, such as location and shape of stream channels. A program can also be used to run simple mathematical models such as the USLE or do queries and summaries of both vector and raster data. For this project, one could apply P loading coefficients to particular land uses within a GIS using a raster calculator and then estimate P outputs from subbasins using zonal functions.

V. Facilitated Discussion with Panel of Presenters

Beth Card, NEIWPCC, facilitated a discussion about approaches to identifying CSAs with David Dilks, Rick Baker, Mike Winchell, Keith Robinson, Becky Weidman, Keith Pelletier, and Bill Hegman. The following topics were discussed:

What is the role of the new monitoring sites in modeling?
Data collected now will not be immediately useful, because it must meet quality assurance standards. Deciding who maintains the model and reruns it with incoming data is an important management objective.

The model can estimate the load to the Bay, but can it consider the water quality in the Bay?
HSPF efforts have focused on total P, which is not enough information to determine the effect of the P in the Bay. Modeling will need to be three-dimensional to include P in sediments. Theoretically, we would need information about all forms of P and N for a year to determine how the system works and how P partitions itself. HSPF takes a strong kinetic approach, but it would not be able to determine the quality of the receiving waters.

How can the models account for stream bank erosion?
In some cases, nutrient contributions from eroded sediment outweigh dissolved nutrient contributions. SWAT has been shown to take erosion and sediment into account. It would help to gather background soil P levels, so that stochastic modeling could address certainty and variability. Accurate soil information is difficult, especially in stream banks, because each layer has a different P level. Also, floodplains may contain higher levels of P but are not accounted for by RUSLE because they have a slope of zero.

How do the models handle various land use types?
SWAT focuses on agricultural lands, but it can be used for urban lands as well. However, SWAT will not be able to model urban storm water runoff with a great amount of temporal variability. HSPF has been used more in urban areas that in agricultural ones. It might be a good idea to use a broad model to get a general understanding and then focus on more specific areas with different, appropriate models.

Many models estimate annual loads; what time periods are useful?
There are seasonal variations among nutrients that would not be captured by annual models. The Bay would require seasonal and monthly time steps. More sophisticated models can incorporate multiple limiting nutrients, if necessary. Both SWAT and HSPF are comparably sensitive to storm events, which have a significant impact on pollutant loads.

How does scale affect the different models or approaches?
IRDA has done scale variable work, using models for larger areas and then aerial photography for a more detailed assessment. It might be possible to use one model to consider all scales, but it would be very complex and data intensive.

How does the data intensity of models compare?
SPARROW and SWAT are very data intensive. Flow and consistent independent variable data sets are very important for SPARROW. Detailed information about land use, soil properties, and management practices are necessary for SWAT. AVGWLF used SPARROW data and monitoring results with other data to get a view of watershed issues.

The agricultural and urban hydrologic networks are very different and not well documented (tiling and sewer networks). The SPARROW model would apply different loading coefficients to urban and agricultural lands that would take the effect of these networks into account. HSPF simulates combined sewer overflows (CSOs) in a separate model from the land use model because of they are event-influenced. SWAT can address the fact that more water passes through tiles than over the surface; in the absence of mapped tiles, assumptions can be made about how flow is affected (e.g. row crops are more likely to be tiled). Multispectral imagery may show where tile drainage is located (as done in Canada).

Is there any way to get farm data?
Information can be obtained by county from the Agricultural Census. It might be possible to aggregate this on the subwatershed level. Every field that spreads manure has soil P test data; farmers might be willing to share these if they would not individually be identified. In Canada, a neutral organization collected data from individual farmers and aggregated it in groups no smaller than five farms, thus avoiding confidentiality issues. In Quebec, if the model results go directly back to farmers through extension workers, then farmers are willing to share In the Basin, we may need to make individual agreements in order to assuage people's fears. We need to think about why there were no farmers, crop consultants, or representatives from the Farmers Watershed Alliance at the workshop.

How necessary are models to accomplish project objectives? How will they be accepted by the public?
A model can go beyond what is already known by practitioners, for example, the New England SPARROW model found that there were larger than anticipated N contributions by atmospheric sources. Data generated by models are a good starting point for management decisions, especially when local stakeholders are able to collaborate on model inputs. If everyone participates in and agrees to the process, then the results will have more strength as a basis for action. Political will and broad-based support can build confidence in the model results and prevent finger-pointing. This process should include determining realistic P reduction targets for adaptive management. Also, direct observations should match predicted improvements within a specified time range, otherwise the model has failed and management practices will lose support. It will also be politically important to address both urban and agricultural contributions. Another possibility would be to use multiple models to validate each other.

What is the value of focusing on relative ranking of sources rather than their actual contributions?
A basin-wide ranking of large and small sources of P, as well as a ranking of management responses for these sources, might be feasible. If the initial assumptions are sound, this could be a very effective approach. However, the time-scale of the ranking must be considered – the largest contributor annually may only be active at certain times of year or during certain weather events. The feedbacks between these sources and transport require that a ranking consider physical processes.

It's all about the end product!
We need to remember to pick the model that can best guide management, rather the one that can best simulate a complex watershed. If our goal is to identify CSAs to target phosphorus reduction in the lake, then we need to find a model that will help us manage the lake. For example, if we are concerned about blue green algae, we need to reduce dissolved phosphorus; if tile drainage reduces total P to the lake but not dissolved P, then it is not an effective practice for our goals.

VI. Closing Remarks and Adjourn

Bill Howland thanked everyone for attending and providing input. The accomplishments of this project will be constrained by data but also informed by the knowledge gained from this workshop.

Workshop Attendees

Name	Organization
Caroline Alves	VT Natural Resource Conservation Service
Richard Baker	Numeric Environmental Services
Bill Bartlett	private consultant
Isabelle Beaudin	Institut de Recherche et Développement Agroenvironnement
Tom Berry	The Nature Conservancy
Willem Brakel	International Joint Commission
Dave Braun	Stone Environmental, Inc.
Beth Card	New England Interstate Water Pollution Control Commission
Helen Carr	University of Vermont
Jeff Carter	University of Vermont
Jessica Clark	Milone and MacBroom, Inc.
Brian Cote	Milone and MacBroom, Inc.
Jeff Deacon	United States Geological Survey
David Dilks	LimnoTech, Inc.
Laura DiPietro	Vermont Agency of Agriculture Food & Markets
Scott Fitscher	NY Natural Resource Conservation Service
Evan Fitzgerald	Fitzgerald Environmental
Sally Flis	Bourdeau Brothers
Russ Ford	University of Vermont
Dave Franzi	SUNY Plattsburgh
Nikos Fytilis	UVM-Civil and Environmental Engineering
Ben Gabos	Vermont Agency of Agriculture Food & Markets
Lula Ghebremichael	University of Vermont
Bill Hegman	Middlebury College
Brian Jerose	Waste Not Resource Solutions
Matt Kittredge	Vermont Agency of Agriculture Food & Markets
Stephen Kramer	Miner Institute
Daniel LeBlanc	Ministère du Développement Durable, de l'Environnement et des Parcs
Suzanne Levine	University of Vermont
Paul Madden	Friends of Missisquoi Bay
Bree Mathon	UVM-Civil and Environmental Engineering
Tom McAuley	IJC Ottawa
Don Meals	private consultant
Martin Mimeault	Ministère du Développement Durable, de l'Environnement et des Parcs
Megan Moir	Vermont Agency of Natural Resources
Julie Moore	Vermont Agency of Natural Resources

Leslie Morrissey	University of Vermont
Lin Neifert	United States Geological Survey
Abigail Pajak	Vermont Agency of Agriculture, Food & Markets
Bob Paquin	Senator Leahy's Office
Andrea Pearce	University of Vermont
Keith Pelletier	University of Vermont Spatial Analysis Lab
Staci Pomeroy	Vermont Department of Environmental Conservation
Kip Potter	VT Natural Resource Conservation Service
Rich Redman	NY Natural Resource Conservation Service
Donna Rizzo	UVM-Civil and Environmental Engineering
Keith Robinson	United States Geological Survey
Roy Schiff	Milone and MacBroom, Inc.
Jamie Shanley	United States Geological Survey
Andrew Sharpley	University of Arkansas, Fayetteville
Reed Sims	VT Natural Resource Conservation Service
Eric Smeltzer	Vermont Agency of Natural Resources
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