Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

Statement of Critical Regional or State Water Problem

New Hampshire's surface waters are a very valuable resource, contributing to the state's economic base through recreation (fishing, boating, and swimming), tourism and real estate values. Many rivers and lakes also serve as local water supplies. New Hampshire currently leads all New England states in the rate of development and redevelopment (2000 Census). The long-term impacts of population growth and the associated changes in land use to New Hampshire's surface waters are uncertain. Of particular concern are the impacts of non-point source pollution to the state's surface waters (e.g. septic systems, urban runoff, stormwater, road salt application, deforestation and wetland conversion). Long-term datasets that include year-to-year variability in precipitation, weather patterns and other factors will allow adequate documentation of the cumulative effects of land use change and quantification of the effectiveness of watershed management programs.

Statement of Results or Benefits

The proposed project will provide detailed, high-quality, long-term datasets which will allow for a better understanding of the impacts of land use change and development on surface water quality. This could occur through the development, testing and refinement of predictive models, accurately assessing the impacts of watershed management practices, and potentially early warning of dramatic changes to surface water quality in the region resulting from rapid development.

Objectives of the Project

This project allows for the continued collection of long-term water quality data in New Hampshire. It will use UNH staff, students and volunteers from local communities to collect samples from the College Brook watershed (Durham, NH), the Lamprey River Watershed, and the Ossipee River Watershed.

Water samples will be collected from the following sub-projects.

The **College Brook** watershed, which is dominated by the University of New Hampshire, receives a variety of non-point pollution from several different land uses. Nutrient concentrations (Cl^-, SO_4^{-2}, Na^+, K^+, Mg^{+2}, Ca^{+2}, NO_3, NH_4, PO_4, DOC, TDN, SiO_2), pH and conductivity will be measured to assess water quality. Samples from 3 sites will be collected monthly throughout the year. Sampling of College Brook began in 1991. Sample collection will be done by UNH staff and/or students. The Water Quality Analysis Lab at UNH will analyze 2/3 of these samples as part of the non-federal match.

The **Lamprey River** has been sampled weekly and during runoff events since October 1999. Samples are analyzed for total dissolved nitrogen (TDN), nitrate (NO_3-N), ammonium (NH_4-N), DON, DOC and orthophosphate (PO_4-P). Additionally, samples collected since October 2002 are also analyzed for dissolved inorganic carbon (DIC), pH, conductivity, dissolved oxygen (DO), temperature, total suspended sediment, particulate carbon, particulate nitrogen, silica and major anions and cations. In January of 2004, we began routine sampling of additional Lamprey sites for nitrogen, phosphorus and DOM. Since November of 2003, weekly bulk precipitation samples have been collected at numerous locations throughout the basin for analysis of nitrogen, phosphorus, DOM, major cations and anions and silica. Several homeowners have been monitoring precipitation volume throughout the basin since October 2003.

Precipitation and stream sampling was scaled back in FY05. Precipitation data from FY04 indicate that rain chemistry within the Lamprey watershed does not vary spatially, therefore we'll only sample from one collector on an event basis. Homeowners will continue to monitor precipitation gages throughout the watershed as precipitation amount is spatially variable. The frequency of stream sampling will be curtailed to monthly (instead of weekly) for 10 of our sampling sites. The remaining 3 streams will continue to be sampled weekly. These water samples will be analyzed by the Water Quality Analysis Lab at UNH.

Groundwater Chemistry and nutrient dynamics.

Monthly ground water well samples have been collected from the James Farm and L1 well fields in Lee, New Hampshire within the Lamprey River watershed. James Farm monthly samples were collected from January to September of 1995 and from July 2004 through December 2006. L1 monthly samples were collected from July 2004 through December 2006. Quarterly groundwater samples were collected in FY07 and FY08.

Ossipee Watershed

Volunteers of the Green Mountain Conservation Group will sample streams within the Ossipee watershed of New Hampshire. Samples will be collected every 2 weeks from May to November, and monthly during the winter months. Water chemistry (Cl^-, SO_4^{-2}, Na^+, K^+, Mg^{+2}, Ca^{+2}, NO_3, NH_4, PO_4, DOC, TDN) will be measured on selected samples by the WQAL. WRRC staff will assist in data interpretation.

Methods, Procedures and Facilities

Samples will be collected at intervals described above. Samples will be filtered in the field using pre-combusted glass fiber filters (0.7 uM pore size), and frozen until analysis. All samples will be analyzed in the Water Quality Analysis Lab of the WRRC on the campus of UNH, Durham, NH.

The Water Quality Analysis Laboratory (WQAL) was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH Water Resources Research Center and housed in the Spaulding Life Sciences building. Dr. William McDowell is the Laboratory Director, and Jeffrey Merriam is the Laboratory Manager. Together, they have over 40 years of experience in water quality analysis, and have numerous publications in the fields of water quality, biogeochemistry, and aquatic ecology.

Methods for analyses include ion chromatography (Cl^-, NO_3^-, SO_4^{-2} and Na^+, K^+, Mg^{+2}, Ca^{+2}), discrete colorimetric analysis (NH_4, PO_4, NO_3/NO_2), and High temperature Oxidation (DOC, TDN). All methods are widely accepted techniques for analysis of each analyte.

Principal Findings and Significance

College Brook

Previous work on College Brook in the early 1990's (McDowell unpublished) shows that the UNH campus had a severe impact on water quality and was negatively affecting stream biota and the integrity of downstream ecosystems. By any yardstick, campus operations could not be considered sustainable. There was clear evidence that the UNH incinerator was causing excessive organic matter loading, resulting in high biochemical oxygen demand (BOD) and low dissolved oxygen (DO) in stream water. Since the incinerator has been closed, BOD and DO are no longer at levels detrimental to in-stream biota. Our monthly sampling regime was scaled back beginning October 2006 to the 3 stations that have historically shown the greatest changes, and we eliminated the BOD and TSS measurements (both which change little over the reach since the incinerator was closed). The most downstream sampling location is now closer to where the stream empties into the Oyster River in an effort to better quantify inputs to the Great Bay estuary. We also added a 4^{th} site in May 2008 that was previously sampled at Pettee Brook. Analyses of samples collected through 2008 have been completed and we are in the process of updating our website
http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm.

Dissolved Oxygen (DO) in the brook is lower at the upstream stations. This difference is presumably due to hydrologic properties of the upstream sampling location which resembles a wetland (i.e. slow flow, higher organic matter and organic carbon). DO increases downstream as flow becomes faster and re-aeration higher.

Data from 2000-2008 indicates that the steam is strongly impacted by road salt at its origin, which is essentially a road-side ditch leading to a wetland area. Average Sodium and Chloride concentrations, as well as specific conductance, appear to have remained reasonably constant since 2001, but are much higher than in 1991. Concentrations are highest at the upstream stations and tend to decline downstream as the stream flows through the athletic fields and then increase as the stream passes through the heart of campus and downtown Durham.

Another export to Great Bay that is a cause of concern is nitrogen and especially nitrate. As College Brook becomes more aerated as it moves downstream ammonium decreases and nitrate increases indicating that nitrification is occurring in the stream channel, however the mass of each and an increase in total nitrogen indicates that there is additional sources of nitrate to the stream. This is possibly from fertilization of the athletic fields and/or storm water runoff. There also appears to be a slight, but insignificant, increase in nitrate over time. This will need to be closely monitored as algal blooms and loss of Eelgrass have become a concern in Great Bay.

Lamprey River Watershed

The Lamprey River watershed is a rural watershed located in southeastern NH and is under large development pressure as the greater area experiences the highest population growth in the state. The Lamprey River Hydrologic Observatory (LRHO) is a name given to the entire Lamprey River basin as it serves as a platform to study the hydrology and biogeochemistry of a suburban basin and is therefore used by the UNH community as a focal point for student and faculty research, teaching and outreach. Our goal for the long-term Lamprey water quality monitoring program is to document changes in water quality as the Lamprey watershed becomes increasingly more developed and to understand the controls on N transformations and losses. We have continued to sample the Lamprey River at the USGS gauging station in Durham, NH (referred to as "LR 73.3"), the North River at the former USGS gauging station in Epping, NH (NR 26.9) and a small tributary to the Lamprey River in Lee, NH (WHB 1.03) on a weekly basis and 13 other stations throughout the watershed on a monthly basis. Analyses of samples collected through 2008 have been completed and we have updated the LRHO website (http://www.wrrc.unh.edu/lrho/index.htm). The USGS discontinued the operation of the North River gauging station in October 2006 and since then we have been recording weekly stage height and calculating flow based on the USGS rating curve. We are able to record stream flow at WHB 1.03 using an electronic distance meter in combination with a rating curve that we have developed for this site. We have also developed a stream flow model for WHB 1.03 where daily discharge can be estimated from meteorological measurements (such as precipitation and temperature) and this model is useful for estimating historic flows. We continue to collect precipitation at Thompson Farm (UNH property located in Durham, NH) to document nitrogen inputs to the basin and this data is posted on the AIRMAP website (http://airmap.unh.edu/).

Results of stream chemistry to date show a significant increase in nitrate concentrations over time (FY00-FY08) in the Lamprey River (Figure 1) and no change in nitrate concentrations in the North River or Wednesday Hill Brook over a shorter time period (FY 2004-2008). We have shown previously that stream water nitrate is related to watershed population density (Daley 2002) and since suburbanization continues to occur throughout the greater Lamprey River watersheds, population growth is likely responsible for the increase in stream water nitrate. Wednesday Hill Brook watershed is near its development capacity, unless the Town of Lee, NH changes its zoning regulations, and the lack of increase in WHB nitrate may be due to the limited population growth in this watershed, that this watershed has reached nitrogen saturation or that the relatively short period of data collection is not reflective of long-term trends.

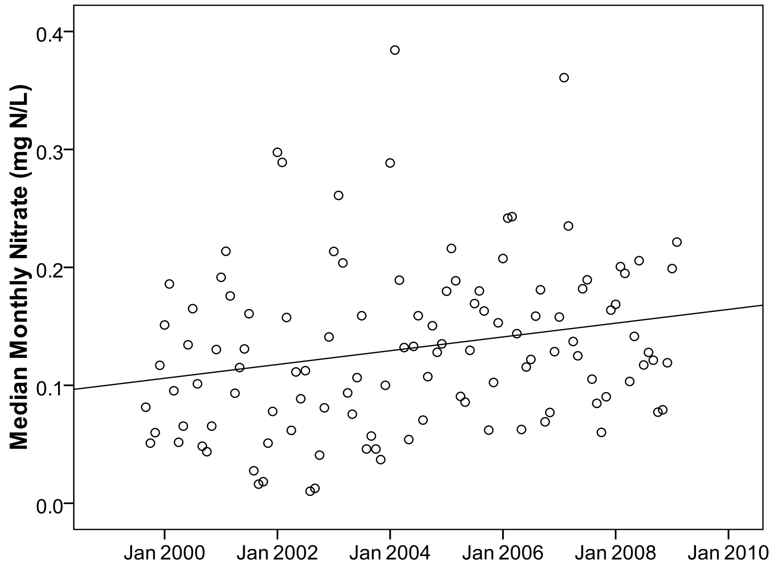

Figure 1. Median monthly nitrate concentrations over time in the Lamprey River at the USGS gauging station in Durham, NH.

When we combine our specific conductance data (FY02 – FY08) with data collected by the USGS (FY78 - FY99), we see a long-term increase in specific conductance in the Lamprey River (Figure 2). Sodium and chloride concentrations are directly related to specific conductance ($r^2 = 0.95$, $p<0.01$ for Na^+; $r^2 = 0.93$, $p < 0.01$ for Cl^-) and we conclude that this increase in specific conductance indicates a corresponding increase in NaCl. Sine Na^+ and Cl^- are strongly correlated with impervious surfaces in southeast NH (Figure 3) and road pavement among southeastern and central NH basins. We conclude that the associated road salt application to these surfaces is responsible for these spatial and temporal changes in streamwater NaCl.

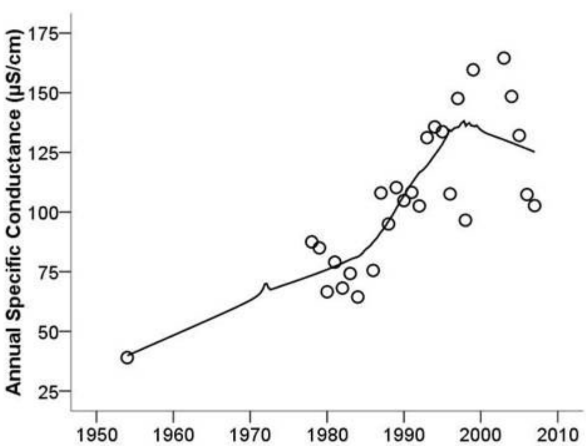

Figure 2. Mean annual specific conductance in the Lamprey River at the USGS gauging station in Durham, NH

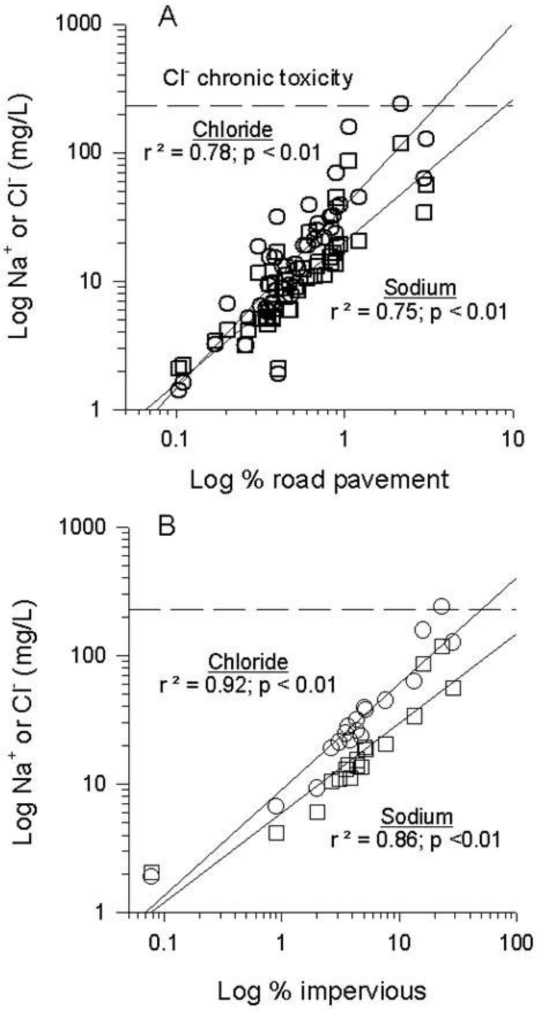

Figure 3. Relationship between both average concentrations of Na^+ (squares) and Cl^- (circles) and a.) % road pavement (College Brook, Lamprey and Ossipee sub-basins) and b.) % impervious surfaces (College Brook and Lamprey sub-basins only).

Results of precipitation monitoring show that wet deposition is the largest input of N to the Lamprey watershed and precipitation chemistry can be linked to airmass chemistry. DOC and TDN in precipitation are related to biogenic airmass sources, NH_4-N, NO_3-N and SO_4-S are related to urban/industrial airmasses and Na and Cl are weakly related to ocean aerosols.

Groundwater Chemistry and Nutrient Dynamics.

James Farm ground water nitrate concentrations have decreased throughout the past ten years. L1 ground water nitrate concentrations have remained constant or decreased slightly from FY04-FY08 with the exception of one well (L1A-21) where nitrate increased from <0.2 to 3.0 mg N/L. Decreased concentrations in recent years may reflect dilution by two 100 flood events in 2006 and 2007. James Farm and L1 ground water data demonstrates higher NO_3^- concentrations with low dissolved organic carbon

(DOC) concentrations as well as low NO_3^- concentrations with high DOC concentrations, which suggests possible denitrification influencing ground water NO_3^- concentrations.

Ossipee Watershed

Collaboration with the Green Mountain Conservation Group and their sampling of the Ossipee River watershed has continued to be beneficial. Volunteers sampled streams within the watershed every 2 weeks from April through October, and monthly winter sampling at 7 sites, with approximately 340 samples collected from 30 sampling locations. Many presentations were made to planning boards, conservation commissions and other local government groups (see Information Transfer section below). Data have been used to heighten awareness of the impacts of excessive road salting and snow dumping in local streams. The impact of road salting in this central NH watershed is similar to what we see in coastal NH (Figure 3a). Communication with local road agents has led to the remediation in one development where road salting was an issue. Samples collected and data generated from this funding have shown an improvement in water chemistry following reduced salting and snow dumping. Data has also been useful in promoting low impact development techniques and best management practices where new development has been proposed in proximity to rivers and streams within the watershed.

Publications:

Daley, M.L., J.D. Potter, W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: Impacts of road salt and hydrologic variability. *Journal of the North American Benthological Society*, *submitted*.

McDowell, W.H., M.L. Daley, B. Sive, R. Talbot. Factors controlling atmospheric deposition at a coastal suburban site. *Journal of Geophysical Research (Atmospheres), in prep*.

Conference Proceedings & Abstracts:

Daley, M.L. 2008. Highlights from the Northeast. NSF EPSCoR Water Dynamics Workshop, Burlington, VT. November 2008.

Frades, M. M. Davis, J. Bryce, and W. H. McDowell. 2008. A pilot study of watershed flow using stable water isotopes in support of the development of the Lamprey River Watershed (southeast New Hampshire) as a Hydrologic Observatory. EPSCOR National Conference on Water Resources, Burlington, VT, November, 2008.

McDowell, W.H. 2008. Chemical, Biological and Physical Disturbance of the Suncook River Avulsion. The New Hampshire Watershed Conference, Concord, NH. November 2008.

McDowell, W.H. and M.L. Daley. 2008. Suburbanization and water quality in SE New Hampshire – The Lamprey River Hydrologic Observatory. Second Symposium on Urbanization and Stream Ecology, Salt Lake City, Utah, May 23, 2008.

Salisbury, J., J. Campbell, B. Jonsson, A. Mahadevan, D. Vandemark, C. Hunt, and W.H. McDowell. 2008. Spatial and temporal variability of the colored organic matter fluorescence - salinity relationship in plume waters and its relevance to remote sensing of coastal salinity and DOC. Ocean Sciences Meeting, American Society of Limnology and Oceanography, Orlando, FL March 2008.

Gregory, T.K, J.R. Morrison, M.G. Novak and B. McDowell. 2008. Progress in observing estuarine and coastal ocean processes with the Great Bay Coastal Buoy. Ocean Sciences Meeting, American Society of Limnology and Oceanography, Orlando, FL March 2008.

Information Transfer:

Daley, M.L. 2008. Salinization of suburban streams and groundwater. Lamprey River Watershed Association Annual Meeting. Epping, NH. November 2008.

Daley, M.L. 2008. Salinization of suburban streams and groundwater. Ossipee Watershed Water Quality & Source Water Protection. Chocorua, NH. November 2008.
Daley, M.L. 2009. Salinization of Suburbanizing New Hampshire Streams and Groundwater. Second Annual Lamprey River Symposium. Durham, NH. January 2009.

Galvin, M. 2009. Proposed Research and Preliminary Findings on Nutrient Dynamics in a Lamprey River Floodplain. Second Annual Lamprey River Symposium. Durham, NH. January 2009.

McDowell, W.H. 2009. The Lamprey River Hydrologic Observatory. Second Annual Lamprey River Symposium. Durham, NH. January 2009.

Presentations made by the Green Mountain Conservation Group staff March 2008 - February 2009.

March 17: Auto Salvage Yard Forum
April 11: WQM Presentation & Volunteer Training
May 13: Effingham Conservation Commission, Planning Board, BOS WQM Presentation
May 19: Calumet Staff WQM Program Training
May 27: Calumet WQM Program
May 28: Calumet WQM Program
May 29: Calumet WQM Program
June 3: Calumet WQM Program
June 6: Camp Director WQM Presentation
June 12: Town Ordinance & Groundwater Protection Workshop
June 16: Radio Program on WQM & Source Water Protection

June 21: Landscaping at the Water's Edge: An Ecological Approach workshop
June 24: GPS/GIS Workshop mapping potential contamination sources
June 26: BMP Training Workshop
July 3, 4: VLAP & WQM with camps
July 16 & 17: VLAP & WQM with camps
July 30 & 31: VLAP & WQM with camps
July 29: BMP Training Workshop & Survey
August 2: Household Hazardous Waste Day Outreach & Hand Out Well Testing Kits
August 9: Province Lake Event/Dr. Newton Presentation
August 18: VBAP & WQM training program
August 21: Ossipee Conservation Commission WQM Presentation
November 15: GMCG/WQM presentation @ Concord DES Conference
November 20: Regional Presentation of PCS Inventory, WQM Data & Source Water Protection Report
December 4: Madison Conservation Commission WQM Presentation
January 14: Kiwanis WQM Presentation

Number of students supported:

Three Master's students (Emily, Kate and Michelle) and three undergraduate hourly employees.