New York State Water Resources Institute
Annual Technical Report
FY 2007

Introduction

Susan Riha, Cornell University's Charles L. Pack Professor in the Department of Earth and Atmospheric Sciences, was appointed director of the New York State Water Resources Institute (WRI) effective September 30, 2007. She succeeds Keith Porter, an adjunct professor of law, who has directed WRI since 1986. Keith will continue to teach Water Law and Land Use Law Clinics at Cornell's Law School.

WRI continues to devote most of its resources to facilitating research, outreach, education and information transfer to assist in state and local government problem−solving. The Director, staff and cooperating Cornell faculty are enmeshed in New York States water resources management processes in its several major watersheds, focusing on scientifically demanding water problems.

WRI also collaborates with regional, state, and national partners to increase awareness of emerging water resources issues and to develop and assess new water management technologies and policies. WRI connects the water research and water management communities.

In collaboration with partners, WRI continues to:

- Build and maintains a broad, active network of water resources researchers and managers;
- Bring together water researchers and water resources managers to address critical water resource problems; and
- Identify, adopt, develop and make available resources to improve formation transfer to water resources management and technologies to educators, managers and policy makers.

Research Program Introduction

FY2007 Competitive Grants Program Background. NY WRI's FY2007 competitive grants program was conducted jointly with the Hudson River Estuary Program (HREP), NYS Department of Environmental Conservation. A total of $91,487 was provided ($45,000 from the HREP and $46,487 from WRI). A primary objective of the FY2007 grants program is to foster the involvement of New York's higher education community, in partnership with concerned agencies and communities, to become active in achieving local watershed planning and implementation strategies in watersheds across the state.

Additionally, proposals were requested whose results would contribute to the goals of the HREP, including:

1. Fostering interdisciplinary teams to address integrated technical and social aspects of watershed issues;
2. Featuring innovative research projects that begin the development of new and innovative areas (seed projects);
3. Assisting in filling local and regional knowledge and research gaps identified in existing watershed conservation and management plans; and
4. Supporting information or educational transfer that enhance communication of research results to teachers, technical providers or to watershed communities.

Projects were solicited competitively from about approximately 100 academic entities in NY.

Proposals were evaluated by representatives from agencies, universities and private organizations from across the State. Project oversight is primarily through reports submitted for the annual technical report. Also, for students and interns involved in carrying out research in FY2007, a special roundtable will be convened in the Fall of 2008 to recognize their contribution to the research and to share their results with the wider community.

Research Projects. WRI FY2007 activity under the Federal Water Resources Research Act consisted largely of research and information transfer projects funded from FY2003 through FY2007. One national 104G project report, five 104B project reports, and the NYS WRI Director's Office information and transfer reports are included in this report.

The FY2003 104G project examines statistical patterns in low stream−flows. This project begin May 2005 and has been extended through July 2007. Five FY2007 projects reflect WRI's objective to foster partnerships between higher education, agencies and communities in the Hudson River Watershed. These included:

1. Modeling urbanization effects on water resources in the Moodna Creek Watershed to develop a tool for community watershed management;
2. Determining best management practices for managing stormwater runoff from developing areas in the Hudson catchment;
3. Evaluating the health of the lower Esopus Creek using water quality and benthic macro invertebrates;
4. Solving the mystery of chloride in Hudson Valley streams involving local citizens and government in puzzle−solving; and
5. Partnering scientists, policymakers, and the public toward the creation of a management plan for the Casperkill Watershed in Dutchess County, New York.

An Assessment of New Advances in Low Streamflow Estimation and Characterization

Basic Information

Title:	An Assessment of New Advances in Low Streamflow Estimation and Characterization
Project Number:	2003NY33G
Start Date:	8/1/2003
End Date:	7/31/2007
Funding Source:	104G
Congressional District:	25
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Water Use, Non Point Pollution
Descriptors:	risk assessment, geographic information system, watershed hydrology, statistical
Principal Investigators:	Chuck Kroll

Publication

An Assessment of New Advances in Low Streamflow Estimation and Characterization

Chuck Kroll, SUNY ESF, Principal Investigator

Principal findings:

Research on this project began in May 2004. We have focused our primarily research on two data sets: the USGS's Hydro-Climatic Data Set (HCDN) and a study area encompassing eastern Tennessee and western North Carolina that was chosen by personnel from the USGS's Reston, VA office. Using these study areas, the following has been found:

1. Most of the underlying assumptions of the baseflow correlation technique appear to be valid for the continental United States.
2. The baseflow correlation technique can be improved if multiple sites are used to transfer information to the ungauged site. These improvements are greatest when less than 8 baseflow observations are available, and diminish with more than 8 observations.
3. In the eastern Tennessee/western North Carolina study area, lowflow regional regression models were greatly improved by inclusion of mapped values of the baseflow index. These findings have encouraged us to pursue an investigation of spatial interpolation of watershed hydrogeologic characteristics.
4. The horizontal resolution of the DEM employed to derived watershed boundaries had little impact on the quality of the derived watershed characteristics. This may have to do with the large horizontal resolution of the raster datasets employed in this study.
5. The use of raw MODIS data appears to have some predictive information for hydrologic modeling, though interestingly it appears to have more of an impact on floods than droughts. We are further investigating this issue with multi-band remotely sensed indexes.
6. Regional regression and baseflow correlation perform similarly in the eastern Tennessee/western North Carolina study area, with regional regression outperforming baseflow correlation, especially when the baseflow index is included in the regression models.
7. We are now beginning research in Idaho, where the USGS has been performing numerous low streamflow investigations. We also hope to select a more arid study region, as low streamflow estimation typically performs poorly in these areas.

Notable Achievements:

This research has resulted in two notable achievements. The first is the development of a GIS tool to automate the calculation of descriptive statistics from multiple raster datasets across watersheds in a region of interest. This tool was created to be of use with any polygon coverage, and thus can be employed with state, county, city, property, or any other boundaries of interest. Such flexibility makes this tool of wide interest to many researchers, not only hydrologists. The tool is freely available to the public and can be downloaded at www.esf.edu/erfeg/kroll. A tutorial has been created to aid users of this tool.

The second notable achievement is that this research has inspired the creation of an International Association of Hydrologic Sciences (IAHS) Prediction at Ungauged Basins (PUBs) low streamflow work group. This group is currently being formed as a joint venture with the Northern European Flow Regimes from International Experimental and Network Data (NE FRIEND), and will focus on international cooperation and information exchange with respect to low streamflow estimation. Through this group, a number of low streamflow study areas will be created throughout the world. These study areas will be the focus of long-term low streamflow research. Research from this group will help us better understand the performance of various estimators of low streamflow statistics at ungauged river sites in different hydrologic setting, as well as the uncertainty associated with these estimators.

Student support:

1. Zhenxing Zhang, PhD, Area of Study: Water Resource Engineering, PhD Topic: Baseflow Correlation.
2. Satoshi Hirabayashi, MS, Area of Study: GIS and Water Resources, MS Topic: GIS Tools Watershed Characterization.
3. Adao Matonse, PhD, Area of Study: Water Resource Engineering, PhD Topic: Hillslope Models for Low Streamflow Prediction.
4. Satoshi Hirabayashi, PhD, Area of Study: GIS and Water Resources, PhD Topic: Advanced Mapping Techniques to Aid in Low Streamflow Prediction.

Publications: Journal Articles (numerous articles are in progress)

1. Zhang, Z, and C N Kroll, 2005, A Closer Look at Baseflow Correlation, submitted to the ASCE Journal of Hydrologic Engineering, July 2005. Decision Pending.
2. Hirabayashi, S, and C N Kroll, 2006, Automating regional descriptive statistic computations for environmental modeling, resubmitted to Computers & Geosciences, January 2006. Decision Pending.

Theses

3. Hirabayashi, S, Examining the Impact of Raster Datasets on Flood and Low Streamflow Regional Regression Models Using a Custom GIS Application, MS Thesis, December, 2005.
4. Zhang, Z, Advances in Low Streamflow Statistics Estimation Using Baseflow Correlation, PhD Thesis, December, 2005.
5. Luz, J., Investigating Improvements in Low Streamflow Regression Models, PhD Thesis, January, 2005.

Conference Proceedings/Presentations

6. Zhang, Z, and C N Kroll, 2005, Estimation of low streamflow statistics at ungauged sites using baseflow correlation, American Geophysical Union conference, New Orleans, LA; Spring 2005.

7. Hirabayashi, S, and C N Kroll, 2005, Developing a geospatial data model to derive watershed characteristics for low streamflow prediction, American Geophysical Union conference, New Orleans, LA, Spring 2005.
8. Matonse, A H, and C N Kroll, 2005, Simulation of baseflow and low streamflow statistics using the SAC-SMA model and a SAC-SMA/Hillslope-Storage Boussinesq model, Fall AGU meeting, San Francisco, California, December 2005.
9. Kroll, C N , Z Zhang, and S Hirabayashi, 2005, A comparison of regional regression and baseflow correlation for estimating low streamflow statistics, Fall AGU meeting, San Francisco, California, December 2005.
10. Zhang, Z, and C N Kroll, 2006, Estimation of low streamflow statistics using baseflow correlation with multiple gauged sites, American Geophysical Union conference, Baltimore, MD; Spring 2006.

Assessing the ecosystem services of open space for water resource protection in the Moodna Watershed, NY

Basic Information

Title:	Assessing the ecosystem services of open space for water resource protection in the Moodna Watershed, NY
Project Number:	2006NY81B
Start Date:	3/1/2006
End Date:	7/31/2007
Funding Source:	104B
Congressional District:	25 &19
Research Category:	Water Quality
Focus Category:	Water Quantity, Floods, Management and Planning
Descriptors:	
Principal Investigators:	Karin Limburg, Valerie Luzadis

Publication

1. Ramsey, Molly, Karin Limburg, and Valerie Luzadis, 2006, Modeling urbanization effects on water resources in Moodna Creek Watershed, NY: Developing a tool for community watershed management, IN Annual Meeting proceedings of the New York State Chapter of the American Fisheries Society, Thayer Hotel, West Point, NY, February 2006.
2. Ramsey, Molly, Karin Limburg and Valerie Luzadis, 2007, Urbanization and the Sustainable Management of Water and Land Resources in the Moodna Creek Watershed, NY: An Ecological Economics Approach, In conference proceedings for the US Society for Ecological Economics, New York City, NY, June 23−27, 2007.

Progress Report

Assessing the Ecosystem Services of Open Space for Water Resource Protection in the Moodna Watershed, NY

Karin Limburg, SUNY-ESF, Principal Investigator

Background

Orange County is currently the fastest-growing county in NY State and management of water quality and quantity is a major concern in terms of drinking water, biodiversity, erosion and flood control, and other priorities. The Hudson River/Moodna Creek is identified in the county's Open Space Plan as one of four Selected Priority Watersheds, and the New York State Coastal Management Program has designated areas along the Moodna Creek as "irreplaceable" Significant Coastal Fish and Wildlife Habitats. Water *quality* is impacted by urbanization in the Moodna watershed, and these sites show symptoms of nutrient enrichment and other pollution (Nolan, 200). Water *quantity* is also impacted by urbanization, as large portions of the Moodna basin are dependent on groundwater for drinking water. Certain areas, including the Village of Washingtonville, use wells directly connected to Moodna Creek. During a dry spell in 2005, the Village was forced to tap emergency wells and implement water conservation requirements due to low water levels; yet, this dry spell was not considered a real drought. Ongoing development is expected to exacerbate the potential for water shortages both by increasing water demand and creating new impervious surfaces. Several municipal water districts in the Moodna basin (including Cornwall-on-Hudson and New Windsor) use water from NY City's Catskill Aqueduct, and a proposed new pipeline could lead to increased withdrawals from the City's system to serve areas in and adjacent to the Moodna basin. Unless a more sustainable approach for managing water resources is adopted, these pressures are only likely to increase over time. Land use planning and site design strategies can help to mitigate these problems; these include: open space protection, low impact development approaches for clustering, minimizing impervious surfaces, and optimizing treatment and infiltration of runoff. Acceptance and implementation of these strategies is, however, dependent on demonstrating the future impacts of current practices and comparing them to the potential benefits of alternative planning and design scenarios. Such information needs to be communicated to elected and appointed officials, regulatory agencies, developers, and other stakeholders.

Principal findings

A new-generation watershed loading model, called ReNuMa (Swaney et al., manuscript in preparation), based on GWLF but with a hydrological routing algorithm, was used to simulate groundwater quantity and streamflow in Moodna Creek watershed in Orange County, NY. The watershed was divided into 14 sub-catchments and model analysis could be done simultaneously. Four different scenarios were analyzed: (a) all forested; (b) all urbanized (i.e. 100% impervious surface); (c) current land use pattern, based on 2001 National Land Use Dataset; and (d) a 15% increase in urbanization (buildout scenario).

Average annual groundwater infiltration was slightly lower for the 15% buildout scenario compared to the current land use. The 100% impervious or urban land use had the lowest groundwater infiltration overall, with annual average infiltration barely above zero cm. The 100% forested scenario had the highest groundwater infiltration (45-69 cm). The sub-catchments varied somewhat with the Silver Stream sub-catchment, with the highest percentage of urbanized land, having the lowest groundwater annual average infiltration and the Mineral Spring Brook, with the highest percentage of forested land, having the highest. Simulated streamflows were consistent between sub-catchments and land uses, except for the 100% urban. In this land use scenario, streamflow was higher, reflecting the higher runoff coefficients used for this land use in the model. As impervious surfaces cover the land in urbanized settings, precipitation hits the land surface and instead of infiltrating into the soil and potentially being stored in groundwater, the water runs off down-slope to the stream. Runoff rates were very high relative to other land use scenarios for the 100% urban. The 15% buildout scenario had slightly higher annual average rates versus the current land use. The lowest runoff rates were for the Mineral Spring Brook sub-catchment, with the highest percentage of forested land. Highest runoff rates were predicted for the sub-catchment with the highest percentage of urbanized land, Silver Stream.

An integrated watershed condition model (Hong et al., in review) was used to analyze streamwater quality. The model was run for the Woodbury subcatchment for four different land use scenarios: current, 100% forested, 100% agriculture, and 100% urban land use. Chloride concentrations were much higher for the 100% urbanized scenario, followed by the current land use, and then the 100% agriculture. Total phosphorous and nitrogen concentrations were highest in the agricultural land use scenario, followed by the urban land use scenario for the Woodbury sub-catchment. This is largely due to larger contributions from organic nutrients predicted for the agricultural and urban scenarios vs. forested scenarios (the current land use of the Woodbury is primarily forested).

Water quality conditions were simulated for the current land use for each subwatershed. Sub-catchments with more forest lands (for example, Mineral Spring Brook) had higher biotic integrity index, lower nutrient concentrations, higher dissolved oxygen contents, and lower stream temperatures for than urbanized sub-catchments. Sub-catchments with a higher proportion of agricultural land (e.g. Otter Kill) had the lowest dissolved oxygen concentrations. The most urbanized sub-catchments (e.g. Silver Stream) had the highest proportion of nutrients and heavy metal concentrations. It will be helpful to compare these individual sub-catchments with further analyses to determine how their water quality changes with different land use scenarios but particularly with water quality data collected from the Moodna Creek and its tributaries. Although the statistical relationships of the model were derived from regional watersheds, a more accurate understanding will only be gained when the modeled results are validated with field data.

Notable achievements.

A presentation was given to stakeholders in 2007. Also, a paper was presented at the United States Society of Ecological Economics Biennial Conference in June 2007.

Student support

Academic and research support was provided for Molly Ramsey during the fall and spring semesters (2006-7), a Master's student in the Environmental Science Department at SUNY-ESF, Syracuse, NY. Financial support included tuition, salary, and travel expenses.

Travel funds were used to attend several meetings of the Moodna Watershed Coalition at Black Rock Forest, Cornwall, New York and at the Orange County Office of Planning in Goshen, New York. Funds were also used to support travel to and participation in the biennial conference of the United States Society for Ecological Economics, where Ms.

Ramsey presented her work as an oral paper. Funds were also used to support her travel to Orange County from Syracuse, NY, to scope out potential sites for installation of a stream gage.

Publications generated to date

An abstract for an oral presentation in the conference proceedings for the United States Society for Ecological Economics Conference, June 23 – 27, 2007, New York City, NY. The title of the presentation is the "*Urbanization and the Sustainable Management of Water and Land Resources in the Moodna Creek Watershed, NY: An Ecological Economics Approach*" by Molly Ramsey, Karin Limburg, and Valerie Luzadis of SUNY College of Environmental Science and Forestry.

Also, a thesis is in preparation.

Evaluation of the health of lower Esopus Creek using water quality and benthic macro invertebrates

Basic Information

Title:	Evaluation of the health of lower Esopus Creek using water quality and benthic macro invertebrates
Project Number:	2007NY100B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	22
Research Category:	Water Quality
Focus Category:	Groundwater, Surface Water, Hydrology
Descriptors:	
Principal Investigators:	Shafiul H. Chowdhury

Publication

1. Chowdhury, Shafiul, 2008, Evaluation of the Health of the Lower Esopus Creek, Geological Society of America Annual meeting, October, 2008, Huston, Texas. Abstract prepared.

Evaluation of the Health of the Lower Esopus Creek

Kerri DeGroat
Katherine Landi
Colin Mills
Shafiul Chowdhury

SUNY New Paltz, Geology Department

Abstract

Water quality studies were conducted on the Lower Esopus Creek from June 2007 to October 2007. This study consisted of two components, chemical parameters and biological parameters using Benthic Macro invertebrates (BMI). For the first component, thirteen sites along the Esopus Creek were selected. Environmental parameters including; temperature, conductivity, pH and dissolved oxygen (DO) were measured at the site. Water samples were then collected and taken back to the lab for further chemical analysis. The chemical analyses preformed by titration, a DIONEX IC-3000 Ion Chromatograph and a HACH™ DR/2400 Spectrophotometer. The chemical constituents that were analyzed include: bicarbonate, total organic carbon, copper, iron, total chorine, chloride, sodium, sulfate, magnesium, calcium, fluoride, ammonia, nitrate and nitrite. The turbidity of each of the thirteen sites was also analyzed using the HACH™ 2100P Turbidimeter. The BMI samples were collected along seven riffle zone sites in accordance with NYSDEC guidelines. The BMIs were then identified to the family level. The Biological Assessment profiles for water quality using the BMIs, range from non-impacted to moderately impacted.

Introduction

The Esopus Creek is located in southeastern New York State and is a tributary of the Hudson River. It begins at Winisook Lake in the Catskill Mountain Range and joins the Hudson River in the Village of Saugerties in Ulster County New York. The Ashokan Reservoir, which is part of New York City's water supply reservoir system, divides the creek into two sections. The portion located upstream of the Ashokan Reservoir is known as the "Upper" Esopus and the reach downstream is referred to as the "Lower" Esopus.

The study reach is a section of the Lower Esopus that extends from Marbletown at the upstream end and Glenerie at the downstream end. This reach sees various types of developments on its shores ranging from agriculture, minor residential areas and city-like conditions as the river runs through the City of Kingston. Then the land use becomes more residential toward the confluence when it flows into the Hudson River. The New York State Department of Environmental Conservation (NYSDEC) has designated the waterway as Class B and B (T) within the reach studied. The classification of a stream is based off of the quality of the water and whether or not it is suitable for fish propagation and in some cases specifically trout, which is designated by (T). According to Part 861.4 of the NYSDEC guidelines the portion classified as B (T) extends "from former [tributary] 21 (Tannery Brook) in City of Kingston to [tributary] 41, which enters from north approximately 0.7 miles east of Ashokan Dam (www.dec.ny.gov)". Class B waters are best used for primary and secondary contact recreation and fishing (NYSDEC Water Quality Regulations). According to the NYSDEC, These waters shall also be suitable for fish propagation and survival.

This project focused on collection of monthly environmental data in the field, collection of water samples for chemical analysis and the biological analysis of riffle zones. This data was also compared to land use to aid in the determination of the health of the Esopus Creek. Data was collected in early June, late June, July, August, September, and October. During sample collection about 500mL to 1000mL of stream water was collected. Temperature, pH, dissolved oxygen and conductivity were measured in the field using hand probes. Chemical components were analyzed using the HACH™ DR/2400 Spectrophotometer and the DIONEX IC-3000 Ion Chromatograph. The constituents analyzed for include total chlorine, nitrate, chloride, nitrate, iron, copper, fluoride, sulfate, sodium, magnesium, calcium, ammonia and total organic carbon. Turbidity was measured using the HACH™ 2100P Turbidimeter. Land use was determined using ground proofing and a computer map generated in ArcMap 9. This map was based off of Ulster County parcel data from the Tax Assessors office. Soil information was gathered using soil survey data published for Ulster County.

The NYSDEC had conducted studies on the Lower Esopus Creek at various times in the mid 1990s. This stretch of the Esopus Creek was chosen for this study in 2007 due to the large lapse of time. It is important to attain multiple data sets over time so that trends can be discovered and any increase or decrease in the quality of the water body can be monitored. This study was done as a follow up to NYSDEC testing done at various times in the mid 1990's. It is important to attain multiple data sets over time so that trends can be discovered and any increase or decrease in the quality of the water body can be monitored. The results of this project will be used as a baseline for future studies along the Lower Esopus as well as a comparison to previous work already accomplished by the NYSDEC.

Benthic macro-invertebrates (BMIs) are often used as biological indicators to determine water quality. Benthic macroinvertebrates, also known as bottom dwellers, are animals without backbones that live on the bottom of streams and other aquatic areas. BMIs are larval insects such as dragonflies, caddisflies, stoneflies or organisms such as worms, mollusks and crustaceans. Benthic animals are the predominate food for many fish and they also regulate populations of phytoplankton and zooplankton (J.S. Levinton, and J. R. Waldman). BMIs have several characteristics that make them useful as water quality indicators. BMIs have a relatively long life cycles and limited migration patterns. This enables them to be easily studied and sampled. Since BMIs are not very mobile, they are often unable to escape from polluted areas. Benthic macro-invertebrates assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (USEPA).

Methods

The purpose of this project was to determine the water quality of the Esopus Creek through both biological and chemical studies. Thirteen sites for chemical analysis were chosen along the Esopus Creek that allowed for easy access to the creek. These sites ranged from Marbletown to Lake Katrine.

Chemical

Each site was sampled once monthly, from June to October 2007, with the exception of June which was sampled twice. See appendix for specific dates. At each site, water samples were collected and stored in High Density Poly-Ethylene (HDPE) bottles. Other environmental parameters, such as pH, temperature, dissolved oxygen (DO), and conductivity was measured on site using an YSI-550A Dissolved Oxygen meter, an OAKTON pH/Conductivity meter, and a Pulse Instrument IQ125 handheld pH meter. All samples were refrigerated upon return to the lab, and during transport were kept in a cooler. In order to preserve the cations present in the samples, 30 mL of each sample were acidified to an approximate pH of 2.0 using concentrated nitric acid.

Tests for the common cations and anions were done using a HACH™ DR/2400 Spectrophotometer and a DIONEX IC-3000 Ion Chromatograph. The HACH™ DR/2400 Spectrophotometer tested for Total Organic Carbon, copper, iron, total chlorine, and ammonia. The DIONEX IC-3000 Ion Chromatograph tested for nitrate, nitrite, fluoride, sulfate, chloride, sodium, magnesium, and calcium. The procedure for all HACH™ tests can be found in the HACH™ instruction manual. All measurements for the HACH™ tests were done using Thermo Scientific Finnpipettes and the pre-measured reagent packets provided. The DIONEX IC-3000 Ion Chromatograph was calibrated for cation and anion analysis using prepared standards. Each cation sample was run through a CSRS-2mm column and each anion sample was run through an ASRS-2mm column. Before testing, both cation and anion samples were prepared with a 0.2um Nalgene filter. This filter removed any large particles that could damage the ion chromatograph. Samples ready for analysis were placed in 10 mL DIONEX vials covered with sterile membrane caps. This helped to protect the sample from any contamination and prevent any evaporation during analysis.

Tests were also run to determine the levels of bicarbonate and turbidity. To determine bicarbonate levels, a 60 ml volume of the sample was titrated with 0.1 M HCl. When the Bromcresol green pH indicator dye turned from blue to green, the end point was reached. The volume of HCl used was noted, and calculations were done. Turbidity was determined using the HACH™ 2100P Turbidimeter. Sample water was put in a 10 mL vial and inverted 2-3 times to ensure even distribution of any suspended sediment. The outside of the vial was wiped with oil to remove any fingerprints and fill in any scratches that would possibly skew the results.

Biological

The seven sites sampled were: ESOP 01, ESOP 02, ESOP 03, ESOP 04, ESOP 06, and ESOP 07A and SAWK 01. Each of these seven sites corresponded with previous testing sites of the DEC, and was easily accessible to riffle portion of the stream. The BMI samples were collected on July 12, 2007, following the New York State DEC Quality Assurance Work Plan (Bode et. al 2002).

At the time of sampling, physical and chemical environmental data were collected. This includes, but is not limited to, the depth, velocity, temperature, dissolved oxygen (DO) levels, pH, and salinity. Physical habitat parameters were also measured.

After all the physical and chemical environmental parameters were measured, the BMIs were collected. The sampling technique utilized was the kick sampling method. Kick sampling uses a net with a mesh of 800 x 900 microns and has a width of 18 inches.

The collection net was placed approximately six inches downstream of one's feet and the kick method employed for approximately five meters along the width of the riffle zone. The debris and BMI trapped in the net was transferred into a pan and examined. A quick field inspection yielded the diversity of the ecosystem to the taxonomic level of order. The collected matter was then placed in a jar and preserved with 95% ethyl alcohol.

An analysis of water quality was conducted on August 14 and August 15, 2007 by identification and evaluation of community structure. A subsample of 100 organisms was taken from the preserved sample. A spoonful of material was scooped out of the container, and the first 100 organisms found were removed for identification under a 40x dissecting microscope. Identification was accomplished with the assistance of a taxonomic key and organisms were identified to the level of family.

Based on the families present, four metric parameters are calculated. These metrics are used to determine overall water quality of each site. The four metrics calculated were EPT family richness (F-EPT), Family Richness (FR), Family Biotic Index, Percent Model Affinity (PMA), and the Biological Assessment Profile Score (BAP). The F-EPT accounts for the total number of families that are in the orders; Ephemeroptera (mayflies) Plecoptera (stoneflies) and Trichoptera (caddisflies). These three orders are considered to be mostly clean water organisms are generally associated with good water quality. The FR is the total number of families present from all orders in the sub sample. The higher the FR value, the more likely the stream will have a better water quality evaluation. The FBI is a metric based off of the Hilsenhoff Biotic Index. This index assigns individual values to BMI based on their tolerance levels to pollutants. The values range from 0 to 10. A score of zero is intolerant to pollutants where as a score of ten is most tolerant. The PMA compares the sub sample community to a DEC model of a non-impacted community to determine the water quality in the sub sample. The DEC model community has 40% Ephemeroptera, 5% Plecoptera, 10% Trichoptera, 10% Coleoptera, 20% Chironomidae, 5% Oligocheata and 10% other. Taken together, the four values give the Biological Assessment Profile (BAP). Each of the four previous metrics was converted to a scale of 10 and then averaged together to determine the Biological Assessment Profile Score (BAP). Depending on the results, the BAP could fall within four ranges: Non Impacted (BAP 7.5-10), Slightly Impacted (BAP 5-7.5), Moderately Impacted (BAP 2.5-5), or Severely Impacted (BAP 0-2.5).

Results

Chemical

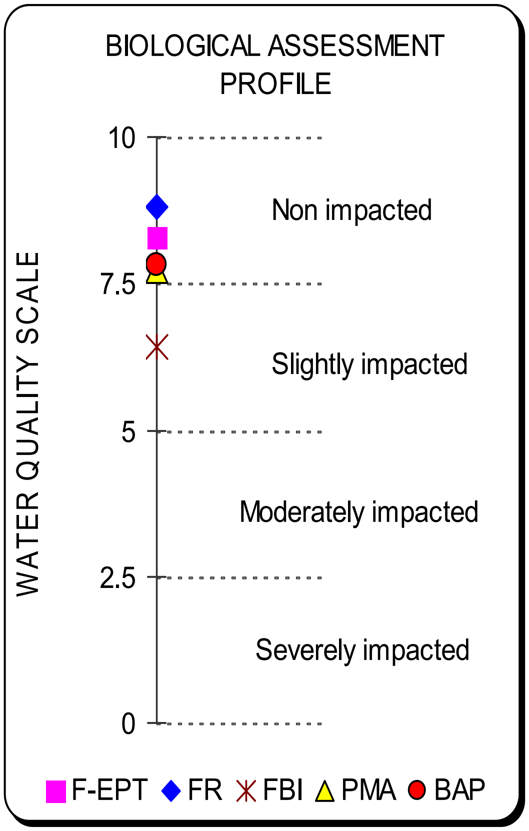
See Appendix.

Biological Results

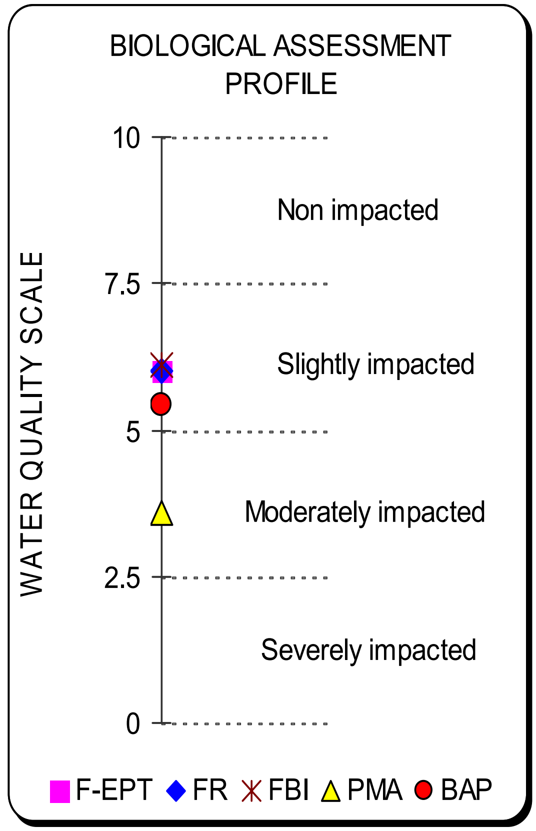
Profile 1, ESOP 01, was determined to be in the non-impacted range. The F-EPT had a value of eight families, the FR had fifteen families present, the FBI was 4.9, and the PMA was 66%. Total BAP was 7.8.

Profile 2, ESOP 02, was determined to be in the slightly impacted range. The F-EPT had a value of four families, the FR was eleven families present, the FBI was 5.1, and the PMA was 41%. Total BAP was 5.4.

Profile 1. ESOP 01



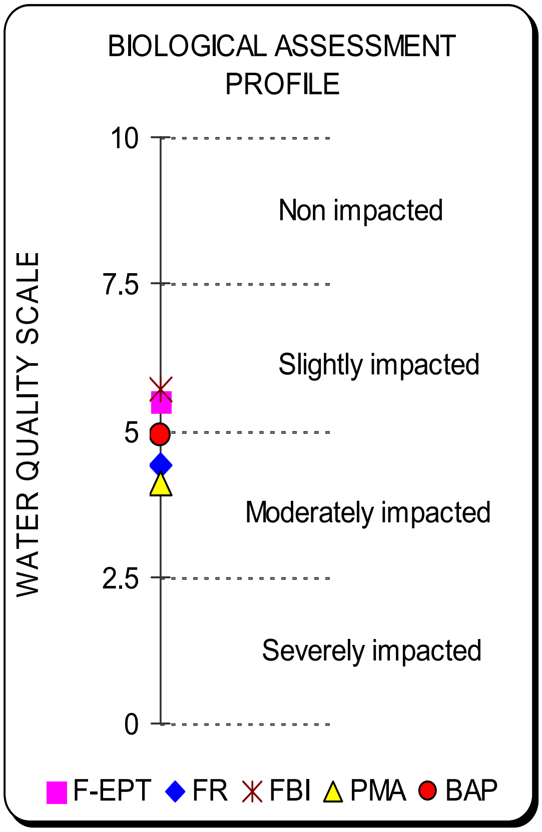
Profile 2. ESOP 02



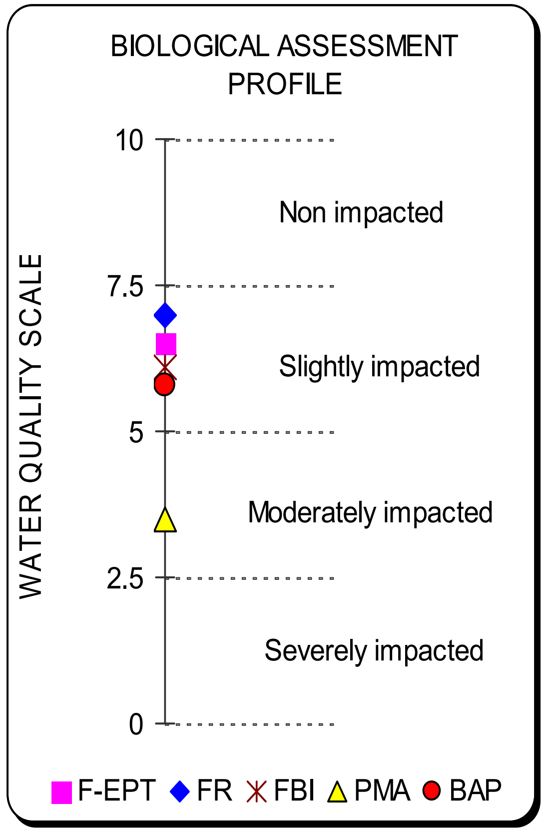
Profile 3, ESOP 03, was determined to be in the moderately impacted range. The F-EPT had three families, the FR was nine families present, the FBI was 5.5, and the PMA was 44%. Total BAP score was 4.9.

Profile 4, ESOP 04, was determined to be in the slightly impacted range. The F-EPT had a value of five families, the FR had thirteen families present, the FBI was 5.2, and the PMA was 40%. Total BAP was 5.8.

Profile 3. ESOP 03



Profile 4. ESOP 04

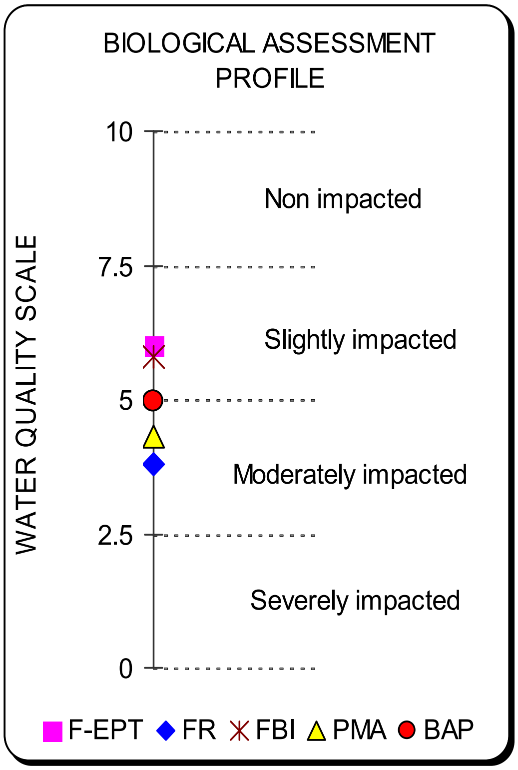


Profile 5, ESOP 06, ranged in between slightly and moderately impacted with an overall BAP score of 5.0. The F-EPT had four families, the FR had eight families present, the FBI was 5.4, and the PMA was 45%.

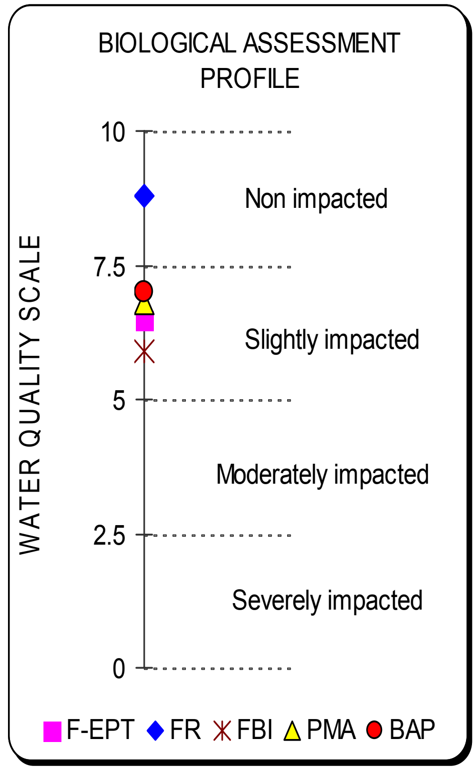
Profile 6, ESOP 07A, was determined to be in the slightly impacted range. The F-EPT had a value of five families, the FR had fifteen families present, the FBI was 5.3, and the PMA was 60%. Total BAP was 7.

Profile 7, SAWK 01, was determined to be in the slightly impacted range. The F-EPT had a value of six families, the FR had eleven families present, the FBI was 4.2, and the PMA was 45%. Total BAP was 6.3.

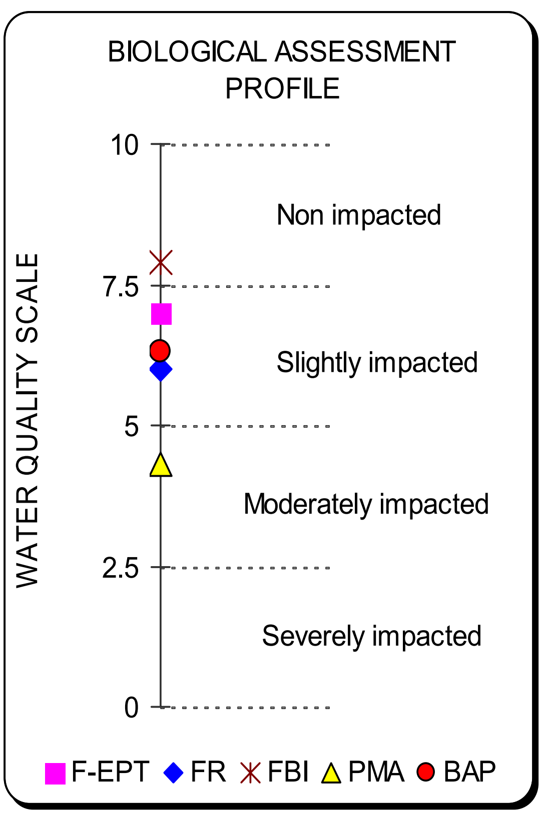
Profile 5. ESOP 06



Profile 6. ESOP 07A



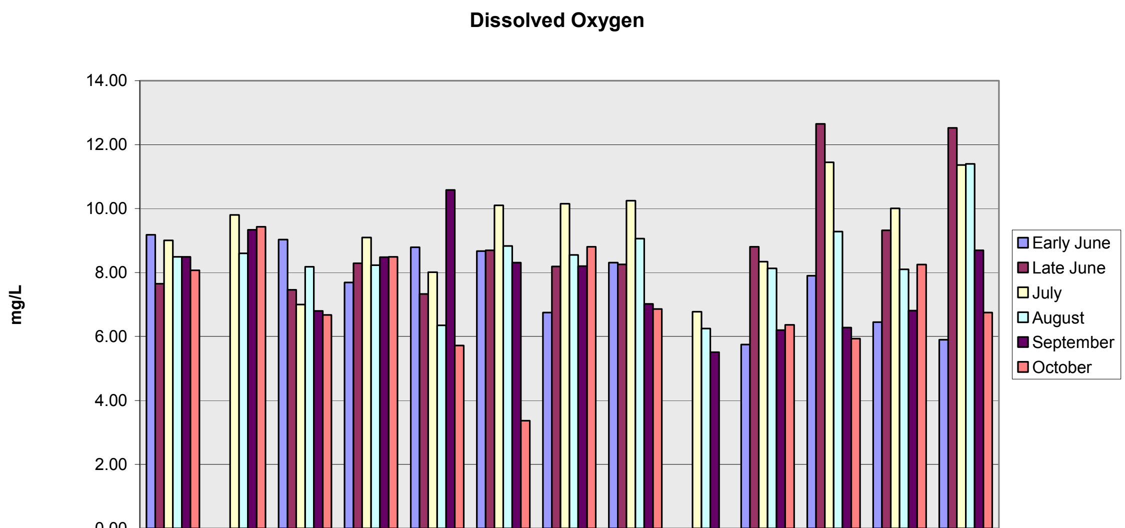
Profile7. SAWK 01



Discussion

Chemical

Dissolved Oxygen:

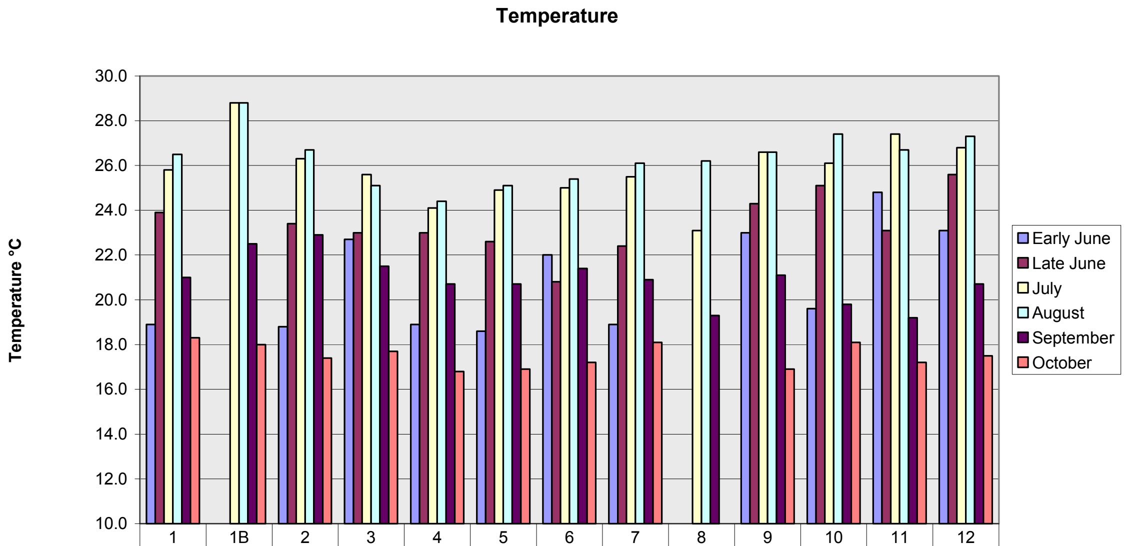


Site #	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	9.18		9.03	7.69	8.79	8.67	6.75	8.31		5.75	7.90	6.45	5.90
Late June	7.65		7.46	8.29	7.33	8.69	8.19	8.26		8.81	12.65	9.32	12.52
July	9.00	9.80	7.00	9.10	8.01	10.10	10.15	10.25	6.77	8.34	11.45	10.01	11.36
August	8.49	8.60	8.18	8.23	6.35	8.83	8.55	9.06	6.25	8.13	9.28	8.10	11.40
September	8.49	9.34	6.80	8.48	10.58	8.31	8.20	7.02	5.51	6.20	6.28	6.81	8.69
October	8.07	9.43	6.67	8.49	5.72	3.37	8.81	6.86		6.36	5.93	8.25	6.75

Site #

Dissolved oxygen (DO) is the measure of the amount of oxygen that is dissolved and available in the water column. The DEC standard for dissolved oxygen in class B streams states that at no time shall the DO concentration be less than 5.0 mg/L for trout waters and for non trout waters it shall not be less that 4.0 mg/L. The dissolved oxygen was measured in the afternoon daylights hours when the levels were generally high. The only value that fell below the DEC standard at the time of measurement was site 5 in October. Photosynthesis of benthic plants could cause the DO levels to be supersaturated during the day and plummet during the nighttime hours. High algal growths were seen during late June, July and August in sites 10, 11 and 12. Unfortunately, DO measurements were not taken during the late evening hours to make comparisons with the daytime levels.

Temperature:

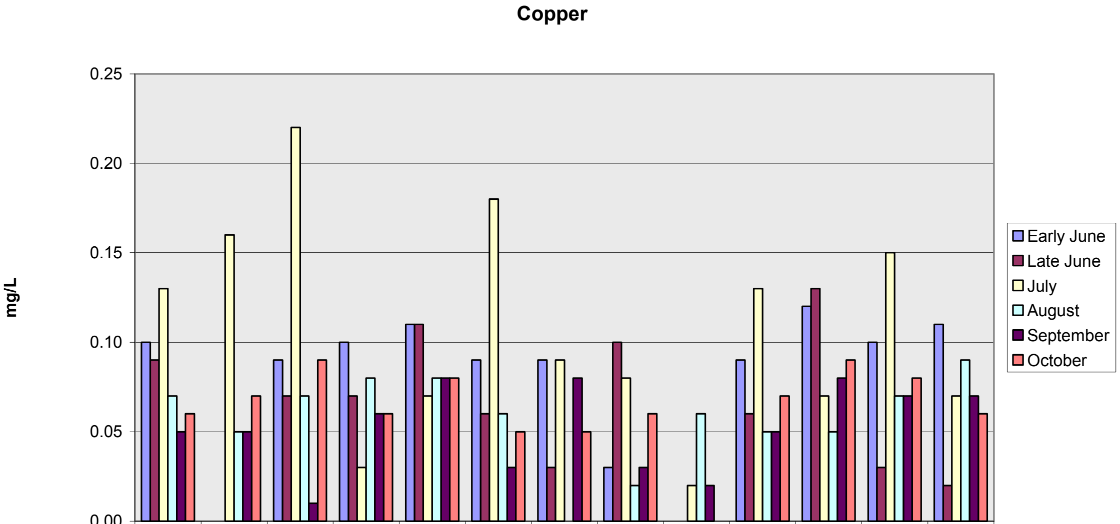


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	18.9		18.8	22.7	18.9	18.6	22.0	18.9		23.0	19.6	24.8	23.1
Late June	23.9		23.4	23.0	23.0	22.6	20.8	22.4		24.3	25.1	23.1	25.6
July	25.8	28.8	26.3	25.6	24.1	24.9	25.0	25.5	23.1	26.6	26.1	27.4	26.8
August	26.5	28.8	26.7	25.1	24.4	25.1	25.4	26.1	26.2	26.6	27.4	26.7	27.3
September	21.0	22.5	22.9	21.5	20.7	20.7	21.4	20.9	19.3	21.1	19.8	19.2	20.7
October	18.3	18.0	17.4	17.7	16.8	16.9	17.2	18.1		16.9	18.1	17.2	17.5

Site #

Temperature is an important factor for what organisms may be able to survive in a given location or the solubilities of any of the chemical constituents. In general, the temperature of the stream followed seasonal trends. August and July may also have been warmer due to low flows. Sampling was generally done in between the hours of 10 am to 4 pm where temperatures were closer to their maxima. Temperature readings were also taken near the shoreline at shallower depths; this may give higher readings than if these temperatures were taken in the center at deeper depths.

Copper:

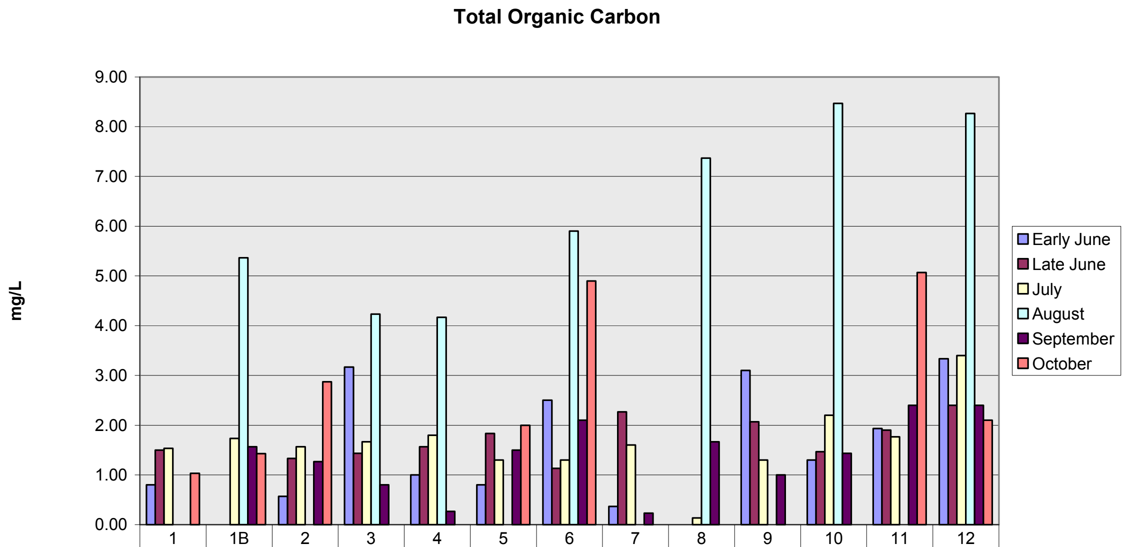


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.10		0.09	0.10	0.11	0.09	0.09	0.03		0.09	0.12	0.10	0.11
Late June	0.09		0.07	0.07	0.11	0.06	0.03	0.10		0.06	0.13	0.03	0.02
July	0.13	0.16	0.22	0.03	0.07	0.18	0.09	0.08	0.02	0.13	0.07	0.15	0.07
August	0.07	0.05	0.07	0.08	0.08	0.06	0.00	0.02	0.06	0.05	0.05	0.07	0.09
September	0.05	0.05	0.01	0.06	0.08	0.03	0.08	0.03	0.02	0.05	0.08	0.07	0.07
October	0.06	0.07	0.09	0.06	0.08	0.05	0.05	0.06		0.07	0.09	0.08	0.06

Site #

Some sources of copper in surface waters can arise due to runoff from road pollution, street refuse and industrial pollution. The anticipated secondary contaminant level for copper is 1 mg/L (V. Novotny and G. Chesters). All of the tested site concentrations fell below this level. There is no listed DEC standard for copper in Class B waters; however the standard for Class A waters and ground water is listed at 200 µg/L or 0.20 mg/L. In July, site 2 is slightly above at this standard level with a concentration of 0.22 mg/L.

Total Organic Carbon:

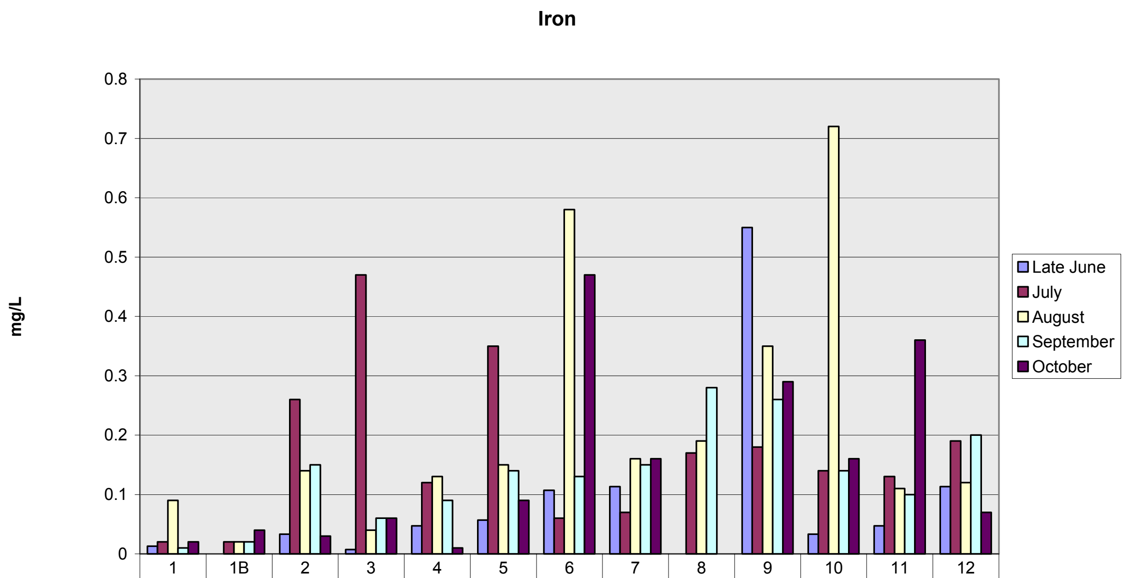


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.80		0.57	3.17	1.00	0.80	2.50	0.37		3.10	1.30	1.93	3.33
Late June	1.50		1.33	1.43	1.57	1.83	1.13	2.27	0.00	2.07	1.47	1.90	2.40
July	1.53	1.73	1.57	1.67	1.80	1.30	1.30	1.60	0.13	1.30	2.20	1.77	3.40
August	0.00	5.37	0.00	4.23	4.17	0.00	5.90	0.00	7.37	0.00	8.47	0.00	8.27
September		1.57	1.27	0.80	0.27	1.50	2.10	0.23	1.67	1.00	1.43	2.40	2.40
October	1.03	1.43	2.87			2.00	4.90					5.07	2.10

Site #

These values include both organic carbon from neutral sources and organic carbon for anthropogenic sources. Increased levels of total organic carbon could occur from industrial waste, water treatment and sewage treatment plants. Large increases are seen throughout the sites during the month of August. One possible explanation could be due to the increase in concentration due to low flows.

Iron:

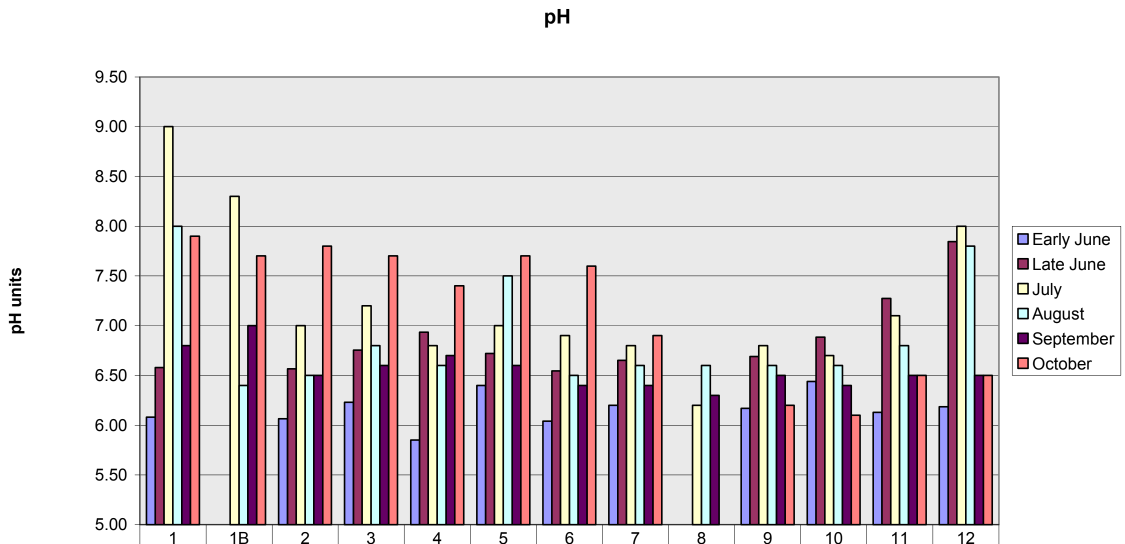


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Late June	0.013		0.033	0.007	0.047	0.057	0.107	0.113		0.55	0.033	0.047	0.113
July	0.02	0.02	0.26	0.47	0.12	0.35	0.06	0.07	0.17	0.18	0.14	0.13	0.19
August	0.09	0.02	0.14	0.04	0.13	0.15	0.58	0.16	0.19	0.35	0.72	0.11	0.12
September	0.01	0.02	0.15	0.06	0.09	0.14	0.13	0.15	0.28	0.26	0.14	0.1	0.2
October	0.02	0.04	0.03	0.06	0.01	0.09	0.47	0.16		0.29	0.16	0.36	0.07

Site #

The presence of iron can occur naturally in bedrock or can be caused by pollution from sources such as mines. Iron can also occur when iron salts coming from areas where large amounts of organic material cause reducing potentials in the subsoil water generally in conditions where the pH is low, this forms a solution of ferrous bicarbonate. When this solution reaches the open stream, carbon dioxide is lost, the pH rises and the ferrous iron is oxidized, and ferric hydroxide is deposited as a flocculent brown film (Hynes, 2001). The NYS DEC standard for Iron in class B waters is 300 µg/L or 0.30 mg/L. In late June, site 9 was above the DEC standard range with a concentration of 0.55 mg/L. Sites 3 and 5 for the July sampling dates also fall above the DEC standard with concentrations at spikes above the DEC standard range are also seen in August on sites 6, 9, and 10. During the September sampling, all sites were within range of the DEC standard. In October, spikes above the standard range were seen at sites 6 and 11.

pH:

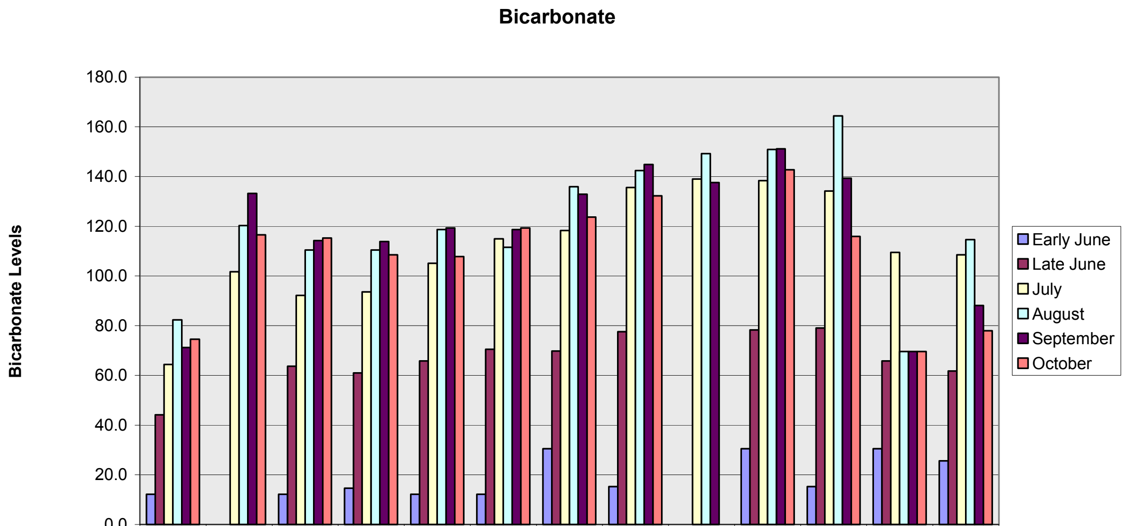


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	6.08		6.07	6.23	5.85	6.40	6.04	6.20		6.17	6.44	6.13	6.19
Late June	6.58		6.57	6.76	6.94	6.72	6.55	6.65		6.69	6.89	7.28	7.85
July	9.0	8.3	7.0	7.2	6.8	7.0	6.9	6.8	6.2	6.8	6.7	7.1	8.0
August	8.0	6.4	6.5	6.8	6.6	7.5	6.5	6.6	6.6	6.6	6.6	6.8	7.8
September	6.8	7.0	6.5	6.6	6.7	6.6	6.4	6.4	6.3	6.5	6.4	6.5	6.5
October	7.9	7.7	7.8	7.7	7.4	7.7	7.6	6.9		6.2	6.1	6.5	6.5

Site #

According to the NYS DEC Water Quality regulations, the pH shall not be less than 6.5 or more than 8.5 for class B streams. Most aquatic species prefer a pH near neutral, but can withstand a pH in the range of about 6 – 8.5 (V. Novotny and G. Chesters). During the early June, Sites 1 – 12 did not fall within the range of the DEC standards for class B streams. For late June, the pHs were within normal range. During July, Site 1 had a very high pH of 9.0. Site 8 for July had a pH of 6.2, which is just below the DEC standard. For the August sampling date the pH ranges were within the DEC standards. For the September sampling date, Site 8 and site 10 had pHs just below the standard range. For the October sampling date site 9 and 10 were below the DEC standard range for Class B streams.

Bicarbonate:



	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	12.2		12.2	14.6	12.2	12.2	30.5	15.3		30.5	15.3	30.5	25.6
Late June	44.1		63.7	61.0	65.8	70.5	69.8	77.6		78.3	79.0	65.8	61.7
July	64.4	101.7	92.2	93.6	105.1	114.9	118.3	135.6	139.0	138.3	134.2	109.5	108.5
August	82.4	120.3	110.5	110.5	118.7	111.5	135.9	142.4	149.2	150.9	164.4	69.6	114.6
September	71.2	133.2	114.2	113.9	119.3	118.7	132.9	144.8	137.6	151.2	139.3	69.6	88.1
October	74.6	116.6	115.3	108.5	107.8	119.3	123.7	132.2		142.7	115.9	69.6	78.0

Site Number

Bicarbonate can exist in the water column from a variety of sources. Bicarbonate can occur from water which has percolated through the soil which is rich in carbon dioxide and similarly rich in hydrogen ions (Hynes). This can be seen by the relationship:

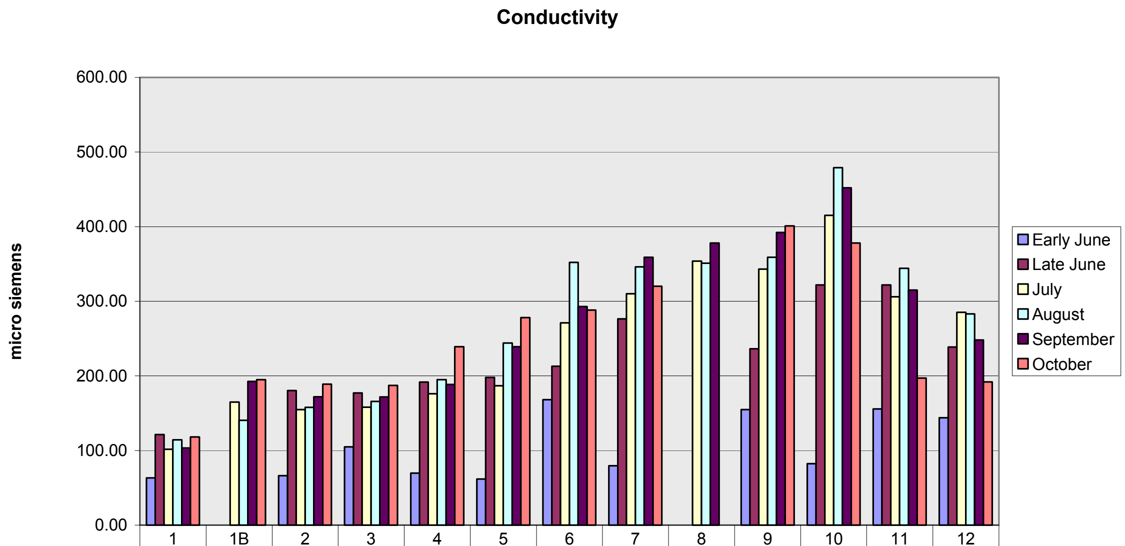
$$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

Bicarbonate is also present largely due to calcium carbonate. Calcium carbonate is a common constituent of many rocks including limestone. Calcium carbonate is soluble in carbonic acid and it has the relationship:

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2 \rightarrow Ca^{2+} + 2HCO_3^-$$

Higher levels of bicarbonate are seen during the warmer months, this is most likely due to its increase in solubility due to warmer waters. Bicarbonate plays an important role in streams due to its buffering capacity. Bicarbonate contributes to the alkalinity in the stream and helps to stabilize the pH.

Conductivity:

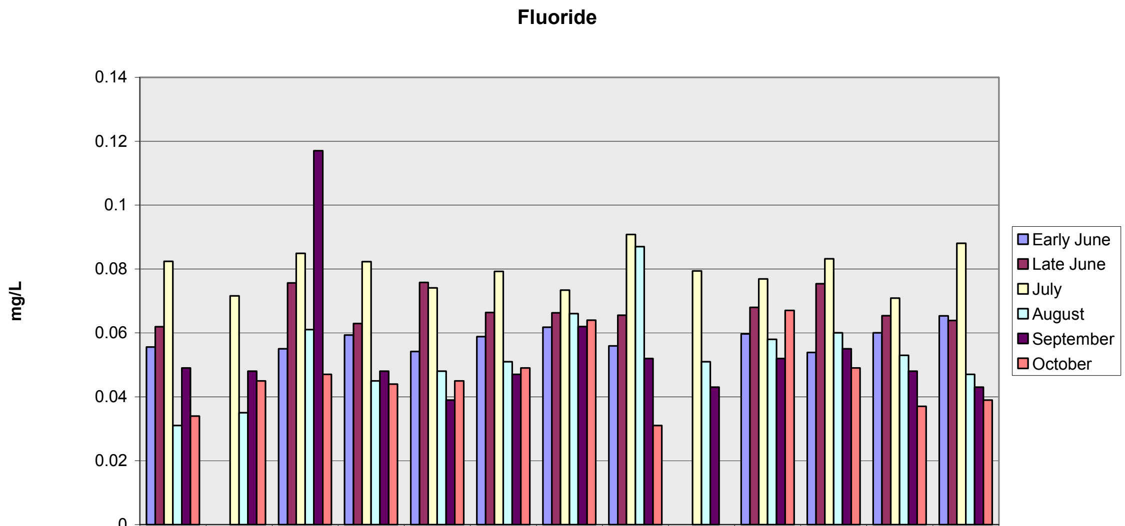


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	63.30		66.30	104.70	69.65	61.70	168.05	79.50		154.80	82.20	155.60	143.70
Late June	121.40		180.30	177.10	191.60	198.00	212.75	276.50	0.00	236.50	322.00	322.00	238.50
July	101.5	164.9	155.0	158.0	176.0	186.7	271.0	310.0	354.0	343.0	415.0	306	285.0
August	114	140	158	166	195	244	352	346	351	359	479	344	283
September	103.4	192.5	171.9	171.6	188.5	239	293	359	378	392	452	315	248
October	118.0	195.0	189.0	187.0	239.0	278	288	320		401	378	197	192

Site #

Conductivity is a measure of the total dissolved solids that are suspended in the water column. There is a significant increasing trend moving downstream from Marbletown to Lake Katrine. The highest levels of conductivity are found at the sites located in Kingston. This is due to the increased amount of impervious surfaces that are associated with more industrialized and urbanized areas. The source of the total dissolved solids that allow for the measurement of conductivity is primarily runoff consisting of road salt, and any salt substances that are used in industrial and urbanized areas. The values decrease as the sites near Lake Katrine, which is mostly a residential area, increasing the amount of porous surfaces, reducing runoff.

Fluoride:

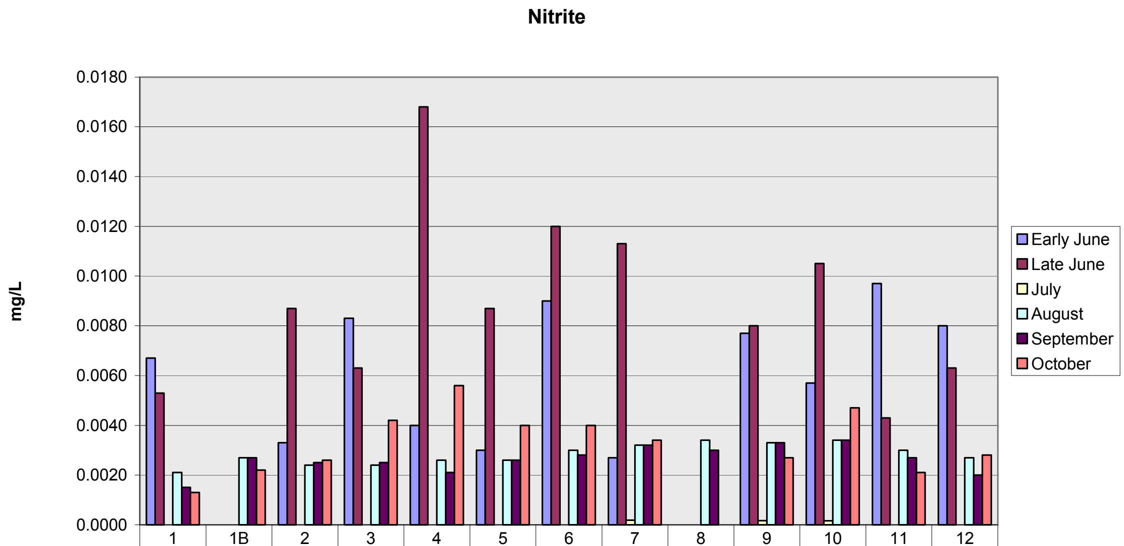


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.0556		0.055	0.0593	0.0542	0.0588	0.0618	0.0559		0.0597	0.0539	0.06	0.0653
Late June	0.0619		0.0756	0.0629	0.0758	0.0664	0.0663	0.0655		0.068	0.0754	0.0654	0.0639
July	0.0824	0.0716	0.0849	0.0823	0.0741	0.0792	0.0734	0.0908	0.0794	0.0769	0.0832	0.0709	0.0881
August	0.031	0.035	0.061	0.045	0.048	0.051	0.066	0.087	0.051	0.058	0.06	0.053	0.047
September	0.049	0.048	0.117	0.048	0.039	0.047	0.062	0.052	0.043	0.052	0.055	0.048	0.043
October	0.034	0.045	0.047	0.044	0.045	0.049	0.064	0.031		0.067	0.049	0.037	0.039

Site #

The standard for Fluoride as set by the DEC is 1.5 ppm for potable water. There was no standard given for Class B streams. All results are well below the drinking water standard. Fluoride can enter the groundwater through contact with fluorine containing rocks and minerals, as well as through pollutants such as refrigerants, plastics, and pesticides.

Nitrite:

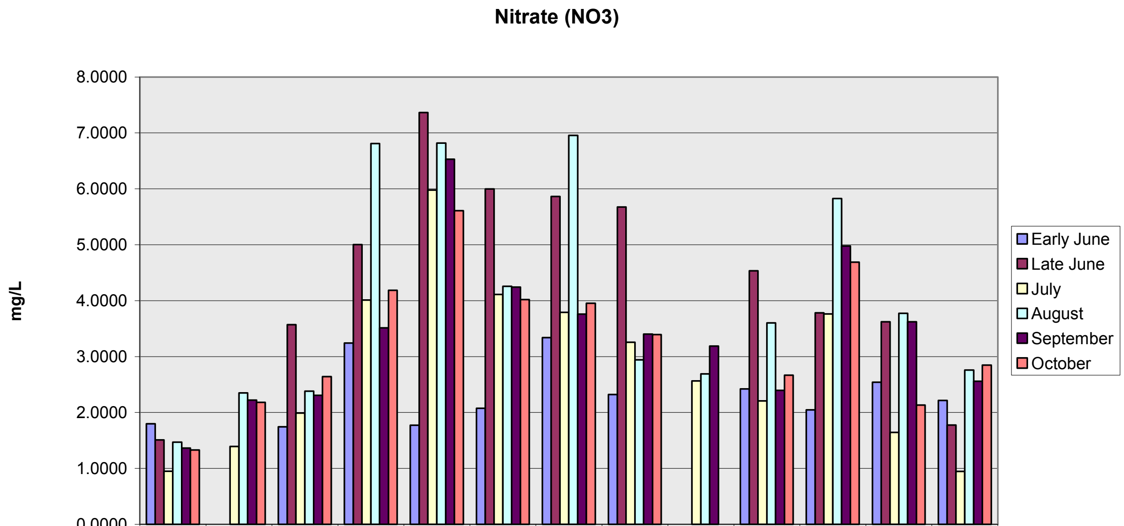


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.0067		0.0033	0.0083	0.0040	0.0030	0.0090	0.0027		0.0077	0.0057	0.0097	0.0080
Late June	0.0053		0.0087	0.0063	0.0168	0.0087	0.0120	0.0113		0.0080	0.0105	0.0043	0.0063
July								0.00019		0.00017	0.00016		
August	0.0021	0.0027	0.0024	0.0024	0.0026	0.0026	0.0030	0.0032	0.0034	0.0033	0.0034	0.0030	0.0027
September	0.0015	0.0027	0.0025	0.0025	0.0021	0.0026	0.0028	0.0032	0.0030	0.0033	0.0034	0.0027	0.0020
October	0.0013	0.0022	0.0026	0.0042	0.0056	0.0040	0.0040	0.0034		0.0027	0.0047	0.0021	0.0028

Site #

The standard for nitrite as set by the DEC is 0.1 mg/L for warm water fishery waters and 0.02 mg/L for cold-water fishery waters. All values are well below the standard. The values for nitrite spike at the sites within the town of Hurley. This area is primarily used for agricultural purposes. Because fertilizer is high in nitrogen based substances, the runoff that comes from the farms would be rich in nitrite.

Nitrate:

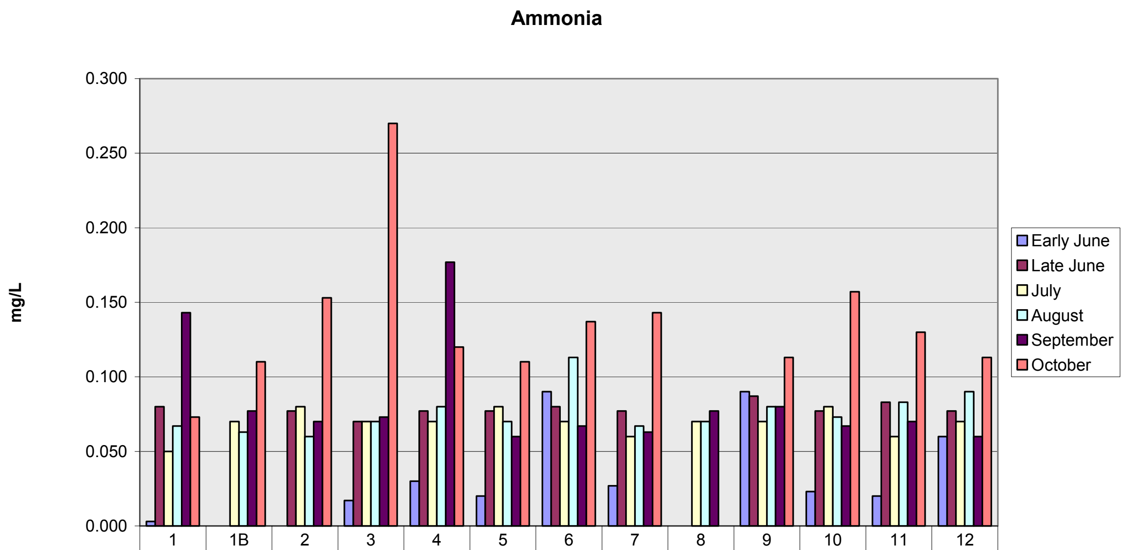


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	1.7984		1.7447	3.2401	1.7739	2.0773	3.3395	2.3217		2.4221	2.0467	2.5414	2.2182
Late June	1.5083		3.5711	5.0033	7.3648	5.9960	5.8621	5.6741		4.5339	3.7831	3.6227	1.7751
July	0.9500	1.3933	1.9906	4.0117	5.9774	4.1113	3.7895	3.2552	2.5616	2.2043	3.7606	1.6413	0.9445
August	1.468	2.349	2.383	6.809	6.82	4.257	6.957	2.941	2.691	3.6040	5.826	3.772	2.757
September	1.3650	2.22	2.3070	3.5140	6.5310	4.2420	3.7580	3.4020	3.1880	2.3980	4.9800	3.6220	2.5610
October	1.3280	2.181	2.6420	4.1840	5.6110	4.0180	3.9530	3.3930		2.6690	4.6880	2.1340	2.8480

Site #

The standard for nitrate as set by the EPA is 10 mg/L for potable water. There is no standard found for class B streams. All results are well below the standard for drinking water. The results for Nitrate are very similar to that of Nitrite. Nitrate also spikes around the agricultural areas along the Esopus Creek. This indicates that the most likely source for Nitrate is also agricultural runoff.

Ammonia:

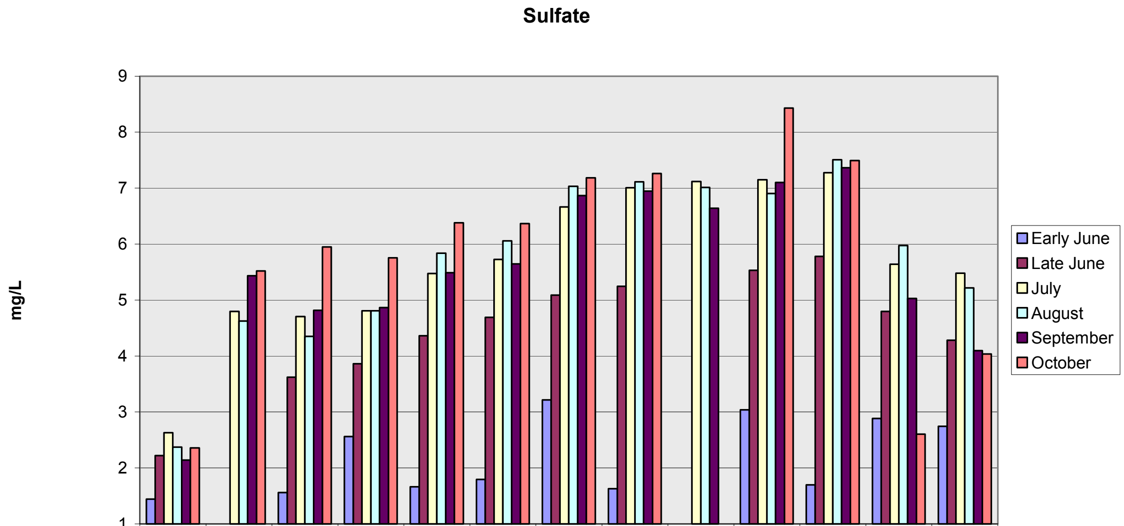


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.003		0.000	0.017	0.030	0.020	0.090	0.027		0.090	0.023	0.020	0.060
Late June	0.080		0.077	0.070	0.077	0.077	0.080	0.077		0.087	0.077	0.083	0.077
July	0.05	0.07	0.08	0.07	0.07	0.08	0.07	0.06	0.07	0.07	0.08	0.06	0.07
August	0.067	0.063	0.060	0.070	0.080	0.070	0.113	0.067	0.070	0.080	0.073	0.083	0.090
September	0.143	0.077	0.070	0.073	0.177	0.060	0.067	0.063	0.077	0.080	0.067	0.070	0.060
October	0.073	0.110	0.153	0.270	0.120	0.110	0.137	0.143		0.113	0.157	0.130	0.113

Site #

The standard for ammonia as set by the DEC for Class B waters varies with both pH and temperature. The lowest possible standard is for pH 6.5 from 15-30 $^{\circ}$C at 1.9 mg/L. All results are well below this level. The trends for ammonia show two spikes, one in the agricultural areas (sites 1-5) and the second in the industrial area (sites 6-12). The highest spikes occur during the October sampling date at site 3 and site 10. Possible sources for these spikes are agricultural runoff at site 3, and industrial runoff at site 10.

Sulfate:

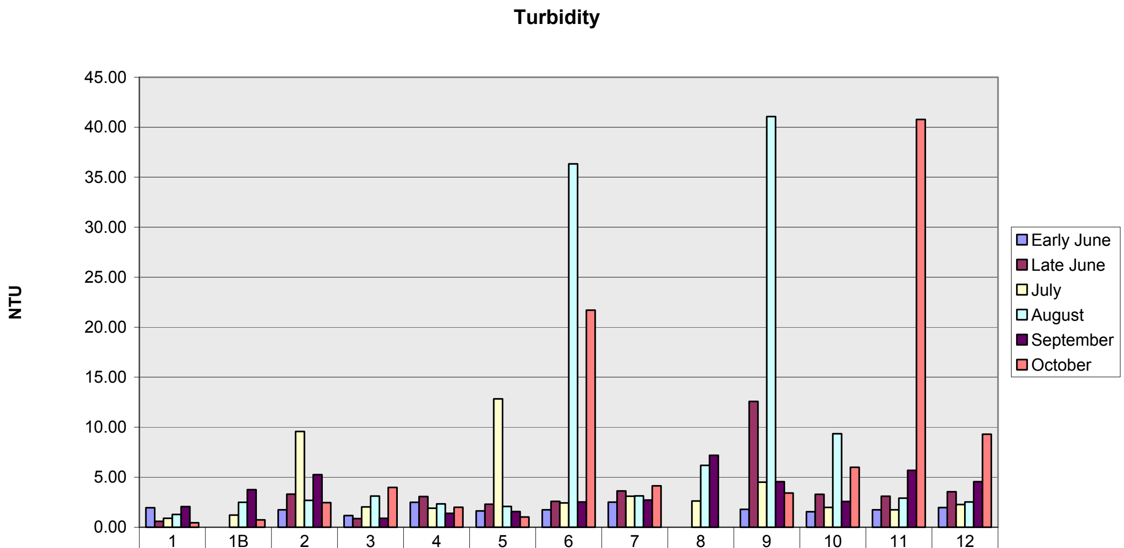


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	1.4452		1.5591	2.558	1.6626	1.7932	3.2182	1.6298		3.0394	1.695	2.8859	2.7435
Late June	2.2193		3.6194	3.8621	4.3615	4.6885	5.0884	5.2467		5.5299	5.7803	4.7989	4.2824
July	2.6277	4.7977	4.7056	4.8099	5.4713	5.7257	6.6639	7.0058	7.1201	7.1484	7.276	5.6386	5.4791
August	2.371	4.626	4.349	4.809	5.836	6.056	7.031	7.111	7.010	6.903	7.506	5.976	5.217
September	2.140	5.432	4.817	4.867	5.488	5.648	6.865	6.947	6.639	7.102	7.366	5.029	4.096
October	2.359	5.52	5.949	5.753	6.379	6.365	7.184	7.261		8.431	7.491	2.604	4.035

Site #

Sulfur is an element common to groundwater and in many minerals in the soil. As a result, sulfates are naturally occurring in groundwater. Possible natural sources for this occurrence are the oxidation of sulfur containing minerals, such as pyrite, and the oxidation of other organic materials. Sulfates can also be present due to anthropogenic activity. The plumes from industrial areas often contain oxides that react with the sulfur naturally present in the atmosphere, thus causing acid rain (Novotny, 1981). With the slight increase in the data from site 6 to site 10, it appears that the increased urbanization and industrial nature of the City of Kingston has caused an increase in levels.

Turbidity:

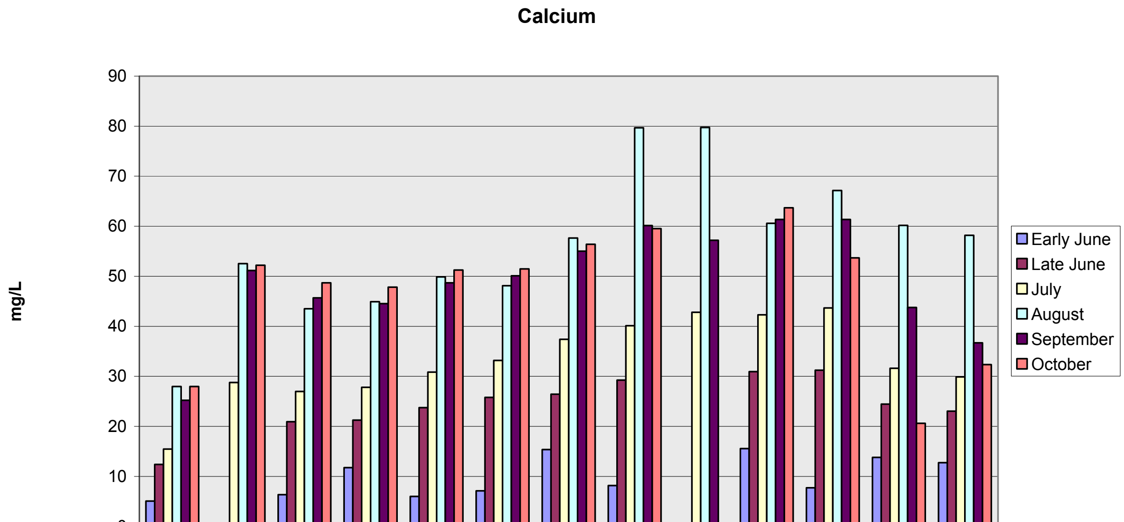


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	1.95		1.74	1.17	2.48	1.62	1.73	2.51		1.78	1.55	1.74	1.96
Late June	0.58		3.30	0.85	3.06	2.30	2.58	3.62		12.6	3.28	3.08	3.54
July	0.88	1.20	9.58	2.03	1.91	12.83	2.43	3.10	2.62	4.5	1.97	1.74	2.25
August	1.27	2.48	2.68	3.11	2.33	2.06	36.3	3.12	6.18	41.1	9.35	2.90	2.52
September	2.05	3.75	5.25	0.89	1.38	1.56	2.52	2.71	7.19	4.54	2.56	5.68	4.55
October	0.45	0.73	2.45	3.98	1.99	1.02	21.70	4.14		3.42	5.99	40.77	9.29

Site #

Turbidity is the measure of total suspended solids present in the water column. The higher the turbidity, the less light is able to penetrate the water column. This would affect the rate of photosynthesis in aquatic plants, as well as cause adverse effects on the benthic organisms living in the stream. The higher levels of iron may have contributed to the increase in values of sites 6 and 9 for the month of August. Also, on October 19, there was a rain event (see Appendix), which may have contributed to the spikes in sites 6 and 11. Upstream from site 6, the soil is primarily the Unadilla silt loam, and site 11 has Tioga fine sandy loam and a borrow pit. With increased precipitation, the soils in the borrow pit may have been disturbed and these fine grains could be carried downstream to the sampling sites.

Calcium:

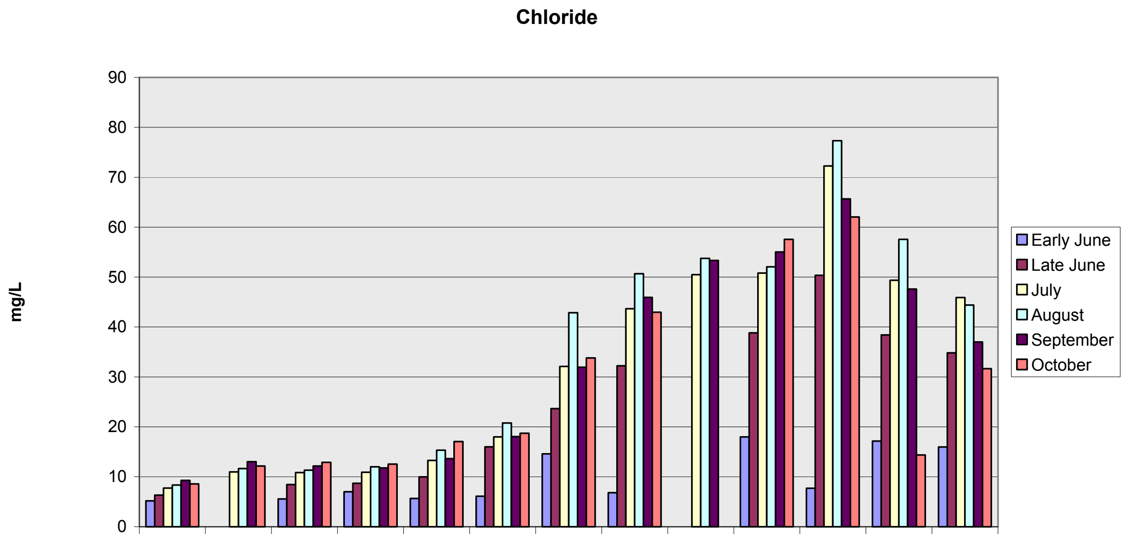


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	5.0808		6.3506	11.7482	6.0012	7.1336	15.3697	8.1554		15.5494	7.721	13.8134	12.7439
Late June	12.3977		20.9337	21.2257	23.7354	25.7821	26.4404	29.2372		30.9256	31.2418	24.4402	23.03
July	15.4594	28.763	26.9685	27.8148	30.8308	33.1836	37.3863	40.1024	42.8143	42.2858	43.6601	31.6221	29.8846
August	27.953	52.51	43.494	44.907	49.887	48.122	57.661	79.665	79.720	60.590	67.145	60.164	58.178
September	25.206	51.144	45.674	44.516	48.692	50.079	55.003	60.139	57.187	61.332	61.342	43.759	36.680
October	27.951	52.206	48.684	47.813	51.252	51.450	56.371	59.523		63.658	53.673	20.608	32.340

Site #

Calcium is a standard component of most fresh water since it is a commonly occurring element in soil and bedrock. Carbonates are very common in bedrock, and as they are weathered and dissolve, calcium is released into the soil and groundwater. Calcium is also present in road runoff (Novotny, 1981). At site 3 the stream passes by Stockbridge-Farmington gravely silt loams (SmB), which has limestone bedrock according to the Soil Survey of Ulster County, NY. The highest level of calcium was located at sites 7 and 8 in the City of Kingston area and at the golf course (site 8) in August where the totals were 79.665 mg/L and 79.720mg/L respectively. These high values for the month of August are possibly due to the low flow rate of the creek. Calcium is more soluble in the warmer waters therefore increases may be seen in the warmer months.

Chloride:

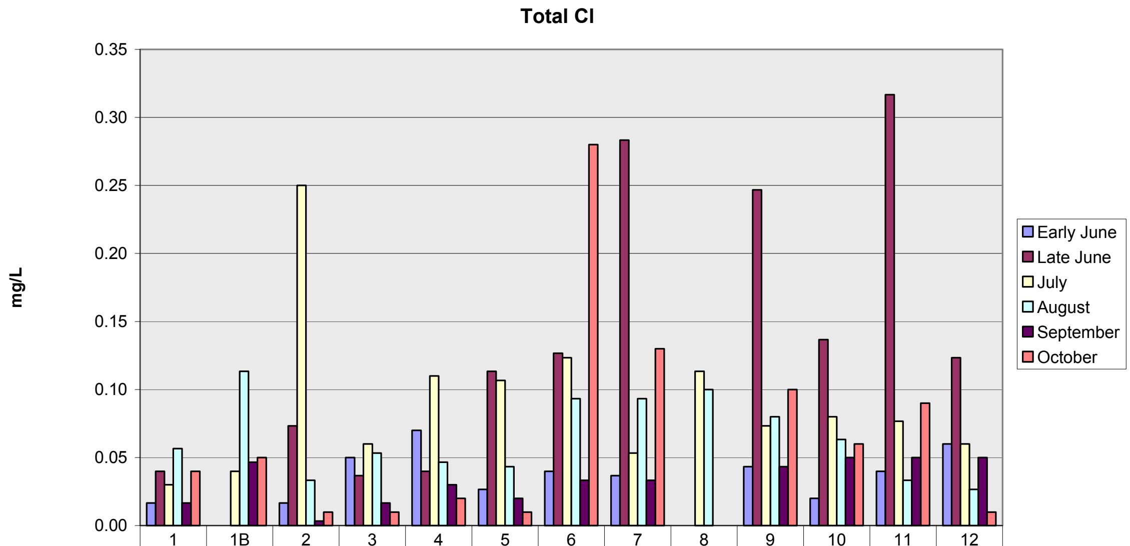


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	5.1859		5.55	7.0008	5.6461	6.1008	14.5851	6.7937		17.9941	7.7223	17.1428	15.9792
Late June	6.3259		8.4367	8.7079	9.9803	16.0209	23.6392	32.2462		38.8184	50.3606	38.4227	34.8355
July	7.7301	10.9676	10.8319	10.9121	13.2762	17.9778	32.1032	43.6539	50.4837	50.8194	72.2475	49.3591	45.9171
August	8.369	11.645	11.318	11.999	15.315	20.766	42.878	50.672	53.775	52.067	77.3	57.545	44.419
September	9.269	13.019	12.161	11.777	13.623	18.043	31.951	45.923	53.329	55.037	65.649	47.62	37.012
October	8.577	12.148	12.895	12.526	17.068	18.719	33.805	42.969		57.573	62.045	14.362	31.662

Site #

Chloride has no regulated limit in a Class B stream according to the NYSDEC Water Quality Regulations. However, the more stringent Class A regulated limit is set at 250 mg/L. The highest level measured, 77.3 mg/L at site 10 in August, falls well under the maximum contaminant level of 250 mg/L. Chloride levels can vary depending on the amount of dissolved sodium chloride or other salts such as potassium chloride. As the creek enters into the urban areas (City of Kingston), there is an increasing trend in the level of chloride present in the water. This can be attributed to the increased runoff that occurs in more urbanized areas, due to increased impervious surfaces.

Total Chlorine:

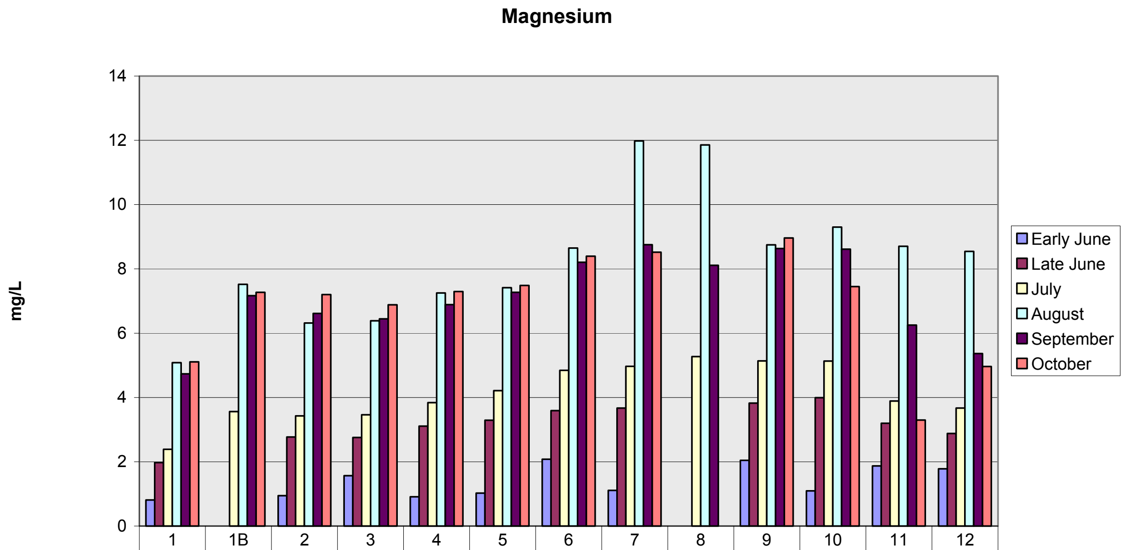


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.02		0.02	0.05	0.07	0.03	0.04	0.04		0.04	0.02	0.04	0.06
Late June	0.04		0.07	0.04	0.04	0.11	0.13	0.28		0.25	0.14	0.32	0.12
July	0.03	0.04	0.25	0.06	0.11	0.11	0.12	0.05	0.11	0.07	0.08	0.08	0.06
August	0.06	0.11	0.03	0.05	0.05	0.04	0.09	0.09	0.10	0.08	0.06	0.03	0.03
September	0.02	0.05	0.00	0.02	0.03	0.02	0.03	0.03	0.00	0.04	0.05	0.05	0.05
October	0.04	0.05	0.01	0.01	0.02	0.01	0.28	0.13		0.10	0.06	0.09	0.01

Site #

For total chlorine levels, the NYSDEC has a 5 µg/L limit for Class B waters. At every site, the chlorine levels are well above the set standards for almost every month. Possible sources for the levels of chlorine are road runoff and human activity. Chlorine is also used in certain compounds for farming, as well as in sewage treatment plants (Haslam, 1990). This could explain the spikes in both the agricultural as well as the urbanized areas along the creek. Just upstream of site 11, a sewage treatment plant is present, which may contribute to the chlorine content of the water.

Magnesium:

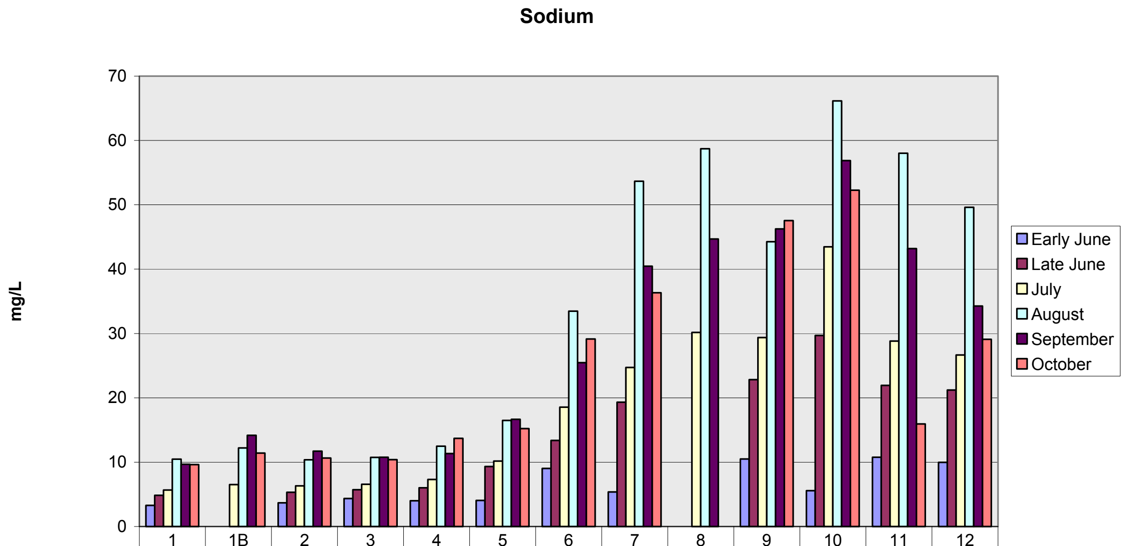


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.8067		0.9457	1.5641	0.9094	1.0239	2.0743	1.1075		2.0421	1.0891	1.8671	1.7749
Late June	1.9741		2.7675	2.7517	3.1044	3.2904	3.5886	3.6697		3.822	3.9929	3.1951	2.8787
July	2.3832	3.5599	3.4226	3.4564	3.834	4.2093	4.8438	4.9705	5.2669	5.137	5.1328	3.8846	3.6700
August	5.081	7.517	6.314	6.386	7.253	7.415	8.648	11.982	11.856	8.745	9.299	8.701	8.543
September	4.734	7.166	6.612	6.447	6.887	7.272	8.202	8.75	8.108	8.635	8.613	6.25	5.364
October	5.108	7.272	7.197	6.883	7.292	7.484	8.393	8.519		8.962	7.448	3.296	4.959

Site #

The NYSDEC does not limit magnesium in surface waters designated as Class B streams. The Class A surface water limit is set at 35 mg/L. Magnesium levels all fall below the Class A surface water limit. Magnesium is a constituent of many minerals and thus is commonly found in soils and bedrock. Magnesium Oxide is also a chemical compound found in certain types of agrochemical products. There was a slight increase in the levels of magnesium for the month of August at sites 7 (11.982 mg/L) and 8 (11.856 mg/L). This is most likely due to the increase in urbanization. Magnesium trends also appear to follow temperature and have increased levels during warmer months. Calcium and magnesium levels also appear to follow the same trend.

Sodium:



	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	3.2651		3.669	4.337	3.9993	4.0255	9.0044	5.3574		10.4896	5.5591	10.7732	9.9659
Late June	4.8348		5.3128	5.7035	5.998	9.3047	13.3639	19.3203		22.8358	29.6928	21.9291	21.2094
July	5.6682	6.4966	6.3088	6.5712	7.2962	10.1607	18.5366	24.71	30.1494	29.3515	43.4732	28.8191	26.6553
August	10.46	12.209	10.354	10.717	12.485	16.486	33.454	53.652	58.7	44.26	66.139	58.005	49.588
September	9.664	14.155	11.692	10.756	11.328	16.652	25.44	40.451	44.667	46.237	56.852	43.191	34.262
October	9.617	11.399	10.638	10.398	13.692	15.212	29.149	36.328		47.539	52.254	15.913	29.085

Site #

Sodium is found naturally in running waters from a variety of sources. It is a major constituent of many minerals, a major component of sea spray, which can be carried far inland, and appreciable amounts of sodium, can be found in rain water. The highest totals were found during the month of August. The higher concentration is most likely due to the lower flow levels during seen in August. In the later months, higher levels were also found near the City of Kingston. This may be an effect of runoff from increased urbanization.

Biological

ESOP 01

Site ESOP 01 is located off of Tongore Rd in Marbletown, NY. Algae were prevalent at this site. Ephemeroptera, Plecoptera and Trichoptera were well represented. Pteronarcyidae was present, which has a tolerance value of 0. Overall this site had a profile assessment score of 7.8 in the non-impacted category.

ESOP 02

ESOP 02 is located off of County Route 5 in Marbletown, NY. This site had an overall BAP score of 5.4 in the slightly impacted category. The lower assessment score could be due to the presence of the two impoundments upstream of the sample site. The first impoundment consisted of a stream diversion. The second impoundment, directly upstream of sampling site, was due to the streambed being utilized as a truck crossing directly. There was also a small lake, which appeared to be created by the stream diversion. Hydropsychidae and Simuliidae had the greatest abundance in the sub sample. These organisms have been found to be especially abundant below lakes (Hynes, 2001(Muller, 1954c)). The abundance of filter feeding organisms below dams may also result from the exclusion of predators ((Petts, 1984) Ward, 1976a). Both of these organisms have a tolerance value of 5. There were no stoneflies seen in the sub sample or on site.

ESOP 03

ESOP 03 was located off of Creekside Road in Hurley, NY. This site had an overall BAP score of 4.9, which just places this site in the moderately impacted category. The abundant invertebrates present here were Hydrosychidae, Chironomidae and

Empididae. These organisms have tolerance values of 5, 6, and 6, respectively. There were no stoneflies seen in the sub sample or present at the site. The lower assessment may be due to agricultural runoffs and the upstream impoundment effect.

ESOP 04

ESOP 04 is located Below the Route 29A Bridge in Hurley, NY. No stoneflies were seen at the site. This site had an overall BAP score of 5.8 and falls into the slightly impacted category. There was also an abundance of Hydropsychidae present at this site. There were forty Hydropsychidae present in the sub sample, which is the maximum number allowed by the NYSDEC. The land use was also agricultural near this site and the lower assessment may be due to runoff.

ESOP 06

ESOP 06 is located off of Van Etten Lane in Lake Katrine, NY. This site had and overall BAP score of 5.0 falling in between slightly and moderately impacted. Filamentous algae were very abundant at the time of sampling. Forty percent of the sub sample consisted of Chironomidae. The substrate present at sampling area consisted of approximately ninety-five percent bedrock. Supersaturated DO levels were present at this site. This may lead to plummeting DO levels at night limiting the survival of some organisms. Stoneflies appear to be locally extinct from ESOP 02 to ESOP 06.

ESOP 07A

ESOP 07A is located off of Rt. 9W near Glenerie, NY. This site fell into the slightly impacted category with an overall BAP score of 7.0. Stoneflies were present in the field sample but not in the sub sample. Very little algae were seen at the site. Overall, there was improved water quality.

SAWK 01

SAWK 01 is the Sawkill creek and is located near the confluence of the Esopus Creek. This site was chosen as a comparison to the Esopus Creek. This site fell into the slightly impacted category with an overall BAP score of 6.3. Chloroperlidae (stonefly) was seen in the sub sample which has a tolerance value of 0. There was a large density of organisms seen at this site. The lower assessment is most likely de to the high percentage of filter feeding caddisflies (Hydropsychidae and Philopotamidae).

Conclusion

Due to increases in population, urbanization, industry and other anthropogenic effects; regular biological stream monitoring is needed. Surface water monitoring is essential when waters are used for recreation, fishing and other human uses. Land areas hold only 2.8% of the world's total water and more than 75% of this water is locked in glacial ice or is saline (C.W. Fetter). Therefore, very little of the earth's water is available for human use. In recent years the housing and population in Ulster County and near the Esopus has increased dramatically. With an ever increasing population proper measures should be taken to protect and monitor this resource. Assessing water quality is also important to determine whether a stream meets its classification. In the Biological Assessment Profiles for the BMI studies, profiles ranged from non-impacted to falling just within the moderately impacted categories. As expected, the biological and chemical data suggest that as one moves closer to more urbanized areas the overall water quality of the stream appears to decrease. Chemical parameters such as calcium, magnesium and bicarbonate appear to be lower and of natural occurrence, whereas higher levels of constituents such as total chlorine and iron appear to be of anthropogenic nature. This may contribute to a decrease in water quality. Some sections of the stream may be limiting to fish propagation and may not meet their NYSDEC classification. Mitigation and remediation efforts might be considered to improve overall water quality.

References

Bode, Robert W., Novak, Margaret A., Lawrence, Abele E., Heitzman, Diana L., and Alexander J. Smith. *Quality Assurance Work Plan for Biological Stream Monitoring in New York State.* Stream Biomonitoring Unit, Division of Water, NYS Department of Environmental Conservation Albany, NY 2002.

Fetter, C.W. Applied Hydrogeology 4th ed. Prentice-Hall, Inc. Upper Saddle River, NJ 2001.

Haslam, S.M. River Pollution: An Ecological Perspective. John Wiley & Sons Ltd. New York, 1990.

Hynes, H.B.N. The Ecology of Running Waters. The Blackburn Press. Caldwell, 2001.

New York State Department of Environmental Conservation. *Water Quality Regulations: Surface Water and Groundwater Classifications and Standards New York State Codes, Rules and Regulations; Title 6, Chapter X Parts 700-706*. Secretary of State of New York, 1995-2000.

Levinton, Jeffrey S. and John R, Waldman, ed. The Hudson River Estuary. Cambridge, NY: Cambridge University Press, 2006.

Novotny, Vladimir, and Gordon Chesters. Handbook of Nonpoint Pollution: Sources and Management. New York: Van Nostrand Reinhold, 1981.

"Part 861: Lower Esopus Creek Drainage Basin." New York State Department of Environmental Conservation. Jan. 2008 <http://www.dec.ny.gov/regs/4553.html>.

Petts, G.E. Impounded Rivers: Perspectives for Ecological Management. John Wiley & Sons Ltd. New York, 1984.

Tornes, Lawrence A. Soil Survey of Ulster County, NY. Dept. of Agriculture, Soil Conservation Service. Washington, 1979.

United States Environmental Protection Agency. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Peripyton, Benthic Macroinvertebrates, and Fish 2nd Ed.* Washington D.C. 1999.

Modeling urbanization effects on water resources in Moodna Creek Watershed, NY: Developing a tool for community watershed management

Basic Information

Title:	Modeling urbanization effects on water resources in Moodna Creek Watershed, NY: Developing a tool for community watershed management
Project Number:	2007NY91B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	25
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	Karin Limburg, Valerie Luzadis

Publication

Modeling urbanization effects on water resources in Moodna Creek Watershed, NY: Developing a tool for community watershed management.

Karin Limburg, SUNY-ESF; Principal Investigator
Co-PI Valerie Luzadis, SUNY-ESF;
Co-PI Laura Lautz, SUNY-ESF;
Collaborator Simon Gruber, Consulting Project Manager, Orange County Water Authority.

Statement of critical regional or state water problems.

Rapid increases in population and land development of an area pose critical threats to the quantity and quality of the water resources. The Moodna Creek watershed (466 km^2) in Orange County, NY, exemplifies this growing environmental problem. As part of the fastest growing county in the state, the Moodna Creek watershed is of special concern.

At a regional scale, the water problems of the Moodna Creek watershed include potential shortages of groundwater resources for drinking water and the contamination of surface and groundwater with non-point source pollutants and nutrients. In fact, rapid urbanization in the watershed has increased the frequency of dry wells in recent years. Because a significant percentage of the water supply for the watershed and county are provided for by individual and public groundwater wells rather than artificial reservoirs, these issues are difficult to manage. The increasing demand for groundwater was the impetus for several Orange County Water Authority studies including estimation of available groundwater supplies and projections of water demands and modeling of the location and volume of municipal aquifers.

At a broader scale, degraded water quantity and quality have ramifications for the fish and wildlife that utilize the Moodna Creek and its tidal marsh, which have been designated as "irreplaceable" Significant Coastal Habitats by the New York State Coastal Management Program. The reduction in freshwater flows due to water withdrawals and degradation of water quality due to non-point source pollution potentially increases nutrient concentrations and decreases dissolved oxygen concentrations in the larger Hudson River Estuary drainage basin. The Moodna Creek watershed, which includes Stewart State Forest, Goosepond, and Schunnemunk Mountain, also plays an important role in the 'Hudson Highlands,' a greenbelt of forested mountains, lakes and streams across several counties in New York that links to a larger 'Highlands' greenbelt extending from the Appalachians in Pennsylvania to Connecticut.

Water problems arising from human activities such as development are difficult to address. Decisions about land use are made at the local scale, and the cumulative effects of development on water resources at the watershed scale are complex and rarely considered. Tools for assessing these problems, such as the use of computer simulation models of watershed/land use interactions, are often highly technical, requiring extensive environmental data and trained experts in engineering, hydrology, and planning. Land use and water resource decisions for the Moodna Creek watershed are influenced by the Orange County Department of Planning, which has developed plans for conserving open space areas in the watershed. The Orange County Water Authority has extensive data on groundwater resources for municipal supplies in the county including municipalities in the Moodna Creek watershed. However, stream discharge and on-going water quality data necessary for implementing predictive hydrological models are not available.

Accomplishments in FY2006

The following accomplishments were completed in our ***FY2006*** project:

- We compiled background information necessary for generating model land use change scenarios to run in the Generalized Watershed Loading Function model (GWLF) for the

Moodna watershed. These scenarios reflect the interests and concerns of citizen stakeholders and county government agencies including 1) sub-watersheds with proposed large residential development, 2) sub-watersheds of low to high development intensity, 3) various stormwater management techniques for different development intensities, and 4) a 'control' or no development scenario.

- We successfully ran the GWLF model showing realistic output for current land use as validated by stream flow data from the Ramapo River (a watershed similar in size and land use adjacent to the Moodna that has a USGS stream gauge).
- We engaged citizen stakeholders and representatives from government agencies in a dialogue about our computer modeling process and about how we can effectively present our work to the general public of the watershed.
- We calibrated the GWLF model with site-specific data on soils, weather patterns, and land cover/land use.

Objectives for ***FY2007***:

- Stream discharge data for the Moodna Creek watershed. A stream gauge will generate these data; we will provide and install the gauge at an appropriate location (i.e. near the mouth of the creek above the head of tide). This monitoring station can become part of county or state property. A professor, Teresa Thornton, of Mount St. Mary College, in Newburgh, NY (near Moodna watershed) committed her labor and technical expertise in maintaining the equipment after FY2007. The data can then be used for long term monitoring data and for community watershed management and planning. The minimal funds required for the long-term upkeep (after the completion of the WRI project) of the gauge (estimate of ~ $500 over several years) will be sought from county, state, and/or federal agencies.
- Simulated groundwater and surface water flows (spatially and hydrologically distributed) for the Moodna watershed using the land use change scenarios developed by the stakeholders in the FY2006 project. In FY2007, we propose to use the models SWAT and MODFLOW, which are hydrologically distributed and have a high spatial resolution. The results from SWAT and MODFLOW can be used for predictive decision-making such as determining appropriate areas for conservation and development, necessary to provide stimulate economic growth and maintain reliable water quantity. In order to run these more detailed models, stream discharge data are required for calibrating and validating the model. The stream gauge that we propose to purchase and install in the Moodna watershed will provide these stream discharge data.
- A user-friendly interface will be added to the linked models so that non-technical watershed stakeholders (such as members of the Moodna Watershed Coalition) can be trained to use the models for community watershed management projects. Both SWAT and MODFLOW are free-ware models that can be 'bundled' and operated via a graphical user interface including certain model parameter values unavailable for modification. This ensures that individuals without modeling experience can run the model with minimal, site-specific parameter values.
- Estimates of drinking water demands and associated groundwater withdrawals for the different modeled land use change scenarios.
- We will also provide modeled projections that reflect potential climate change effects on weather patterns and resulting altered hydrology of the watershed.

13. Related Work

Hydrological models are useful tools for understanding and predicting the effects of human activities on watersheds. Models range from simplistic estimations such as event-based rainfall-runoff models to highly complex site-specific systems models (Voinov et al. 1999). These models vary in terms of their spatial refinement, input data requirements, complexity of hydrological processes simulated, and type of modeling such as numerical vs. mechanistic. Heuristic and broad policy guidance applications require less robust model calibration and validation as the simulated processes are based on more simplistic relationships. For predictive management applications, more complex, spatially explicit models are required. SWAT and MODFLOW provide more spatially and hydrologically refined estimates of watershed processes. SWAT and MODFLOW have been used extensively as stand-alone models (Borah and Bera 2003, Barlow and Harbaugh 2006). SWAT has been used for simulations of surface water responses to agriculture including estimation of pesticides in runoff and development. MODFLOW has been used for a wide range of applications including groundwater flow dynamics, delineation of public well protection areas, and hyporheic interactions with ground and surface water. Their utility as linked models simulating both surface and groundwater has been demonstrated in studies on watershed responses to land use change and water withdrawals (Galbiatti et al. 2006, Said 2005) and agricultural activities (Sophocleous et al. 1999). In these studies the models were used as predictive tools for community water resource management.

Watershed models have been used in community watershed management/planning (Cartwright and Connor 2003, Simonovi and Fahmy 1999, Stave 2003, Tidwell et al. 2004) as tools for predicting effects of human activities on water resources and for educating and engaging the public in decisions at the interface of environmental science and public policy. In the Hudson River watershed and estuary, watershed models have been used for informing watershed management such as GWLF for estimating nutrient and sediment flows (Howarth et al. 1991) and HSPF for estimating water budgets for the Rondout/Wallkill watersheds (Chan et al. 2003). More direct use of watershed models as tools for management and planning efforts include occurred in the Fishkill watershed of the Hudson. In Limburg et al.'s study (2005) a land use/economic/biophysical model was created to predict the effects of a new large-scale business on the water quality and biological community of the Fishkill Creek. In our proposed study, the linked hydrological models (SWAT and MODFLOW) will be used as a tool for watershed management and planning policies related to meeting human demands for water and assessing the effects of human activities (e.g. development) on the future supply of water.

Principal findings or significant results.

- The model **GWLF** was used to estimate the effect of land use change on the hydrology and water quality of the Moodna Creek watershed. The model simulating hydrology was run for different land use scenarios: 100% forested, 100% urban, current land use, and 15% increase in urbanized land from c urrent land use ('15% buildout'). Preliminary results from this first phase of the project show that a 15% increase in the urban land, reduces groundwater flows in the sub-basins. The sub-basins with the highest amount of urbanized land (e.g. Silver Stream) show the greatest decrease in groundwater compared to their groundwater flows for the current land use scenario. Groundwater flows are highest for the 100% forested scenario while runoff rates are much higher for the 100% urbanized scenario. The water quality model showed trends of increasing chloride concentrations in stream water with increasing % of urbanized land. A relationship was also found between increasing nutrient concentrations with increasing % of agriculture land. Nutrient concentrations were also higher in urbanized land compared to sub-basins dominated by forested land.
    - These preliminary results represent simulations only and have not been validated with measured streamflow data in the Moodna. The next step in the project is to validate the modeled results with measured streamflow and water quality monitoring data from a nearby analog watershed, the Ramapo watershed (outlet at Suffern, NY). Because these results have not been validated it is important to consider them as preliminary only;

their value is in presenting general trends of hydrology and water quality that may be expected for the different land use scenarios tested.
    - A more technical and detailed description of this watershed modeling work, including input data, land use maps, and modeling results is presented in Appendix A.
    - The next tasks of the first phase of the modeling project involve running the nutrient and sediment component of GWLF for the four different land use change scenarios. In the second phase, the modeled results will also be validated with data from the Ramapo watershed in New York.
- The second phase of the project is the installation of a stream gage along the Moodna Creek outlet (See Appendix A, Figure 23) and the calibration and validation of a physically-distributed, water routing model (surface and subsurface flows). This more data intensive, spatially-explicit watershed model will better inform water and land resource management for the watershed. A stream gage data on the Moodna will also provide important hydrological data for characterizing the watershed and how it may change with increased urbanization (i.e. increase in impervious area and withdrawals from groundwater), including, peak discharge or streamflow that can be used to develop flood frequencies for the watershed. Flood frequency analyses will allow the calculation of probabilities of exceeding peak flow rates, in this way predicting flood recurrences. An understanding of how these relate to changes in land use patterns is therefore another useful tool for developing future water and land resource management. For example, predicted streamflow rates for different land use change scenarios can be compared to measured discharge rates representing flooded conditions. The stream gage site was identified, and permission from the Town of New Windsor was granted for access and installation. The gage is scheduled for installation for 2008. The modeling work will be completed in 2009 and 2010.

Notable achievements.

- Further refinement, calibration, and running of GWLF for the Moodna watershed;
- Site determination and permission for installation of a stream gage.
- Technical report written to be incorporated into the Moodna Creek Watershed Management Plan.

Student support

Academic and research support was provided for Molly Ramsey during the fall and spring semesters (2006-7), a Master's student in the Environmental Science Graduate Program at SUNY College of Environmental Science and Forestry, Syracuse, NY. Financial support included tuition, salary, and travel expenses. A thesis is in preparation.

Funds were used to support travel to and participation in the biennial conference of the United States Society for Ecological Economics, where Ms. Ramsey presented her work as an oral paper. Funds were also used to support her travel to Orange County from Syracuse, NY, to scope out potential sites for installation of a stream gage.

Appendix A:

Watershed Modeling: Estimating Impact of Future Land Use Change on Water Quantity and Quality in Moodna Creek Watershed, Orange County, NY

Molly Ramsey, SUNY College of Environmental Science and Forestry

Watershed Models

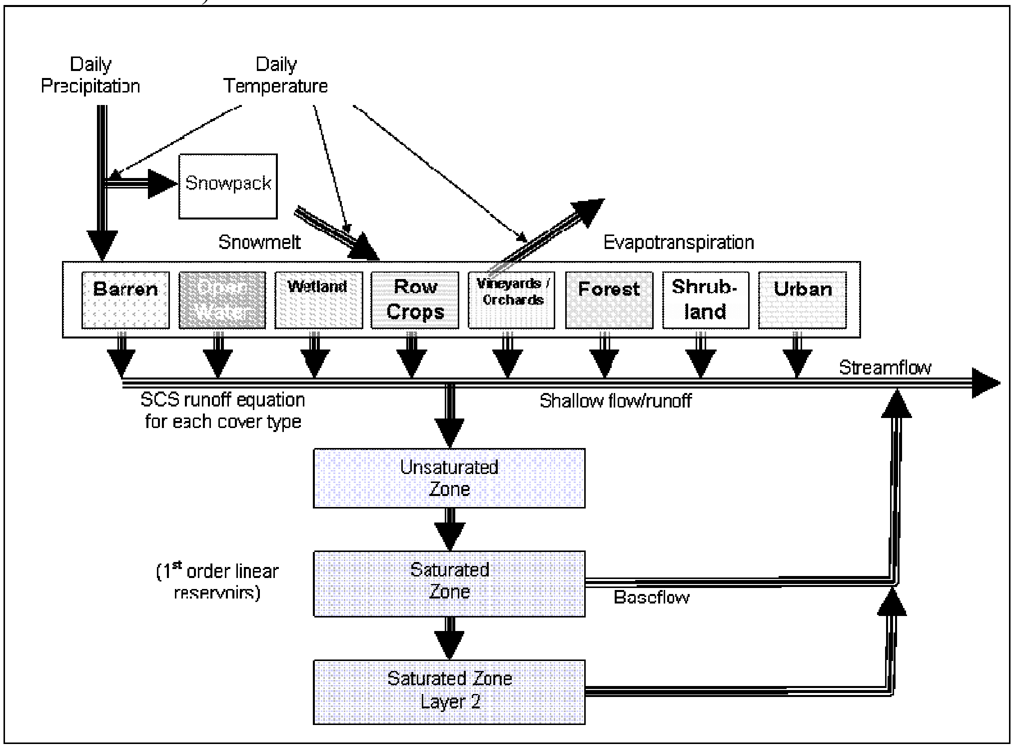
Generalized Watershed Loading Function Model

The Generalized Watershed Loading Function model (GWLF) is a hydrologic model that simulates water (including stream water flow, infiltration, runoff, and storage; groundwater will be estimated by difference) and loading of sediments and nutrients to receiving watersheds. Although the model is not spatially explicit, spatial approximations can be made by breaking up the watershed into sub-catchments and running the model separately in each of these. The model can be used to represent multiple land uses including forest, wetland, meadow, and urban with varying degrees of imperviousness. Output is simulated on a daily time step and averaged on monthly and annual time steps. Key model parameters are the Soil Conservation Service curve number for simulating runoff and the Universal Soil Loss Equation for simulating erosion. A schematic of the model is included in **Figure 1**.

The model has been used for similar purposes, although it has been more widely used for simulating sediment and nutrient loads, including the Hudson River (Swaney et al. 1996), the Choptank River (Lee et al. 2000, 2001), and the Susquehanna River (Chang et al. 2001). Similar studies estimating freshwater discharge, sediment and organic carbon loads from tributaries of the Hudson River reported that the GWLF model gave similar results to measured rates (Howarth et al. 1991, Swaney et al. 1996).

The model used in this project was actually the Regional Nutrient Management (ReNuMa) Model, a recently-developed model, based on GWLF (http://www.eeb.cornell.edu/biogeo/nanc/usda/renuma.htm; Swaney and Hong 2007). The hydrological framework of ReNuMa is the same as GWLF. The advantage to using ReNuMa for this project is that the model could be run a single time for all of the sub-watersheds, i.e. it could be run in batch-mode. A hydrologic connectivity sub-routine is built into ReNuMa that is not part of GWLF, therefore, hydrological inputs from the different subwatersheds were routed to downstream subwatersheds and considered in their output.

Figure 1: Schematic of the model, Generalized Watershed Loading Function (GWLF) Model (Haith and Shoemaker 1987).



Land Use Change Scenarios

Generalized Watershed Loading Function (GWLF) Model

Four different land use change scenarios were run in the GWLF model:

1) all forested
2) all urbanized (i.e. 100% impervious surface)
3) current land use pattern, based on 2001 National Land Use Dataset
4) 15% increase in urbanization.

These scenarios were applied to the major subwatersheds of the Moodna (**Figure 2**). GWLF has a range of 7 different land uses (with corresponding model parameter values such as runoff curve numbers, erosion coefficients) including open water, developed/urban, planted/cultivated, shrubland, barrenland, and forested. **Figure 3** is a map of the land use pattern used in GWLF representing the current land use of the Moodna watershed based on the 2001 National Land Use Dataset. **Figures 4** and **5** detail the acreage and proportion of land use in the watershed. Model input data is described in **Table 1**.

Figure 2: Subwatershed designation for Moodna Creek Watershed. The 14 subwatersheds simulated in the watershed models include the Moodna Creek Outlet, Moodna Creek 2, Silver Stream, Mineral Spring Brook, Woodbury Creek, Moodna Creek 3, Moodna Creek 4, Perry Creek, Satterly Creek, Cromline Creek, Otter Kill, Seeley Brook, Trout Brook, and Black Meadow Creek.

Figure 3: Classification of current land use pattern for GWLF, based on 2001 National Land Use Dataset

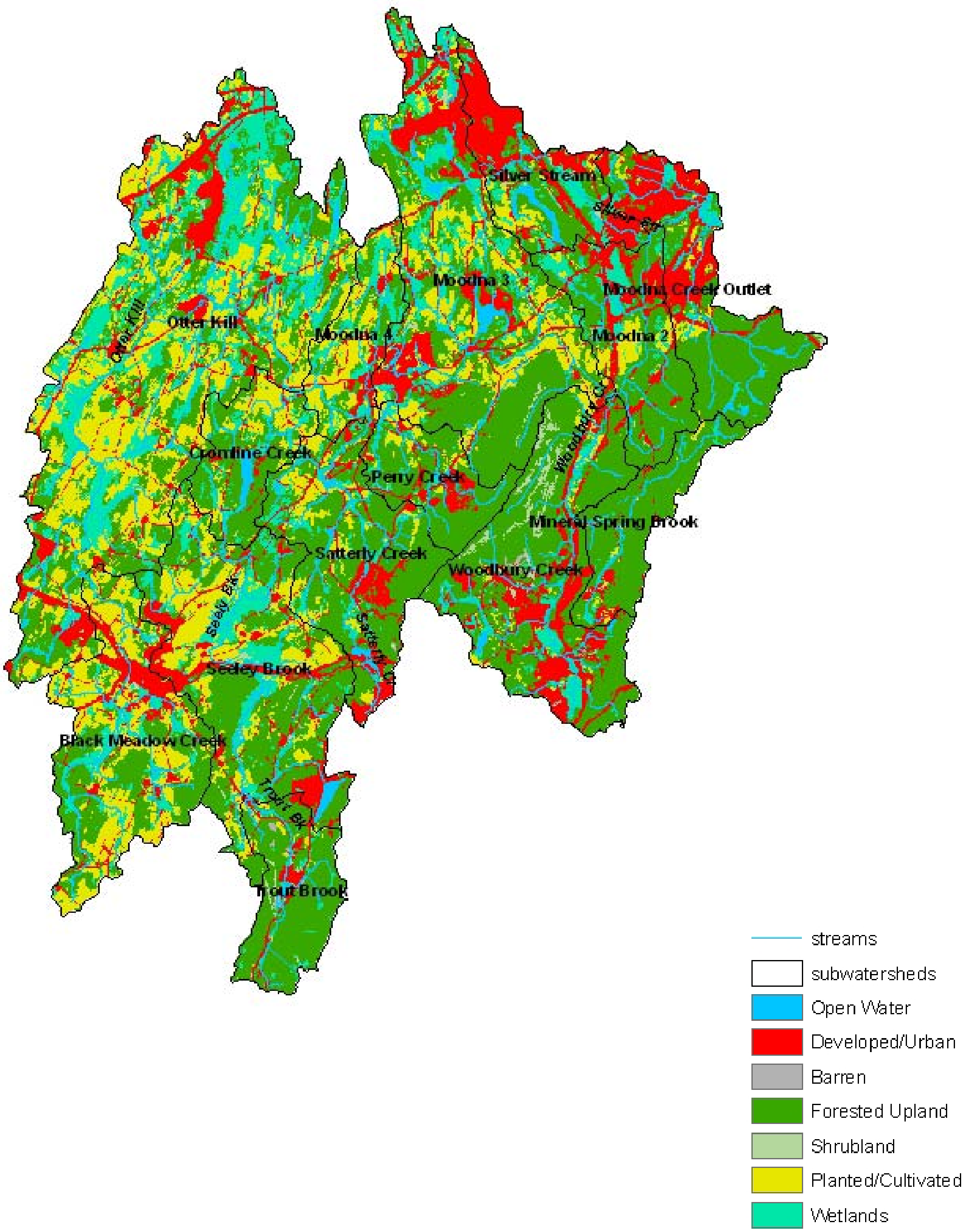


Table 1: Data Inputs to GWLF model.

Model Parameter	Input Value
Weather	Westpoint, NY (1990 – 2006); NOAA
Recession Constant	0.2
Erosivity Coefficient	0.68 (May – Oct)) 0.18 (Nov – April)
Sediment Delivery Ratio	0.1
Runoff Curve Number	Planted/Cultivated = 72 Orchards/Vineyards = 58 Shrubland = 48 Barren = 82 Forested Upland = 55 Developed/Urban = 98 Open Water = 100 Wetlands = 100
Evapotranspiration Cover Factor	0.9 (November - April) 1.0 (May – October)

Figure 4: Size and land use pattern of subwatersheds in Moodna Creek watershed.

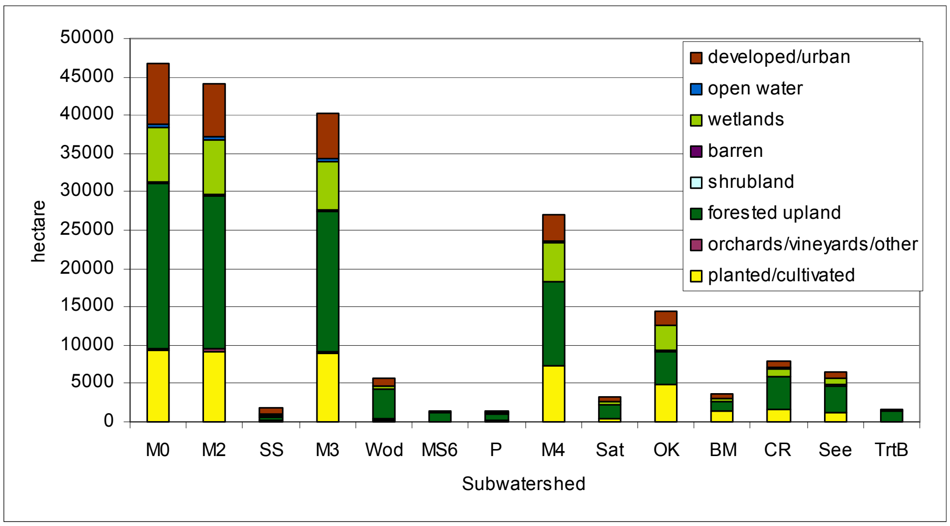
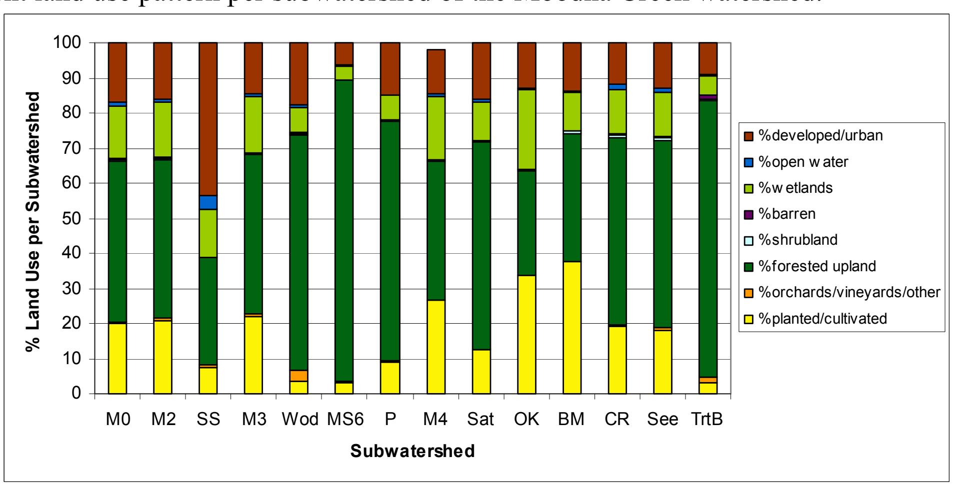


Figure 5: Current land use pattern per subwatershed of the Moodna Creek watershed.



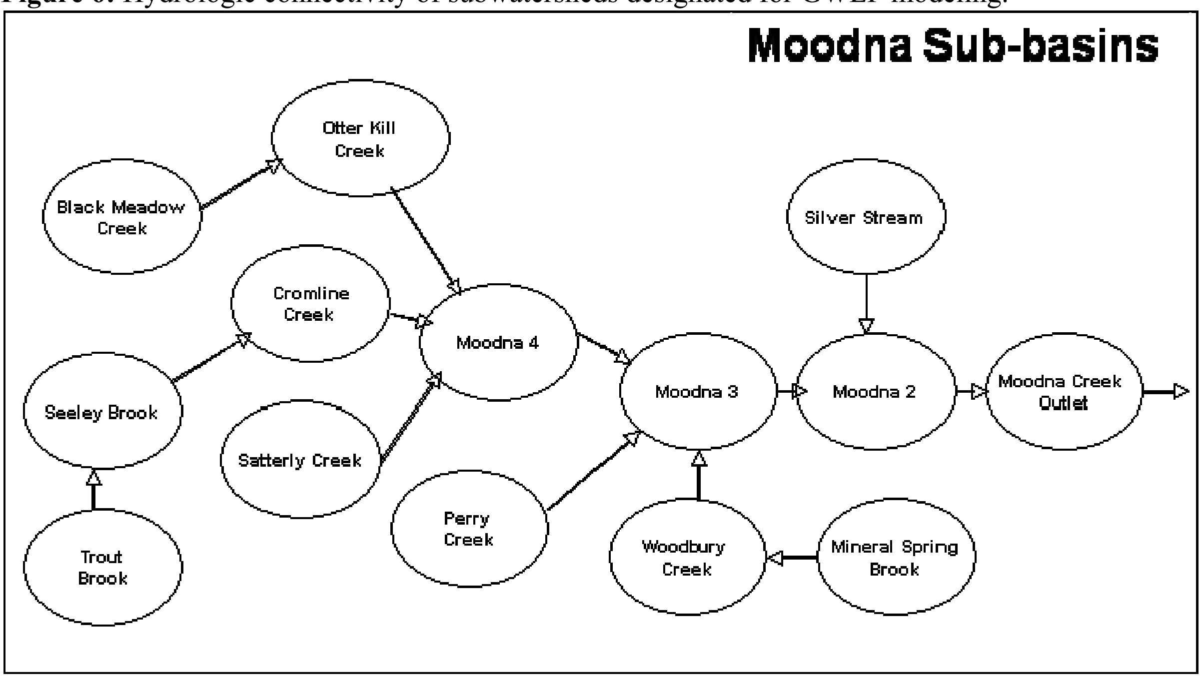
Spatial Aggregation in GWLF

The streamflow, runoff, and groundwater simulated by GWLF represents conditions at the outflow of a subcatchment. Each subcatchment has one simulated streamflow, runoff, and groundwater rate per time-step. The different land uses within each subcatchment affect hydrological conditions; for example, runoff rates will be higher in subcatchments where a higher percentage of the land surface is developed versus a subcatchment dominated by forest.

The Moodna watershed was designated into 14 different sub-basins (**Figure 6**). Model output is generated for each of these 14 sub-basins.

GWLF is not a physically-distributed model; the consideration of land use effects with respect to watershed position, recharge areas, proximity to stream channel within a subcatchment cannot be evaluated using GWLF.

Figure 6: Hydrologic connectivity of subwatersheds designated for GWLF modeling.



Preliminary Results

Hydrological Component of GWLF

Average annual groundwater rates (**Figure 7**; averaged over 16 years based on weather record from 1990 – 2006) were slightly lower for the 15% buildout scenario compared to the current land use. The 100% impervious or urban land use had the lowest groundwater rates overall with annual average rates barely above zero. The 100% forested scenario had the highest groundwater rates. The subcatchments varied somewhat with the Silver stream subcatchment, with the highest percentage of urbanized land, having the lowest groundwater annual average rates and the Mineral Spring Brook with the highest percentage of forested land having the highest groundwater annual average rates. Simulated streamflow rates (**Figure 8)** were consistent between subcatchments and land uses except for the 100% urban. In this land use scenario, streamflow was higher reflecting the higher runoff coefficients used for this land use in the model. As impervious surfaces cover the land in urbanized settings, precipitation hits the land surface and instead of infiltrating into the soil and potentially being stored in groundwater, the water runs off and downslope to the stream. Runoff rates were very high relative to other land use scenarios for the 100% urban (**Figure 9**). The 15% buildout had slightly higher annual average rates versus the current land use. The lowest runoff rates were for the Mineral Spring Brook subcatchment with the highest percentage of forested land and vice versa for the subcatchment with the highest percentage of urbanized land, Silver Stream.

The GWLF simulations showed only small differences between the current land use and 15% buildout for all of the subcatchments. This trend was reflected in the annual average rates as well as the monthly averages. An analysis of each subcatchment was calculated with results shown for the Moodna Outlet (**Figures 10 - 12**) and for the Silver Stream subcatchment (**Figures 14 - 16**) and the Woodbury subcatchment (**Figures 18 - 20**). Runoff ratios were also calculated and compared between land use scenarios and sub-basins. The runoff ratio is calculated by dividing runoff by precipitation, this can indicate the type of climate of the sub-basin (e.g. hotter climates have higher evapotranspiration and so less runoff vs. precipitation) or the amount of impervious or disturbed land surface resulting in higher runoff rates. **Figure 13** shows the monthly runoff ratios for the Moodna Creek Outlet with higher ratios for the 15% buildout scenario. Runoff ratios were also higher for the 15% buildout scenario in the Woodbury and Silver Stream subbasins as shown in **Figure 17** and **21.** An attempt was made to determine if there was a higher annual or monthly (not averaged) frequency of time-steps with zero groundwater or peak streamflow rates between the two scenarios but this was not found. This is most likely an artefact of the aggregated, non-spatially explicit nature of GWLF. As experienced in the Moodna, flooding can be localized and most likely varies with watershed topographic position and proximity to recharge areas and/or streambank. This cannot be simulated appropriately with GWLF. It is possible that with a larger buildout, more significant differences will be simulated between the land use scenarios. However, the GWLF output does support the hypothesis of a general trend of greater runoff and lower groundwater rates with increased urbanization. This modeling exercise underscored the need for a physically-based, spatially-explicit water routing model.

Figure 7: Average annual groundwater (equivalent depth per subcatchment) simulated by GWLF for the four different land use scenarios.

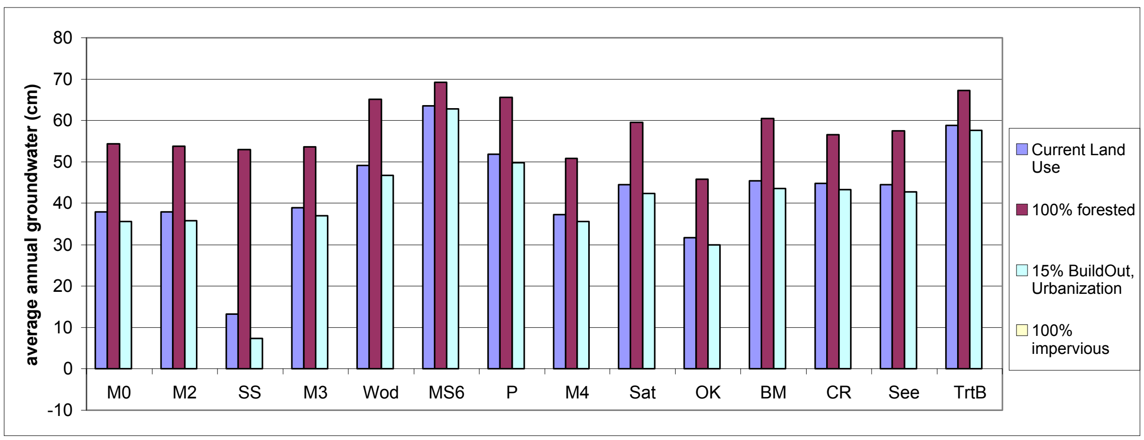


Figure 8: Average annual streamflow (equivalent depth per subcatchment) simulated by GWLF for the four different land use scenarios.

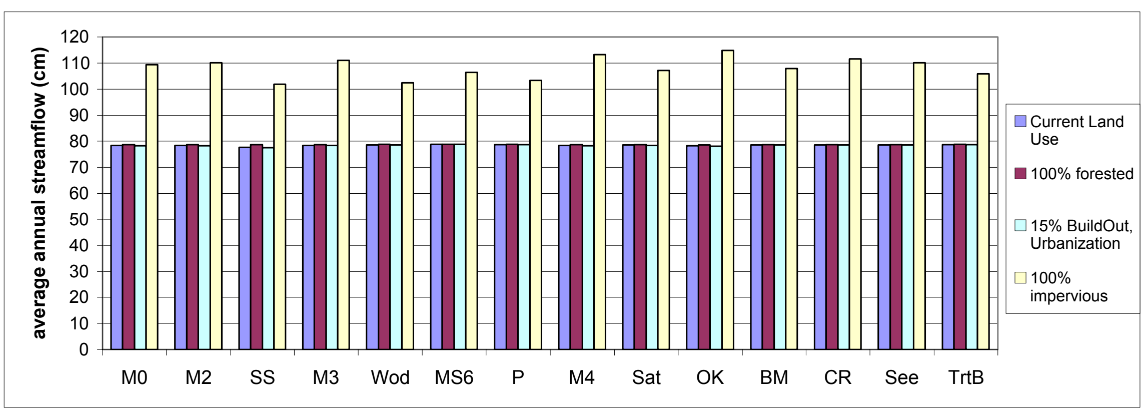


Figure 9: Average annual runoff (equivalent depth per subcatchment) simulated by GWLF for the four different land use scenarios.

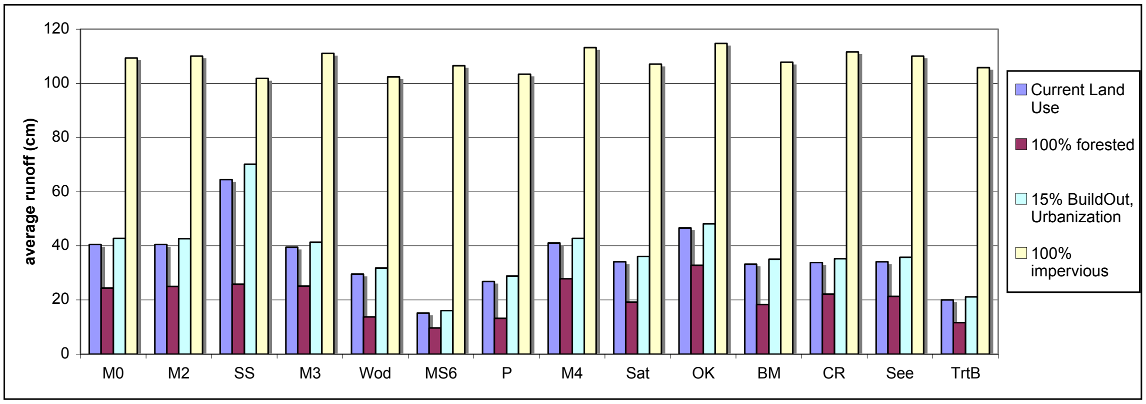


Figure 10: Average monthly streamflow (equivalent depth per subcatchment) simulated by GWLF for the Moodna Creek Outlet subcatchment for the current and 15% buildout land use scenario. The numbers 1 – 12 refer to the months January through December consecutively.

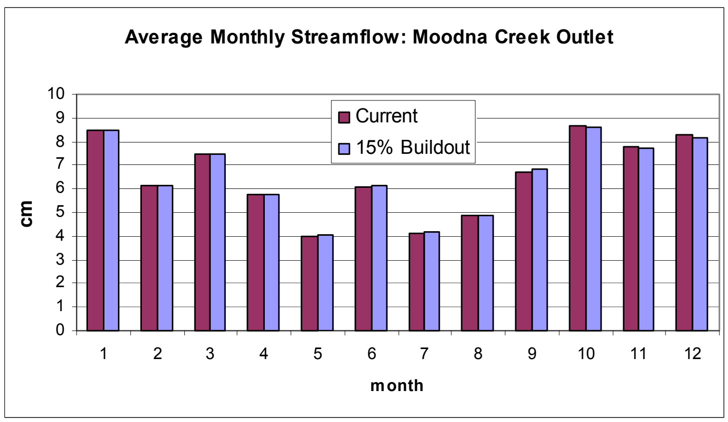


Figure 11: Average monthly groundwater (equivalent depth per subcatchment) simulated by GWLF for the Moodna Creek Outlet subcatchment for the current and 15% buildout land use scenario. The numbers 1 – 12 refer to the months January through December consecutively.

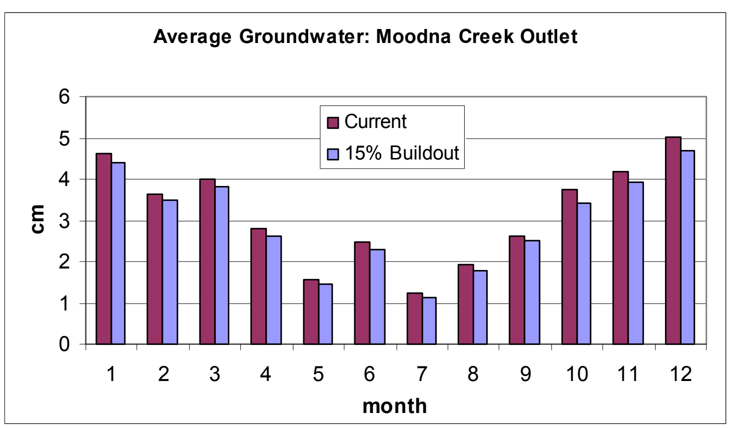


Figure 12: Average monthly runoff (equivalent depth per subcatchment) simulated by GWLF for the Moodna Creek Outlet subcatchment for the current and 15% buildout land use scenario. The numbers 1 – 12 refer to the months January through December consecutively.

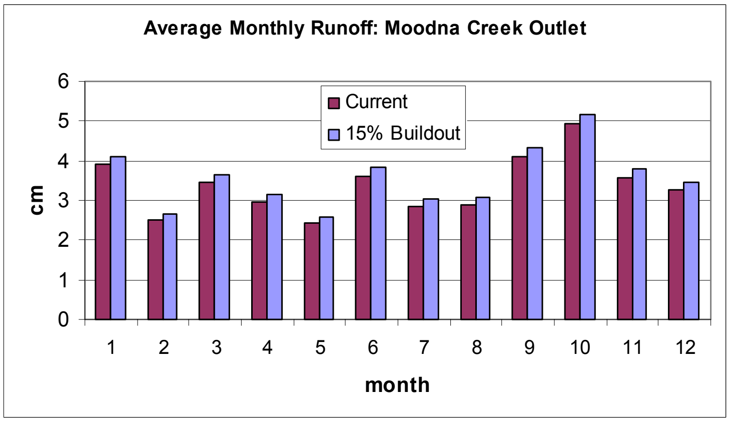
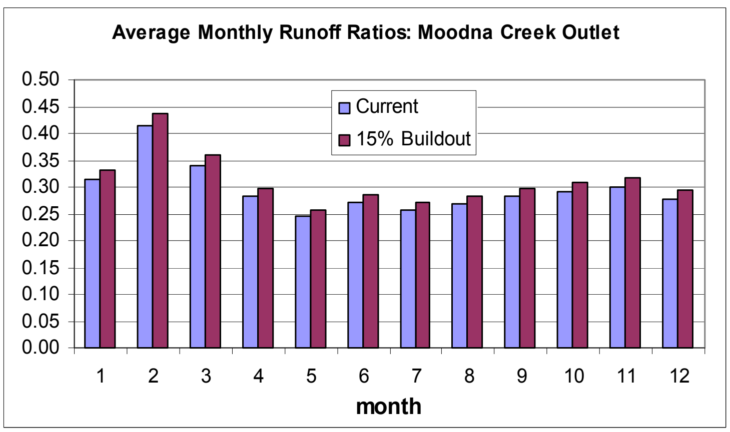
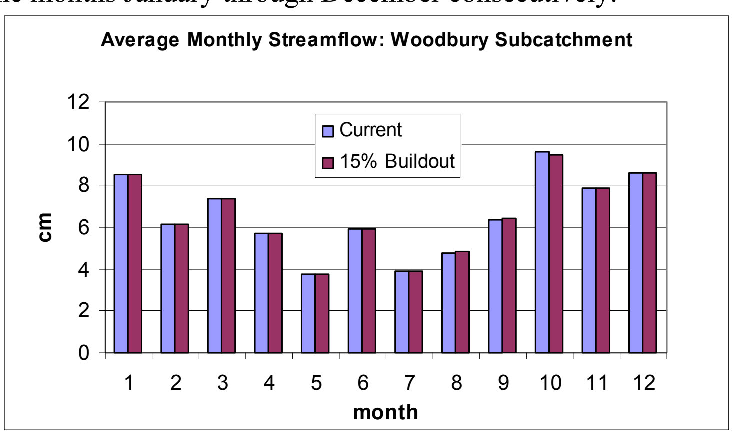
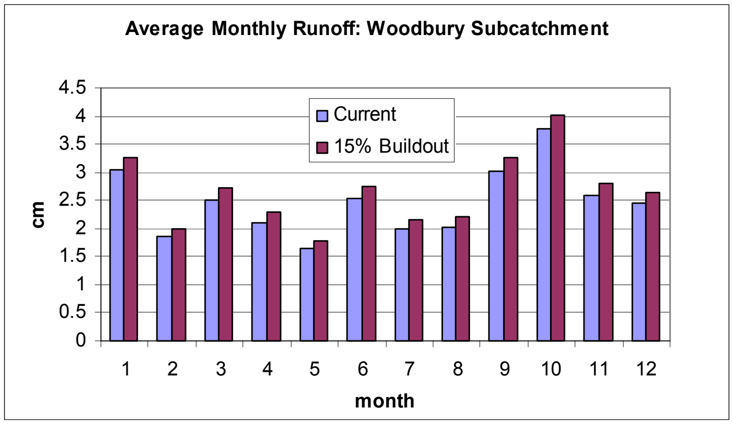


Figure 13: Runoff ratio (runoff/precipitation) calculated for the Moodna Creek Outlet subcatchment using GWLF runoff and precipitation rates for the current and 15% buildout land use scenario. The numbers 1 – 12 refer to the months January through December consecutively.



Figures 14 -16: GWLF output for the Woodbury subcatchment; comparison of current and 15% land use. The numbers 1 – 12 refer to the months January through December consecutively.





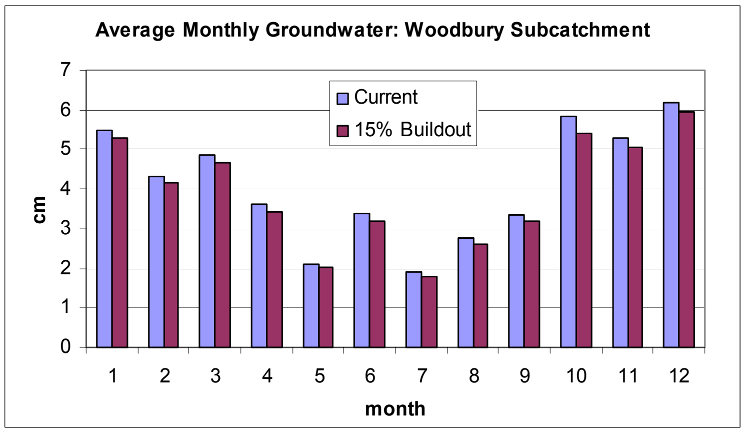
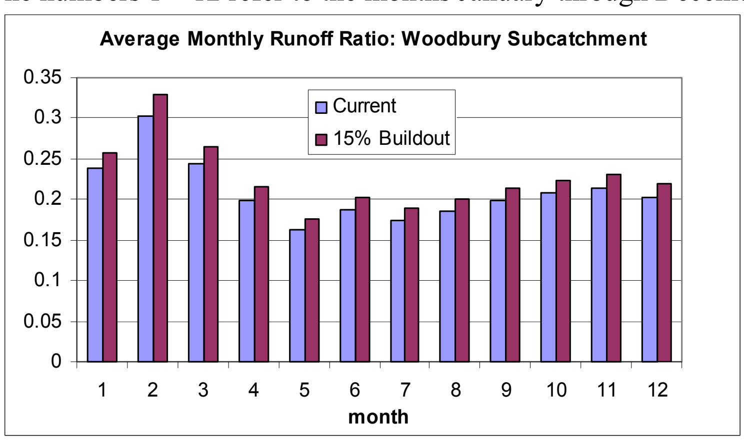
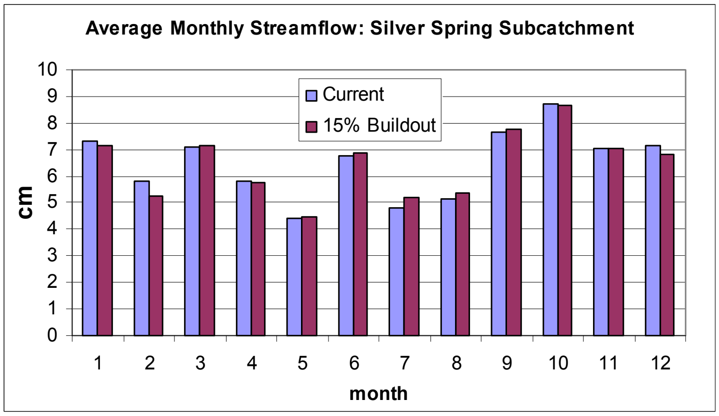
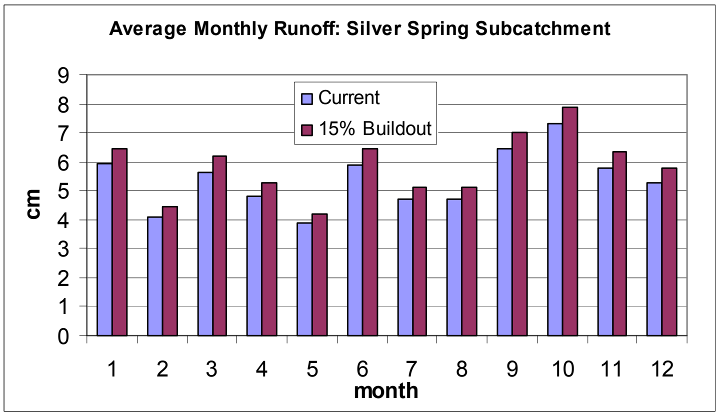


Figure 17: Runoff ratio (runoff/precipitation) calculated for the Woodbury subcatchment using GWLF runoff and precipitation rates. The numbers 1 – 12 refer to the months January through December consecutively.



Figures 18 – 20: GWLF output for the Silver Stream subcatchment; comparison of current and 15% land use. The numbers 1 – 12 refer to the months January through December consecutively.





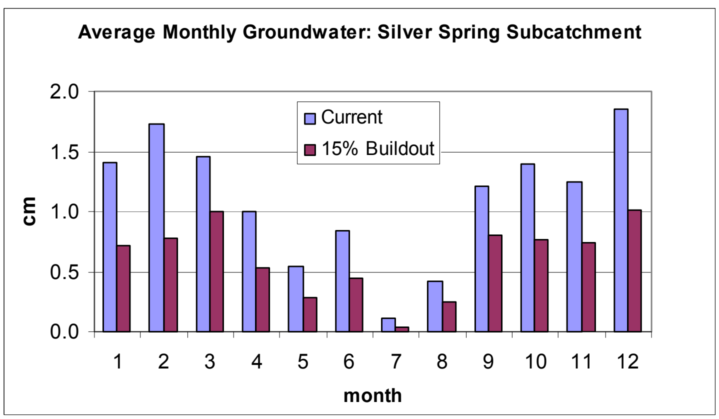
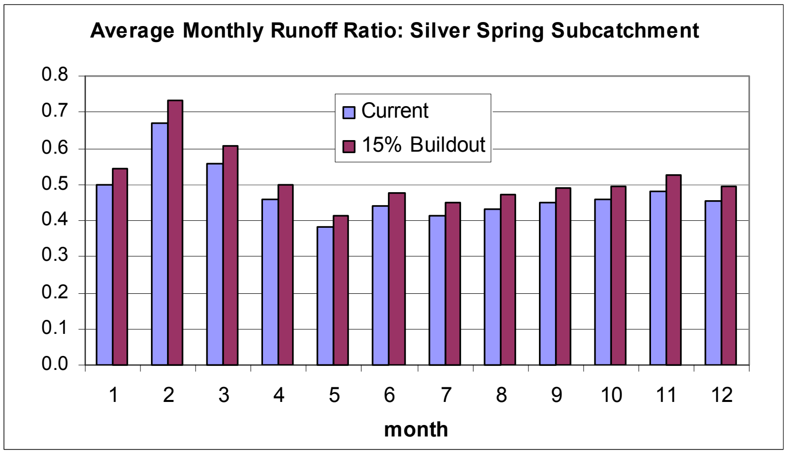


Figure 21: Runoff ratio (runoff/precipitation) calculated for the Woodbury subcatchment using GWLF runoff and precipitation rates. The numbers 1 – 12 refer to the months January through December consecutively.



Integrated Watershed Condition Model

The Integrated Watershed Condition Model is a statistical model predicts how watershed urbanization affects a large suite of water quality and biological variables. The modeled stream water quality is derived from multiple linear regression relationships calculated from stream water quality monitoring data and the land use characteristics of the associated watersheds obtained from the USGS NAWQA (National Water Quality Assessment Program) dataset (http://water.usgs.gov/nawqa). The dataset used in this model is restricted to the NY/NJ/PA area so that sufficient data sets could be analyzed without compromising specific characteristics of the region.

This model has been applied to the Wappinger and Fishkill Creek watersheds in Dutchess County, NY. Three different land use types were run: forested, urban, and agriculture. The current land use pattern (based on the 2001 National Land Use Dataset) for the Moodna watershed were re-classified into the three land use types. Simulated water quality including surface water chemistry and biological health indices were calculated for each of the subwatersheds. The model was also run for 3 additional land use scenarios for the Woodbury subcatchment: all forested, all agriculture, and all developed/urban. Model input data is described in **Table 2**.

Preliminary Results

Chloride concentrations in streamwater are highest for the subcatchment with the highest percentage of urbanized land, Silver Stream (**Figures 22** and **23**). While not a strong relationship, a few subcatchments with lower urbanized land had higher chloride concentrations. This may be due to a relatively higher percentage of agricultural land. The model was run for the Woodbury subcatchment for four different land use scenarios: current, 100% forested, 100% agriculture, and 100% urban (**Figure 24**). Chloride concentrations were much higher for the 100% urbanized followed by the current land use and then the 100% agriculture. Total phosphorous and nitrogen concentrations were highest in the agricultural land use scenario, followed by the urban land use scenario for the Woodbury (**Figures 25 and 26**). This is largely due to larger contributions from organic nutrients predicted for the agricultural and urban scenarios vs. forested scenrios (the current land use of the Woodbury is primarily forested).

The simulated water quality conditions for the current land use for each subwatershed are presented in **Table 3**. The general trends included a higher biological index, lower nutrient concentration, higher dissolved oxygen content, and lower temperature for the subcatchments with the most forested land (for example, Mineral Spring Brook). The subcatchments with a higher proportion of agricultural land (e.g. Otter Kill) had the lowest dissolved oxygen concentrations. While, the subcatchments with the highest proportion of urbanized land (e.g. Silver Stream), had the highest proportion of nutrients and heavy metal concentrations. It will be helpful to compare these individual subcatchments with further analyses and how their water quality changes with different land use scenarios but particularly with water quality data collected from the Moodna Creek and its tributaries. Although the statistical relationships of the model were derived from regional watersheds, a more accurate understanding will only be gained when the modeled results are validated with field data.

Table 2: Input data for the Integrated Watershed Condition Model. Land use is the input data for the model.

	% Forested	% Agriculture	% Urban
Moodna Outlet (MO)	45.84	19.97	16.86
Moodna 2 (M2)	45.26	20.87	15.99
Silver stream (SS)	30.35	7.34	43.69
Moodna 3 (M3)	45.26	22.14	14.55
Woodbury (Wod)	67.14	3.63	17.72
Mineral Spring (MS)	85.73	3.24	6.14
Perry Creek (P)	68.38	9.11	14.90
Moodna 4 (M4)	40.19	27.10	12.87
Satterly Creek (Sat)	59.01	12.51	15.96
Otter Kill (OK)	29.91	33.67	12.91
Black Meadow Creek (BM)	36.49	37.46	13.90
Cromline Creek (CR)	53.33	19.17	11.65
Seeley Brook (See)	53.45	18.09	13.08
Trout Brook (TrtB)	78.69	3.21	9.10

Figure 22: Chloride concentrations simulated from the Integrated Watershed Condition Model versus % urban land use per subcatchment for the current land use change scenario.

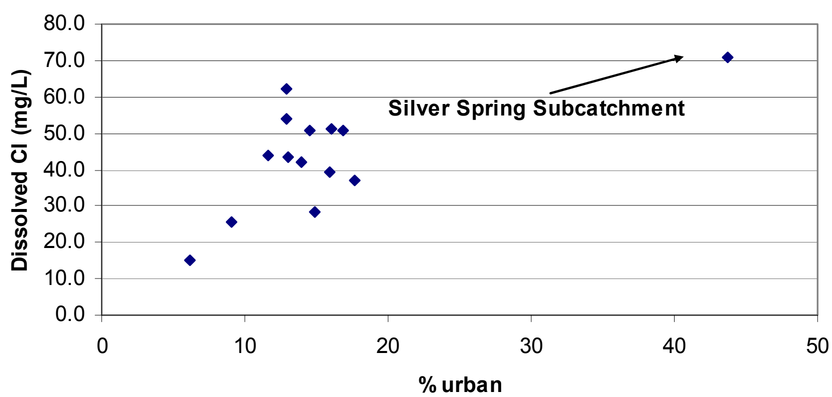


Figure 23: Chloride concentrations simulated from the Integrated Watershed Condition Model for the current land use change scenario.

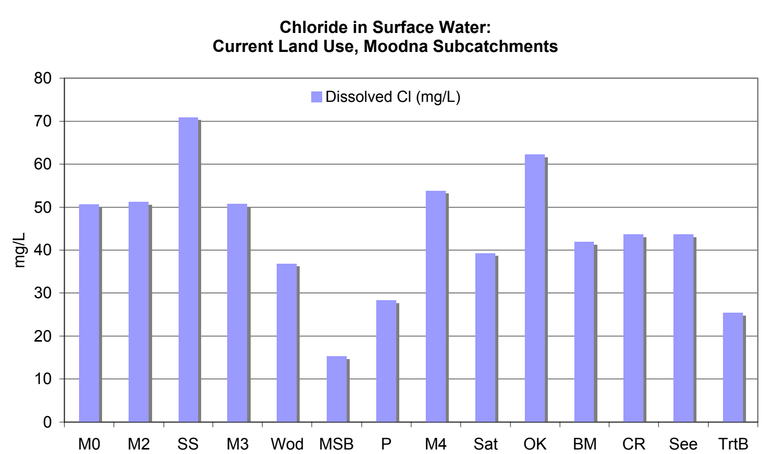


Figure 24: Chloride concentrations simulated from the Integrated Watershed Condition Model for the Woodbury subcatchment for four different land use change scenarios: current, 100% forested, 100% urban, and 100% agriculture.

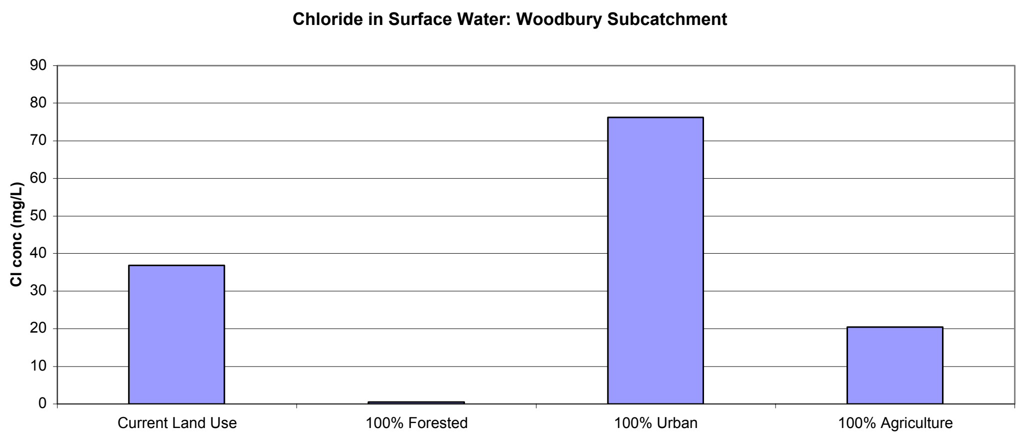


Figure 25: Total phosphorous (inorganic and organic phosphorous) concentrations simulated from the Integrated Watershed Condition Model for the Woodbury subcatchment for four different land use change scenarios: current, 100% forested, 100% urban, and 100% agriculture.

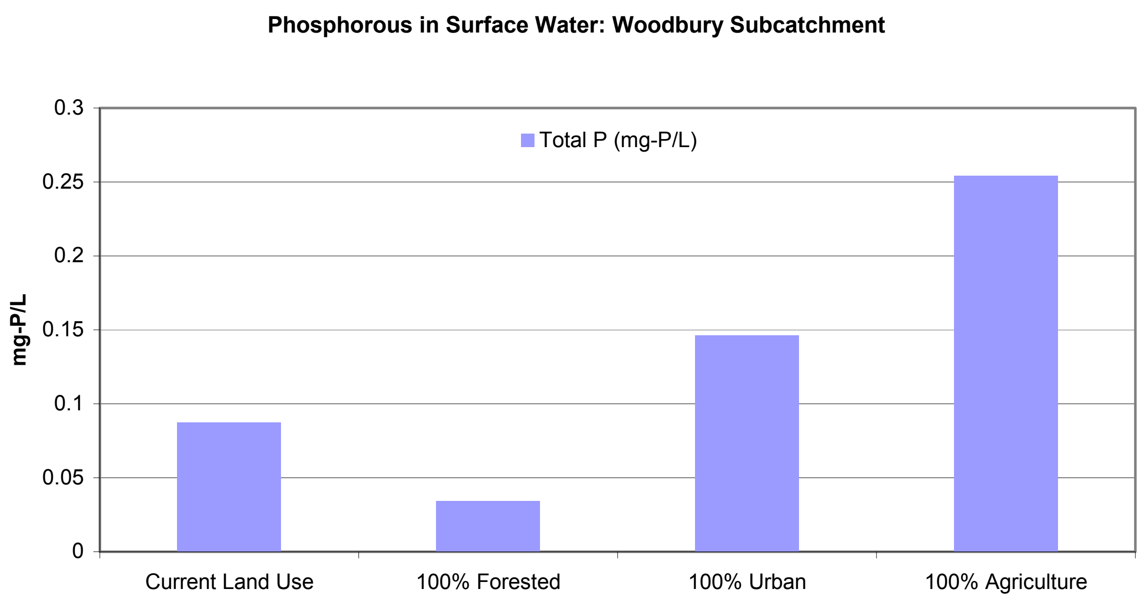


Figure 26: Total nitrogen (inorganic and organic nitrogen) concentrations simulated from the Integrated Watershed Condition Model for the Woodbury subcatchment for four different land use change scenarios: current, 100% forested, 100% urban, and 100% agriculture.

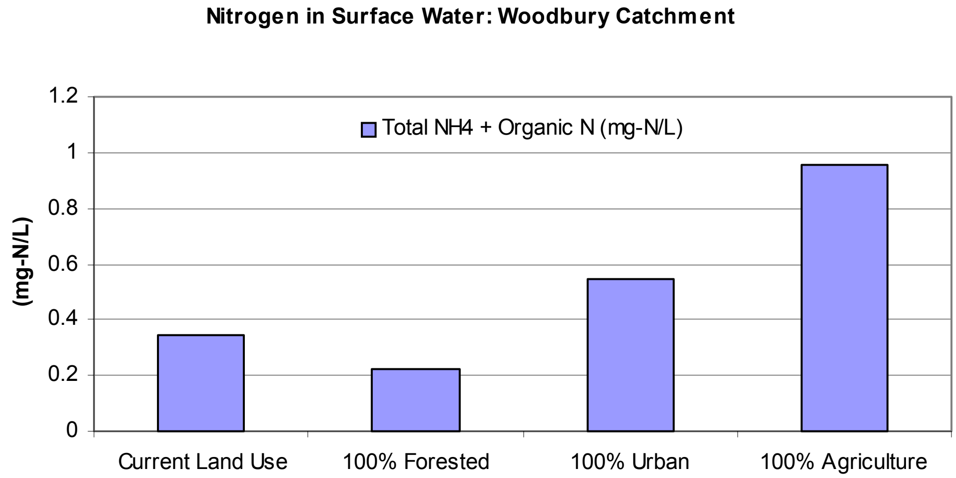


Table 3: Results from Integrated Watershed Condition Model, Current Land Use Scenario.

Variable	M0	M2	SS	M3	Wod	MSB	P	M4	Sat	OK	BM	CR	See	TrtB
Water Temperature (degree C)	13.47	13.51	13.81	13.53	12.44	11.72	12.42	13.80	12.85	14.29	13.96	13.19	13.16	12.02
[95% Lower Bound]	13.08	13.12	13.32	13.14	11.91	11.01	11.89	13.38	12.41	13.79	13.52	12.78	12.75	11.38
[95% Upper Bound]	13.86	13.90	14.30	13.93	12.97	12.44	12.95	14.22	13.30	14.79	14.40	13.60	13.57	12.65
Specific Conductance (micro-S/cm)	546.19	557.09	636.70	559.96	358.57	171.82	293.43	610.57	411.74	714.30	510.41	489.00	481.15	267.12
[95% Lower Bound]	460.93	468.84	542.68	470.67	306.93	151.79	261.97	510.92	353.93	593.26	451.35	412.60	407.35	229.11
[95% Upper Bound]	631.46	645.35	730.72	649.25	410.22	191.84	324.88	710.23	469.55	835.35	569.47	565.40	554.95	305.13
Dissolved Oxygen (mg/L)	10.40	10.37	10.44	10.35	10.86	11.09	10.84	10.23	10.66	10.01	10.16	10.48	10.51	10.98
[95% Lower Bound]	10.28	10.25	10.28	10.23	10.70	10.87	10.68	10.09	10.53	9.85	10.02	10.36	10.38	10.79
[95% Upper Bound]	10.52	10.50	10.60	10.48	11.02	11.31	11.00	10.36	10.80	10.17	10.30	10.61	10.63	11.17
pH	7.59	7.59	7.61	7.60	7.45	7.36	7.45	7.63	7.50	7.70	7.65	7.55	7.55	7.40
[95% Lower Bound]	7.56	7.56	7.57	7.57	7.41	7.31	7.41	7.60	7.47	7.66	7.62	7.52	7.52	7.35
[95% Upper Bound]	7.61	7.62	7.64	7.62	7.48	7.41	7.48	7.66	7.53	7.73	7.68	7.58	7.58	7.44
Dissolved Ca (mg/L)	61.78	63.26	67.89	63.91	37.73	17.11	31.11	70.62	45.24	83.55	60.12	55.56	54.35	27.92
[95% Lower Bound]	48.68	49.70	53.42	50.19	29.79	14.05	26.30	55.31	36.37	64.95	51.07	43.83	43.02	22.09
[95% Upper Bound]	74.88	76.82	82.37	77.62	45.66	20.17	35.93	85.93	54.11	102.15	69.17	67.29	65.68	33.74
Dissolved Mg (mg/L)	8.33	8.51	8.90	8.63	4.47	2.11	4.48	9.66	6.06	11.49	10.24	7.43	7.29	3.12
[95% Lower Bound]	8.01	8.19	8.51	8.30	4.04	1.53	4.05	9.31	5.70	11.07	9.87	7.09	6.95	2.61
[95% Upper Bound]	8.65	8.83	9.29	8.95	4.90	2.69	4.91	10.01	6.42	11.91	10.60	7.76	7.62	3.63
Dissolved Na (mg/L)	34.17	34.68	45.31	34.49	24.67	10.73	18.60	36.83	26.28	42.68	27.40	29.94	29.73	17.70
[95% Lower Bound]	21.53	21.60	31.35	21.26	17.02	7.78	13.96	22.06	17.73	24.74	18.67	18.63	18.80	12.08
[95% Upper Bound]	46.80	47.76	59.26	47.72	32.33	13.68	23.24	51.59	34.84	60.62	36.13	41.26	40.66	23.32
Dissolved K (mg/L)	1.26	1.25	1.47	1.25	0.96	0.93	1.25	1.30	1.19	1.38	2.03	1.16	1.18	0.83
[95% Lower Bound]	0.35	0.30	0.46	0.29	0.41	0.72	0.92	0.23	0.57	0.07	1.40	0.34	0.39	0.42
[95% Upper Bound]	2.18	2.20	2.48	2.21	1.52	1.15	1.59	2.37	1.81	2.68	2.67	1.98	1.98	1.24
Alkalinity (mg/L)	22.84	21.84	25.45	21.79	17.89	25.52	33.26	22.07	25.33	20.78	57.40	21.41	22.49	16.82
[95% Lower Bound]	0.00	0.00	0.00	0.00	2.14	19.42	23.68	0.00	7.74	0.00	39.50	0.00	0.05	5.23
[95% Upper Bound]	48.76	48.67	54.06	48.92	33.63	31.63	42.84	52.34	42.92	57.54	75.31	44.64	44.93	28.42
Dissolved Cl (mg/L)	50.62	51.18	70.90	50.69	36.81	15.22	28.26	53.82	39.19	62.24	41.86	43.66	43.61	25.37
[95% Lower Bound]	26.71	26.43	44.49	25.65	22.33	9.64	19.48	25.88	23.00	28.29	25.35	22.25	22.93	14.74
[95% Upper Bound]	74.53	75.93	97.31	75.72	51.29	20.80	37.04	81.77	55.38	96.18	58.38	65.07	64.30	36.01

Table 3: Results from Integrated Watershed Condition Model, Current Land Use Scenario.

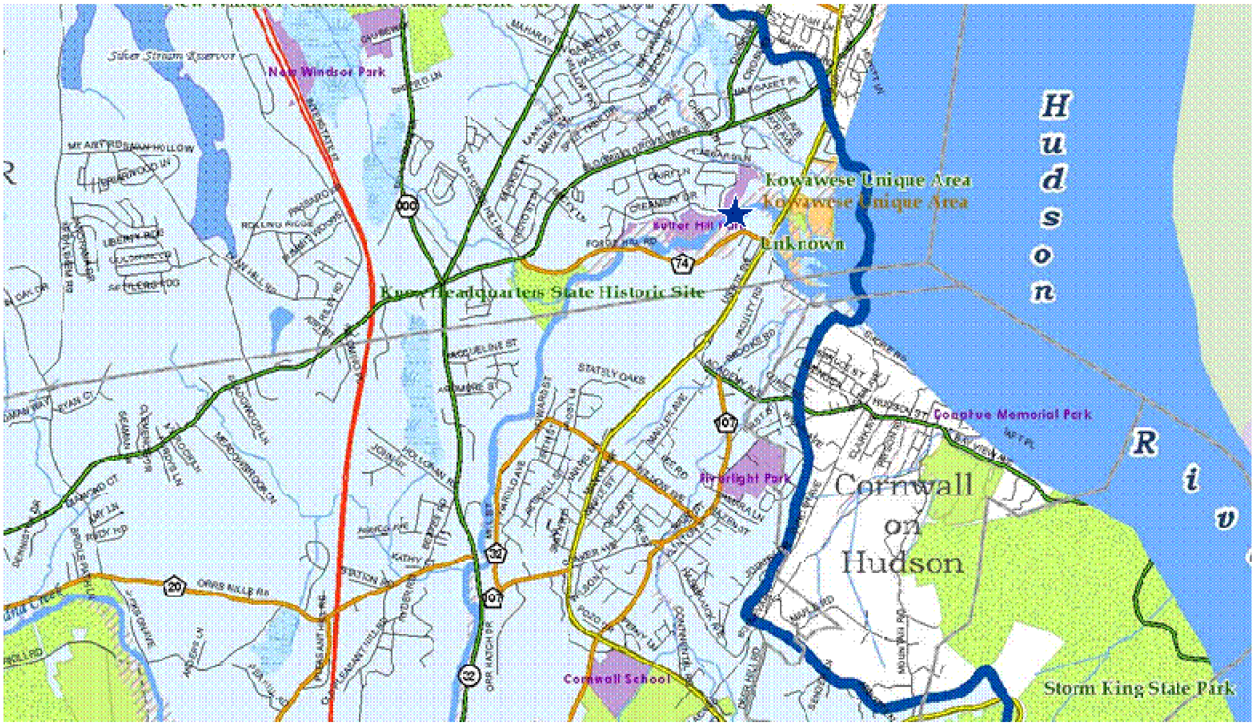
Variable	M0	M2	SS	M3	Wod	MSB	P	M4	Sat	OK	BM	CR	See	TrtB
Dissolved SO4 (mg/L)	165.60	171.11	177.70	173.34	97.31	29.75	63.68	193.62	113.47	233.88	129.42	148.88	144.05	69.92
[95% Lower Bound]	137.16	141.67	146.25	143.56	80.16	23.17	53.30	160.36	94.25	193.44	109.77	123.44	119.47	57.36
[95% Upper Bound]	194.04	200.56	209.16	203.13	114.47	36.32	74.05	226.88	132.69	274.32	149.07	174.33	168.63	82.48
Dissolved F (mg/L)	0.19	0.19	0.20	0.19	0.16	0.13	0.15	0.20	0.17	0.21	0.17	0.18	0.18	0.15
[95% Lower Bound]	0.16	0.16	0.16	0.16	0.14	0.12	0.13	0.16	0.14	0.17	0.14	0.15	0.15	0.14
[95% Upper Bound]	0.22	0.22	0.23	0.22	0.18	0.14	0.16	0.23	0.19	0.26	0.19	0.21	0.20	0.16
Dissolved SiO2 (mg/L)	5.97	5.96	7.07	5.92	5.48	4.72	5.38	6.00	5.63	6.25	6.11	5.65	5.68	4.97
[95% Lower Bound]	5.84	5.83	6.91	5.78	5.30	4.47	5.19	5.85	5.48	6.07	5.96	5.51	5.54	4.75
[95% Upper Bound]	6.11	6.10	7.24	6.06	5.67	4.97	5.56	6.15	5.78	6.42	6.27	5.79	5.83	5.19
Dissolved Fe (micro-g/L)	128.88	130.48	159.06	129.98	103.69	63.78	83.95	136.36	106.67	152.73	103.47	117.52	116.72	84.69
[95% Lower Bound]	93.73	94.08	120.21	93.16	82.41	55.57	71.04	95.27	82.86	102.81	79.18	86.04	86.31	69.05
[95% Upper Bound]	164.04	166.87	197.90	166.79	124.98	71.99	96.86	177.45	130.48	202.66	127.75	149.00	147.14	100.32
Dissolved Mn (micro-g/L)	162.17	166.42	189.85	167.29	107.69	41.63	73.48	182.83	117.70	216.54	120.22	145.17	141.84	79.41
[95% Lower Bound]	140.24	143.73	165.62	144.33	94.41	36.51	65.43	157.20	102.85	185.40	105.08	125.54	122.87	69.66
[95% Upper Bound]	184.09	189.11	214.07	190.24	120.96	46.75	81.54	208.45	132.55	247.67	135.36	164.80	160.80	89.16
Dissolved Residue (mg/L)	373.46	381.91	429.48	384.57	235.87	102.18	187.30	422.36	274.73	498.69	344.28	333.58	327.15	172.08
[95% Lower Bound]	303.89	309.90	352.63	311.73	193.73	85.91	161.73	341.06	227.60	399.92	296.23	271.28	266.96	141.11
[95% Upper Bound]	443.03	453.92	506.32	457.42	278.01	118.44	212.87	503.66	321.86	597.47	392.34	395.88	387.34	203.04
Dissolved NH4 (mg-N/L)	0.33	0.34	0.37	0.34	0.22	0.10	0.16	0.38	0.25	0.44	0.26	0.30	0.29	0.17
[95% Lower Bound]	0.23	0.24	0.26	0.24	0.16	0.08	0.12	0.26	0.18	0.30	0.19	0.21	0.21	0.13
[95% Upper Bound]	0.43	0.45	0.49	0.45	0.28	0.12	0.20	0.49	0.31	0.59	0.33	0.39	0.38	0.22
Dissolved NO2 (mg-N/L)	0.08	0.08	0.09	0.08	0.06	0.03	0.04	0.09	0.06	0.10	0.06	0.07	0.07	0.04
[95% Lower Bound]	0.04	0.04	0.05	0.04	0.03	0.02	0.03	0.05	0.04	0.05	0.04	0.04	0.04	0.03
[95% Upper Bound]	0.12	0.12	0.13	0.12	0.08	0.04	0.06	0.13	0.09	0.16	0.09	0.11	0.10	0.06
Dissolved NO2 + NO3 (mg-N/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00
[95% Lower Bound]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
[95% Upper Bound]	0.83	0.85	0.86	0.87	0.01	0.00	0.29	1.08	0.44	1.41	1.77	0.65	0.64	0.00
Dissolved NH4 + Organic N (mg-N/L)	0.53	0.54	0.55	0.54	0.37	0.24	0.33	0.59	0.42	0.68	0.53	0.49	0.48	0.31
[95% Lower Bound]	0.33	0.33	0.34	0.34	0.25	0.19	0.26	0.36	0.29	0.39	0.39	0.31	0.31	0.22
[95% Upper Bound]	0.73	0.74	0.77	0.75	0.49	0.28	0.40	0.82	0.55	0.96	0.67	0.67	0.65	0.39

Table A-2: Results from Integrated Watershed Condition Model, Current Land Use Scenario.

Variable	M0	M2	SS	M3	Wod	MSB	P	M4	Sat	OK	BM	CR	See	TrtB
Total NH4 + Organic N (mg-N/L)	0.48	0.48	0.48	0.49	0.34	0.28	0.36	0.53	0.41	0.59	0.58	0.45	0.45	0.30
[95% Lower Bound]	0.44	0.45	0.43	0.46	0.30	0.22	0.32	0.50	0.37	0.55	0.55	0.42	0.41	0.25
[95% Upper Bound]	0.51	0.52	0.53	0.52	0.39	0.34	0.41	0.56	0.45	0.62	0.61	0.49	0.48	0.36
Dissolved PO4 (mg-P/L)	0.15	0.16	0.17	0.16	0.10	0.05	0.08	0.17	0.12	0.20	0.13	0.14	0.14	0.08
[95% Lower Bound]	0.09	0.09	0.10	0.09	0.06	0.03	0.06	0.10	0.07	0.11	0.09	0.08	0.08	0.05
[95% Upper Bound]	0.22	0.23	0.25	0.23	0.14	0.07	0.10	0.25	0.16	0.30	0.18	0.20	0.20	0.11
Dissolved P (mg-P/L)	0.19	0.19	0.21	0.19	0.12	0.06	0.10	0.21	0.14	0.25	0.16	0.17	0.17	0.10
[95% Lower Bound]	0.11	0.11	0.13	0.11	0.08	0.04	0.07	0.12	0.09	0.14	0.11	0.10	0.10	0.06
[95% Upper Bound]	0.26	0.27	0.29	0.27	0.17	0.08	0.12	0.30	0.19	0.35	0.21	0.24	0.23	0.13
Total P (mg-P/L)	0.14	0.14	0.14	0.14	0.09	0.06	0.09	0.15	0.11	0.17	0.16	0.12	0.12	0.07
[95% Lower Bound]	0.12	0.13	0.13	0.13	0.07	0.04	0.07	0.14	0.09	0.16	0.15	0.11	0.11	0.05
[95% Upper Bound]	0.15	0.15	0.15	0.15	0.10	0.08	0.10	0.16	0.12	0.19	0.17	0.14	0.13	0.09
Fish Diversity	1.58	1.58	1.45	1.59	1.59	1.68	1.64	1.59	1.61	1.58	1.66	1.61	1.61	1.64
[95% Lower Bound]	1.53	1.54	1.38	1.54	1.52	1.59	1.57	1.55	1.55	1.53	1.61	1.56	1.55	1.56
[95% Upper Bound]	1.63	1.63	1.52	1.64	1.66	1.77	1.71	1.64	1.66	1.62	1.70	1.66	1.66	1.72
Invertebrate Diversity	2.62	2.62	2.44	2.63	2.74	2.90	2.78	2.60	2.71	2.54	2.61	2.69	2.68	2.84
[95% Lower Bound]	2.56	2.56	2.36	2.57	2.66	2.80	2.69	2.55	2.64	2.49	2.56	2.62	2.62	2.75
[95% Upper Bound]	2.69	2.68	2.53	2.69	2.83	3.01	2.86	2.66	2.78	2.60	2.66	2.75	2.75	2.94
Fish IBI	38.66	38.69	37.49	38.76	38.62	39.12	38.74	38.83	38.69	38.83	38.78	38.88	38.82	38.99
[95% Lower Bound]	37.45	37.48	36.12	37.53	37.42	37.79	37.52	37.59	37.48	37.59	37.55	37.63	37.58	37.70
[95% Upper Bound]	39.86	39.91	38.86	39.98	39.82	40.45	39.96	40.07	39.91	40.07	40.02	40.14	40.06	40.28
Bird IBI	35.63	35.65	32.59	35.71	38.22	40.51	37.84	35.20	37.06	34.09	33.26	36.77	36.68	39.95
[95% Lower Bound]	34.48	34.52	29.54	34.62	36.30	38.29	36.28	34.05	35.69	32.63	31.54	35.65	35.54	37.84
[95% Upper Bound]	36.79	36.78	35.64	36.81	40.13	42.74	39.40	36.35	38.43	35.54	34.98	37.89	37.82	42.05

Stream Gage

Figure 23: Map showing proposed location of stream gage (designated by blue star on map) along the Moodna Creek Outlet, ahead of tide within Butter Hill Park. Results from the gage will be used to calibrate and validate watershed models.



References

Haith DA, Mandel R, and R Shyan Wu. 1996. GWLF: Generalized Watershed Loading Functions. Version 2.0. User's Manual. Downloaded from http://www.eeb.cornell.edu/biogeo/nanc/usda/renuma.htm.

Hong B and DP Swaney. 2007. Regional Nutrient Management (ReNuMa) Model. Version 1.0. User's Manual. Downloaded from http://www.eeb.cornell.edu/biogeo/nanc/usda/renuma.htm.

Howarth RW, Fruci J, and D Sherman. 1991. Inputs of Sediment and Carbon to an Estuarine Ecosystem: Influence of Land Use. Ecological Applications 1: 27 – 39.

Lee K-Y, Fisher TR, Jordan TE, Correll DL, and Weller DE. 2000. Modeling the hydrochemistry of the Choptank River basin using GWLF and Arc/Info: 1. Model calibration and validation. Biogeochemistry 49: 143-173.

Lee K, Fisher TR, and E Rochelle-Newall. 2001. Modeling the hydrochemistry of the Choptank River basin using GWLF and Arc/Info: 2. Model Validation and Application. Biogeochemistry 56: 311-348.

Swaney DP, Sherman D, and R.W. Howarth. 1996. Modeling Water, Sediment, and Organic Carbon Discharges in the Hudson-Mohawk Basin: Coupling to Terrestrial Sources. Estuaries 19: 833-847.

Best management practices for managing stormwater runoff from developing areas in the Hudson catchment

Basic Information

Title:	Best management practices for managing stormwater runoff from developing areas in the Hudson catchment
Project Number:	2007NY92B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	22
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Management and Planning
Descriptors:	None
Principal Investigators:	Tammo Steenhuis, Brian Richards

Publication

1. Steenhuis, Tammo, 2007, Best management practices for managing stormwater runoff from developing areas in the Hudson Catchment, 7th Annual Southeast New York Conference and Trade Show (sponsored by The Lower Hudson Coalition of Conservation District), Beacon, New York

BEST MANAGEMENT PRACTICES FOR MANAGING STORMWATER RUNOFF FROM DEVELOPING AREAS IN THE HUDSON CATCHMENT

Tammo S. Steenhuis, Principal Investigator
Zachary M. Easton, and Brian K. Richards, Co-PIs
Department of Biological and Environmental Engineering, Cornell University

Principal findings/ achievements

During the reporting year, instrumentation was installed in two rain gardens for measuring water quantity and quality; planned activities in an additional rain garden are pending awaiting commercial construction and/or permission to sample the respective sites. In addition we participated in several extension meetings and presented our initial findings on better engineering techniques and improved siting for rain gardens at a conference/trade show sponsored by The Lower Hudson Coalition of Conservation District in Beacon, New York.

In Orange County the landscape treatment system for a large parking lot was instrumented in October 2007 with field equipment consisting of two water observation wells (4 and 13 ft deep) directly below the rain garden and next to the river; a 13-ft monitoring well equipped with an automatic water sampler (ISCO) for collecting water samples; monitoring station for quantity and quality of water samples from the street curvet using a capacity probe and an automatic water sampler (ISCO); a digital rain gauge and a rainfall water sampler. Duplicate water samples have been collected for rainfall events. All water samples have been analyzed in the ICP for Fe, Mn, P, Pb, Zn, L, Cu, Cd, Ca, NO_3-N and NH_4-N. In addition, an existing rain garden for intercepting street runoff was similarly instrumented.

Orange County Meetings: The first meeting took place in the Soil & Water Conservation District office in Orange County in the spring of 2007, including Cornell participants (Tammo Steenhuis, Brian Richards, Tony Salvucci, Cody Charwood and Luis Caballero), and Mike Maillet and Kevin Sumner from the Orange County Soil Conservation District. During the meeting project plans were presented and agreements were made on how to proceed with field work. On June 26th 2007, a meeting in Kingston, New York and field visit took place to the Village of Walden where a rain garden was to be built by the Orange County extension service. Tammo, Jens, Tony, Cody and Shree Giri participated from the Soil and Water group, as well as Gregory Rusciano, Chris Obropta and Madeline Flahive from Rutgers Cooperative of Extension in New Brunswick, New Jersey and Kevin Sumner from Orange County Soil Conservation District. Basic field evaluation and observations were made in order to plan instrumentation. On October 27th and 28th field installation took place by Jens Liebe and Luis Caballero, coordinated with Kevin Sumner.

Student support:
Cody Charwood (Master's student, Biological & Environmental Engineering)

Publications generated to date
None. Initial findings presented at the 7th Annual Urban Southeast New York Conference and Trade Show sponsored by The Lower Hudson Coalition of Conservation District held in Beacon, New York. 7th Annual Southeast NY Stormwater Conference and Trade Show October 17, 2007 at the Dutchess Manor, Beacon, New York

The mystery of chloride in Hudson Valley Streams: An opportunity for involving local citizens and government in puzzle solving

Basic Information

Title:	The mystery of chloride in Hudson Valley Streams: An opportunity for involving local citizens and government in puzzle solving
Project Number:	2007NY93B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	21
Research Category:	Water Quality
Focus Category:	Methods, Groundwater, Surface Water
Descriptors:	None
Principal Investigators:	Stuart Findlay, Gary Kleppel

Publication

PROJECT SUMMARY – EXPLAINING CHLORIDE PATTERNS IN STREAMS OF DUTCHESS COUNTY, NY

Stuart Findlay
Cary Institute of Ecosystem Studies
Findlays@ecostudies.org
845 677 5343
Supported by a Grant from the Water Resources Institute, Cornell University

The goal of the project was to better understand the spatial and temporal patterns of the chloride ion (CL-) in local streams. This question is driven by observations that Cl- concentrations have risen almost two-fold over the past 10+ years in some local streams despite a lack of significant new road construction (Kelly et al. 2007). Moreover, summertime concentrations are as high as other times of year even though this period is long after application of road salt. Chloride levels found previously in some surface waters are high enough to affect aquatic biota and cause concern for humans on a low salt diet (Riva-Murray et al. 2002).

A budget of Cl sources in a small Dutchess County watershed showed that road salt is the only source large enough to significantly influence streamwater concentrations (Kelly et al. 2007, Kaushal et al 2005). Moreover, there are large increases in summertime streamwater CL levels as streams pass through more densely populated portions of the County (see below). All of these facts suggest that there is some mechanism causing retention of winter-applied road salt within the watersheds. This project was designed to re-affirm patterns in Cl across the County and obtain samples of groundwater from

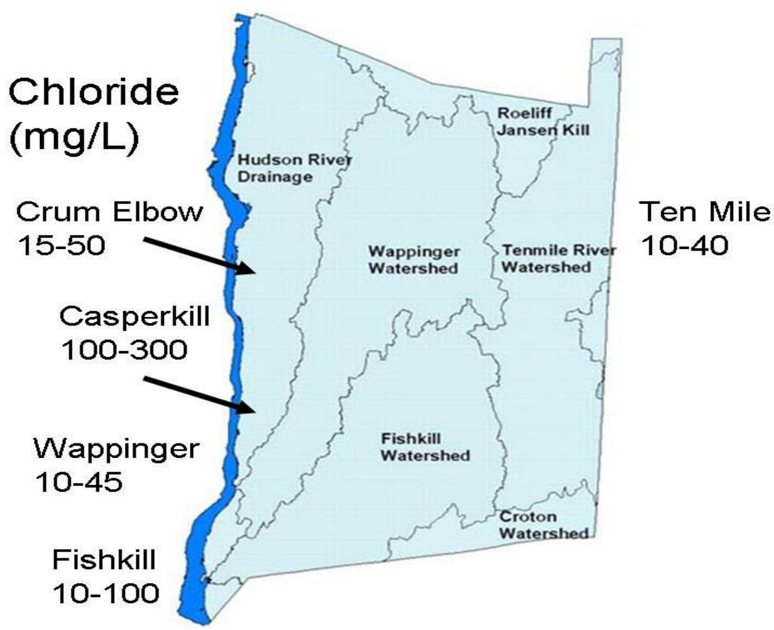


FIG 1: Major watersheds of Dutchess County, NY showing the range in summer baseflow chloride concentration. In general, low values occur in headwaters and higher values downstream. Arrows indicate approximate location of smaller watersheds.

individual wells to determine whether high chloride concentrations in aquifers could be contributing to long-term increases and high summer levels. Documentation of high chloride levels would suggest the deeper groundwaters are maintaining high summertime stream concentrations and, in some instances, might be high enough to be of concern from a drinking water quality perspective.

An equally important aspect was the assistance provided by local watershed groups who helped with streamwater sampling and facilitated collection of water from private wells. We also intend for these groups to help disseminate results of the project on the local level by direct communication with their town officials and other interested parties. These outreach efforts are appearing now as final project results for specific watersheds become available.

Findings – Surface water Cl levels show substantial contamination of several streams particularly the lower Fishkill Creek and the Casperkill. Figure 1 is a map of Dutchess County showing broad patterns of surface water concentrations derived from multiple locations and dates. Clearly the more densely populated watersheds tend to have the highest concentrations.

Samples collected from the two largest basins in the County (Wappinger Creek and Fishkill Creek) showed longitudinal increases in concentration with levels below 20 mg Cl/L in upper reaches while values from the more urbanized parts of the county were frequently > 100 mg/L. These patterns are present even in summertime long after road salt application has ended and suggest salt has been retained in soils of some groundwater pool for some period of time.

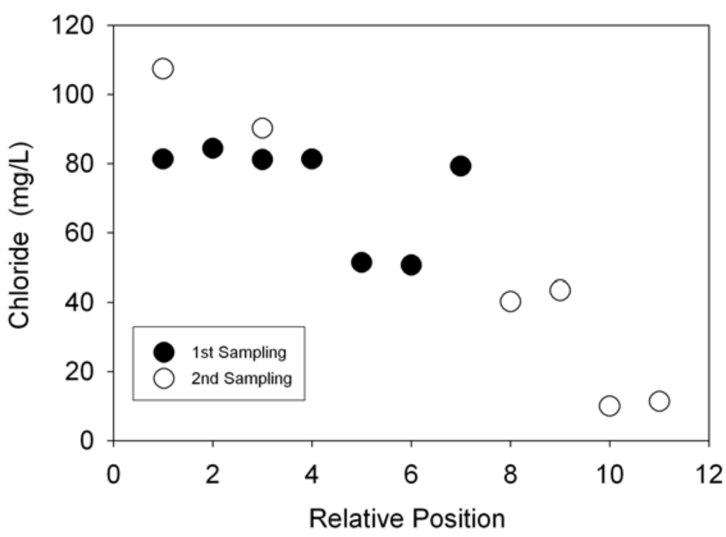


Fig 2 Longitudinal increase in chloride along Fish Creek from headwaters to mouth (relative position is 0 near point of discharge to the Hudson, high values near headwaters). Symbols are from two separate sampling excursions in July of 2007. Each point is the mean of two replicates.

To begin an assessment of direct and indirect inputs of Cl a continuously-monitoring Water Quality Data Sonde (YSI 6000) was deployed in the mid-reaches of the Fishkill Creek above Hopewell Jct. The conductivity record from this instrument was lab-calibrated to chloride. The record shows cases of both Cl spikes with rising discharge suggestive of direct salt input particularly in the first three weeks of deployment. Later in the record there is an inverse relationship between stage and chloride typical of dilution acting on a more constant Cl source. A plausible explanation for these patterns is direct salt run-off during treatment of icing events causing spikes. Immediate run-off from roads or salting of bridges could cause such a pattern. The spike in Cl is very transient and moves rapidly downstream. After the first week of February, chloride declines during rises in stage (increasing water volume) suggesting new water inputs are diluting a more persistent input. Such a pattern is consistent with (although not proof of) a constant supply of higher Cl groundwater or some unidentified point-source which is diluted by new low-chloride sources of run-off.

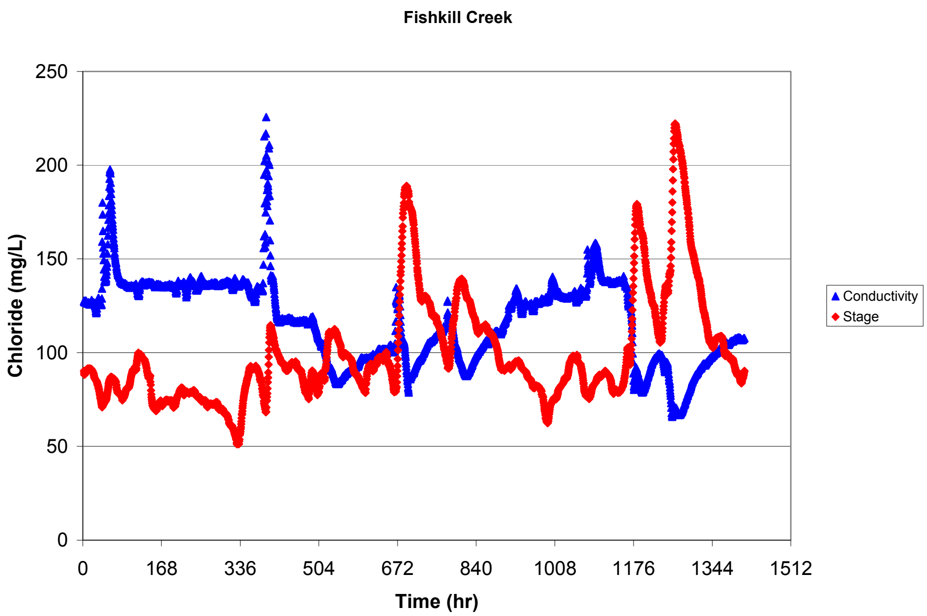


Fig. 3: Time series of chloride (conductivity converted to chloride with lab calibration of YSI 6000 Conductivity probe) monitored with a YSI Sonde from Jan 16 to Mar 15 2008. The location is roughly halfway down the watershed. The time axis is hours since Noon on Jan 16, each 168 hrs is one week. For the event Feb 1-2 (hr ~ 400) concentrations almost double following this icing event but rapidly return to pre-ice levels. Later in the record chloride is inversely related to water volume.

Groundwater – Well samples obtained from multiple locations can be used to describe general spatial patterns but these were not randomly distributed across the County and so can not be used as statistical measures of aquifer chloride concentrations. None-the-less we did receive over 50 samples from many locations across the County. Over 40%

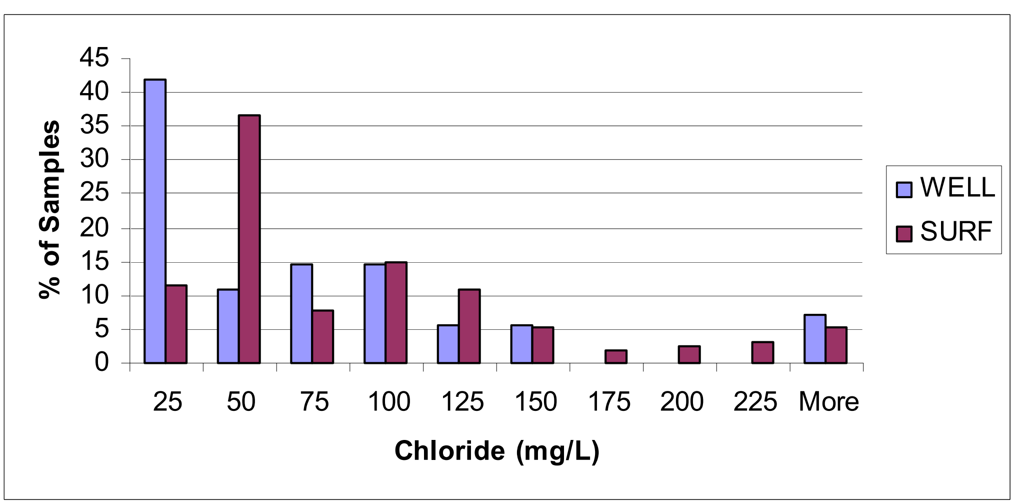


Fig. 4: Frequency distribution of chloride concentrations in surface and well samples from Dutchess County.

of the well samples were below 25 mg Cl/L which is well-below any of the commonly applied advisory levels (100 mg/L for individuals on restricted salt diets and 250 mg/L as the EPA Drinking Water secondary standard). Based on these results there does not appear to be wide-spread contamination of Dutchess County aquifers with surface-applied salt. However, almost 20% of the well samples submitted were over 100 mg/L pointing to at least local areas of some concern. Because of the non-random nature of the samples this result should be viewed as cautionary rather than indicative of wide-spread aquifer contamination but it does show that some drinking water wells in the County have troubling levels of chloride. Surface water samples had a median concentration of between 75 and 100 mg/L indicating that significant portions of at least some streams have salt levels approaching the cautionary 100 mg/L level. Moreover, the finding that at least some wells are yielding reasonably high Cl concentrations implies that deeper groundwaters may be a significant reservoir of winter-applied road salt in Dutchess County. At this time we have not finished integrating these data into a GIS so we can not yet look for associations with particular aquifers, landcovers or high surface water concentrations.

Training and Dissemination – Lana Lau, a Graduate student from SUNY-Albany helped with sample collection, coordinating volunteer groups and data management during summer 2007. Cornell Cooperative Extension of Dutchess County has helped over the past year with acquiring samples from numerous individuals and provided opportunities to present results at their regular meetings of citizens and CAC members. Over the past year several local watershed groups (Fishkill Creek Watershed Committee, Wappinger Creek Intermunicipal Council, Town of Clinton Conservation Advisory Committee) and faculty of Vassar College have participated through sample collection and analyses. Findings from this project are being distributed to the interested groups along with interpretations relevant to local municipal officials. The Dutchess County Water and Wastewater Authority has been kept apprised of progress and we plan to work with them as the County finishes the first round of their private well-testing program.

Publications – No papers have been submitted yet since some spatial analyses and lab cross-checks on water chemistry have yet to be completed. We anticipate at least one peer-reviewed publication based on our results and preparation of a short project summary suitable for public distribution.

LITERATURE CITED

Kaushal, S,S; Groffman, P.M.; Likens, G.E.; Belt, K.T; Stack, W.P. Kelly, V.R. 2005, Increased salinization of fresh water in the northeastern United States, PNAS, 102, 13517–13520

Kelly, V.A., G.M. Lovett, K.C. Weathers, S.E.G. Findlay, D.L. Strayer, D.I. Burns, and G.E. Likens. 2008. Long-term sodium chloride retention in a rural watershed: Legacy effects of road salt on streamwater concentration. Environmental Science and Technology 42:410-415

Riva-Murray, K., R.W. Bode, P.J. Phillips, and G.L. Wall. 2002. Impact source determination with biomonitoring data in New York State: Concordance with environmental data. Northeastern Naturalist 9:127-162.

Partnering scientists, policymakers and the public torward the creation of a management plan for the Casperkill Watershed, Dutchess County, New York

Basic Information

Title:	Partnering scientists, policymakers and the public torward the creation of a management plan for the Casperkill Watershed, Dutchess County, New York
Project Number:	2007NY97B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	19 &20
Research Category:	Water Quality
Focus Category:	Surface Water, Non Point Pollution, Management and Planning
Descriptors:	None
Principal Investigators:	Kirsten Menking

Publication

1. Menking, KM, Jost, AB, Smith, KC, Salls, WB and Dunningham, MA. 2008. Mass balance of chloride from deicing salts in a small Hudson River tributary. Northeastern Section meeting of the Geological Society of America, Buffalo, NY, March 28, 2008. http://gsa.confex.com/gsa/2008NE/finalprogram/abstract_135172.htm
2. Salls, WB, Jost, A, and Gillikin, DP. 2008. Unusual stable carbon and nitrogen isotope values in freshwater filamentous algae. Northeastern Section meeting of the Geological Society of America, Buffalo, NY. March 28, 2008. http://gsa.confex.com/gsa/2008NE/finalprogram/abstract_135112.htm
3. Pregnall, M, Cunningham, MA, Menking, K, Belli, S, and Schlessman, M. 2007. Changing land use effects on water quality in the Casperkill, a Hudson River estuary tributary. Estuarine Research Federation meeting, Providence, Rhode Island, November 5, 2007. http://www.erf.org/cgi−bin/conference07_abstract.pl?conference=erf2007
4. Cunningham, MA, Menking, KM, Belli, SA, and Foley, C. 2008. Patterns of road salt concentration in developing suburban watersheds. Association of American Geographers annual meeting, Boston, Massachusetts. April 15, 2008. http://communicate.aag.org/eseries/aag_org/program/AbstractDetail.cfm?AbstractID=18324
5. Cunningham, MA, Menking, KM, Belli, SL, Gillikin, DP, Freimuth, CP, Smith, KC, Pregnall, AM, Schlessman, MA and Batur, P. In Review. Can urban stream water quality recover longitudinally? Submitted to Urban Ecosystems.

Partnering Scientists, Policymakers, and the Public Toward the Creation of a Management Plan for the Casperkill Watershed, Dutchess County, New York

Participants

- Principal investigator: Kirsten Menking (Vassar College)
- Collaborators: Pinar Batur, Stuart Belli, Mary Ann Cunningham, David Gillikin, Marshall Pregnall, and Mark Schlessman (Vassar College); Allison Morrill Chatrchyan and Carolyn Klocker (Cornell Cooperative Extension Dutchess County Environment Program)

Background

The Casperkill is a small (17-km long, 31 km^2 drainage area) tributary of the Hudson River that flows through the Town of Poughkeepsie in Dutchess County, NY. The stream is featured in the municipality's draft master plan, where it is recognized as a natural, aesthetic, and recreational resource. However, its health is challenged by existing and proposed development that impairs the riparian buffer, contributes non-point-source pollution, and leads to flooding and sewage overflows into the backyards of homeowners. Though the draft master plan calls for the protection and restoration of the creek along its entire length, the Casperkill, like many headwater streams in the Hudson River estuary, appears to have few official advocates. Indeed, as recently as the summer of 2007 parts of the stream were diverted into culverts in order to allow for parking lot expansion at a local department of transportation office. Concern for the creek led students and faculty at Vassar College to begin characterizing its health in the spring of 2006, measuring water quality parameters such as dissolved oxygen, temperature, nutrient levels, and bacterial loads. Preliminary results were presented at a forum in September 2006 for community residents, who responded by sharing their own concerns about pollution, flooding, and loss of biodiversity.

With New York Water Resources Institute funding acquired in the spring of 2007, Vassar faculty and students partnered with staff from Cornell Cooperative Extension Dutchess County's Environment Program (CCEDC) to initiate a comprehensive watershed assessment program and to identify stakeholders who might be interested in forming a watershed protection group. It is hoped that the scientific and policy information generated by Vassar, combined with the citizen involvement cultivated by CCEDC, will provide the municipal council of the Town of Poughkeepsie with the knowledge and support it needs to make informed environmental decisions related to aquatic resources in the area. In addition, the watershed protection group will initiate stream cleanups and riparian buffer restoration projects that will benefit the Poughkeepsie community and the aquatic ecosystem.

Due to delays in the funding process in late spring of 2007, some of our work started later than originally scheduled, and we have therefore been granted an extension to complete the project. As such, this report summarizes the work done to date and is not meant to be a final report.

Goals and Results

The NYWRI grant has four primary objectives:

1) Further development of scientific knowledge of the Casperkill, its surrounding watershed, and potential threats to the aquatic ecosystem
2) Increasing cooperation between a higher education institution, Vassar College, working to gather scientific data on the stream, and a local non-profit organization, CCEDC, that is involved in environmental education, facilitation, and training, particularly on watershed issues
3) Increasing community awareness and participation in protecting the watershed
4) Providing hands-on training and educational opportunities for Vassar College students in environmental science and in translating scientific data into public outreach

We have made great progress on all of these fronts. In the summer of 2007 seven Vassar faculty members and nine students (six of whom were supported by this grant) conducted multi- and inter-disciplinary research on the Casperkill to characterize the health of the aquatic ecosystem and surrounding riparian buffer. Twenty-one sampling sites from the headwaters of the stream to near its mouth were sampled monthly for conductivity, temperature, pH, dissolved oxygen, nutrient levels, discharge, major cations and anions, and metals. Standard methods of analysis were used in all cases and will be presented in detail in a watershed assessment document that is presently in preparation.

Students also developed independent research topics, which included determining the potential impact of chloramines originating from sewage overflows on aquatic ecosystem health; origin and quantity of microbiological contaminants such as *E. coli*; identification of emerging contaminants such as caffeine, phthalates, and pharmaceuticals in stream water; creation of a geochemical budget for chloride derived from winter road salting; use of carbon and nitrogen isotopes in stream organisms to look for evidence that a landfill is contributing leachate to the stream; assessment of brownfields legislation and grant opportunities for remediation of that landfill; and a public interest survey sent to ~400 households to gauge knowledge about and interest in the stream.

Faculty and student members presented their work at the 2nd annual Casperkill public forum held on campus in September 2007 and also presented to the Town of Poughkeepsie supervisor and town board in July 2007. Major findings include elevated chloride levels in the stream during summer, which nearly approach the EPA threshold for chronic toxicity of 250 mg/L; a strong relationship between chloride and the amount of impervious cover (pavement, rooftops, etc.) upstream of each sampling site; *E. coli* and total fecal coliform levels that exceed New York State Department of Environmental Conservation limits for bathing; confirmation, through the presence of emerging contaminants, that human sewage is contributing to elevated bacterial counts; and a clear relationship between stream water quality, as measured by benthic macroinvertebrates, and vegetated buffer width along the stream.

Another aspect of the Casperkill project that got underway this year was the creation of the Casperkill Watershed Alliance, a group of citizens interested in promoting the health of the stream. Organized by Vassar College Environmental Research Institute fellow Kelsey Smith and CCEDC Watershed Educator Carolyn Klocker, this group has met four times thus far to share information, develop ideas for projects, and to do riparian buffer planting. Alliance members plan to develop a Casperkill watershed educational display for the Town of Poughkeepsie Town day to be held in late June 2008 and also plan to contribute a "Valley Views" article to the Poughkeepsie Journal to talk about the work occurring on the stream.

Student involvement

As mentioned, nine Vassar College students participated in the field and laboratory work involved in this project throughout the summer of 2007. As part of the project, all students acquired training in water sampling, nutrient analysis via spectrophotometry, alkalinity titration, discharge determination, and use of a Yellowsprings Instruments probe to measure dissolved oxygen, pH, temperature, and conductivity. In addition to these skills, individual projects exposed students to microbiological analysis, techniques of identifying and counting benthic macroinvertebrates, gas chromatography, inductively coupled plasma atomic emission spectroscopy, use of datalogging equipment, and measurement of canopy cover via densiometry.

In addition to research conducted by Vassar students, Poughkeepsie High School students involved in a CCEDC "No Child Left Inside" grant participated in water sampling, and the Vassar Environmental Research Institute fellow worked with the coordinator of Jewish Family Services to organize a stream cleanup of the Fonteynkill for Mitzvah Day in mid-May, which involved several junior high and high school students.

As already mentioned, students and faculty also presented research results to the Town Board and at a public forum in summer of 2007. The local branch office of the Time Warner Cable company did a news story discussing some of our results and advertising the forum.

Future work

In the months remaining on the grant, we will complete the watershed assessment document, which is intended to provide local decision makers with both specific and general information about the impact of development on the aquatic ecosystem. Drafts of this document will be circulated to members of the Casperkill Watershed Alliance who will comment on its readability for a lay audience and provide suggestions for improvement.

We will also work with the Alliance to develop a mission statement for the organization and a vision statement for the watershed, and will assist the Alliance in developing educational displays for the Town of Poughkeepsie town day and the Dutchess County Fair.

Information Transfer Program Introduction

WRI continues to promote the engagement of the wider academic community in water resource management issues in New York State according to its federal and state mandates. Under the direction of its new Director, Susan J. Riha, WRI facilitates information transfer through existing sponsored programs such as the Hudson River Estuary Program and the NY Project WET (Water Education for Teachers), as well as emerging issues: climate change and reactive nitrogen.

Director's Office Information Transfer

Basic Information

Title:	Director's Office Information Transfer
Project Number:	2007NY102B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	22
Research Category:	Not Applicable
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	None
Principal Investigators:	Susan S. Riha

Publication

1. Woodbury, Peter, and Porter, Mary Jane, Eds. 2007. Progress Report: Understanding Sources and Sinks of Nutrients and Sediment in the Upper Susquehanna River Basin. Agricultural Ecosystems Program, College of Agriculture and Life Sciences, Ithaca, NY 14853−2701.
2. Porter, Keith S., 2007, Good Alliances Make Good Neighbors: The Case for Tribal−State−Federal Watershed Partnerships, 16 Cornell Journal of Law and Public Policy, p 495−593.

Outreach, Education and Information Transfer

Hudson River Estuary Program

One of WRI's partnership programs with the NYS Department of Environmental Conservation (DEC) is the Hudson River Estuary Program. Beginning in the Adirondack Mountains, the Hudson River flows 322 miles into the ocean at lower New York Harbor. In 1996, the governor released The Hudson River Estuary Action Plan. In 1998, the Hudson River was designated as one of the nation's first American Heritage Rivers. WRI continues working in partnership with the NYS Department of Environmental Conservation in carrying out the Action Plan's twelve goals.

New York's Project WET Program

Another of WRI's partnership programs with the DEC is the NY Project WET (Water Education for Teachers), is now in its ninth year. The goal of the program is to facilitate and promote awareness, appreciation, knowledge and stewardship of water resources. Project WET's Curriculum and Activity Guide, complete with activities for Kindergarten through 12-grade, is the source for most of the activities.

In addition to basic water education, NY's Project WET assists the State regulatory agency with stormwater education for municipalities as part of their stormwater management plans. Education staff members are also adapting activities from the Curriculum and Activity Guide to raise awareness for flooding and drought, and other issues resulting from climate change. Climate change will continue to be a major focus for FY2008.

Susquehanna River Basin

A continuing focus for WRI's outreach is the watershed comprising the headwaters of the Chesapeake Bay. The Susquehanna River is the nation's 16th largest river and provides fifty percent of the freshwater to the Chesapeake Bay. New York has entered into an interstate agreement with other Chesapeake Bay watershed states to reduce nutrient and sediment loading to the bay. Collaboration in the Basin is with the Upper Susquehanna Coalition (USC) and the Agricultural Ecosystems Program (AEP).

- The USC is a network of county natural resource professionals, spanning 17 counties, who develop strategies, partnerships, programs, and projects to protect the headwaters of the Chesapeake Bay.
- Understanding sources and sinks of nutrients and sediment in the upper Susquehanna River Basin is the basis of the research being conducted in the AEP. The program is lead by faculty at Cornell University.

Transboundary Indigenous Waters Program (TIWP)

Over the past two years, WRI has worked in partnership with the academic and Indigenous communities and supporting agencies in New York State, the Northeastern US and the international Great Lakes Basin to raise awareness of the critical water issues facing American Indian communities and their neighbors. As the first step to that end a joint conference and symposium on native water law, sovereignty, and cultural survival was convened in 2006 at the Cornell University Law School.

Planning for a Summer Institute for 2009 in the Great Lakes Basin has been the focus of this fiscal year's activities. The proposed three-week Institute on Integrated Water Law will enhance and consolidate the legal capacity of Native American law students and tribal leaders. Objectives are to teach new skills on: water law, native treaties, rights and legal responsibilities; and to develop future leaders who will help build social and technical capacities in both Native and non Native communities.

International Outreach – Rural Economy and Land Use Programme

Colleagues from Imperial College, the Westcountry Rivers Trust, and the University of East Anglia, United Kingdom, completed the Rural Economy and Land Use (RELU) Programme funded by the UK Research Councils in FY2005. The focus was building a network for a capacity building program for creating catchment strategies in the UK that exploited successful management options from the eastern US and European continent.

Three US watershed programs that were highlighted as successful watershed programs and presented to UK stakeholders were the NYC Watershed Program -- Delaware County Action Plan, the upper Susquehanna River Basin, and the Hudson River Estuary Program. The initial RELU project resulted in considerable dialog with watershed groups in the UK, giving rise in 2007 to funding for a three-year grant from the UK Research Councils for "Developing a Catchment Management Template for the Protection of Water Resources: Exploiting Experience from the UK, Eastern USA and other European Countries. Workshops are planned for summer 2008 in two UK pilot areas.

Emerging Information Transfer Activities

Climate Change

Indications of climate change are already evident in New York -- total precipitation has increased by more than three inches since 1950 with significantly less falling as snow, and extreme precipitation events are occurring more frequently. Model projections suggest these trends will continue, and the Northeast will experience more summer droughts as the climate warms. These trends pose significant new challenges to sustainable water resource management in New York. Municipal planners, natural resource managers, and many business owners will benefit from sector-specific risk management strategies addressing these challenges. WRI is working to catalyze academics, state and cooperative extension system partnerships to advance the science and best practices to achieve sustainable water resource management in a changing climate.

WRI's Director also serves on an advisory committee for the new initiative, *Rising Waters: Helping Hudson Valley Communities Adapt to Climate Change.* The New York State Water Resources Institute, the Nature Conservancy-Eastern NY Chapter, the NYS Department of Environmental Conservation Hudson River Estuary Program, Hudson River National Estuarine Research Reserve, Institute for Ecosystem Studies, and Sustainable Hudson Valley are partnering to engage scientists and regional stakeholders in the Hudson Valley in a two-year planning process to outline regional threats associated with climate change, outline natural and human communities at highest risk, and develop recommendations for regional adaptation over the long term.

Reactive N

High levels of nitrogen (N) compounds in the environment from anthropogenic sources (agriculture, vehicle exhaust, coal-burning power plants, waste-water discharge, lawns, and septic systems) are recognized as important pollutants in New York and are negatively impacting surface and groundwater and the ecological function of natural areas. In response to emerging regulatory and resource quality issues, it is important to better assess the current sources of anthropogenic N. This will allow for better targeting of management interventions and regulatory policies to improve environmental quality while maintaining economic vitality. WRI has convened and facilitated two advisory groups – Cornell faculty on campus and State officials and leaders of NY watersheds to assist in targeting management interventions.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR−USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	11	0	0	0	11
Masters	3	0	0	0	3
Ph.D.	3	0	2	0	5
Post−Doc.	0	0	0	0	0
Total	17	0	2	0	19

Notable Awards and Achievements

FY2007NY97B: An aspect of the Casperkill project that got underway this year was the creation of the Casperkill Watershed Alliance, a group of citizens interested in promoting the health of the stream. Organized by Vassar College Environmental Research Institute fellow Kelsey Smith and CCEDC Watershed Educator Carolyn Klocker, this group has met four times thus far to share information, develop ideas for projects, and to do riparian buffer planting. Alliance members plan to develop a Casperkill watershed educational display for the Town of Poughkeepsie Town day to be held in late June 2008 and also plan to contribute a “Valley Views” article to the Poughkeepsie Journal to talk about the work occurring on the stream.

FY2007NY91B: −−Further refinement, calibration, and running of GWLF for the Moodna watershed; −−Site determination and permission for installation of a stream gage. −−Technical report written to be incorporated into the Moodna Creek Watershed Management Plan.

FY2007NY100B: The Town of Hurly and the Sawkill Watershed Alliance indicated that the project findings will be very helpful for making future land use planning decisions. Electronic Copies of the report were distributed.

FY2007NY102B: Three US watershed programs that were highlighted as successful watershed programs and presented to UK stakeholders on an initial one−year grant were the NYC Watershed Program, the Delaware County Action Plan (DCAP), the upper Susquehanna River Basin, and the Hudson River Estuary Program. This project prompted a considerable dialog with watershed groups in the UK, giving rise in 2007 to a new three−year grant for “Developing a Catchment Management Template for the Protection of Water Resources: Exploiting Experience from the UK, Eastern USA and other European Countries.