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USGS WRRC Status Report 2004: Effects of Land Use on Water Quality in a Changing Landscape

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Jeff Schloss – USGS WRRC Status Report 2004
Problem and Research Objectives:

State: New Hampshire
Project Number: NH761
Title: Effects of Land Use on Water Quality in a Changing Landscape
Project Type: Research Project
Focus Category: Water Quality, Non Point Pollution, Nutrients
Keywords: lake, stream, water quality, nutrients, land use
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Congressional District: 1
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Objectives:

1- The continued collection and analysis of long-term water quality data in selected watersheds.
2- The dissemination of the results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.
3- To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
4- To further document the changing water quality in selected lake and river watersheds (Lake Winnipesaukee, the Squam Lakes, Ossippee Lake and the Saco River) in the face of land use changes and management efforts.
5- To continue to document the effectiveness of constructed BMPs in the Chocorua Lake Watershed and provide the final sproject summary results.
6- To determine the next steps for further analysis of long-term data sets.

Methodology

Lake and stream monitoring through the LLMP generally involved a minimum of monthly sampling from spring runoff through lake stratification, and weekly to bi-weekly sampling from stratification until fall overturn. Water clarity, chlorophyll a, acid neutralizing capacity, color, dissolved oxygen and nutrients (total N, total P and nitrate) was the default suite of parameters measured for lakes while nutrients, turbidity, color and flow were the parameters of choice for the lake tributary work. On occasion, student field teams traveled to join the volunteer monitors to perform quality assurance checks and do more in-depth analysis and lake profiling.
Land cover changes to study subwatersheds was documented on our established GIS data base and new management practices or conservation efforts were also documented. Particular emphasis was placed on the Squam Lakes Watershed this year.
This project was coordinated from the University of New Hampshire, which supplied the office and laboratory space (analytical and computer). The Center for Freshwater Biology Analytical Water Quality Laboratory has a Quality Assurance Project Plan for surface water analysis on file with the US Environmental Protection Agency Region 1 Office (EPA New England). Besides nutrient analysis (Total Phosphorus, Total Nitrogen, Nitrate), other water quality measurements included chlorophyll a, dissolved oxygen, dissolved Co2, acid neutralizing capacity, specific conductivity, pH, ORP, turbidity, water clarity, iron and E.coli. UNH Cooperative Extension and the Natural Resource Department provided vehicles for travel for PI's, students and interns at a cost (mileage) basis. A dedicated GIS PC NT workstation was provided for use including Arc/Info and ArcView Software, ArcView Extensions: Spatial Analyst, 3D Analyst, Image Analysis and ArcPress. This was used in addition to other data input PC stations, laser printers and a large format (36" wide) ink jet plotter that was made available for the project.

The project utilized an extensive GIS database for the study subwatersheds created through previous WRRC funding to the PI. Updated and additional GIS data including a new land cover dataset for 2000 was made available through the UNH Complex Systems Research Center which manages the NH GRANIT statewide GIS data depository. The extensive data directory contains statewide GIS data layers (usually at 1:24,000 scale) including hydrology, geology, soils, National Wetlands Inventory, land-use, land cover, and digital elevation models. Also available are Landsat Thematic Mapper, SPOT Panchromatic and digital orthophoto imagery.

Principal Findings and Significance

The final year of data analysis of the Lake Chocorua BMP Evaluation Study confirmed that a significant reduction in the phosphous loading was due to the road drainage mitigation techniques. In 2003 we documented from 2003 data that the combination of the use of plunge pools, diversions to settling areas and a large collecting infiltration swale reduced loadings during storm events by 82-94%. The P concentration range from the runoff was also reduced significantly (pre-range of 34 to 281ppb post range of 13 to 23 ppb). Additional monitoring was done in 2003 under a previous USGS WWRC grant to capture spring runoff and additional storm events. Those results were summarized in June of 2004. Some highlights:

- The total phosphorus concentrations documented in the Route 16 drainage culverts prior to BMP implementation (1997, range 25 to 245 parts per billion) were significantly higher than the post BMP total phosphorus concentrations (2003, 2 to 38 parts per billion).
- The spring total phosphorus loading was reduced in Culvert B (a treatment culvert), which constituted our primary comparison site due to the most complete set of water quality data. Even with the marked increase in spring 2003 precipitation, compared to 1997, the spring 2003 total phosphorus loading values were significantly lower than the 1997 data and maintained an average 92% reduction . In addition, the 2003 spring total phosphorus loadings represented a 60% reduction, even when compared to the initial post-BMP installation total phosphorus loading values measured in 2000.
- The greatest total phosphorus (226 ug/L), turbidity and TSS measurements were documented at the control site, MH-1 Rt16 (no BMPs), during the 2003 study period and reached levels considered more typical of an impaired system.
- Total suspended solids were low at the treatment culverts in 2003 and remained near or below detectible limits.
- Turbidity was generally low and generally measured less than 1 NTU during the spring and summer sampling period.
- The natural detention basin located in the McGregor Hill Culvert was highly effective at attenuating nutrients during the intense, September 23, 2003 storm event. The water quality data suggest BMPs should be implemented at this site to assure maximum nutrient attenuation in the future.
- Total phosphorus and total nitrogen were higher late in the season and reflected natural increases in organic matter and nutrient loading (total phosphorus and total nitrogen) during periods of high discharge.
- Significant amounts of organic debris (leaves and twigs) collected in the Route 16 drainage culverts in the spring and fall and thus a regimented culvert cleaning schedule should be implemented to maximize the efficiency of the implemented BMPs.
- A comparison among the total phosphorus data collected prior to BMP implementation (1997), during the early stages of BMP implementation (2000) and following completion of the BMPs (2003) indicates a significant reduction in the range of the annual total phosphorus concentrations collectively reported for the treatment culverts: Culverts A, B, C and the swale. The total phosphorus concentrations ranged from 25 to 245 parts per billion (ppb) prior to BMP implementation (1997), ranged from 2 to 26 ppb during the early stages of BMP implementation (2000), and ranged from 2 to 38 ppb following full BMP implementation (2003). The decrease in the phosphorus range is largely associated with a corresponding reduction in the suspended sediment load into Chocorua Lake. While total suspended solids

were not quantified prior to 2003, historical records indicate significant amounts of sediments were documented in the total phosphorus samples during the 1997 sampling season and corresponded to the high total phosphorus concentrations.

- Annual total phosphorus loading values were compared among the three sampling seasons (1997, 2000 and 2003) at the McGregor Hill (control) culvert to help assess the natural variation in the total phosphorus load among the three years. Since no BMPs were implemented in or adjacent to the McGregor Hill culvert, the annual variation documented at this site is assumed to reflect natural variations in phosphorus loading among years. The annual total phosphorus load decreased by 10% in the year 2000 and increased by 31% in 2003, relative to the 1997 loading value. Thus, when assessing the effectiveness of the implemented Route 16 BMPs, the annual data will be weighted against the annual precipitation data to account for the natural variations in phosphorus loading that are associated with climatic variables and, while beyond our control, had a profound influence on the annual phosphorus loading values.
- A comparison among the pre-BMP implementation (1997), BMP construction phase (2000) and the post-BMP (2003) data was conducted using phosphorus loading values weighted for precipitation. The 2003 spring total phosphorus loading values were significantly lower than either the 1997 (92% reduction) or the 2000 (60% reduction) “normalized” spring phosphorus loading values. During the pre-BMP sampling season (1997) a significant amount of sediment was observed (but not quantified) in the total phosphorus samples while the 2000 and the 2003 samples contained negligible amounts of sediments; the 2003 suspended sediment samples were near or below detectible limits in the treatment culverts. The low suspended sediment levels, documented during the 2003 study season, corroborated the lack of significant sediment load during the post-BMP implementation period.
- The spring runoff period is represented by minimal vegetative cover and high flow periods associated with snowmelt and a saturated water table. Thus, the spring runoff period is oftentimes characterized by a high potential for sediment washout and increased nutrient loading potential, particularly when erosion control measures are not in place in sensitive areas.
- A second comparison was undertaken between the 1997 and 2003 “normalized” spring and fall phosphorus loading data to further assess the effectiveness of the Route 16 BMPs. Note: limited rainfall during the fall of 2000 limited the late season runoff and thus the BMP construction phase (2000) data were excluded from this comparison. The composite of the spring and fall water quality data revealed a 30% reduction in the annual phosphorus load when comparing the pre-BMP (1997) and the post-BMP (2003) data. An intense, September 23, 2003, storm event accounted for a significant amount of the phosphorus load and reflected a storm event that exceeded the capacity of the Route 16 BMPs to attenuate the nutrient load. If the anomalous nutrient loading data from the September 23, 2003 storm event are removed from the pre and post-BMP comparison the data indicate a 58% reduction in the phosphorus loading values. The fall 2003 water quality data reflect a worse case scenario for sediment and nutrient loading due to the saturated soil conditions that coincided with atypically high rainfall, coupled with intense storm events that occurred in September and October, 2003. The result was an atypically high runoff period in 2003 during which, even with the implemented BMPs, the discharge volume exceeded the capacity of the BMPs to attenuate nutrients. On the other hand, the 30% reduction in the 2003 phosphorus load is testament to the effectiveness of the BMPs even through the discharge volumes at times exceeded the BMP capacities.
- The BMP nutrient attenuation efficiency was reduced when the fall water quality data were incorporated into the comparison. The fall data were collected when significant vegetative cover characterized the drainage basin and when deciduous leaf senescence was occurring. The 2003 fall water quality samples consistently contained organic debris (i.e. decomposing leaf debris) that appears to have contributed to the reduced efficiency of the BMPs at attenuating nutrients. The rip-rap, and plunge pools are very effective at removing inorganic debris such as sand and other relatively heavy inorganic particles. On the other hand, the organic debris is light and is more likely to remain suspended in the streamflow and enter Chocorua Lake. Thus, it appears the reduced efficiency of the BMPs in the fall are associated

with the natural shift in particulate debris from “heavy” sediment rich effluent, that is rapidly attenuated by the BMPs, to a mix of lighter organic and inorganic particles, much of which will reach the lake before being attenuated. While seasonal fluctuations in the BMP effectiveness do exist, the data that were collected in the Route 16 culverts indicate the erosion control measures have been quite effective at mitigating the historical sediment washout problems.

Ongoing collection of ambient water quality data across the state continues. We added new sites for our statewide lake study. We saw a 6% increase in monitoring samples collected statewide with over 30% of that increase in samples collected specifically in the Lakes region of NH: In all, we saw the addition of 2 new lakes, and the expansion of programs on 8 other lakes with the addition of new or reactivated sampling sites. We provided training for 18 new volunteer monitors!

Further analysis of the Squam Lake Watershed nutrient budget results and a more limited tributary sampling in 2004 disclosed that subwatersheds with construction activity, active agriculture and the more extensive road drainage networks were the largest contributors of phosphorous on an aerial basis. Further study will be done on analysis of the effect of riparian buffer extent and updated nutrient export coefficients will be calculated in the upcoming year as part of a Ph’D dissertation.

Students involved or funded (#, undergrad, Masters, and PhD)

Name	**Major/Class**	**Degree**
Maggie Bartlett --	Sociology / Fr	BA
Zach Bodah --	Marine & Freshwater/ Jr	BS
Shane Brand	Zoology	PHD
Nicole Cappadona --	Undeclared/ Fr	?
Jonathan Gravel --	WARM/ Sr	BS
Marissa Grier --	WARM/ Jr	BS
Matt Hinderlitter	Zoology	MS
Kara Houghton --	English/ Jr	BA
Caitlin Milone --	Psychology/ Fr	BA
Cassandra Payne --	Hospitality/ So	BA
Julie Shelly--	Biology/ Fr	BS
Katie Sinnott --	Undeclared/ So	?
Michelle Williams	Extension (Colorado State)	MS

This totals to 10 Undergraduate, 2 Masters and 1 PhD student

In addition: water quality and GIS data were used in:
WARM 604- Watershed Hydrology -9 students
Zoology/Botany 719/819- Field Limnology- 12 students
Biology/Zoology 896- Multidisciplinary Lake Management- 12 students

Any publications, reports, presentations, from this work.

Publications:
Newsletters:
Schloss, Jeff and Ellie Ely. 2004. Measuring Clarity, Transparency, Turbidity, and TSS. 2004. “Volunteer Monitor” National Newsletter of Volunteer Water Quality Monitoring. Winter Edition link: http://www.epa.gov/owow/monitoring/volunteer/newsletter/volmon16no1.pdf

Proceedings/ Abstracts:

Schloss, Jeffrey A. 2004. Participatory Watershed Monitoring: Linking Citizens to Scientists Through the NH Lakes Lay Monitoring Program. National Water Quality Monitorng Council Conference. May 2004. Chattanooga TN.
Powerpoint:
http://water.usgs.gov/wicp/acwi/monitoring/conference/2004/conference_agenda_links/power_points_etc/04_ConcurrentSessionB/36_Rm11_Schloss.pdf
ExtendedAbstract:
http://water.usgs.gov/wicp/acwi/monitoring/conference/2004/conference_agenda_links/title_pages/block_b/attach_36.pdf

Reports:
R. Craycraft and J. Schloss. 2004. Lakes Lay Monitoring Program Annual Report for 2003. A series of more than 50 individual lake reports distributed to lake associations, towns, conservation and planning commissions, and state agencies.

J. Schloss and R. Craycraft and 2004. Lake Chocorua Watershed Road Drainage Best Management Practice Evaluation and Wetlands Study. Final Report for Phase 3 of the NH Department of Environmental Services Nonpoint Source Pollution Program. UNH Cooperative Extension, UNH Center for Freshwater Biology, Carrol County Consrvation District, Lake Chocorua Association.

J Schloss 2004 Squam Lakes Diagnostic Watershed Study. UNH Center for Freshwater Biology Project Report.

Presentations by Jeff Schloss covering all or parts of research study:

Name of Organization	Focus of Meeting	Date and Location	Topic
National Water Quality Monitoring Council	Water Quality Monitoring Conference	May 2004 Chattanooga, TN	Invited Presentation: "Participatory Watershed Monitoring: Linking Citizens to Scientists Through the NH Lakes Lay Monitoring Program,
New England Chapter-North American Lake Management Society/	New England Lakes Management Conference	June 2004 Kingston, RI	Conducted Following the Flow NPS Assessment Workshop
New Hampshire Lakes Association	Annual Lakes Congress	June 2004 Concord, NH	Invited Presentation: "Lake Monitoring: Data to Action".
New Hampshire Lake lay Monitoring Program	25 Year Celebration and Workshop	July 2004	"Over 25 Years of Participatory Monitoring: What we know now"
Plymouth State College and NH Department of Environmental Services	Annual Lakes Region Water Conference	December 2004	Invited Speaker: "Over 25 of Monitoring the Squam lakes Watershed: What have

			we learned?”
USDA CSREES 406 Water Quality Program	Annual Extension Water Quality Program Conference	February 2005 San Diego, CA	Invited Volunteer Monitoring Workshop Presenter: “Empowering Local Citizens for Watershed Protection”