New York State Water Resources Institute
Annual Technical Report
FY 2006

Introduction

The New York State Water Resources Institute (WRI) devotes most of its resources to research and outreach to assist in state and local government problem-solving as well as demonstration projects. Staff and many cooperating Cornell faculty have been enmeshed in New York States (and more recently New York City) water resources management processes in its several major watersheds, focusing on the most scientifically demanding water problems.

NY WRIs FY2006 competitive grants program acquired a new a new partner. The Hudson River Estuary Program, NYS Department of Environmental Conservation, contributed $45,000 of State funding to increase the number of seed research grants. A primary objective of the FY2006 grants program is to foster the involvement of New York's higher education community, preferably in partnership with agencies and communities concerned, to become active in achieving local watershed planning and implementation strategies, as well as linking to priorities of the regional Hudson River Estuary Program. Criteria used in determining proposal selection included:

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;
4. Supporting information or educational transfer that enhance communication of research results to teachers, technical providers or to watershed communities; and finally,
5. Budgeting to insure that students and interns secured a larger part of the funds.

Projects were solicited competitively from about 50 academic entities in NY.

Projects were evaluated and selected for funding by a panel consisting of representatives from New York State agencies as well as private organizations from the Hudson River Valley. Project oversight is primarily through submission of project reports for the annual technical report to USGS. For students and interns carrying out research in FY2006 grants program, a special event will be convened to recognize the contribution to the research by the students and their faculty mentors. Date to be determined.

Research Projects

WRI FY2006 activity under the Federal Water Resources Research Act consisted largely of research and information transfer projects funded from FY2003 through FY2006. One national 104G project report, three 104B project reports, and the NYS WRI Directors Office information and transfer progress reports are included in this report.

The FY2003 104G project, which did not begin until May 2005 and has now been extended through July 2007, examines statistical patterns in low stream-flows. Three FY2006 projects reflect WRIs objective to foster partnerships between higher education, agencies and communities in the Hudson River Watershed. Projects for FY2006 included:

- Assessing the ecosystems services of open space for water resource protection in the Moodna Creek Watershed;
- Studying the effects of urban runoff on seasonal and spatial trends in the water quality of the Saw Mill River; and
- Studying the use of eel ladders for passage over barriers to increase the amount of available habitat for eels in the Saw Kill River.

Research Program

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

1. 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.
2. Hirabayashi, S, 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.
3. Matonse, AH 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.
4. 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.
5. Zang, 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.
6. Zang, Z and C N Kroll, 2005, A closer look at baseflow correlation, submitted to the ASCE Journal of Hydrologic Engineering, July 2005. Decision pending.
7. Hirabayshi S, and C N Kroll, 2006, Automating regional descriptive statistic computations for environmental modeling, resubmitted to Computers & Geosciences, January 2006. Decision pending.
8. Hirabayashi, S, 2005, Examining the Impact of Raster Datasets on Flood and Low Streamflow Regional Regession Models Using a Custom GIS Application,MS Thesis, Dept. of Environmental Resources and Forest Engineering, SUNY College of Environmental Science and Forestry, Syracuse, NY
9. Zhang, Z, 2005, Advances in Low Streamflow Statistics Estimation Using Baseflow Correlation, PhD Thesis, Dept. of Environmental Resources and Forest Engineering, SUNY College of Environmental Science and Forestry, Syracuse, NY
10. Luz, J, 2005, Investigating Improvements in Low Streamflow Regression Models, PhD Thesis, Dept. of Environmental Resources and Forest Engineering, SUNY College of Environmental Science and Forestry, Syracuse, NY

Title: An Assessment of New Advances in Low Streamflow Estimation and Characterization

PI Chuck Kroll

Principal findings or significant results:
Research on this project began in May 2004, and thus we have completed 2 years of this 3 year project. 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.
1. 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)

- 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.
- Hirabayashi, S, and C N Kroll, 2006, Automating regional descriptive statistic computations for environmental modeling, resubmitted to Computers & Geosciences, January 2006. Decision Pending.

Theses

- 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.
- Zhang, Z, Advances in Low Streamflow Statistics Estimation Using Baseflow Correlation, PhD Thesis, December, 2005.
- Luz, J., Investigating Improvements in Low Streamflow Regression Models, PhD Thesis, January, 2005.

Conference Proceedings/Presentations

- 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.
- 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.
- 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.
- 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.
- 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. Abstract prepared.

1. Title.

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

4. Duration. March 1, 2006 – February 28, 2007

5. Federal Funds requested. $20,000

6. Non-federal funds requested. $25,000 (match)

7. Principal Investigators.

Karin Limburg, SUNY-ESF; co-PI Valerie Luzadis, SUNY-ESF; Collaborators Simon Gruber, Coordinator, Moodna Watershed Coalition; William Schuster, Director, Black Rock Forest Consortium; James Beaumont, Executive Director, Orange County Water Authority; and David Church, Commissioner, Orange County Department of Planning.

8. Congressional District. District 25 (includes Syracuse), District 19 (includes Orange County)

9. Statement of critical regional or state water problems.

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. ***This proposal addresses the first two priority topics in the RFA.***

10. Statement of results or benefits.

The results of this project will provide:

- An understanding of how future land use scenarios impact the water balance, including water availability and water quality, of the Moodna sub-watersheds.
- Data on areas to target protection initiatives for key recharge areas, wetlands, stream corridors, steep slopes and other sensitive areas.

- Data for the Moodna Watershed Management Plan about strategies addressing open space conservation, municipal water resource supplies, and land use planning.
- Opportunities for public dialogue about potential land use scenarios for the Moodna watershed, and the value of open space and water resources.
- Community visions of future land use for development and conservation in the Moodna watershed.
- An enhanced public understanding of computer models and their use in environmental decision-making.

11. Nature, scope, and objectives

Human activities generate the economic demand for land that has resulted in an increasingly urbanized landscape with serious impacts to the ecosystem services (Daily 1997) provided by the natural environment. As human populations grow, the economic demand for land and the pressure for greater conversion of forests, wetlands, meadows and fields to residential and commercial development increase. This urbanization is a major reason for the degradation of key watershed and freshwater ecosystems (Carpenter et al. 1998, Postel 2000, Nilsson et al. 2003, Limburg et al. 2005 in press). Decisions about development and land conversion are typically made in piecemeal fashion, rather than by some concerted effort such as regional planning. Kahn (1966) referred to "the tyranny of small decisions" which describes the evolution of unintended economic consequences of decisions made on the basis of short-term, marginal gains. While the intention of environmental impact assessments is to prevent the negative environmental effects of human activities, these are carried out on a project-by-project basis. Thus, the cumulative effects of open space being converted to urbanized areas not anticipated. While many people are concerned about the loss of open space for aesthetic reasons, another widespread concern is the effect on drinking water quality and availability. Alternative approaches for development and land use planning decisions (Tidwell et al. 2004, Hulse et al. 2004) are more spatially broad, e.g. watershed-scale or bio-regional scale, and are more participatory, bringing together scientists, engineers, land use planners, business community leaders, environmentalists, and other stakeholders in an interactive way to discuss and evaluate future land use scenario and understand impacts to ecosystem services.

Open space areas provide key ecosystem services for the freshwater streams and groundwater flows of a watershed. Forests, meadows, fields, and wetlands provide sites for groundwater recharge, infiltration, and uptake of nutrients, thus reducing runoff rates, maintaining base flows and water quality, and regulating temperature (Daily 1997). With the conversion of land comes a hardening of the surface with concrete, reducing the connection of precipitation with groundwater recharge, and accelerated discharge of runoff water, sediment, and chemicals into recipient streams and rivers. It is recognized, that of the many aspects of urbanization, impervious surface is likely to have some of the most adverse effects on stream ecosystems (Klein 1979; CWP 2003). In small catchments (3^{rd} order or less), an impervious surface cover > 10% is often associated with degradation of stream quality, with severe alterations when impervious surface exceeds 25% of the catchment area (CWP 2003).

Within the middle reaches of the Hudson Valley of New York, the pace of open space loss is rapid (Orange, Ulster, and Dutchess counties). In the Moodna watershed (466 km^2) of Orange County, development and new impervious surfaces have led to the filling of floodplains and wetlands, and the reduction of infiltration and base flows. Water availability is a serious concern, as wells are influenced by the level of the Moodna Creek. During the dry summer months of 2005, drinking water had to be shipped in from neighboring counties. In response to the environmental problems of development, Moodna (under the auspices of the Orange County Water Authority) watershed stakeholders have put several initiatives into place including the development of a watershed management planning proposal funded by the Hudson River Estuary Program (HREP). The stakeholders involved include the Orange County Water Authority, the Moodna Watershed Coalition, municipal leaders, and other county departments (e.g. Orange County Planning Department, Soil and Water Conservation District). This watershed management plan includes the development of water quality protection, long-term water quantity, habitat and open space protection, and long-term watershed management goals and opportunities. A key component of this work is envisioning future land use change and estimating the impacts of the potential development on water resources. ***We propose to study how development may alter the delivery of hydrologic ecosystem services provided by open spaces within the Moodna Creek watershed in Orange County, NY. For this project, we propose to coordinate with the Moodna Creek Watershed Steering Committee to help develop the watershed management plan by modeling present and projected distributions of water (surface and groundwater) and water quality as land use changes through development. The modeling will be an iterative, participatory process with future land use scenarios being developed by the steering committee members and the intern. We also propose to communicate these findings to local stakeholders, to aid in policy development.***

12. Methods, processes, and facilities.

To evaluate the effects of potential development on the Moodna water resources, two models will be implemented that simulate potential land use change and the effects of land use on water quantity and quality.

The water balance of the Moodna watershed with present and potential land uses will be simulated using the Generalized Watershed Loading Function model (Haith and Shoemaker 1987). The GWLF model is an event-based, 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. The effect of land use change on water resources will be evaluated using this model by running it with different development scenarios. Changes in water quantity, infiltration rates, and runoff rates will be compared between development scenarios. Some scenarios will represent development efforts that conserve open space; others will represent more intense development. How these different land use patterns affect water in the Moodna will reveal the importance and manner for conserving open space.

A coupled land use change – ecosystem health model (Polimeni 2002, Limburg et al. 2005, Hong and Limburg, in preparation) originally developed for Dutchess County, NY will be used to simulate urbanization effects on water quality in the Moodna. The land use model is a binomial logit regression that uses tax parcel data (locations, sizes, assessment values, land classification, number of houses permitted per parcel, etc.), demographic data (population change, income distribution change) and geographic factors (e.g., distance to business centers) to generate probabilities of unoccupied parcels (undeveloped land) being converted to occupied parcels (developed land). Restrictions, such as regulations for zoning or protecting steep slopes, hydric soils, or wetlands, can be imposed to prevent land conversion. The output of the model is a simulated land use map. (The land use data from the model can be input to the GWLF.) The % land use change from the simulated land use map is then fed into the ecosystem health component of the model. The ecosystem health model is a multiple linear regression model dataset that predicts how watershed urbanization affects a large suite of water quality and biological variables. The % land use change and coefficients representing relationships between land use composition and water quality are the inputs to this regression model. The coefficients for the multiple linear regression model are derived from data extracted from the USGS NAWQA (United States Geological Survey National Water Quality Assessment Program), restricted to the NY/NJ/PA area so that sufficient data sets could be analyzed without compromising specific characteristics of the region (Hong and Limburg, in preparation). The results of this modeling effort will be used to forecast water quality conditions for various land use change scenarios in the Moodna basin.

The modeling effort will be an iterative, participatory process involving the Moodna Watershed Steering Committee and the general public of the Moodna watershed communities. These individuals will partner with us to develop the different land use scenarios used in the models. The Moodna watershed-planning project funded by the HREP will include creation of a Watershed Steering Committee composed of local officials, business leaders, planning and design professionals, organizations, water suppliers, scientists, outdoor recreation groups, builders, cultural and arts organizations, and others. The Steering Committee will be invited to participate in planning the research and modeling process. The stakeholders from the Moodna Watershed Steering Committee include municipal leaders, members of the Moodna Watershed Coalition (citizens from watershed communities interested in planning issues), and experts with the Orange County Planning Department and the Soil and Water Conservation District. The intern will work with our collaborators (Gruber, Schuster, Beaumont, and Church) and the Moodna Watershed Steering Committee to develop future land use scenarios and to review the land use change/ecological health and hydrologic model results. Interaction with the Moodna watershed communities will occur during public meetings where the Moodna Watershed Steering Committee will also be describing the results of the watershed management plan development. Feedback from these public meetings can be used to evaluate and refine the future land use scenarios of the model results. The watershed management planning process will benefit from the modeling project beyond the specific implications of the model results. The participatory nature of the modeling project will result in a more in-depth dialogue between citizens about land use, open space, and water resource issues as well as an awareness of the potential serious impacts of urbanization.

Facilities and resources available for this project include SUNY-ESF, Orange County Planning Department, Orange County Water Authority, and the Black Rock Forest Consortium. The Orange County Planning Department and Water Authority will provide GIS data support for the intern. The intern will be based at SUNY-ESF and will complete the majority of the modeling, analysis and synthesis there. Meetings with stakeholders will be held at the Black Rock Forest Science and Education Center and at municipal offices in watershed communities. A final watershed summit where the project results will be disseminated to local officials and other stakeholders in the Moodna will be held at the Black Rock Forest Center.

Timeline of Project Intern

Spring 2006:	Planning and Background Work including working with the Moodna Watershed Coalition to convene the Steering Committee (the watershed stakeholders that will be involved in the modeling process and other aspects of the Watershed Plan)
Spring/Summer 2006:	Work with Watershed Steering Committee to develop land use change scenarios
Summer/Fall 2006:	Intern gathers data, parameterizes and executes models, does analysis, meets with stakeholders
Winter/Spring 2006/2007:	Intern updates and refines data, executes models and analysis; Communicate model results to stakeholders
Spring 2007:	Communicate project results to scientific community – public presentation(s) and begin to draft an article for a peer-reviewed journal

13. Related work.

The use of computer models to simulate hydrological effects of land use change is well documented (Kite 2001, Fohrer et al. 2002, Bhaduri et al. 2000, Burges et al. 1998). Recent efforts include a GIS coupled to a hydrologic model to estimate surface and groundwater resource conditions affected by land use change and climate change in Jordan (Al-Abed et al. 2005), a distributed hydrologic model (RHESSys) that estimated streamflow based on vegetation patterns in a semiarid shrubland in California (Tague et al. 2004), a rainfall-runoff model to estimate effects of land use on surface water runoff in multiple watersheds of the Rhine basin (Hundecha and Bardossy 2004), and a distributed watershed model (LISFLOOD) to simulate frequency and intensity of floods with changes in flood control measures and land use change in the Oder Basin in Poland, Germany and the Czech Republic

(DeRoo et al. 2003). In this project, we propose to use the hydrologic model Generalized Watershed Loading Function model (GWLF; Haith and Shoemaker 1987) to model the water balance of the Moodna sub-watersheds with varying land uses. The model has been used for similar purposes, although more emphasis on the simulation of sediment and nutrient loads, including the Hudson River (Swaney et al. 1996), the Choptank River (Lee et al. 2000, 2001), the Cannonsville watershed in New York (Schneiderman et al. 200), and the Susquehanna River (Chang et al. 2001).

Using stakeholder guidance to develop and model land use scenarios has been implemented in several projects including the Willamette River Basin Alternative Futures project (Hulse et al. 2004, Dole and Niemi 2004), the Middle Rio Grande, New Mexico system dynamics model for community-based water planning (Tidwell et al. 2004), and the future land use scenario analysis for northern Wisconsin (Peterson 2003a and 2003b). The stakeholder participation component of the project provides the advantages of greater scenario variation and political plausibility due to the unique and diverse perspectives of the stakeholders versus the standard approach of using scientist's input only (Peterson 2003b; Hulse et al. 2004). In a similar project where stakeholders developed land use scenarios for a rural area in northern Wisconsin, the participation of stakeholders strengthened community understanding of the potential environmental effects of tourism and second home development on the ecosystem services of the freshwater lakes in the watershed (Peterson et al. 2003a, 2003b). The stakeholder participation for predicting future land use scenarios in these studies is similar to that proposed in our study. However, our project is unique in that we intend to use the information on land use scenarios to simulate the land use change on water resources. In the models described above, models were used to estimate future water demands and did not simulate land use impacts on water quanitities.

Past and ongoing environmental research in the Moodna watershed is extensive and will provide water quality data that can be used to calibrate and validate the ecological health model. Water quality surveys on streams in undeveloped areas of the Black Rock Forest, a state park in the upland region of the watershed were conducted several years ago and are currently being published. Other water quality studies include a baseline study on streams in the Hudson (Stevens et al. 1994) and county wide bio-monitoring stream studies (Nolan 2004). The Orange County Water Authority has conducted several groundwater and surface water studies and produced GIS of water resource sites in the county.

14. Investigator's qualifications.

See attached CV's for Limburg (PI) and Luzadis (co-PI).

15. Training potential.

The project is specifically designed to train an intern, Ms. Molly Ramsey. Ms Ramsey is a second-year doctoral student at SUNY-ESF who has great interest in the linkages between land use, environmental quality, and how societal decisions affect these. The project will give the intern the opportunity to learn the skills necessary for scientific watershed assessment and communications with stakeholders. Results of this project will be shared with students and faculty of academic institutions through the Black Rock Forest Consortium, a membership organization of educational institutions; and, through the recently-formed Highlands Environmental Research Institute and the Highlands Coalition, respectively a scientific initiative and a coalition of environmental organizations, both interested in questions about water resources, open space, and development in the Highlands region, which includes part of the Moodna basin.

16. Principal findings or significant results.

To date the significant results of the project include the development of model scenarios to run in the watershed computer simulation model, GWLF (the Generalized Watershed Loading Function Model). The scenarios were developed at a meeting with the Moodna Watershed Coalition in July 2006. The scenarios represent the concerns and interests of the coalition. Two scenarios test worst and best-case scenarios, i.e. 100% impervious surface vs. 100% forested land cover. The other two scenarios represent specific development projects that are of concern to the watershed stakeholders. These scenarios are in sub-watersheds of the Moodna and the model will be run at the sub-watershed scale instead of the entire watershed.

17. Notable achievements.

Presentations to the Moodna Coalition, the watershed stakeholder group for the Moodna Creek watershed, were held in May and July 2006. These presentations gave an overview of the WRI project and developed the land use change scenarios for the watershed simulation model. Interests and concerns of the coalition members about the project were discussed and considered in the future development of the project and goals for the second year of the project (WRI grant 2007). Final results from the work done for the WRI 2006 project (watershed simulation modeling using GWLF) will be presented at a watershed summit meeting that will be held in October 2007 in Cornwall, New York (this meeting is being organized by the Moodna Watershed Coalition).

A second year of funding through the WRI was secured in December 2006. The second year of the project (2997-2008) will build upon the first year of the project with the installation of a stream gage on the Moodna and the calibration and validation of a spatially-explicit, water routing model.

Two professional oral presentations were given on the watershed modeling project – one to the New York chapter of the American Fisheries Society in February 2007 and another to the United States Society of Ecological Economics Conference in June 2007.

18. Student support (including names of students and area of study).

Academic and research support was provided for Molly Ramsey during the fall and spring semesters (2006-7), a doctoral 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. Travel funds were also used to the 2006 3rd National Conference on Coastal and Estuarine Habitat Restoration "Forging the National Imperative" in New Orleans, LA. The national conference was held December 9 – 14th. The conference focused on coastal restoration issues including the human dimensions of restoration, education, and outreach, best practices, measuring and communicating results. The conference brought together academics, professionals, and citizen stakeholders involved in restoration research on terrestrial and coastal watershed and estuarine research. The conference was a great experience to hear and speak with scientists, government agencies, and NGO's involved in collaborative partnerships related to watershed planning. Case studies of projects similar to my own included the Hudson, Chesapeake Bay, Mississippi River, and Puget Sound. This was a very beneficial experience that helped provide a context for my own work, definitive and appropriate venues for future presentations about this project, and contacts for shared feedback from scientists, government agency, and NGO workers at the national-scale. I had several opportunities to discuss the WRI project with fellow conference attendees during several social events, question and answer periods following oral presentations and during my own poster presentation of an ecological economic project on the rebuilding of New Orleans. Seeing the positive feedback from others particularly related to public communication piece of this poster developed my current plans to organize a similar public workshop in the Moodna Creek Watershed that is the focus of my project for the WRI grant.

19. Publications generated to date (journal articles, theses, conference proceedings, etc. even those in press or submitted).

Publications include abstracts in two conference proceedings. An abstract for an oral presentation is published in the proceedings for the annual meeting of the New York state chapter of the American

Fisheries Society held in February 2006. The title of the presentation was *"Modeling urbanization effects on water resources in Moodna Creek Watershed, NY: Developing a tool for community watershed management."* An abstract for an oral presentation is published 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.

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Effect of urban runoff on seasonal and spatial trends in the water quality of the Saw Mill River

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Effect of urban runoff on seasonal and spatial trends in the water quality of the Saw Mill River
Report submitted to the New York State Water Resources Institute

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MANHATTAN COLLEGE

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Project Overview

The Saw Mill River is a tributary to the Hudson River in the Lower Hudson River Drainage Basin. The headwaters of the River are located in the Village of Chappaqua in the town of New Castle. The River has several designated uses over its entire stretch, indicating diverse surroundings as it travels from Chappaqua to Yonkers, NY where it eventually discharges into the Hudson River. Additionally, along the Yonkers stretch, the river has been severely altered over the past 30 years by flood control projects and re-routing (Pearce, 1999). The most extreme case of this is in south Yonkers, where the river has a concrete bottom (at Old Nepperhan Rd.) and eventually flows underground (at Elm St.) for its final 800 feet before reaching the Hudson.

Urban runoff is one of the leading sources of water quality impairment in surface waters (Usepa, 2000b). According to USGS estimates (Wall et al., 1998), the Saw Mill River watershed of 23.8 mi^2 is 63.4% urban, 35.4% forested, and 1.0% agricultural. This high percentage of urban areas makes the Saw Mill susceptible to contamination from urban runoff. Pollutants usually associated with urban runoff include nutrients (nitrogen and phosphorous), metals (cadmium, copper, lead and zinc), and coliform bacteria (Usepa, 2005).

The primary objective of this work was to conduct a year-long continuous monitoring program for the entire stretch of the Saw Mill River. The following water quality parameters related to urban runoff were monitored: surface water nutrients (ammonia, nitrate and total phosphorous) and fecal coliform bacteria. Temperature, conductivity, pH, total suspended solids and turbidity were also measured. This data is being made available on the Saw Mill River Coalition website (http://www.sawmillrivercoalition.com) via our partnership with Groundwork Yonkers.

Our final objective of this project was to measure the spatial profile for sediment-bound metals in the Saw Mill River. This work is being conducted this summer through matching funds provided by the Saw Mill River Coalition/Groundwork Yonkers. Ten to twelve sediment samples will be collected at sites along the entire stretch of the Saw Mill River and analyzed for concentrations of the toxic metals of copper, lead, nickel, cadmium, zinc, arsenic, and chromium.

The results of this work will be presented at the New York Water Environment National Meeting University (student) symposium in February 2008. Additional conferences highlighting the efforts of undergraduate research will be targeted for poster and/or platform presentations. Follow-up work on the Saw Mill River is been perused through a collaborative USEPA Targeted Watershed Grant proposal that was submitted in Fall 2006 by the Saw Mill River Coalition/Groundwork Yonkers.

Personnel

This work included partnerships with Groundwork Yonkers and Saunders Trade and Technical High School in Yonkers. Groundwork Yonkers is a non-profit organization developed in 1999 dedicated to revitalizing, greening, and connecting people to the urban environment in lower Westchester County. It follows a model developed nearly twenty years ago in the United Kingdom (UK) designed to regenerate towns with long histories and aging infrastructures. Groundwork Yonkers is the coordinator of the Saw Mill River Coalition, a partnership of non-profit groups, government agencies, and businesses, aimed to revitalize and protect the Saw Mill watershed. Saw Mill River Coalition/Groundwork Yonkers was periodically updated on progress and key findings throughout the duration of the project.

Another key partner in the project is the environmental science and technology program at Saunders High School in Yonkers which has been working with junior and senior classes for more than two years on water quality monitoring efforts along the Saw Mill. Two students, Nicole Kerrison and Leslie Guadron were involved in field sampling and laboratory analysis of water quality parameters through a paid summer internship. Nicole and Leslie worked in the environmental engineering laboratories at Manhattan College three days a week for eight weeks. They were trained in the laboratory analyses for nutrients and assisted in all analytical work. After the conclusion of her work on the project Nicole Kerrison has been working in our labs on her senior project.

Two undergraduate students, Jason Lumish and Erica Hanley worked approximately six to eight hours per week throughout the school year and thirty-five hours a week for ten weeks from June 1 to August 15 as paid undergraduate research assistants (URAs). They were trained in all aspects of sample analysis, and performed the majority of the analytical work for the project. Two graduate students, Michael Lynch and Eric Spargamino worked approximately 6 hours per week on the project. They were utilized to collect samples and perform some limited sample analysis. All personnel listed in Table 1 were trained in all aspects of sampling and analysis prior to work on the project.

Table 1: Personnel on this project

	Level	Field of Study	Institution	Role
Jason Lumish	Undergraduate (Junior)	Civil Engineering (major; Environmental Engineering (minor)	Manhattan College, Riverdale, NY	Field sampling, sample analysis
Erica Hanley	Undergraduate (Sophomore)	Environmental Engineering	Manhattan College, Riverdale, NY	Sample analysis
Christopher Fanelli	Undergraduate (Sophomore)	Environmental Engineering	Manhattan College, Riverdale, NY	Database management
Eric Spargamino	Graduate student	Environmental Engineering	Manhattan College, Riverdale, NY	Field sampling, sample analysis
Michael Lynch	Graduate student	Environmental Engineering	Manhattan College, Riverdale, NY	Field sampling, sample analysis
Nicole Kerrison	Junior	Environmental technology	Saunders Trades and Technical School, Yonkers NY	Sample analysis
Leslie Guadron	Sophomore	Environmental technology	Saunders Trades and Technical School, Yonkers NY	Sample analysis

Methods

Water samples were collected in 1 L acid-washed polypropylene bottles. After collection, they were stored in a cooler filled with ice until arrival in the lab. Samples were transferred to a refrigerator and stored at 4 °C prior to analyses.

Sample pH was measured using a pH meter (Accumet Model 15, Fisher Scientific, Hampton, NH) employing a combination hydrogen ion electrode (Model 910600, Thermo Orion, Boston, MA). Sample conductivity and temperature were determined using Oakton CON 200 Series total dissolved solids/ conductivity/ temperature probe. Turbidity was measured using a Hach Turbidimeter (Model 2100P, Loveland, CO).

HACH spectrophotometric (Spectrophotometer Model DR 2010) test methods were used to measure nitrate (cadmium reduction method), total ammonia (Nessler method) and total phosphorus (ascorbic acid method) on filtered samples. Fecal coliform bacteria levels were determined using the membrane filtration method (Clseceri et al., 1998).

Sample Site Selection

Sites were selected along the Saw Mill River so that a representative spatial profile of water quality could be obtained (Table 2). Site-to-site distances along the river were determined using USGS maps and the MapTech mapping software package. We are reporting these distances as "Distance from Elm St.," which is the location at which the Saw Mill River travels underground in Yonkers. It was not possible to find maps detailing the exact geographic position of the river along this final stretch as it flows into the Hudson River. A map of all sites is presented in Figure 1. Sample site S6 (Executive Blvd) is in a small brook that empties into the Saw Mill River in Elmsford, NY. Since it is not along the main stem of the Saw Mil River, we have not reported a distance in Table 2.

Sampling Frequency

Samples were collected approximately every one to two weeks over the period of June 26, 2006 to October 23, 2006. In some instances, complete analysis of the data for all parameters was not possible within the EPA recommended holding times. In these instances, only a subset of the water quality parameters was analyzed. The remaining parameters were analyzed for at the following sampling event.

Table 2: Sampling Locations

Site ID	Location	Lat	Long	Distance from Elm St. (mi)
S12	Walsh Rd., Yonkers, NY	40.9379	-73.8893	0.40
S11	Torre Pl., Yonkers, NY	40.9517	-73.8779	2.17
S10	Hearst, St., Yonkers, NY	40.9744	-73.8688	4.13
S9	Lawrence St., Ardsley, NY	41.0025	-73.8563	6.57
S8	V.E. Macy Park, Ardsley, NY	41.0183	-73.8463	8.26
S7	Woodlands Lake (spillway), Dobbs Ferry, NY	41.0240	-73.8452	8.62
S6	Executive Blvd, Elmsford NY	41.0704	-73.8082	N/A
S5	Warehouse Lane, Elmsford NY	41.0637	-73.8170	12.61
S4	Saw Mill River Road (Rosedale Nursery), Hawthorne, NY	41.0952	-73.8108	16.33
S3	Saw Mill Road, Eastview, NY	41.0811	-73.8287	14.50
S2	Pleasantville Rd/Manville Rd., Pleasantville, NY	41.1332	-73.7962	19.48
S1	Chappaqua Metro North Station, Chappaqua, NY	41.1565	-73.7756	22.93

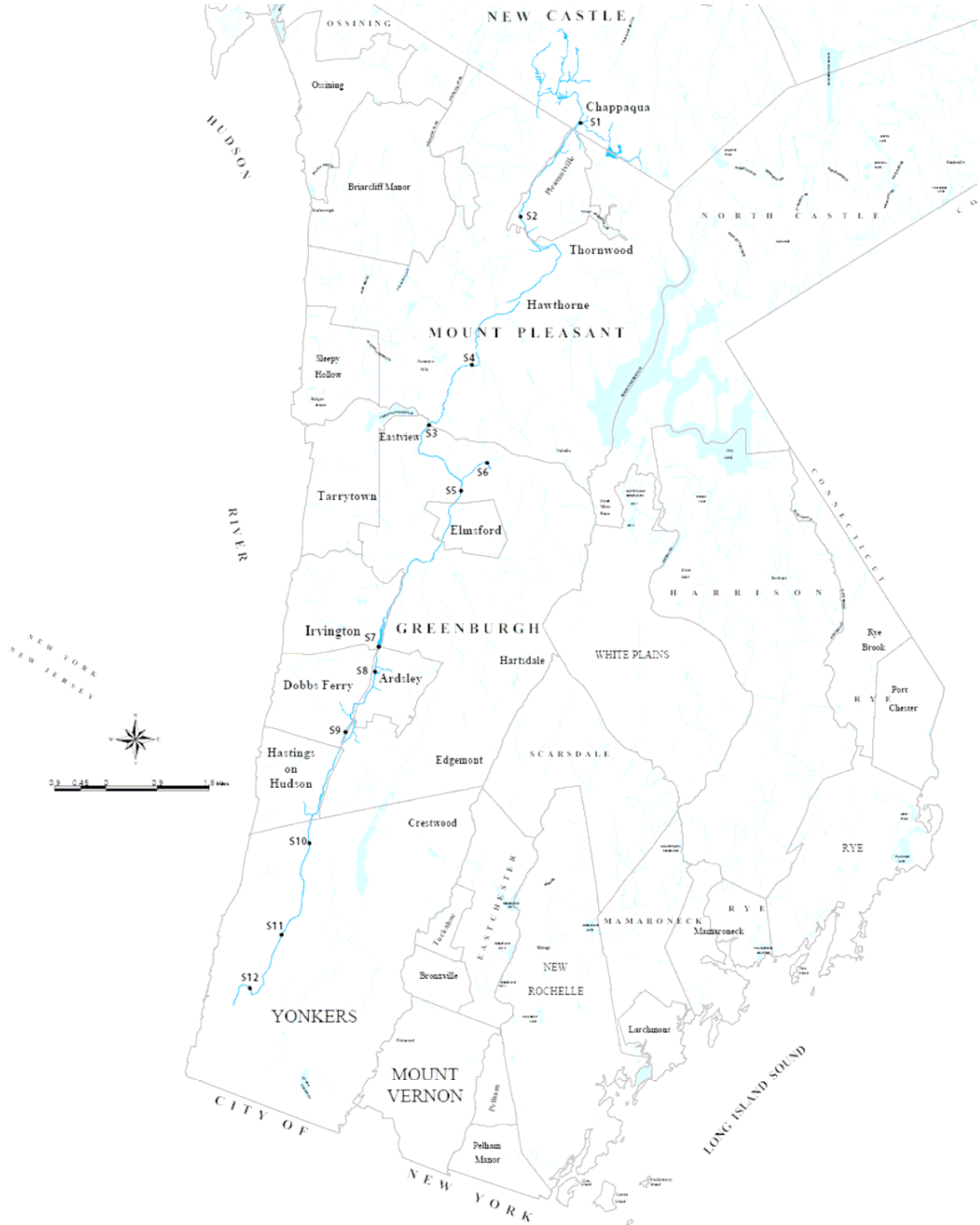

Figure 1: Map of all sampling locations (S1 to S12).

Results

Basic Water Quality

A summary of basic water quality parameters (pH, conductivity TSS and turbidity) are reported in Table 3. Median, minimum, maximum, and standard deviations are listed. We are in the process of posting the complete database on the Saw Mill River Coalition website.

Table 3: Summary of Basic Water Quality Parameters[(a)]

Site	pH	Conductivity (μS/cm)	TSS (mg/L)	Turbidity (NTU)
S1	7.36 (7.10 - 7.70) ; 0.19	632 (186 – 891); 190	2.9 (1.0 – 17) ; 11	3.84 (1.6 - 10.9) ; 3.56
S2	7.62 (7.32 - 7.90) ; 0.20	605 (190 – 793); 170	1.6 (0.5 - 35) ; 18	1.87 (0.74 - 18.6) ; 5.09
S3	7.60 (7.32 - 7.90) ; 0.19	663 (249 – 829); 173	2.1 (1.0 - 61) ; 23	1.46 (1.02 - 38.9) ; 11.2
S4	7.53 (7.16 - 7.80) ; 0.20	621 (222 – 795); 176	2.1 (0.9 - 46) ; 21	2.19 (0.91 - 27.2) ; 7.6
S5	7.46 (7.13 - 7.85) ; 0.22	755 (190 – 1041); 245	2.1 (1.1 - 14) ; 7.6	2.52 (2.08 - 16.8) ; 4.48
S6	7.64 (7.22 - 7.90) ; 0.22	781 (389 – 1005); 165	3.2 (1.6 - 64) ; 23	2.39 (1.79 - 42.1) ; 11.9
S7	7.60 (7.14 – 8.00) ; 0.25	674 (198 – 823); 182	4.8 (3.7 - 60) ; 17	4.88 (2.66 - 59.1) ; 17.3
S8	7.70 (7.32 – 8.00) ; 0.20	666 (185 – 824); 193	4.6 (1.9 - 41) ; 11	3.11 (1.97 - 46.9) ; 13.2
S9	7.57 (7.23 - 7.90) ; 0.21	762 (184 - 846) ; 203	3.9 (2.3 - 61) ; 17	3.21 (1.00 - 60.1) ; 17.2
S10	7.72 (7.17 – 8.00) ; 0.22	758 (192 - 869) ; 203	4.4 (1.6 - 64) ; 18	3.07 (1.50 – 53.0) ; 15.2
S11	7.81 (7.28 - 8.17) ; 0.27	740 (205 - 826) ; 187	6.9 (3.1 - 58) ; 15	3.86 (2.73 - 45.6) ; 12.7
S12	7.67 (7.31 - 8.02) ; 0.23	751 (205 - 862) ; 197	4.9 (2.5 - 59) ; 16	3.89 (2.33 - 46.1) ; 12.8

(a) Data reported as median (min – max); standard deviation

The pH of the Saw Mill River showed very little spatial and temporal variability and is generally within the acceptable levels for freshwater streams. NYS DEC regulations (1999) state that pH shall not be less than 6.5 nor more than 8.5. The median pH of all samples was 7.59 with a standard deviation of 0.23. The lowest and highest pH values reordered were 7.10 and 8.17 respectively.

Electrical conductivity (EC) showed large temporal variability, in part due to very low conductivity readings recorded on 8/28/06 during the middle of a heavy rainfall event. The low conductivity readings are the result of dilution from rainwater. In general, the EC values are on the high side of freshwater streams, and not uncommon for streams impacted by urban runoff.

Factors which can affect EC include the surrounding geology, the size of the watershed area relative to the area of the waterbody, wastewater point and non-point sources, and salt water intrusion. Electrical conductivity estimates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. The TDS concentration can be related to EC of the water, but the relationship is a function of the type and nature of the dissolved cations and anions in the water and possible the nature of any suspended materials. High TDS water can be harmful to fish and plants and may limit biodiversity.

The TDS (in mg/L) usually ranges from 0.5 to 1.0 times the EC (in μS/cm). Assuming a conversion factor of 0.7, the approximate median and maximum TDS of all samples taken from the Saw Mill River are 500 and 700 mg/L respectively. NYS DEC regulations (1999) for the entire stretch of the Saw Mill River streams state that TDS should be kept low to maintain the best usage of waters but in no case shall it exceed 500 mg/L. While there is some uncertainty in our choice of conversion factor for TDS, the river appears to be impacted by dissolved solids.

Fecal Colform Bacteria

Monitoring results for fecal coliform bacteria are presented in Figures 3 and 4. In Figure 3, a box plot is used to show spatial variability in fecal coliform bacteria concentrations along the entire stretch of the Saw Mill River. The boundary of the box closest to a value of zero on the y-axis indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. The error bars above and below the box indicate the 90th and 10th percentiles, respectively. Sample sites S11 (Torre Pl., Yonkers, NY) and S12 (Walsh Rd., Yonkers, NY) had the highest median fecal coliform counts. These two sites are the southernmost sites sampled, and are in a highly urbanized area of downtown Yonkers. Median fecal coliforms of all other sites were extremely constant. Sample site S1 (Chappaqua Metro North Station), does not have a significantly different median than sites S2 – S10, however, the highest single fecal coliform measurements were for this site (1.2×10^5 and 8.4×10^4 org/100 mL).

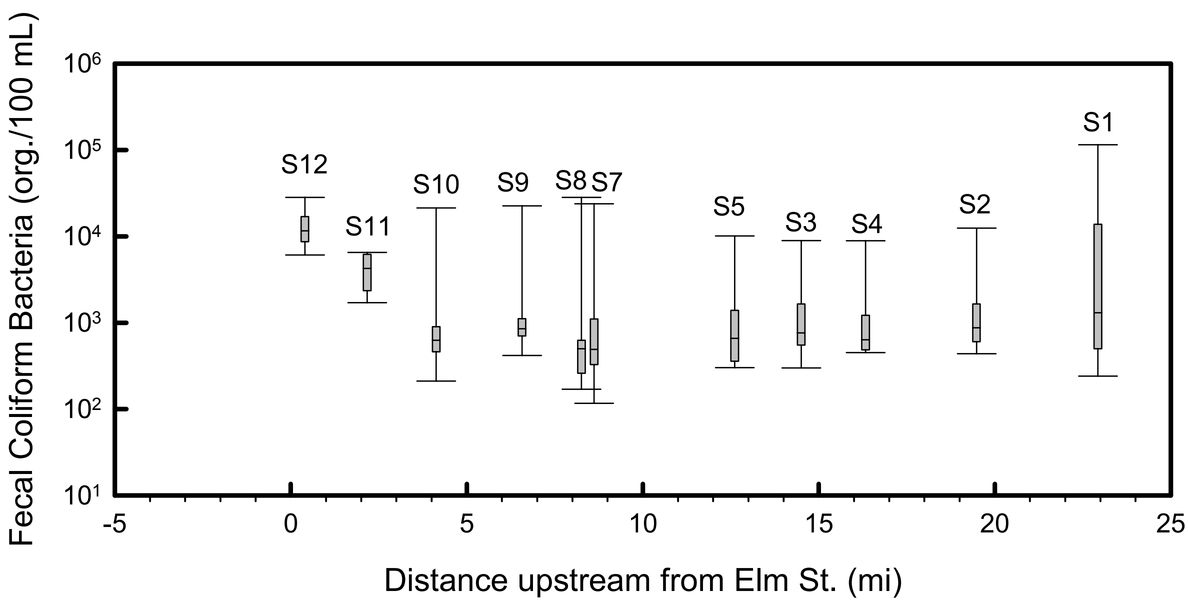

Figure 3: Box plot of fecal coliform bacteria as a function of distance upstream from Elm St., Yonkers NY.

In Figure 4, fecal coliform bacteria is shown as a function of time at sample stations S1, S4, S8 and S12. Also indicated on the plot is the daily precipitation recorded at Westchester County Airport. An increase in fecal coliform bacteria seems to be directly related to rainfall. This can be seen in the plots by examining data points that fall in or slightly to the right of significant rainfall events (more than 1.0 inch/day). These data points are consistently higher than baseline for all sample sites.

All median fecal coliform bacteria values were above 200 org./100 mL. This is significant because the NYS DEC criteria (1999) for fecal colifoms states that the monthly geometric mean, from a minimum of five examinations, shall not exceed 200 org./100 mL. Bacterial contamination can originate from point or nonpoint sources. Point sources may include municipal or Industrial discharges of wastewater. Nonpoint sources may include storm water runoff, animal waste, application of manure and biosolids to fields, crop irrigation from contaminated storage ponds, failed septic systems, litter or landfill leakage, or direct discharge of marine-craft sewage. For the Saw Mill River watershed, stromwater runoff, and municipal wastewater discharges are likely causes of the observed high fecal coliform bacteria counts.

Typical pollutant concentrations found in typical urban storm water runoff are on the order of 3600 org./100 mL (Mde, 1999). While fecal coliform bacteria are subject to inactivation upon direct exposure to sunlight, portions of the Saw Mill River are under canopy and rapid die-off is unlikely. It is therefore possible that the high baseline levels of fecal coliform bacteria are the due directly to urban run-off.

Wastewater generated from much of the area of the Saw Mill River is treated by only the Yonkers Wastewater Treatment plant (Mulligan et al., 2005). This plant serves a population of half a million people, a total area of 108 mi^2 and receives an average daily flow of 96 million gallons per day (Mulligan et al., 2005). Thus, wastewater generated in the upper Saw Mill River watershed travels south through county trunk lines until it reaches the Yonkers WWTP. While the recorded values at site S1 may seem extremely high ($\approx 10^5$ org/100mL), they are significant less than levels commonly found in raw sewage and sewer overflows. Typical fecal coliform bacteria concentrations in raw sewage are on the order of 10^7 org/100 mL (Thomann and Mueller, 1987). A 1:100 dilution of raw sewage therefore puts it into the range of our observed values. Coliform bacteria in combined sewer overflows range from 10^5 to 10^6 org./100 mL (Thomann and Mueller, 1987). Sewer overflow(s) occurring during wet weather in the upper watershed may therefore be responsible for high fecal coliform bacteria counts at site S1.

For the two sites in Yonkers (S11 and S12), the source of the high coliform levels do not appear to be weather related. The surrounding area is highly urbanized and has the largest density of impervious services. Thus, stormwater runoff may be a contributing a larger load in this area than at the more sub-urban upstream sites. In addition, sewage discharges from homes or businesses tied to storm sewers may be present in this older section of Yonkers. Further investigation is required if such connections exist.

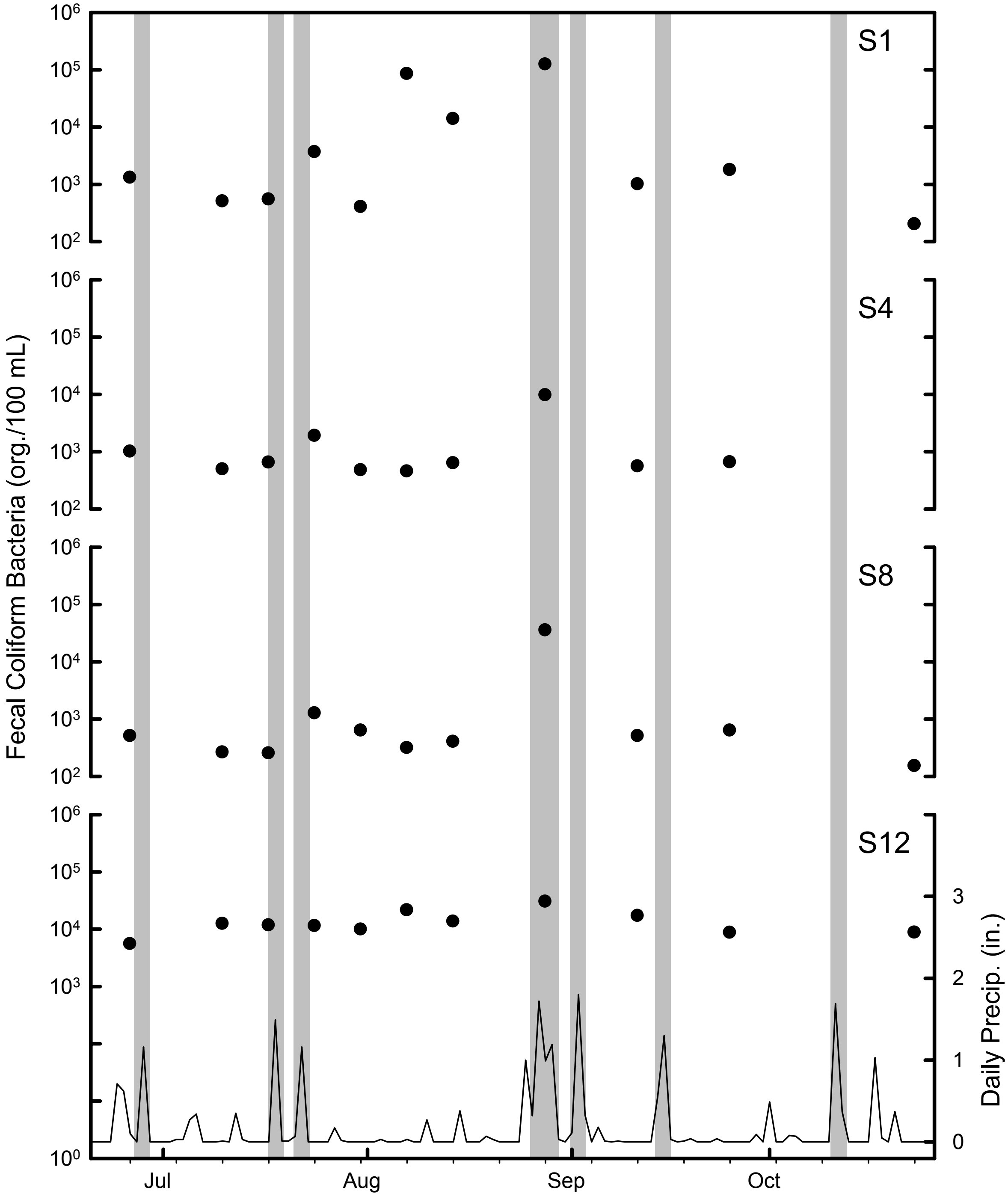

Figure 4: Fecal coliform bacteria at sample stations S1, S4, S8 and S12. Also indicated on the plot is the daily precipitation (in.). Grey bars represent days where daily precipitation was greater than 1.0 in.

Ammonia

Total ammonia concentrations as a function of time are shown as a box plot in Figure 5. In general, all ammonia concentrations are relatively low with most values falling below 0.4 mg N/L, and the largest value recorded being 0.79 mg N/L. The CCC (chronic criterion concentration) established by EPA for total ammonia is both pH and temperature dependent (Usepa, 1999). All samples collected from this study were considerably lower than their standard determined at their respective temperature and pH. Median total ammonia levels are generally slightly higher during or after storm events as indicated by the daily precipitation record.

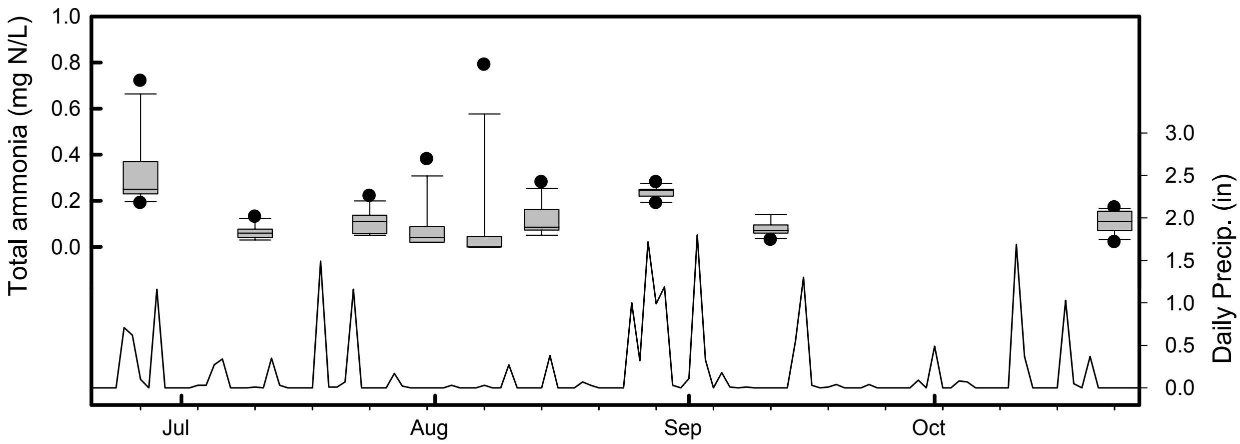

Figure 5: Box plot of total ammonia concentrations as a function of time. Also indicated on the plot is the daily precipitation (in.).

A stormwater sampling event performed on August 11, 2004, also showed increases in total ammonia after a significant rainfall event. An ISCO automated sampler was deployed at the Hearst St. (site S10), and programmed to take a series of twenty-four 1.0 L samples at 45 minute intervals. The sampler was deployed at 2:00, the first sample was collected at 2:30 pm. The results of total ammonia and conductivity from this sampling are shown in Figure 6.

We do not have a rainfall estimate for the August 11 storm, however a short period of intense rainfall was observed at 2:45 pm (15 minutes after sampling started) and intermittent rainfall was observed throughout the night starting at 7:00 pm (270 minutes after sampling started). The temporal profile for conductivity appears to give an excellent indication of the rainfall period. The conductivity of the first sample was 755 µS; this value is very consistent with the conductivity at this sampling station during baseline sampling. By the time of the second sample, it had already started raining quite hard. Correspondingly, conductivity had decreased to 448 µS, due to dilution from the input of stormwater to the river. With the next few samples conductivity began to increase until it reached the original baseline conductivity levels. During this period, there was a lack of rain in the area, and the river water upstream of the site was probably not diluted from significant rainfall. After 4.5 hours, the conductivity began to decrease, corresponding with the start of continual rainfall in the area. The conductivity remained low for the remainder of our sampling, indicating that the upstream waters were also receiving significant rainfall. Thus, tracking conductivity levels with time is a viable way of indirectly monitoring stormwater inputs to the river.

Total ammonia levels clearly increase during rainfall. This is evident by comparing the temporal profiles for ammonia and conductivity. Throughout the 18 hour sampling period, increased ammonia levels corresponded to decreased conductivity and vice versa. A cross plot of ammonia versus conductivity yielded a correlation coefficient for ammonia and conductivity of 0.86 (n = 24). Therefore, stormwater runoff is an important non-point source of ammonia to the river.

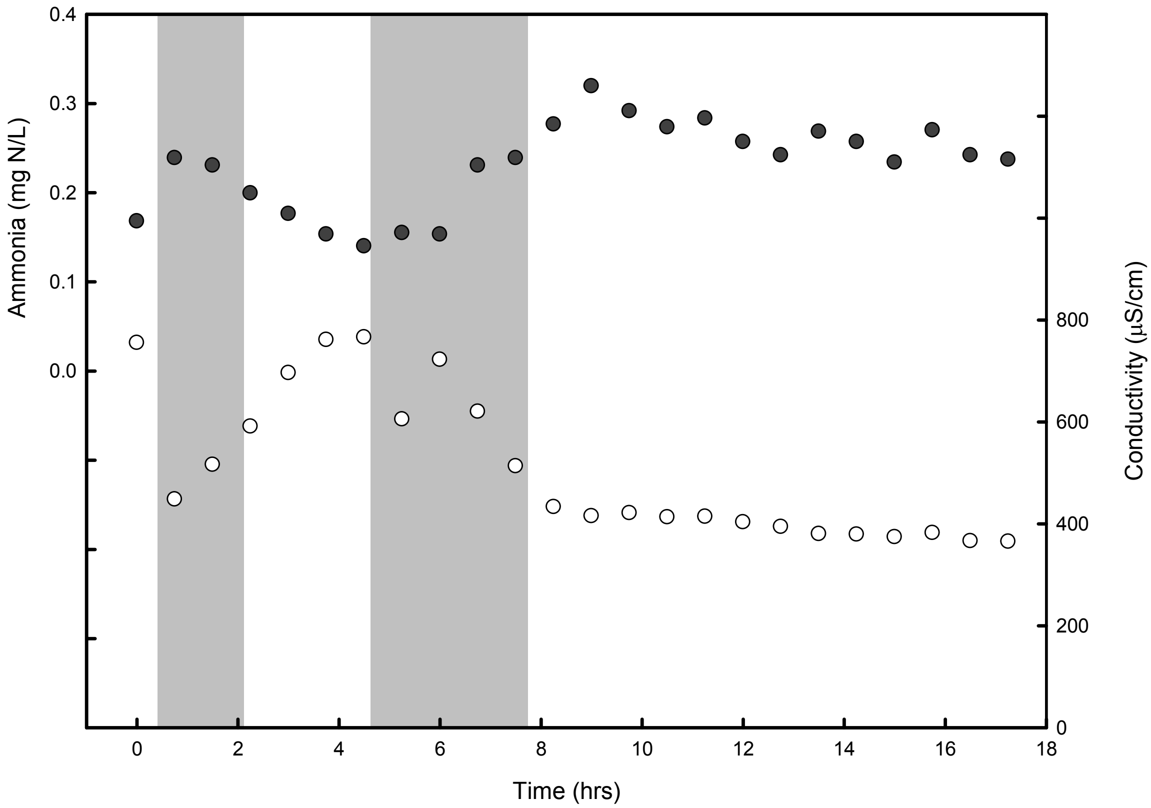

Figure 6: Total ammonia (closed circles) and conductivity (open circles) for a storm event captured on August 11, 2004 at site S10 (Hurst St., Yonkers, NY). Grey bars represent periods of significant rainfall.

In Figure 7, total ammonia is plotted versus distance as a box plot. The medians of total ammonia are fairly constant along the entire stretch of the river, however, sites S10, S11 and S12 exhibited higher values during a few sampling events than those observed at the upstream sites. Municipal wastewater, agricultural runoff, fertilizers, and animal feedlots are potential sources of ammonia (and nitrate) to streams. At sites S11 and S12, both ammonia levels and fecal coliform bacteria are higher than that observed at points upstream, both of which can result from municipal wastewater discharges.

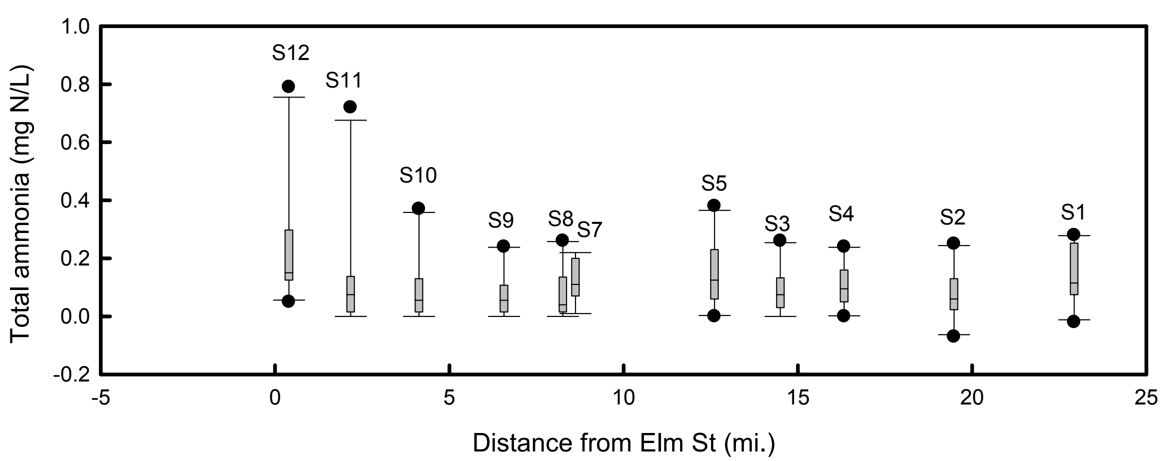

Figure 7: Box plot of total ammonia concentrations as a function of distance.

Nitrate and Phosphorus

As much as half of the waterbodies surveyed by states do not adequately support aquatic life because of excess nutrients (Usepa, 2002). Furthermore, urban streams are second only to agricultural streams in terms of their nitrate and total phosphorus levels (Barth, 1995). There are several nonpoint sources of nitrate and phosphorus in urban areas: fertilizers in runoff from lawns, pet wastes, failing septic systems, and atmospheric deposition from industry and automobile emissions. Moderately high concentrations of nitrogen and phosphorus can result in excessive plant growth in rivers and streams.

EPA has recently set nutrient criteria for rivers and streams that are based upon conditions observed in unimpacted waterbodies (Usepa, 2000a). As part of this effort, the US was divided into various ecoregions (lower New York being part of Nutrient Ecoregion XIV). These criteria provide recommendations to States agencies for establishing their own water quality standards for nutrients. The aggregate Nutrient Ecoregion XIV reference conditions are 31.25 μg P/L for total phosphorus and 0.71 mg N/L for total nitrogen (Usepa, 2000a).

Nitrate concentrations in the Saw Mill River did not show a large amount of spatial variability. Median and maximum nitrate concentrations from all sample sites did increase however from summer to early fall, and then decreased through to late fall (Figure 8). The small decrease in nitrate observed for the August 28 sampling corresponded with a large rainfall and is probably due to dilution. A summary of nitrate concentration data for each site is presented in Table 4. The median and average of all samples collected was 0.38 mg N/L. All nitrate readings were less than 1.0 mg/L. At these levels, nitrate is not expected to be toxic to aquatic life. Many recorded values for nitrate in late summer/early fall exceeded the EPA reference condition for total nitrogen, even without considering contributions of ammonia and organic nitrogen. If we consider total nitrogen to be the sum of the ammonia and nitrate concentrations, we arrive at a mean total nitrogen of all samples of 0.49 mg N/L.

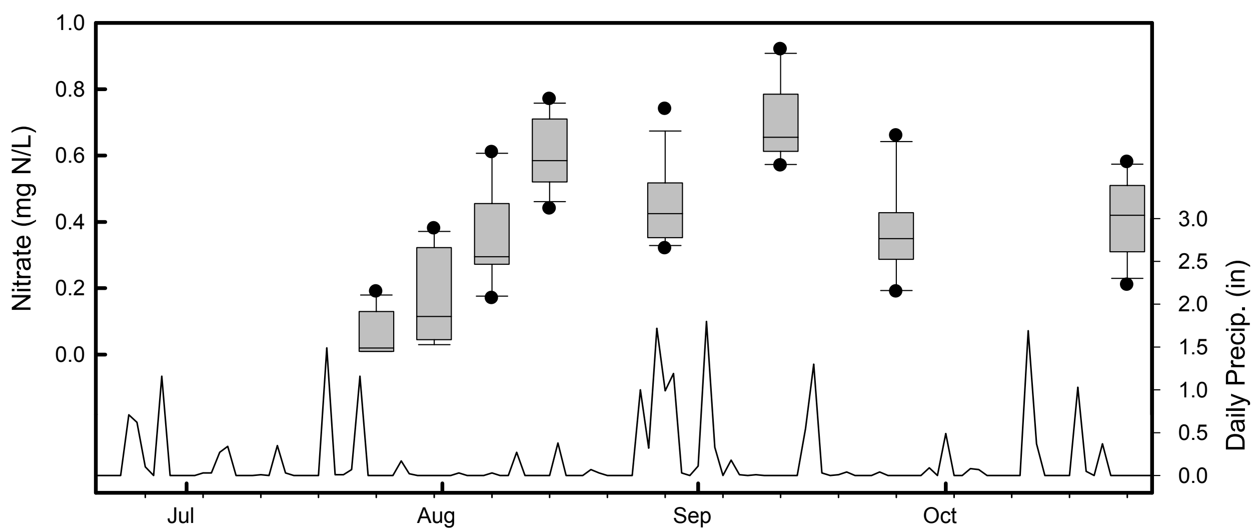

Figure 8: Box plot of nitrate concentrations as a function of time.

Table 4: Summary of Nitrate and Total Phosphorus[(a)]

Site	Nitrate (mg N/L)	Total Phosphorus (mg P/L)
S1	0.28 (0.13 - 0.72) ; 0.19	0.07 (0.02 - 0.13); 0.03
S2	0.52 (<0.10 - 0.92) ; 0.29	0.09 (0.02 - 0.83); 0.25
S3	0.31 (<0.10 - 0.80) ; 0.27	0.08 (0.02 - 0.36); 0.10
S4	0.52 (<0.10 - 0.88) ; 0.28	0.11 (0.05 - 0.34); 0.08
S5	0.38 (<0.10 - 0.74) ; 0.23	0.06 (0.04 - 0.27); 0.07
S6	0.39 (<0.10 - 0.63) ; 0.22	0.07 (<0.02 - 0.18); 0.05
S7	0.43 (0.10 - 0.73) ; 0.21	0.06 (0.02 - 0.10); 0.03
S8	0.37 (<0.10 - 0.74) ; 0.23	0.07 (<0.02 - 0.11); 0.03
S9	0.39 (<0.10 - 0.66) ; 0.21	0.08 (0.06 - 0.13); 0.02
S10	0.33 (<0.10 - 0.64) ; 0.23	0.09 (0.04 - 0.13); 0.03
S11	0.39 (<0.10 - 0.71) ; 0.21	0.16 (0.10 - 0.35); 0.08
S12	0.41 (0.11 - 0.77) ; 0.22	0.12 (0.07 - 0.23); 0.05

(a) Data reported as median (min – max); standard deviation

Total phosphorous showed no apparent spatial or temporal trends. A summary of the data is presented in Table 4. Total phosphorus concentrations were quite high for freshwater streams, with average and median values from all samples of 0.10 and 0.08 mg P/L respectively. The N/P ratio (based on the median total N and total P) was equal to approximately 6. Based upon the N/P ratio, the Saw Mill River therefore appears to be N-limited (Thomann and Mueller, 1987).

The total phosphorous values observed here are higher than the USEPA Ecoregion XIV reference conditions, but are in line with levels found for rivers and streams flowing through urbanized areas. Bartsch and Gakstatter (1975) report a mean total P of 0.066 mg P/L from 11 mostly urban areas of the eastern US. Omernik (1977) reports estimated mean total P levels for 75% and 100% urban areas of 0.078 and 0.136 mg P/L, respectively. While freshwater lakes are usually P-limited, freshwater lakes can be either N or P-limited (Thomann and Mueller, 1987).

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The Sawkill Eel Project: Eel restoration in a tributary to the Hudson River

Basic Information

Title:	The Sawkill Eel Project: Eel restoration in a tributary to the Hudson River
Project Number:	2006NY84B
Start Date:	3/1/2006
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Focus Category:	Conservation, Management and Planning, None
Descriptors:	None
Principal Investigators:	Catherine O'Reilly, Robert Schmidt

Publication

1. Schmidt, R.E., C.OReilly, and D. Miller, 2006, Hudson River Tributaries: American Eels and the Estuary Connection. Presented at the Watershed Commons: People, Wildlife, and Water in the Hudson Valley, Hudson River Watershed Alliance Conference, Mohonk Mountain House, New Paltz, NY, 17 November 2006.
2. Schmidt, R.E., C. OReilly and D. Miller, 2007, Observations on American Eels at a Passage Facility on a Hudson River Tributary. Presented at New York State Chapter, Amerian Fisheries Society, Thayer Hotle, West Point, NY, 9 February 2007.

WRI/HREP Grants 2006NY84B

Saw Kill Eel Project Report

Participants

Principal investigators: Dr. Catherine O'Reilly (Bard College) and Dr. Robert Schmidt (Simon's Rock College of Bard)
Collaborator: Dan Miller (Hudson River National Estuarine Research Reserve)

Background

Populations of American eels have been declining for several reasons, including loss of habitat (Haro et al. 2000). American eel *(Anguilla rostrata)* is a catadromous fish that spawns in the Sargasso Sea (central Atlantic Ocean). After hatching, young eels migrate thousands of miles to coastal estuaries and continue their migrations upstream into tributaries and inland ponds and lakes where they grow and mature for up to ten years or more before returning to the Sargasso Sea to spawn and die. Population declines have been so extensive that the American eel has been considered for listing as threatened or endangered. In the Hudson River estuary, access to upstream habitat is severely restricted by numerous small dams that act as barriers to many miles of viable habitat upstream. These dams typically restrict eel habitat to the lower reaches of the tributaries to the Hudson River, leading to high densities, decreased growth rates, and potentially lower recruitment in these reaches.

Eel ladders could provide passageways over these barriers and effectively increase the amount of available habitat. Access to this upstream habitat could increase eel growth rates, fecundity, and ultimately eel recruitment. By establishing a demonstration eel passage facility on the dam on the Saw Kill at Bard College, we hope to show that eels will use such a facility, that the facility will increase the numbers of eels upstream, and that these facilities are relatively cheap to install, monitor, and maintain. Currently, there are no migratory fish passage devices on dams in tributaries to the Hudson River Estuary. Given the large number of dams, and their potential collective impact on eel populations, there may be great potential for eel habitat restoration by providing passage over these historic dams.

As a tributary to the Hudson River, the Saw Kill has undoubtedly supported large eels populations historically throughout its reach. The Saw Kill watershed is 26.6 square miles and land use within the watershed is primarily forested (51.1%), with some agricultural (25.8%) and minimal urban (16.5%) areas. The landscape near the mouth is basically unimpacted secondary forest with some old growth, as the stream is the property boundary between Bard College campus and the historical Montgomery Place estate. The high densities of eels in the lower reach of this tributary (13,000 – 16,900 eels/ha, compared to 2 – 34 yellow eels/ha in the Hudson River) suggest that this relatively protected and undisturbed creek is prime habitat, which is supported by the large annual run of young-of-the-year American eels (elvers) for the Saw Kill (up to 10,000 (NYS DEC 2005)). Other accessible northeastern rivers support eel densities up to 3,000 eels/ha (Oliviera and McCleave 2000, Morrison and Secor 2004). Upstream of a small dam on Bard College campus, eel densities are significantly lower (170-554 eels/ha). These upstream densities are still lower than those found in other northeastern rivers with eel passages (800- 2200 eels/ha (Oliviera and McCleave 2000)), indicating that this upstream habitat could easily support higher densities if it were more accessible. Although eels are adapted for getting around barriers (as evidenced by their presence upstream of the dam) it is clear from the large difference in densities that the dam represents a substantial barrier.

Approach

We installed a trap-and-transfer eel ladder at the dam on Bard College campus. The goal was to design and install an inexpensive eel ladder that could be easily maintained and monitored. In addition to being less expensive, a trap-and-transfer system allowed us to collect information on the numbers, sizes, and movement patterns of eels using the ladder. Eels using this type of ladder would become trapped in a large container at the top of the fish passage device and then need to be manually transferred from the container to the water upstream of the dam, so data collection could be done when the transfer occurred. The collaboration between Bard College and Simon's Rock College of Bard allowed students to actively participate in the research program and helped ensure frequent monitoring.

The eel ladder was designed and installed by Alden Research Laboratory, Inc. (Holden, MA). Greg Allen and Brian McMahon of Alden Research Laboratory, Inc. visited the site February 16 and returned April 16, 2006 to install the ladder. The ladder framework was constructed of aluminum for durability and attached to rocks near the edge of the water below the dam (but was not attached to the dam itself). Alden Research Laboratory, Inc. designed a pressure-driven siphon system to keep upstream water flowing through the ladder. Some improvements were made to the system throughout the summer to help simplify maintenance and operation and reduce the likelihood of escapement from the ladder or container.

The ladder was checked twice each week. Eels were removed from the container and placed into a bucket where they were anesthetized with clove oil, counted, and measured. All eels longer than 16 cm were tagged with a 1 mm coded wire tag (CWT) at the head of the dorsal fin. Trapped eels were also checked to see if they contained a CWT from previous electroshocking and tagging below the dam. Eels were allowed to recover in a bucket of stream water before they were released above the dam.

Students were trained to handle, measure, and tag the eels during the spring, under the supervision of Dr. O'Reilly. During the summer, two other students were trained and worked with Dr. Schmidt.

The eel ladder was completely removed from the stream in late December and stored over the winter.

Results and outcomes

Number and size of eels

From May 15 through September 18, 2006, 132 eels used the ladder. We expect that this number is an underestimate of the total number of eels who would use the ladder. There was evidence that eels could escape from the container at the beginning of the summer. The ladder and container were subsequently modified to reduce the likelihood of escape.

Eels ranged in length from 7.4 to 50.3 cm, with a modal length of 10-15 cm (Fig 1). Of these eels, 42 were larger than 17 cm and were tagged at the beginning of the dorsal fin. The modal length indicates that the ladder was used primarily by younger eels (2-3 years old). This is probably due to competition for food and habitat because eel densities are very high (13,000 – 16,900 eels/ha) downstream of the dam.

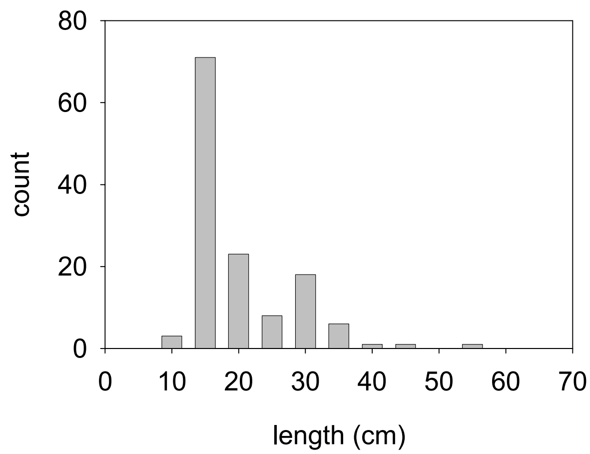

Figure 1. Length-frequency plot of eels using the ladder.

Eel movement patterns

Water temperature during this period was 12 ºC in May through 18 ºC in October. There were several periods of high water level throughout the summer.

Statistically, multiple regression indicated that eel movement was correlated with water temperature ($p<.06$) and depth ($p<.04$). However, it is not clear whether the relationship with temperature is driven by smaller scale patterns or is just an indication of the overall seasonal pattern of warmer water in the summer (Fig 2). Eel movement was not related to mean, minimum, or maximum air temperature. Water depth is associated with discharge, and varies over time depending upon precipitation (Fig 3). There was a very weak but significant relationship between cooler water temperatures and greater depth ($r^2=0.12$, $p=0.4$). When moon phase was included, ANOVA indicated that eel movement was not significantly related to water temperature, but was significantly related to depth ($p<.03$) and darkness of the moon phase ($p<.06$) (Fig 4).

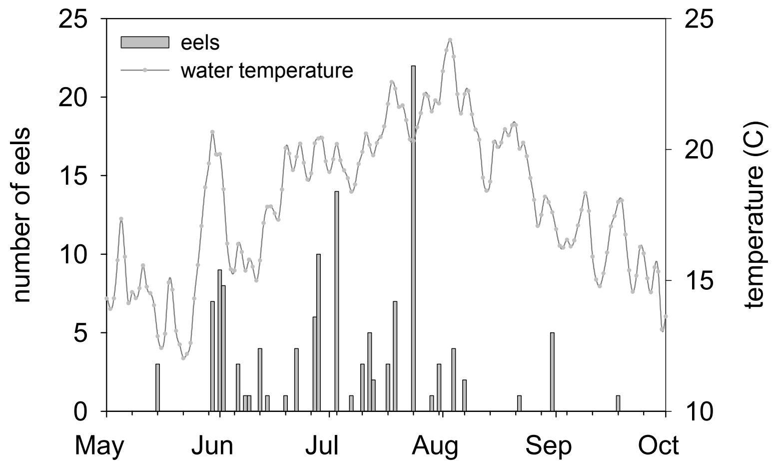

Figure 2. Water temperature and the number of eels using of the ladder.

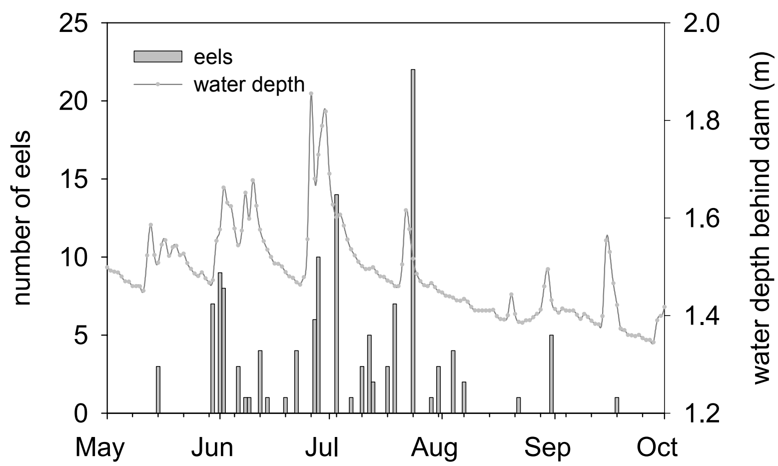

Figure 3. Water depth behind the dam (as an indicator of discharge) and the number of eels using of the ladder.

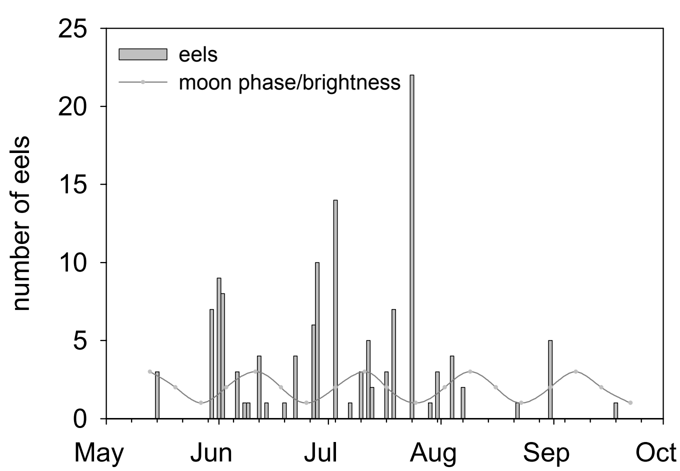

Figure 4. Moon phase (as an indictor of night time brightness) and the number of eels using of the ladder.

Our data have some interesting findings regarding eel movement patterns. Although temperature alone does not provide detail about sub-seasonal movement patterns, temperature probably drives the initiation of movement in the spring and cessation of movement in the fall. There is some evidence that eel movement may be greater during or just after high discharge events. With respect to greater movement during the darker moon phases, it is not clear whether this reflects eel activity and upstream movement patterns in general or just eel movement in the relatively more exposed environment of the ladder. More data is clearly needed to determine the driving factors behind eel movement patterns.

Student involvement

Several students participated in this project. Students participated in electroshocking several reaches of the Saw Kill below the dam and tagging these eels. Students were also trained in the maintenance and monitoring of the eel ladder. Student teams were responsible for checking, maintaining, and monitoring the eel ladder during the academic year, reporting to Dr. O'Reilly after each check. In the summer, students from Simon's Rock College of Bard worked with Dr. Schmidt at the site.

Mer Mietzelfeld, biology major, junior, Bard College
Noah McKenna, biology major, sophomore, Bard College
Andras Huttl, biology major, junior, Bard College
Meredith French, studio art major, freshman, Bard College
Victoria Gono, bioengineering major, freshman, Simon's Rock College of Bard
Mallory Eckstut, biology major, senior, Simon's Rock College of Bard

Presentations, outreach, and media exposure

The research was presented at two conferences:

> Schmidt, R.E., C. O'Reilly, and D. Miller. 2006. Hudson River Tributaries: American Eels and the Estuary Connection. Presented at The Watershed Commons: People, Wildlife, and Water in the Hudson Valley, Hudson River Watershed Alliance Conference, Mohonk Mountain House, 17 November 2006.

> Schmidt, R.E., C. O'Reilly, and D. Miller. 2007. Observations on American eel at a Passage Facility on a Hudson River Tributary. Presented at New York State Chapter, American Fisheries Society, Thayer Hotel, West Point, 9 February 2007.

Several family groups and science classes from both Bard and Simon's Rock were exposed to the eel project on the Saw Kill. Observers were able to watch electrofishing, measurement, and tagging of eels, and were given an explanation of how the eel ladder worked. For classes, students were able to participate in these activities.

The Saw Kill Eel Project was reported in the *Poughkeepsie Journal* (April), *Kingston Freeman* (June 11), *Green Times* (Summer 2006), and *Wildlife Conservation* (October 2006).

Further funding and future work

We have secured future funding for the monitoring of this ladder through Chuck Neider of the Hudson River National Estuarine Research Reserve (HRNERR) (pending continued federal appropriation for HRNERR). The eel ladder was reinstalled in early May of this year and regular monitoring has begun. Dan Miller also secured additional funding through the Hudson River Estuary Program to install one new eel ladder along the Hudson River each year.

Summary of accomplishments

We demonstrated that the eel ladder is effectively used by eels as they attempt to move upstream of the dam. The cost of installation, monitoring, and maintenance are relatively low using this trap-and-transfer system. Our research program involved a large number of undergraduate students, and the data provides the first information about eel movement patterns. Our research was presented at two conferences and received media coverage.

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Information Transfer Program

Director’s Office Information Transfer

Basic Information

Title:	Director’s Office Information Transfer
Project Number:	2006NY86B
Start Date:	3/1/2006
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Descriptors:	None
Principal Investigators:	Keith S. Porter

Publication

1. Porter, Mary Jane, Keith S. Porter and Dean Frazier, 2006, Linking Economic Vitality, Water Quality, and Sound Science, Progress Report, Delaware County Action Plan, Department of Watershed Affairs, 1 Gallant Avenue, Delhi, NY 13753, 70 pages.
2. Wisen, Anthony S. and Keith S. Porter, 2006, Hornless on the Range, The Journal of Water Law. Volume 17 2005 Issue 4 p. 141.
3. Porter, Keith S., 2006, Fixing Our Drinking Water: From Forest to Faucet, Pace Environmental Law Review, Volume 23, Number 2, Summer 2006, pp 389-422.

NY WRI Information Transfer – FY2006

WRI continues to promote the engagement of the wider academic community in water resource management issues in New York State. As in previous years, opportunities to pursue this aim were sought through federal, state, regional and local, public and private partners, and with academic colleagues in New York State and the United Kingdom. Most of the WRI activity with these partners in FY2006 took place in the New York City Watershed Program (Delaware County phosphorus management projects), the Susquehanna River Basin in the Chesapeake Bay Watershed, and the Hudson River Watershed.

Following is a glimpse of specific education, outreach, and information transfer activities for FY2006.

Continuing Outreach, Education and Information Transfer

New York's Project WET Program

One of WRI's partnership programs with the NYS Department of Environmental Conservation, NY Project WET (Water Education for Teachers) is now in its eighth year. New York's program is modeled after the National and International Project WET programs and provides water science education for grades K-12. 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 focus of most of the activities.

Three education staff members provide statewide training and education through workshops; sponsor events, initiate water sampling programs, and participate in State and local events as they are invited. In addition to basic water education, NY's Project WET has been assisting the State regulatory agency with stormwater education for municipalities as part of their stormwater management plans. Education staff members are also working with the State and the National Project WET program to adapt activities from the Curriculum and Activity Guide to raise awareness for flooding and drought, and other issues resulting from climate change. This will be a major focus for FY2007.

In organized activities, the NY Project WET staff members provide formal training through workshops that reach just under 1,000 educators each year. Educational activities are correlated with the NYS Education Curriculum to assist teachers. Also, for 2006, approximately 38,000 individuals were reached through Project WET activities that included stream monitoring, pond ecology, and water studies. Staff members exhibit at Fairs and special water events, host Teacher Institutes each summer, and participate in educational events organized by different entities, such as the Hudson River Paddle and the Susquehanna Sojourn.

The premier activity for FY2006, a Make-A-Splash Festival, an annual event for each state that is sponsored by the National Project WET, was held in New York in October 2006. Over 350 fourth, fifth and sixth-grade students participated in the all day hands-on water activities. As part of this year's Festival, the county Soil and Water Conservation District manager was invited to speak to the students about the past June flood in the area. It was an excellent opportunity to raise the issue of land use and flood plains as the park grounds are adjacent to a tributary of the Susquehanna River and were underwater for several days that summer.

Susquehanna River Basin

A continuing focus for WRI's outreach is in 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 Cheseapeake Bay. New York has entered into an interstate agreement with all other Chesapeake Bay watershed states to reduce nutrient and sediment loading to the bay.

WRI works with two units in New York with programs on the upper Susquehanna River Basin: 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. The coordinator of the USC is employed through the New York State Soil & Water Conservation Committee.
- 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 AEP program's goal is to increase knowledge about the sources and sinks of nitrogen, phosphorus, and sediment. It is lead by faculty at Cornell University. Both programs are conducted in the Susquehanna River Basin and its tributaries in New York State, which is an area of approximately 7,500 square miles.

Outreach activities in both units include convening meetings and poster sessions and the development of materials including brochures and progress reports

Hudson River Tributary Strategies

Beginning in the Adirondack Mountains, the Hudson River flows 322 miles into the ocean at lower New York Harbor. When the River reaches the Troy Dam, which is about halfway to the ocean, it becomes an estuary that ebbs and flows with daily tides. In 1996, the governor released The Hudson River Estuary Action Plan. In 2005 the Program released its report on 10 years of progress. WRI continues to work in partnership with the NYS Department of Environmental Conservation in carrying out its Action Plan.

The Hudson River Estuary Program Action Plan sets the official goals for the Hudson River Estuary Program (HREP). Among the twelve goals contained in the Action Agenda, one goal is defined to protect and restore the streams, their corridors, and tributaries that replenish the estuary and nourish its web of life. Approximately five years ago, the HREP created a new watershed outreach imitative to promote conservation of streams and tributaries to reduce the impacts of land use on the River, as much of the pollution entering the River stems from human activity on the land.

WRI facilitates connecting science to policy, law and decision-making. Currently, WRI has seven staff members working in the HREP working as science educators, watershed program managers, riparian buffer coordinators, special projects coordinators working with stormwater and better site design, as well as climate change issues, and an interpretive/education coordinator. Critical needs in the Hudson River Watershed that WRI is focusing on are to:

- Understand and manage the growing demand for water in the watershed;
- Ensure the most cost-effective and sound balance between the various uses of the water;
- Work in partnership with community leaders and developers to effect low impact solutions to hydrological problems posed by new suburban developments, and providing planning, design technologocal, engineering, legal and regulatory suggestions; and
- Understand the new opportunities, risks and challenges in our future to be brought about by climate change.

A major outreach event for the HREP in FY2006 was a one-day Climate Change conference on December 4, 2006, in the Hudson Valley. Approximately 400 attended the conference. The purpose was to help participants understand the latest scientific findings on climate change and provide information to aid in planning for and managing these impacts in their communities. The morning program covered climate change science and predicted impacts in the Hudson Valley, and the afternoon highlighted actions by communities, and discussed resources available to help communities address climate change.

Transboundary Indigenous Waters Program (TIWP)

Working with faculty leaders in Cornell's American Indian Program, WRI embraced the challenge to facilitate and support education, research, training and technical support to Indigenous communities. Over the past year, 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 under the newly formed TIWP, a joint conference and symposium on native water law, sovereignty, and cultural survival was convened on November 17-18, 2006 at the Cornell University Law School.

The 1st Annual Joint Conference, entitled, "Native Water Law and Public Policy: Critical issues in the Great Lakes and St. Lawrence Watersheds," was sponsored by WRI, the Cornell American Indian Program, and the Cornell Law School. The conference also had twenty co-sponsors. Creating a vitally needed forum for dialog concerning water and community issues and to share strategies for restoring water quality, quantity, and cultural value were the main purposes of the conference. Over two hundred people attended to hear presentations on indigenous survival and Transboundary water challenges, learn about issues in water, law, culture and native education, as well as the learn the milestones in Federal Indian Law.

For TIWP, the joint conference was the stepping-stone leading to a work plan within the components of the TIWP – law, education and cultural encounters. Over the past few months, TIWP members have been devising a work plan that includes:

- Preparing a summary of the conference;
- Developing a portfolio of research ideas crucial to Tribes to share with faculty and students;
- Focusing on K-12 education with a sensitivity to cultures;
- Facilitating the evaluation of water quality issues for Tribes with EPA, and generating funding for those Tribes not having water quality standards; and
- Strengthening our alliances with other groups working on American Indian water issues.

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 project in FY2005. The focus was building a network for a capacity building program for creating catchment strategies in the UK that exploit 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, the Delaware County Action Plan (DCAP), and the upper Susquehanna River Basin. This project prompted a considerable dialog with watershed groups in the UK. Two workshops were convened of UK/US stakeholders, including representatives from agriculture, academia, local government statutory agencies, and the voluntary sector. A major outcome of this project was preparation of a catchment strategy for UK watersheds based on stakeholder inputs. A catchment strategy concept note was submitted to RELU for further consideration of funding in November 2005. UK and US principals were invited to submit a full proposal in the third funding round for capacity building under RELU.

In 2006, our group of US UK and EU principals was given a three-year award for the proposal, “Developing a Catchment Management Template for the Protection of Water Resources: Exploiting Experience from the UK, Eastern USA and other European Countries.” The project is scheduled to begin in the summer of 2007.

Water Law Clinic in the Cornell Law School

Again for 2006, the WRI Director’s Course, *Water Law in Theory and Practice*, in the Cornell Law School, provided students practical opportunities to learn water law and to experience its multiple aspects through meaningful contributions. Students select a project topic, compile relevant facts, critically research the issues, and provide information and conclusions in presentations in the classroom, external seminars, and public community meetings. Clinic projects for 2006 were:

- Local law and landscape design techniques as an instrument to foster sustainable land use and land development in the Hudson River region;
- Local, state and federal legal framework for flood response and mitigation;
- Responding to critical water deficits as illustrated by the Jordan River Valley;

- Application of the Clean Water Act to Watershed Management in Puerto Rico; and
- Treating Indian tribes as if they were states under the Clean Water Act.

An interdisciplinary course was also offered during FY2006 that WRI's Director co-taught, entitled, "Water and Culture in the Mediterranean: A Crisis?" The course addressed the crisis of water in the Mediterranean region through case studies in watershed basins, particularly the Nile and Litany Rivers. The course focused on attitudes, conflicts and relationships of local people towards water, expressed in culture, sanitation, environmental laws and agricultural practices. It also focused on water rights and laws and how they affect the environment. The course was open to graduate students as well as to motivated seniors.

Two students in FY2006's Water Law Clinic assisted in developing another clinic for FY 2007 entitled, "Land Use, Development and Natural Resource Protection Clinic." WRI's Director will also teach this clinic. Also as a direct outcome of their work, the two students last fall proposed and then created a new course in the Department of Landscape Architecture: LA 497. The course, entitled Principles of a Multi-disciplinary Approach to techniques of On-site Stormwater and Wastewater Management, was most successful in engaging a team of faculty from different departments. The dialog fostered by the course, and the associated student project in the Hudson Valley, has stimulated faculty interest in creating integrated inter-disciplinary designs for land development to manage the quantity and quality of water draining across and through the land. Such management is critical to avert the increase risks of floods and the effects of droughts due to land development and management, while protecting the quality of vital water resources. This initiative is expected to serve crucial objectives in the Hudson River Valley.

Water Education and Information "Museum"

The WRI Director is the Chairman of a new Water Museum or Water Discovery Center to be established in the Catskill Mountains within the New York City Watershed. Its purpose is to advance public understanding of the critical water issues. The Center has a site of 44 acres and has recently been awarded $1.0 million in seed funding.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	12	0	0	0	12
Masters	4	0	0	0	4
Ph.D.	4	0	1	0	5
Post-Doc.	0	0	0	0	0
Total	20	0	1	0	21

Notable Awards and Achievements

2006NY81B
A second year of funding for FY 2007 has been awarded for this project and will build upon the first year of the poject with the installation of a strem gage on the Moodna and the calibration and validation of a spatially-explicit, water routing model.

2006NY83B
A proposal was submitted in Fall 2006 for a collaborative USEPA Targeted Watershed Grant by the Saw Mill River Coalition/Groundwork Yonkers. In the summer of 2007, sampling will continue with matching funds from the Saw Mill River Coalition/Groundwork Yonkers.

2006NY84B
We have demonstrated that the eel ladder is effectively used by eels as they attempt to move upstream of the dam. Costs for installation, monitoring, and maintenance are relative low using this trap-and-transfer system. This research program provides the first information about eel movement patterns. Further funding for this project has been secured from the Hudson River National Estuarine Research Reserve. Additional funding through the Hudson River Estuary Program has been granted to install one new eel ladder along the Hudson River each year.

2003NY33G There are two notable achievements: 1)Development of a GIS tool to automate the calculation of descriptive statistics from multiple raster datasets across watersheds in a region of interest; and 2)research in the project has inspired the creation of an International Association of Hydrologic Sciences (IAHS) Prediction at Ungaged Basins (PUBs) low streamflow work group. This group is 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.

Publications from Prior Projects

None