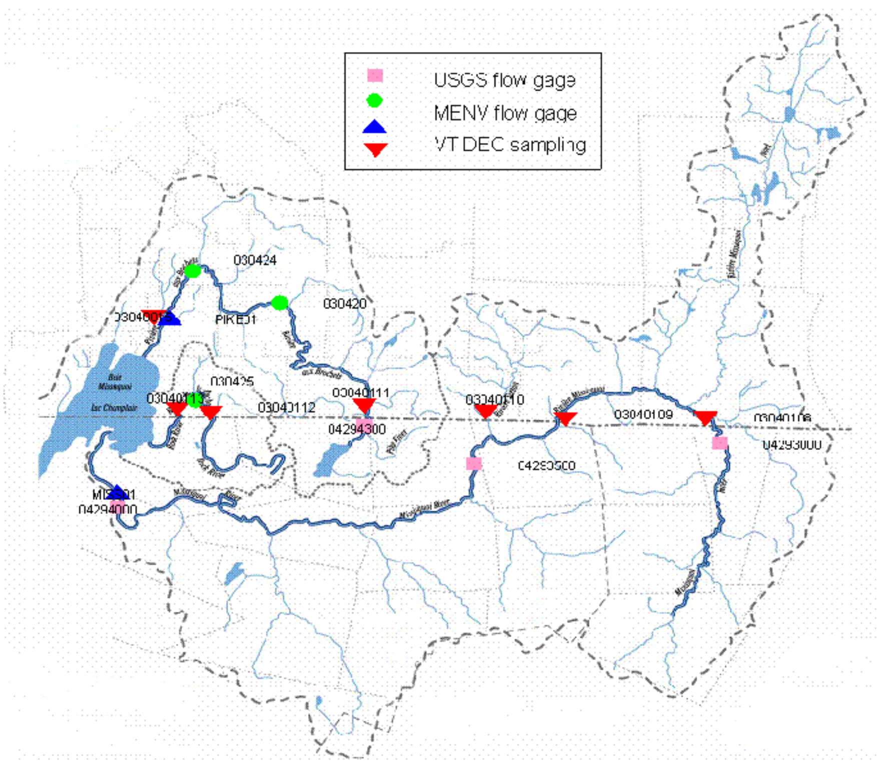
LAKE CHAMPLAIN RESEARCH CONSORTIUM



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ATMOSPHERICS

By
Tom Manley, Pat Manley, Rosa Galvez-Cloutier, Erik Smeltzer, Ning Gao and Greg Hanson

I)Present Knowledge

a. Wind speed and direction can be fairly well documented above the elevation of 2000 ft. through the use of radar.
b. Below 2000 ft., there are only limited resources available.
c. There are nearby meteorological stations within approximately 10 km of the bay's shoreline. Most of these are located in the near vicinity of towns where wind observations can be disrupted by local buildings or forests.
d. There are no meteorological stations situated on or near the water surface that permit direct boundary layer information.
e. Stream flow gauging is extremely good in both the US and Canada surrounding this region.
f. Stream-flow forecasting is also quite good for the region.
g. There has been episodic Hg monitoring in only a few of the rivers in the Lake Champlain basin and is primarily driven by high flow events.

II)Questions

a. What are the long-term characteristics of the atmospheric boundary layer?
b. What variability can be observed in the atmospheric boundary layer?
c. What is the average insulation and precipitation over the lake?
d. What is the effect of atmospheric deposition of toxic substances (e.g., Hg) or other particulates into the bay?
e. Would Point Jameson (Canada) be the best site for a complete atmospheric monitoring station?
f. What are the proper avenues by which we can assure that the stream gauging stations in the bay region will be maintained at their current level in order to provide needed information.

III)Linkages

a. Toxics
b. Nutrients and Lower Food web
c. Fishes
d. Wildlife
e. Biodiversity
f. Social
g. Hydrodynamics
h. Data Management
i. Public Health

IV)Time Estimate

a. 6 years (4 years observations, 1 year analysis, 1 year publications & meetings)
b. Meteorological site continuous for 6 years

V)Cost Estimate ($1.8 Million)

Item	**Duration**	**Cost Estimation**
Meteorological station	6 yrs operation	$50,000
Mercury wet deposition monitoring station	3 yrs duration	$500,000
Source-receptor modeling	4 yrs	$120,000

VI)Projected Programs

a. Source-receptor modeling using Multilinear Engine (ME) with meteorological
b. Parameters to investigate the sources for the reactive gaseous mercury (RGM) in
c. Lake Champlain Basin based on the monitoring data generated by Eric Miller. Cost of the project: $30,000 (for one-year project conducted by one PI, one co-PI, and two research students).

SEDIMENTS

By

Tom Manley, Pat Manley, Rosa Galvez-Cloutier, Mark Malchoff

I)Present Knowledge

a. There have been approximately 10 near surface (~2 m) cores taken within the bay. These cores have only been analyzed for physical parameters (e.g., grain size, deposition rates, and composition).
b. Deposition rates from these cores have shown a 9-fold increase since the 1990's.
c. No biological or chemical information has been extracted from these cores.

II)Questions

a. What can longer-term records of sediment tell us about water quality, sediment deposition rates, biological indicators, paleolimnology, and loading from the watershed, transport of contaminants, their retention, and potential release into the waters of the bay?
b. What are the concentrations of mercury or other new-age toxic components within the bay and watershed?
c. Are their preferential sites of sediment re-suspension and deposition?
d. What are the effects of subsurface hydrology on the bay (i.e., ground water influx)?
e. What is the spatial variation of sediment in the region and has it changed over time?
f. What is required to obtain the best possible bottom bathymetry for the bay?
g. What are the hydrodynamic requirements for sediment re-suspension?
h. What are the implications for satellite imagery and/or aerial photography in determining the movement of sediment within the bay?
i. What are the phosphorus flux rates from the sediments to the water column relative to the overall phosphorus mass balance for the bay, and how would these rates change if external phosphorus loading were reduced?

III)Linkages

a. These linkages are primarily driven by deposition phosphorous and toxics into the lake (Hydrodynamics → Re-suspension → Phosphorous into Water → Algal Blooms → Cyanobacteria → Human Health → Social)
b. Toxics
c. Nutrients and Lower Food web
d. Fishes
e. Wildlife
f. Biodiversity
g. Social
h. Hydrodynamics
i. Data Management

j. Public Health
k. Atmospherics
l. 3 years

IV)Cost Estimate ($428,000)

Item	**Duration**	**Cost**
Side-scan sonar survey & processing	2 years	$25,000
Chrip sonar and survey & processing	2 years	$60,000
Sediment re-suspension dynamics	2 years	$75,000
Physical properties and coring	3 years	$10,000
Sediments and pore- water sampling	2-3 years	$85,000
Sediments and pore- water phys-chem.	2-3 years	$30,000
Sediments and pore- water X-ray & SEM	2-3 years	$10,000
Sediments and pore-water contaminants	2-3 years	$35,000
Sediments and pore- water paleo	2-3 years	$30,000
Sediments and pore-water student stipends	2 years	$60,000
Containment retention – release at 3 sites	2 years	$18,000
Containment retention- release study run	2 years	$ 30,000
Containment retention- release column study	2 years	$5,000
Containment retention-release student stipends	2 years	$60,000

V)Proposed Projects

a. Quality diagnostic study on sediments and pore water:
b. Core sediment sampling with the first year having a minimum 20 sites homogenously distributed in the bay. The second year would only concentrate on previously identified hot spots. Cores would be a minimum length of 1 m.
c. Tasks
d. Physical-chemical profile (grain size, %w, LL, PL, etc.)
e. Run mineralogical analysis (by X-Ray)
f. Contaminant profiles for P, heavy metals (Pb, Cu, Zn, Fe)
g. Paleo-limnology study on one core (dating included)

h. Contaminant retention-release study.
i. Retention studies run in batch reactors, metal distribution: fractions associated to various mineral phases (exchangeables, carbonates, organics, oxides, residual), phosphorus distribution (mineral, extractable, soluble).

HYDRODYNAMICS

By
Tom Manley, Pat Manley, Erik Smeltzer, and Greg Hanson, Rosa Galvez-Cloutier, Malchoff, Mark

I) Present Knowledge

a. Prior to 1997, there were sparse observations.
b. This is a very shallow bay that does not develop, to any degree, significant thermal stratification for any length of time. Generally, the water body is nearly isothermal and almost entirely driven by wind forcing.
c. Bi-directional flow does occur at the Alburg and Missisquoi Bay bridges. At these sites, the primary forcing is wind driven. Observations at the Carry Bay passage indicated that both wind and internal seiche forcing are causes for the bi-directional flow (Binkerd 2004 Carry Bay study).
d. In 1997, ASA was hired to model the circulation in the bay in an effort to better describe the effect of the Missisquoi Bay bridge removal on phosphorous retention (i.e., related to algal blooms) in the bay. The result of the wind-forced 6-month model was that bridge removal could change the phosphorous concentration and sedimentation rate in the bay by ~ 1%.
e. During this modeling program, ASA collected approximately 1 month of high quality observations in the bay. These were 1) water speed and direction at the bridge site, 2) water level at several sites, 3) basic meteorological observations at the bridge, 4) water temperature at the bridge and several locations in the bay, and 5) surface drifters (which did not work very well).
f. The present hydrodynamic program operating in the basin will be located in the Inland Sea in the summer of 2005 (just south of Missisquoi Bay). Part of the program is to install a real-time down-linking flow meter at the Grand Isle Draw Bridge passage (in the GUT). This flow meter will monitor water level, near-surface temperature of the water as well as volume transport through the passage.
g. If additional funding is allocated, it is proposed that a new passage will be instrumented each year to begin the process of long-term observations of water flow into and out of the Restricted Arm. This program is designed to eventually provide observational data that future modeling can use to determine the potential domino effects that causeway removals would have on Missisquoi Bay, the Inland Sea, and Mallets Bay.

II) Questions

a. What is the net long-term circulation pattern of the bay?
b. What variations of circulation exist in the bay?
c. How does river inflow affect the local circulation?
d. What are the dominant forcing functions between wind and water?
e. What are the requirements of wind forcing to produce sediment re-suspension?

f. If other causeways are removed within the lake system (e.g., Carry Bay), what effect, if any will this have on the bi-directional flow into and out of Missisquoi Bay?
g. What are the volume transports through all of the passages within the Restricted Arm? The need for a complete Passage Exchange Network (PEN) is required.
h. What is the best way to integrate hydrodynamic modeling with that of chemical, biological, sediment transport, and other constituent transport models in an effort to create an integrated-system model of the region?
i. What are the implications for satellite imagery and/or aerial photography in providing more synoptic circulation dynamics within the bay?
j. Is hydrodynamic circulation controlling, to a large extent, the formation of toxic algal blooms via sediment re-suspension, turbulent mixing, and eventual transport of cyanobacteria to "preferential" shorelines?

III)Linkages

a. These linkages are primarily driven by the basic need to gather as much continuous high-resolution data in the bay in order to calibrate a numerical model for wind-driven circulation in the bay. This model will eventually provide answers to management driven question.
b. Atmospherics
c. Land Use
d. Sediments
e. Nutrients and Base of the Food Web
f. Data Management

IV)Time Estimate

a. 6 years (4 years observations, 1 year analysis, 1 year publications & meetings)
b. PEN monitoring sites continuous for 6 years

V)Cost Estimate ($1.8 Million)

a. modeling - $600k
b. PEN monitoring sites (all) - $350k
c. new equipment - $400k
d. hydrodynamic field observations – $500k

LCRC LAND USE ISSUES WITH LINKS TO CULTURAL, SOCIAL AND OTHER RELATED TOPICS

By

Aubert Michaud, Jurij Homziak, Chantal D'Auteui
Andre Lavoie, William Howland, Alexey Voinov

I) Present Knowledge

a.) In Canada

i. 3rd research cycle in Canada - Pike watershed
ii. Most work focused on P mobility in agriculture in 3 different scales:
iii. Plots (rainfall simulation);
iv. Fields (subsurface and surface monitoring);
v. 3 experimental watersheds, 6-10 km2 in size;
vi. The whole watershed (spatial water sampling + hydrologic modeling).
vii. User-friendly GIS tools for farmers based on micro-topography, aerial images and terrain data;
viii. SWAT modeling for all Pike
ix. Detailed, spatially referenced farm census data for overall Missisquoi Bay tributaries watersheds.
x. New research project relating historic land use and Bay sediments:
xi. relate land use shifts and sediment quality/quantity in the Bay;
xii. landsat from 1972 every ~4 years;
xiii. classification focus on bare soils, tilled land;
xiv. monitoring terrestrial Cs-137 for soil loss validation;
xv. Relate land use shifts, sediment export and Bay sediments cores.
xvi. Detailed GIS infrastructures for geophysics/land use on significant part of Missisquoi Bay tributary watersheds;:
xvii. Spatio-temporal variability in P fluxes (monitored) loads from agricultural lands;
xviii. Methodology to derive precision conservation tools for soil and water management on farmland.

b) In USA

i) So far no land use / land cover related research or modeling has been performed in the Missisquoi. Bay.
ii) A considerable effort for spatial landscape modeling is underway for St.Albans Bay.
iii) The developed Landscape Modeling Framework is readily available or applications in the Missisquoi Bay
iv) Better land use data will be available from LCBP and ACE in 2005

c) Unknown and/or Less-known:

i.Efficiency of BMP’s in reducing P fluxes

II) Question

The following questions are defined from the needs regarding strategic planning and BMP’s implementation that meets Lake restoration plan and VT/QC P Target loads:1) Develop an overall integrated perspective on Bay tributary watersheds (scaling up existing models 2) Derive environmental efficiencies of land use/BMP's scenarios develop predicting capabilities of existing models 3) Provide farming communities with soil & water management tools.

a.) How can human impacts on fresh water systems be quantified?

i. Research how ecological impacts are conditioned by the spatial pattern of land use and the timing of land use change.
ii. Simulate impacts under probable future land use scenarios (e.g above full buildout under allowable zoning) Research the change in impacts when converting agricultural lands to urban uses
iii. Research the difference in the impacts for different types of agriculture (e.g. row crop, hay, pasture) and for different agricultural BMPs
iv. Research the factors that mediate these relationships, such as riparian buffers, slope, soils and geology.

b.) How has land use changed over time?

i. Need data on land use history for the Basin
ii. Develop a protocol for defining what is considered land use change
iii. Scan and orthorectify more old air photos
iv. Archive and make accessible
v. Digitize land use from those photos
vi. Conduct more automated classification of satellite imagery to get time series of land use change of the last three decades
vii. Collaborate with NRCS, UVM SAL, UVM map library and UVM VT landscape change project to inventory data and make available.
viii. Analyzing land use change over time at a regional scale:
ix. On what type of land has change occurred?
x. How is this changing?
xi. What does this say about where future land use change might occur?
xii. How does this change correlate with historical water monitoring data?

c.) How will use growth change in the future?

i. Conduct spatially explicit urban growth simulation to determine where future growth is likely to occur, using dynamic economic modeling based on historical land use change data and empirically derived statistical relationships.
ii. Analyze hypothetical scenarios to determine how predicted future land use will change under different policies.
iii. Construction of new highways or utility infrastructure
iv. Imposition of growth boundaries or urban service boundaries
v. Changes to zoning
vi. Significant increase in gas tax
vii. Changes to Act 250 (e.g. criteria, triggering mechanisms)
viii. Changes to Current Use Taxation
ix. Changes to Regional Planning Commission powers

x. Based on the land use-water quality relationships discussed above, quantify predicted land use patterns and their impacts on water quality under the specified urban simulation scenarios

xi. Create dynamic geographic outputs and interfaces that allow stakeholders to visualize and comment upon the outcomes and the scenarios

d.) How can the ecosystem services of fresh water systems be quantified?

i. Better non-market valuation of the water-related ecosystem services provided by different natural land covers, including:
   - a.) Disturbance prevention
   - b.) Freshwater regulation
   - c.) Freshwater supply
   - d.) Waste/nutrient assimilation
   - e.) Biodiversity protection
   - f.) Recreation
   - g.) Amenity values

ii. How do differences in the characteristics of those land covers affect estimated non-market value, based on characteristics like:
   - a.) Relative scarcity of the land cover (e.g. is marginal ES value of a given wetland lesser where wetlands are plentiful than where that wetland is the only one around?)
   - b.) Spatial arrangement and context of the land cover (e.g. might a wetland provide a different level of a given ES in a downstream urbanized area than at the top of a forested watershed)
   - c.) Structural characteristics within a given land cover class (e.g. young forest vs. old growth)

e.) What are the economic benefits and tradeoffs for this region?

i. Study the marginal human-oriented benefits from improvements to water quality and other aquatic ecological metrics in the Lake and in contributing rivers
   - a.) Savings for water filtration/ treatment systems
   - b.) Non-market recreation values
   - c.) Market-based tourism income
   - d.) Aesthetic and amenity values (analysis of the impacts of environmental quality on property values)
   - e.) These can be done with benefits transfer methodologies, but locally-based empirical assessment should be targeted
   - f.) Methods: avoided cost, replacement cost, hedonic analysis, contingent valuation, travel cost

ii. Study the costs of making marginal improvements
   - a.) Point sources: treatment plants, pollution control devices for industrial facilites, etc.
   - b.) Non-point sources: education programs for homeowners, feasibility of local homeowner pollution ordinances, design based solutions for storm water (e.g. constructed wetlands), laws to change composition of household products

iii. Look at sensitivity of cost-benefit ratios to changes in:

a.) Assumptions about the impacts of land use on ecosystem services
b.) Assumptions about population and population growth
c.) Interest rates
d.) Cost of energy (affects cost of water treatment)
e.) Consumer preferences

f.) How can an integrated model be developed for the region?

i. Build a scalable spatial watershed model to provide a common language, and link watershed and water body processes
ii. Develop visualization tools to use integrated interactive modeling as a communication tool
iii. Identify scenarios, management practices and policies that are most likely to be implemented in the watershed. Conduct - "what-if" type of analysis
iv. Account for BMPs, build links to watershed planning
v. Calibration, validation, uncertainty analysis
vi. Comparison between various modeling approaches (e.g. LHEM/SME vs. SWAT)
vii. Mostly salary costs (professional, post doc, grad students). Also programming and computer services. Approximately $200,000 per year + overhead. Priorities and timelines should be coordinated with the other groups.
viii. Assume several levels of complexity and resolution in time and space.
    a.) Export coefficient
    b.) Runoff curves
    c.) Local dynamics (farms, fields, lots, residential units, etc.) *versus*
    d.) Dynamic spatial models with horizontal linkage
ix. Optimization
    a.) Apply optimization methods, including spatial optimization, to identify BMPs, optimal spatial allocation of restoration efforts
    b.) Develop objective functions and conditions
    c.) Design "optimal" land use patterns and link them to policies that can be designed to draw development towards these patterns
ix. Scaling
    a.) Integrate models of various scales
    b.) Associate different scales with different goals and priorities in the project
    c.) Learn to translate findings in one scale to another

g.) What are the best methods to incorporate stakeholders in the planning and decision making procedures?

i. How to bring different participants to collaborate? "Why should I be here?" If we want participation, we need to find a benefit for the participant. Example: Remote sensing to identify no-drainage zones
ii. Develop visualization tools, including interactive web pages, and web-based models
iii. How to scale up the social and cultural issues
iv. What is the level of buy-in

v. How stakeholder participation is used for developing BMPs and implementing them
vi. Incentives driven by stakeholders
vii. What is the value to the stakeholders
viii. Cultural and social aspects. What brings the group together and makes it functional On-farm and off-farm benefits
ix. Useful data for farming communities
x. Models for strategic needs
xi. Farmers themselves developing incentives
xii. How can data be made useful?
xiii. Employ modeling as a "process" in a participatory format to enhance understanding of system dynamics and engage stakeholders in the decision-making process

III) Linkages

a. Linkages with "Sediments", "Hydrodynamics" groups are needed to research the effects of urban development and agricultural practices on:
b. Phosphorous, nitrogen and sediment loadings
c. Aquatic in stream ecological indicators (e.g. macro invertebrates and fish)
d. Stream geomorphology
e. Water clarity and turbidity
f. Riparian zones
g. Another obvious connection is with the data management group. We will be assembling extensive spatial and temporal data sets that should be available to other groups and have to conform with some common standards.
h. The Social group can be an important linkage for the participatory studies, where we are bringing in the stakeholders to enhance our models and data.

IV) Time Estimate

a. Time frame: 4 to 5 years knowing all data we have to gather to produce reliable land use/land cover maps and to produce a consistent database (GIS). Maps could be produced with satellite images but would still require ground truth validation data on agriculture, forest, etc. At least 25% of the territory would have to be visited for ground truth confirmation.
b. In addition to land use/land cover, we would require meteorological, topographic, hydrological and agricultural data combined with extended water sampling and analysis in the rivers and the Bay to confirm and validate the models. Satellite images could also be used to try to observe sediment distribution patterns in the Bay.

V) Cost Estimate

a. Remote sensing and mapping: salary (professional, technicians, students), satellite images (Landsat, Ikonos, QuickBird) and image processing, field trip costs and lab. Analysis (water, sediments) etc. Roughly, $150,000 US per year + overhead.

VII) GIS land use data development and analysis (to be adjusted when priorities and scales are set)

a. Develop accurate and current GIS land use maps at 1:20,000 and up to 1:5000 scale for particular areas with high categorical precision; could be built through annual digitizing or automated remote sensing classification; focus such mapping on those classes that are most likely to contribute to non-point source pollutants; devote considerable resources to accuracy assessment of this layer; also develop protocol for updating.
b. Need updates to E911 housing GIS point data, with more attributes about the structures, including number of units, year built, etc.; also develop protocol for updating
c. Need better data on point source polluters, including accurate level of output
d. Complete GIS parcels and develop protocol for maintaining and updating
e. Use high resolution imagery to attribute parcels with information about the amount of tree, grass and impervious cover at that level; this can help identify areas where urban greening would contribute significantly to non-point source reductions in runoff pollutants.
f. Use high resolution imagery to map out tree and grass cover in public rights of way (e.g. street vegetation), in public lands and in riparian areas along agricultural fields.
g. Need GIS layer showing geomorphic classes of segments of major streams
h. Statistically analyze the relationship between socio-economic factors and parcel level management of vegetation, including application of lawn and garden products and types of plantings.
i. Research the difference in the above impacts for different housing market segments: settlement patterns and variations in land management among different social groups.
j. Use existing layers to create maps prioritizing land parcels for conservation based on their contribution to terrestrial and aquatic ecosystem services.
k. Use high resolution LIDAR altimetry data to improve the delineation of urban and suburban watersheds.
l. Create an environmentally meaningful map of urban sprawl showing environmental efficiency of human occupation based on per capita impacts (derived from land use-water quality relationships).
m. Use this map to help planners target areas for growth—that is find areas where impacts are already high relative to the number of people served and hence additional population will marginally contribute less to impacts than elsewhere.
n. Create an ArcSDE geodatabase to house and distribute basin wide GIS layers, allowing for users at multiple institutions to contribute and edit data.

VII) General Comments and further issues to be addressed

a. There is probably some history to it, but currently the program looks very much biased toward the Bay per se, with the watershed studies playing a much downplayed role. Even in the group arrangement, we have only one functional group related to the watershed. I would strongly recommend that this should be somewhat amended, since clearly Bay dynamics are very much determined by what is going on in the watershed.

   i. Basically three needs (regarding strategic planning and BMP's implementation that meets Lake restoration plan and VT/QC P Target loads).
   ii. Develop an overall/integrated perspective on Bay tributary watersheds
   iii. (scaling up existing models);Derive environmental efficiencies of land use/BMP's scenarios(develop predicting capabilities of existing models); Provide farming communities with soil & water management tools
   iv. Quantifying human impacts on fresh water systems
   v. Research how ecological impacts are conditioned by the spatial pattern of land use and the timing of land use change
   vi. Simulate impacts under probable future land use scenarios (e.g. full build out under allowable zoning)
   vii. Research the change in the above impacts when converting agricultural lands to urban uses
   viii. Research the difference in the impacts for different types of agriculture (e.g. row crop, hay, pasture) and for different agricultural BMPs
   ix. Research the factors that mediate these relationships, such as riparian buffers, slope,

Middle Food Web & Exotics – Fishes – Wildlife & Biodiversity

By
Douglas Facey, Rose Paul. Mark Malchoff, Tim Micoc, Pierre Bilodeau, Craig Martin. Mary Watzin

I) Present knowledge

a. Some information about relative abundance/distribution of common species of fish, wildlife, plants in the Bay, tributaries, and wetlands, including the Refuge. There appears to be better information in Quebec than in Vermont.
b. Missisquoi River is a spawning area for migratory species of fishes, including game species and endangered species
c. Presence of some rare species in Missisquoi River, Bay, nearby wetlands – including spiny soft-shell turtle, map turtle, chorus frog, Indiana bat, black terns, mudpuppy, eastern sand darters, brook lamprey, sturgeon, red horses, muskellunge (maybe)
d. Bay/refuge/riparian areas are used by migratory waterfowl, and migratory neotropical birds
e. Drainage into the Bay is heavily impacted by shoreline development and various inputs through tributaries.

II) Questions

a. What is the trophic structure of the Bay ecosystem, including tributaries and wetlands? Which invertebrates/plankton are fishes eating? Does this change seasonally? Does this affect plankton community and perhaps cyanobacterial blooms?
b. Have alewives appeared in Missisquoi Bay? If so, are they reproducing, what are they eating, how might they impact other species?
c. What is the impact of the invasive white perch, which apparently have become very abundant, on the food web? Are they affecting zooplankton community – and might this impact the phytoplankton? Are white perch out-competing native fish species? … Are they preying on eggs (perhaps of walleye)?
d. What is the status and impact of several invasive/nuisance species in the ecosystem? This would include - Eurasian water milfoil, frog bit, purple loosestrife, yellow iris, flowering rush, water chestnut, alewife, white perch, white crappie, sea lamprey, rusty crayfish, cormorants (impact on heron rookery).
e. What is the impact of barriers, dams, causeway to movement of fishes between lake basins, or up into tributaries?
f. What is the role of wetland complexes (including impacts of shifts in emergent vegetation), flood plain, and vernal pools to local species, some of which are rare/protected?
g. What will be the impact of re-routing Highway 78 through the refuge?
h. What are the impacts of shoreline development on wildlife - including effects of wildlife predation on nesting of rare turtles and birds?

i. Are cormorants expanding into the refuge – if so, what is their impact on other species, such as great blue herons?

III) Linkages

a. Nutrient & Lower Food web – for a complete assessment of the ecosystem's food web, including the microbial component
b. Toxics – What are levels of toxins in fishes, including some of the "new generation" toxins? Are toxins in edible portions of fish likely to be eaten by people? Are toxins/pollutants impacting health/reproduction of fish & wildlife? What is impact of cyan toxins on fish & wildlife?
c. Ecosystem Health – Cyanobacteria blooms in recent years indicate and "unhealthy" ecosystem. Is this related to food web/fish/wildlife issues? Would Missisquoi Bay be a good "testing ground" for an initial effort at developing ecosystem health indicators that might eventually be used elsewhere in the Basin?
d. Land Use – impacts of land use on water quality, human use and health, rare/protected species, food web dynamics, abundance/distribution of invertebrates/fish/wildlife/exotics.

IV) Time Estimate

a. About 5 years for most of the work proposed. A few project a bit more time; one particular project would definitely need longer.

V) Cost Estimate

a. $2,721,160 mostly over 5+ years …. Estimates for time and costs follow….
b. One-year cost for a grad student at $22,000 stipend, plus $5000 for research costs, plus 56% indirect costs (approx. university rate)… for a total of $42,120.
c. One-year cost for a post-doc or full-time technician (with experience) at $35,000, plus $6500 for research costs, plus 56% indirect costs…. for a total of $64,740.
d. Summer salary for college/university faculty estimated at $6000 per month, plus $1000 for supplies, plus 56% indirect… for a total of $10,920 for a month of summer commitment
e. For smaller projects, such as for seasonal independent contracts, or supplemental $$ for agencies to hire seasonal or part-time folks I'm estimating about $6000 per year in salary + $2000 for expenses = $8,000 for each "small project".
f. I've kept everything within about a 5-year time frame – probably unrealistic, but a starting point.
g. Food Web dynamics – comprehensive look at the food web, including role of exotics (such as white perch, white crappie); impact of toxins on reproduction (fish and birds), animal health, potential impact on humans; need info on benthic macro invertebrates; linkage of benthic and pelagic food webs

h. Just to look at food web – fish/macro invertebrate/zooplankton diversity and abundance, and fish gut analyses - a post-doc or technician, 2 months of summer faculty time, 2 master's students, and two seasonal hires each year for 5 years = $934,100
i. For impacts of toxins – a post-doc, 2 months of summer faculty, plus a couple of seasonal hires each year for 3 years = $307,740
j. Habitat component
k. Habitat connectivity – impact of barriers, dams, causeway to movement of fishes between lake basins – a Master's student, 2 months of summer faculty, plus part-time/seasonal help for 3 years = $215,880
l. Role of wetland complexes (including impacts of shifts in emergent vegetation), flood plain, vernal pools - tie in with larger study of vegetation (below), plus two "small projects" a year for 3 years = $48,000
m. Impact of re-routed Highway 78 through refuge – would require studies before and after construction. Perhaps a Master's student, 2 months of summer faculty, plus part-time/seasonal help for 2 years = $143,920 for the "before". Then repeat after construction completed – another $143,920 in the future some time (or more for inflation).
n. Land use changes – impacts of shoreline development, including effects of wildlife predation on nesting rare turtles and birds – two "small projects" a year for 3 years = $48,000
o. Trends in Distribution and Abundance
p. Arrival/spread/impact of invasive/nuisance species – including Eurasian water milfoil, frog bit, purple loosestrife, yellow iris, flowering rush, rusty crayfish, alewife, white perch, sea lamprey, cormorants (interaction with great blue heron roosting area)
q. Two year study of aquatic/wetland vegetation, including exotics such as Eurasian water milfoil, frog bit, purple loosestrife, yellow iris, flowering rush, water chestnut. Perhaps a 2-year Master's project with 2 months of faculty for each of 2 summers = $127,920; plus some smaller independent contract work to follow up in the future – an additional $16,000 a year for 3 years after initial study.
r. Sea lamprey work probably already ongoing – no additional $$?
s. Tie work on alewife, white perch, white crappie in to food web work that would already be going on – no additional $$?
t. Study of cormorant interactions with great blue herons – possible 2-year Master's project with 2 months of faculty for each of 2 summers = $127,920
u. Studies of rare/endangered species in bay, tributaries, wetlands, and surrounding terrestrial ecosystem – to include studies of spiny soft-shell turtle recruitment, map turtle, chorus frog, Indiana bat, black terns, mudpuppy, eastern sand darters, brook lamprey, sturgeon, red horses, muskellunge, use of bay/refuge by migratory waterfowl, and use of riparian areas by migratory neotropical birds

v. Perhaps 3 Master's projects – each for 2 years and each including 2 months of summer faculty time… $127,920 per project for a total of $383,760.
w. An additional 8 individual "small projects" at $8000 each = $64,000 per year for 3 years…. for a total of $192,000
x. TOTAL: $2,721,160 mostly over 5 years (one "habitat" project would have to be longer.

Toxics

By

Neil Kanman, Sylvie Blais, Oliver Thomas, Angela Shambaugh, Gregory Druschel

I) Present Knowledge

a. Cyanotoxins – high concentrations. Two good programs are in place that that cover counts, toxins, chemistry, bloom timing/geographic extent
b. Mercury – limited data on sport fish web. While potentially up-to-date, these data may not be from species that are reprehensive of Hg bioavailability in Missisquoi Bay.
c. Atrazine – limited data exists. There are no data relating to other current use pesticides, or to metabolites thereof.
d. Sediment toxics. The last assessment occurred during the early 1990's.
e. Data are available on coli form bacterial mobility in subsurface drains (Note not absolutely certain on this).
f. Data are available on Cryptosporidium and Giardia in subsurface drains (need to verify this too)
g. There is no good correlation between chlorophyll a and cyanobacteria, and LCM station 50, where much of the cha data exists, is not representative of the Bay.
h. We know nothing of new-generation toxins such as plasticizers, flame-retardants, and endocrine-disrupting compounds associated with c.u.p. metabolites or personal care products discharged by WWTF's.

II) Questions

a. Effects of c.u. pesticides/herbicides on algal communities
b. Recent sediment cores acquired by U. Montreal indicate that sediment delivery rates have increased 10X in the last decade. This no doubt will have altered surficial sediment metals/toxics concentrations. If archive material is available from these U. Montreal cores, they should be analyzed for Hg and for SEM.
c. Relatedly, given that the ½ life of microcystin is ~6months, is it possible to use sediments as a record of integrated microcystin production over the course of a year?
d. What is the behavior of cyanobacteria in the winter, can these toxins get into the drinking water pumps?

III) Linkages

a. How do highly eutrophic conditions affect bioaccumulation of mercury?
b. Hypothesis: If we reduce P in Miss Bay, will hg levels in fish increase?
c. Are changes in the food web driving/stimulating cyanobacterial dominance?
d. How do aquatic plants affect nutrient cycling in the food web, and how does this impact cyanobacterial bloom dynamics?

e. Does microbiology play a role in mediating P release from sediments that affects cyanotoxins production?
f. Can remote sensing by satellite or probes effectively identify where/when blooms are occurring?
g. What are the trends in water quality chemistry in Miss Bay before and after the zebra mussel invasion? Is the lack of adult populations there related to a systematic decline in calcium or to toxicity by cyanotoxins, or by an interaction of the two?

IV) Time Estimate

a. Please provide your estimate
b. Neil Kamman: 1 yr planning (once funds in place)
c. year field program
d. 2 year analysis and reporting
e. Funding needed within interest area
f. This is a first guess by Neil K, in 2005 dollars
g. -Cyanotoxins: $250,000 to support continued monitoring and to continue existing projects at augmented scale.
h. -Mercury: $300,000 to support fish collections and analysis, and to establish trophic web interactions
i. -Atrazine and other CU Pesticides: $100,000 for preliminary screening and some tank testing
j. -Sed-tox assessment for metals: $25,000 if core material is available, $65,000 if not (due to need to collect new cores and date them).
k. -New generation toxin screen in WWTF discharges and in relevant matrices in Missisquoi Bay: $100,000.

V) Cost Estimate: $815,000

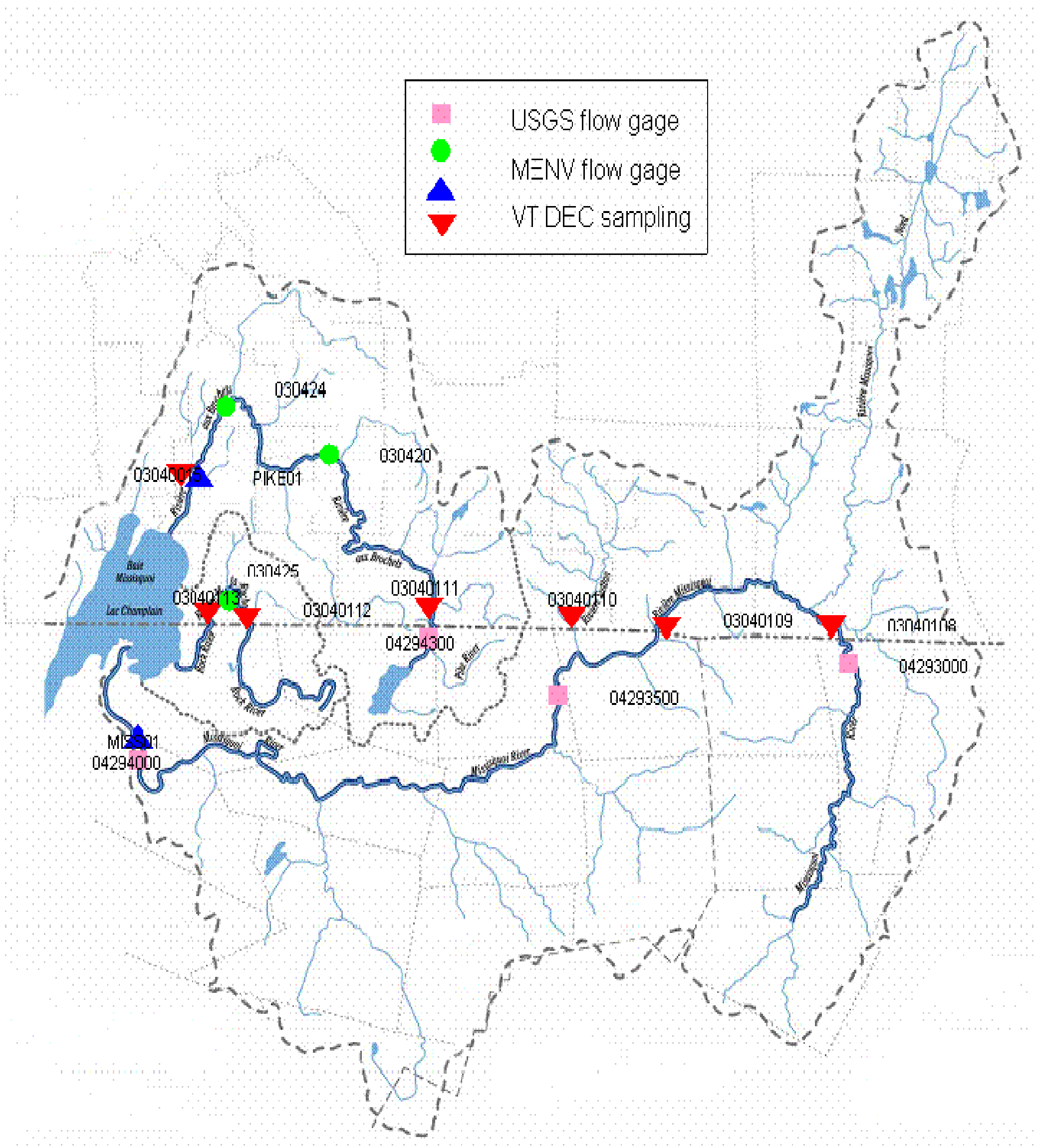

Figure 1 Stream flow gages and phosphorus sampling stations in the Missisquoi Bay watershed.

"Eric Smeltzer" <eric.smeltzer@anr.state.vt.us>

NUTRIENTS AND LOWER FOOD WEB

By Suzanne Levine and Angela Shambaugh

We've divided Nutrients and Lower Food Web below, as both are huge categories, and so important that they really shouldn't be lumped

NUTRIENTS

I) Present Knowledge

a. Gauging of major tributaries and analysis of nitrogen and phosphorus provides data on allochthonous inputs
b. Long-term monitoring has been done at one site (Station 50) since 1992
c. Some point source information is available (don't know if adequate)
d. Analysis of land use and subsequent runoff inputs is underway in Quebec
e. Cores for total P analysis were taken by Univ. Sherbrooke last summer, and presumably can be used to obtain rough estimates of nutrient fluxes from sediments
f. A MSc student at Univ. Quebec Montreal has started a project to measure N_2 fixation and denitrification in the Bay (don't know how involved it is)

II) Questions

a. Can we do mass balances for nitrogen and phosphorus in the bay? Is every input and output needed known? We believe more work is needed in examining the following:
    i. The atmospheric contribution of nutrients. In particular, the nitric acid in acid rain can be a major N source
    ii. Rates of nutrient diffusion from sediments, and controls on these fluxes
    iii. Nutrient inputs (or outputs through adsorption) during sediment resuspension
    iv. The role plants play in "pumping" nutrient from sediment and releasing it into the water
    v. N_2 fixation as a N input
b. How bioavailable is the phosphorus and nitrogen that enters the bay?
c. Have N and P levels in the bay always been as they are today? If not, what were background conditions, and when did they start to change?
d. Are the nutrient levels measured at Station 50 typical of the entire bay

III) Suggested Projects

a. Measure N and P in water collected in rain gauges (may be done in Quebec already; don't know)
b. Measure P and N flux into chambers placed in the bay, or in cores brought into the laboratory. Experiment to determine controls.
c. Do above study with and without macrophytes to assess the impact of plants on fluxes. Also will require estimate of total plant biomass.
d. Use a combination of remote sensing and turbidity probes on buoys to analysis sediment resuspension events and relate them to wind and

currents. Determine resuspended sediment nutrient content, and tendency to desorb nutrient.

e. Have DEC collect samples for nutrient analysis from several sites on a few occasions
f. Examine long-term trends in TP, TN by assessing the nutrient profiles in dated cores; also examine diatom indicators of TP & TN concentration at the time of deposition (the Sherbrooke group may be examine diatoms in the cores collected last summer and applying TP transfer functions)
g. Measure N_2 fixation in the bay over one or more seasons; produce a model that relates rates to light and heterocyst densities (more easily monitored in future than the process rate)

IV) Linkages (most obvious- linkages might be made to any category on the list (and more). After all, it is excess nutrient that causes the blooms that inspire us to focus on the bay)

a. Atmospheric
b. Sediments
c. Hydrodynamics
d. Toxics
e. Data management

V) Time frame

a. Three years for the studies of nutrient contributions from sediments, plants and N_2 fixation and two years for paleolimnology Allochthonous nutrient inputs should be followed for decades to come (with periodic reassessment of internal dynamics)

VI) Costs: $512,000 Total (excluding coring which is tallied under LOWER FOOD WEB)

a. $2000 for extra nutrient analyses involved in monitoring precipitation, doing studies of nutrient distributions
b. $270,000 for analyzing N and P flux from sediments (Druschel's estimate that he also includes under toxics)
c. $60,000 to examine plant impacts on nutrient flux
d. $100,000 for sediment resuspension studies, but this cost might be largely borne by the Sediment group
e. $80,000 for N_2 fixation studies
f. $120,000 for coring to analyze long-term trends in nutrients and algae, and relate to changing land use patterns. (This same figure is given under algae, and thus not included above)

LOWER FOOD WEB

I) Present Knowledge

a. Algal biomass and composition has been monitored at 6 locations since 2001; there are some earlier samples from station 50 (and elsewhere) to examine

b. Some remote sensing data have been collected to show spatial patterns of algae
c. There have been assessments of algal toxins, although their production is not predicatable
d. Macrophyte biomass and species composition has been assessed on the Quebec side (on one occasion, which isn't necessarily representative)
e. We know nothing at all about natural bacterial and protozoan communities

II) Questions

a. How long has the lake been plagued with algal blooms? What was the initial algal community before farming and other activities began? When did conditions deteriorate? Can changes in trophic state be related to changes in land use or point discharges?
b. How are blooms best tracked, with wind blowing algal scums, populations doubling quickly, and algal migrating vertically? (Obviously point sampling is of little value.) Would we know more about standing stocks and distribution with several in-situ chlorophyll probes in place? Should remote sensing be used routinely to track bloom development and movement?
c. What is the level of primary productivity in the bay?
d. ESPECIALLY IMPORTANT. What variables control algal productivity and biomass (and toxin production)? Not just phosphorus, but also nitrogen, light, carbon dioxide and food web interactions may favor cyanobacteria?
e. What is the biomass of macrophytes on the Vermont side of the lake? How much epiphyte biomass is present in the plant beds?
f. What densities of bacteria and protozoa are present in the water, and what roles do they play in food webs and in nutrient cycling?

III)Suggested Projects

a. Obtain at least one core (better two) from the bay, date and analyze for paleopigments, microfossils, and stable isotopes (which provide information about levels of productivity). Relate changes in algal biomass and composition to changing land use.
b. Install chlorophyll probes at two depths at 5 or more stations around the bay (on hydrodynamics buoys). Better (but probably too expensive would be Russ buoys that allow for regular analysis of vertical profiles). Obtain continuous records of biomass change. Buoys might also include CTD units, turbidity meters, dissolved oxygen meters, and probes that measure microcystin in situ (still in development).
c. Measure primary production at least biweekly in summer using the oxygen method, OR use dissolved oxygen probes on buoys to estimate productivity daily (preferred).
d. Use remote sensing to obtain images of the bay for analysis of bloom patterns and their relationship to current and wind dynamics; a satellite with frequent flyover such as Envisat (detecter MERIS) could provide nearly daily images- these are coarse, but good for estimating overall

biomass. A collection of these images could help relate bloom intensities to measured environmental variables.

e. Studies of controls on algal growth rate and species competition to understand conditions leading to cyanobacterial dominance, bloom, and microcystin production. We recommend beginning with laboratory studies of differences in life history, requirements and physiology of the most important algal competitors, followed by competition experiments (in the laboratory). Experiments in in-situ mesocosms should follow, but will be much more expensive and will require special engineering to deal with the wavy environment of the bay. We suggest putting these off until hypotheses are formed through the laboratory studies. (Alternatively they could be done in a nearby small lake with blooms, e.g., Shelburne Pond.)
f. Seasonal study of bacterial and protozoan biomass and species composition in the water column, and in surface sediments.
g. Examination of the role of bacteria in nutrient cycling, especially their impact on P and N retention versus flux from sediments
h. Map macrophytes on the Vermont side of the bay, estimating their biomass and epiphyte burden. Should be done at the same time of the year as the previous Quebec study.

IV) Linkages (most obvious ones. As with nutrients, any of the other programs can be linked to this one, which includes the algae involved in noxious blooms)

a. Sediments
b. Hydrodynamics
c. Toxics
d. Biodiversity
e. Public Health
f. Middle food web
g. Fish
h. Wildlife
i. Date management

V) Time frame

a. One year for macrophyte survey, two for paleolimnology, algal studies in laboratory, high resolution remote sensing, microbial loop study. Duration of program (three years for now) for probe monitoring and Envisat (coarser) remote sensing. State monitoring of algal species composition must continue indefinitely.

VI) Costs: $825,000 (over 3 years)

a. $120,000 for paleolimnology. Two cores both algae and nutrients.
b. $180,000 for remote sensing (10 images with high resolution satellite)
c. $240,000 for three years of probe monitoring at 5 sites (chlorophyll, DO, temperature, turbidity)
d. $45,000 for a primary productivity study without in situ probes (not included in above estimate as we favor the in situ approach
e. $100,000 for laboratory studies of controls on algal growth and competition
f. $120,000 for analysis of the microbial loop (bacteria, protozoa)

g. $20,000 for weed survey

Data Management – Summary

By
Dave Brotzman

I) Introduction

a. The data management aspect is not research oriented but a matter of infrastructure development, programmatic control and capacity expansion. I included creation of a Missisquoi Bay central data node. My cost estimates are based upon locating this node at the Vermont Center for Geographic Information thereby enabling savings for software purchases, system engineering and training. If the data node is to be physically located somewhere else, those additional costs must be considered. There is room to downscope or up-scope depending upon projected needs and level of sophistication desired. Lower costs could be obtained if all that is needed is a common data distribution website. But, that will not deal with the standard data management problems of a large-scale, long-term project such as what is being proposed.

II) Creation of the LCRC Missisquoi Research Central Distribution 'Data Node'

a. With multi-user file management security, check-in/ check-out file access, versioning, archival capability, file owner access control and integration with other National research data nodes. Data management will be a fully networked, internet, enterprise environment. Access to the data will be controlled by the individual researcher until data release. Individual research projects will have overview identification information to provide public access to the project's abstract and contact information. The research and public communities will be able to go to go to the LCRC Missisquoi Research website to know what research has been, is being and needs to be conducted in atmospherics, toxics, land use, cultural, social science, hydrodynamics & sediment, nutrients and lower food webs, middle food webs and exotics, fisheries, wildlife and biodiversity, and ecosystem health. They will be able to get access to tabular and spatial data for any research that has been released by the researcher and published. They will know what research is currently being conducted in the basin, who is the researcher, what questions they are asking and data they are collecting, where and how it is being conducted. The LCRC Missisquoi Research Team will consider networking into appropriate national efforts for data sharing efforts such as the National Biological Information Infrastructure (NBII) and Center for International Earth Science Information Network (CIESIN)

III) Development of data control, format, and access standards

a. For project data including the development and incorporation of a metadata creation tool to ensure consistent and standards based data descriptions and more effective interaction with researchers and data users. This will include the creation of data development and access standards that include accommodation for International (French/English) data team and user needs. This effort will make available to the researchers data formatting capacities and opportunities for data handling that broaden the usefulness of data. Researchers will have access to common data management tools and metadata creation tools as part of the Data

Node. Access to data conversion tools will be provided and data standards will be recommended to support common standards for shared data. A common set of data format, coordinate system and geodesy will be determined for all geographic data collection activities. Minimum essential metadata requirements and recommended protocols will be developed through discussion with the research team.

IV) Lifetime maintenance

a. Project of data management mechanisms to address the need for accession and retention of data by those involved in research and monitoring in the Lake Champlain Basin. Data for the Missisquoi Research Team will be maintained regularly and in accordance with team approved GIS professional protocols. The emphasis for the data management program will be on overall effectiveness and ease of use by the researchers who desire access to data. Data security and privacy will be maintained throughout the sensitive period prior to research publication. The data management capacity will be partially integrated with the Center for Geographic Information to ensure continuity and long term effectiveness. Periodic informational workshops and effective web-based resources for the research and monitoring community will be made available as part of the data maintenance support.

V) Cost

a. Here is what Year one .50 FTE cost for a senior project manager/software and database developer to create the data node automation and storage paradigm for a total of $75,000.

b. Year one .15 FTE cost for a senior project manager/standards developer to resolve data control, access, format, and metadata capacity development for a total of $22,000.

c. Year one through five .25 FTE cost for a staff project manager to provide continual project support to data maintenance, database upgrades, resolve data compatibility issues and maintain data connection with National data sharing nodes for a total of $25,000/ per project year.

List of attendees at the LCRC meeting

Alexey Voinov	alexey.voinov@uvm.edu
Andre Lavoie	Andre.Lavoie@USherbrooke.ca
Angela Shambaugh	angela.shambaugh@anr.state.vt.us
Aubert Michaud	aubert.michaud@irda.qc.ca
Chantal D'Auteuil	cdauteuil@videotron.ca
Craig Martin	craig_martin@fws.gov
Dave Brotzman	davidb@vcgi.org
Erik Smeltzer	eric.smeltzer@anr.state.vt.us
Greg Hanson;	gregory.hanson@noaa.gov
Gregory Druschel	gregory.druschel@uvm.edu
Jurij Homziak	jurij.homziak@uvm.edu
Mark Malchoff	mark.malchoff@plattsburgh.edu
Mary Watzin	mary.watzin@uvm.edu
Neil Kamman	neil.kamman@anr.state.vt.us
Oliver Thomas	olivier.thomas@usherbrooke.ca
Pat Manley;	manley@middlebury.edu
Pierre Bilodeau	pierre.bilodeau@fapaq.gouv.qc.ca
Rosa Galvez-Cloutier	rosa.cloutier@gci.ulaval.ca
Rose Paul	rpaul@tnc.org
Suzanne N. Levine	slevine@uvm.edu
Sylvie Blais	sylvie@blais@menv.gouv.qc.ca
Timothy Mihuc	timothy.mihuc@plattsburgh.edu
Tom Manley	tmanley@middlebury.edu
William Howland	whowland@lcbp.org

List of Contributors

Ning Gao	ngao@stlawu.edu