NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER SUPPLY

2006 Research Objectives Report

This report provides the status of various research programs addressing the sources, fate, and transport of key constituents, and the status of the evaluation of data generated by other agencies. This report also addresses research on watershed processes affecting water quality, special research projects, and contains abstracts from a watershed monitoring seminar later in the year.

Prepared in accordance with the November 2002 United States Environmental Protection Agency Filtration Avoidance Determination

July 2007

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Acronyms and Abbreviations

ASTM	Association of Standards and Testing Materials
BMP	Best management practice
BWS	Bureau of Water Supply
CFI	Continuous Forest Inventory
cfu	colony forming unit
Chla	chlorophyll *a*
cm	centimeter
CREP	Conservation Reserve Enhancement Program
CWC	Catskill Watershed Corporation
DBP	Disinfection by-products
DEP	New York City Department of Environmental Protection
DOT	New York State Department of Transportation
DRBC	Delaware River Basin Commission
DWQC	Division of Drinking Water Quality Control
ELAP	Environmental Laboratory Approval Program
EOH	East-of-Hudson
FAD	Filtration Avoidance Determination
GFS	Global Forecast System
GIS	Geographic Information System
GWLF	Generalized Watershed Loading Function
HPLC	High Performance Liquid Chromatography
IPCC	Intergovernmental Panel on Climate Change
ICR	Information Collection Rule
K	thousand
KWIC	Kensico Watershed Improvement Committee
L^{-1}	per liter
LT2SWTR	Long-term 2 Surface Water Treatment Rule
MCL	Maximum concentration limit
ml^{-1}	per milliliter
mm	millimeter
MOA	New York City Watershed Memorandum of Agreement
MOS	model output statistics
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NMEMS	Nutrient Management Eutrophication Modeling System

NTU	Nephelometric units
NYC	New York City
NYCRR	New York City Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
QA	Quality assurance
QAPP	Quality Assurance Project Plan
SDWA	Safe Drinking Water Act
SPDES	State Pollutant Discharge Elimination System
SPPP	Stormwater Pollution Prevention Plan
SWTR	Surface Water Treatment Rule
THM	Trihalomethanes
THMFP	Trihalomethanes formation potential
TMDL	Total Maximum Daily Load
TOGS	NYSDEC Technical and Operational Guidance Series
TP	Total phosphorus
TSI	trophic state index
UFI	Upstate Freshwater Institute
US ACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
US FWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VSLF	Variable Source Loading Functions
WMP	Waterfowl Management Program
WOH	West-of-Hudson
WRDA	Water Resources Development Act
WRR	Watershed Rules and Regulations
WWTP	Wastewater treatment plant
Z_{SD}	Secchi disk transparency depth
µg	micrograms

1. Introduction

1.1 Purpose

This report addresses the requirement "Submit Research Objectives Report" under Section 5.1 (Watershed Monitoring Program) of the November 2002 New York City Filtration Avoidance Determination (for the Catskill/Delaware Water Supply System). This requirement states: "This report will provide the status of various research programs addressing the sources, fate, and transport of key constituents, and the status of the evaluation of data generated by other agencies. This report will also address research on watershed processes affecting water quality such as key modeling programs. It will also identify special research projects that will be conducted during the following year and will assess the need for conducting a watershed monitoring seminar to disseminate data in the upcoming year and, as appropriate, identify a target date." This report is required to be posted on the DEP website.

1.2 Scope

This report may be viewed as a companion to the Bureau of Water Supply's (BWS) Watershed Water Quality Annual Report (due at the end of July each year). The Annual Report addresses DEP data, obtained from the previous calendar year, whereas this Research Objectives Report focuses on description of current research, future funded research still in the developmental stage, and research programs on the watershed conducted by outside agencies. The goal of the report is to provide an update on progress at the end of 2006 and to highlight the direction of future research.

This report is laid out parallel to the structure of the Filtration Avoidance Determination (FAD). The order of Studies are described in the following headings: Environmental Infrastructure; Protection and Remediation Programs; Watershed Monitoring, Modeling and GIS; and Data and Methods Development.

Although the requirement for this report, as stated in the Purpose above, is to describe ongoing research pertinent to the FAD—which is directed towards the Catskill/Delaware Water Supply System—we have included other studies for completeness including those being conducted East-of-Hudson and those conducted on analytical method development, e.g., for pathogen enumeration.

Periodic seminars on watershed monitoring are part of the City's efforts to foster communication about NYC's watershed and the most recent scientific findings that may influence watershed policy. The need for such seminars must be evaluated on a regular basis and "identified" in the Research Objectives Report. To comply with this requirement, on September 11-12, 2007, the Fifth Annual New York City Watershed Science and Technical Conference will take place in West Point, NY. DEP staff have submitted 10 papers for consideration. These abstracts are presented in the Appendix of this report.

2. Current BWS Research

2.1 Environmental Infrastructure

2.1.1 Kensico Stream Extended Detention Basin Best Management Practices Monitoring Project

Manager: John Canning
Start & Completion Date: January 2000 to December 2007
Status (% Complete): 80
Project Cost: N/A

Objective and Justification:

The objective of this project is to evaluate the effectiveness of Kensico extended detention basin BMPs at reducing storm loads of fecal coliform, total suspended solids, turbidity and total phosphorus. During 1998 - 2004, 10 extended detention basin Best Management Practices were installed on streams discharging to Kensico Reservoir. In 2005, a liner was placed in BMP 74/75 (stream E11) to reduce seepage and raise water level to its design elevation. The purpose of these BMPs was to reduce the loads of fecal coliform and turbidity discharged to Kensico Reservoir from its tributaries during storm events. During 1999, DWQC developed a plan to monitor these BMPs to evaluate their effectiveness at controlling these loads. In addition, the analytes of total phosphorus and total suspended solids were added, as most extended detention basin BMPs are constructed to address these analytes. This monitoring plan has been modified to rotate among five of the constructed BMPs over a 7- year period. This rotational schedule is intended to allow sufficient time for the collection of data that would be necessary to evaluate the effectiveness of these selected BMPs. In 2006, DEP continued to monitor the performance of the Kensico BMPs, as per the schedule previously submitted to EPA.

Implications for Watershed Management:

Data collected from this project will be used to evaluate the effectiveness of structural nonpoint source pollution control programs. Data may also be used to provide information to Stormwater Pollution Prevention Plan (SPPP) applicants.

Problems Encountered: None.

2.1.2 Stormwater Retrofit Sampling Partnership Program

Manager: Tracy Lawrence
Start & Completion Date: September 2003 to December 2006
Status (% Complete): 90
Project Cost: $60K (DEP) + $60K Laboratory Analysis Contract (CWC)

Objective and Justification:

The Water Quality Impact Assessment group of DEP developed and implemented this stormwater BMP monitoring program to determine the effectiveness of retrofitted BMPs to improve water quality. In 2006, automated monitoring equipment was installed at the inflows and outflows of three BMP retrofit sites. A final report for this project is being completed. The West-of-Hudson (WOH) Stormwater BMP Retrofit program was set forth as part of the NYC Watershed Agreement. In the agreement the City allocated $7.6 million for stormwater BMP retrofits to treat stormwater runoff in concentrated areas of impervious surfaces in the WOH district. In a partnership role with the DEP the Catskill Watershed Corporation (CWC) funded a contract which provided for the analyses of all of the project's samples by a commercial laboratory. In 2006, automated monitoring equipment was installed at the inflows and outflows of three BMP retrofit sites. A total of 18 storm events were monitored in 2006 and no further sampling is scheduled for this program. A final report for this project will be completed in 2007.

Implications for Watershed Management:

Despite a significant monitoring effort intended to quantify pollutant removal efficiencies of different types of stormwater BMP retrofit systems, it was realized through this investigation that improperly functioning BMPs had greater impact on water quality than variation in the type of BMP. Many of the BMPs investigated were found to be functioning improperly, providing little to no treatment before discharging stormwater directly to watershed streams. Ensuring that stormwater BMPs are functioning properly will provide a far greater water quality benefit than any differences identified in pollutant removal performance between different BMP types. This observation indicates the importance of routinely inspecting and maintaining stormwater BMP retrofit projects to ensure that they are functioning properly.

Problems Encountered:

Weather-related sampling always poses a unique set of challenges. The ability to predict the timing and amount of rainfall and then to accurately measure runoff volumes is paramount to evaluating BMP performance. Weather-related issues made it logistically difficult to capture all storms at all sites.

2.1.3 Red Falls Sediment Loss Reduction Best Management Practice

Managers: Andrew Bader/James Mayfield

Start & Completion Dates:

Monitoring start date: April, 1998 to December 2011

Conine Water Quality Report due date: 12/31/12

Status (% Complete): 35, estimate uncertain due to construction timetable

Project Cost: N/A

Objective and Justification:

The objective of this study is to quantify the effectiveness of best management practices (BMPs) at reducing turbidity and suspended sediment in the Batavia Kill stream. Observations and sampling have documented that the Batavia Kill delivers a significant amount of suspended sediment and turbid water to Schoharie Creek, the main inflow to Schoharie Reservoir. Major sediment source areas are known above and below Red Falls. Through a contract with DEP's Stream Management Program, Greene County Soil and Water Conservation District will design and implement BMPs to reduce the sediment and turbidity originating in the Red Falls area. DEP has been monitoring several sites on the Batavia Kill prior to BMP implementation, and will continue to do so for several years after implementation. Turbidity and suspended sediment are one of the most important water quality issues facing DEP in the Schoharie watershed; therefore, evaluation of the effectiveness of methods intended to reduce them is a priority research need.

Implications for Watershed Management:

By quantifying the turbidity and suspended sediment loads in the Batavia Kill before and after BMP implementation, we will be able to evaluate the effectiveness of the approach used, and that in turn will guide BMP design for other problem sites in the watershed. Ultimately, information gleaned from this project should help DEP determine the cost-benefit relationship of reducing sediment and turbidity in watershed streams by this approach.

Problems Encountered:

Originally, two areas (Red Falls and Conine) in the Red Falls region were proposed for remediation. Due to numerous project constraints, DEP determined that the Red Falls project was not feasible and EPA concurred. The Conine site, immediately downstream of Red Falls, was approved as a substitute for monitoring the water quality benefits of a demonstration restoration project on the Batavia Kill. During this period of site evaluations, pre-implementation sampling has continued.

2.1.4 Kensico Action Plan

Manager: Dale Borchert
Start & Completion Date: April 4, 2006 to August 15, 2007
Status (% Complete): 75
Project Cost: $331K

Objectives and Justification:

The objective of this project is to evaluate the need for additional best management practices (BMPs) within the Kensico Reservoir watershed. Several BMPs were constructed in the Kensico watershed from 1999 through 2004. This project will model stormwater runoff from the Kensico watershed and through these BMPs to determine whether any additional BMPs should be constructed to capture and treat stormwater runoff from the Kensico watershed. In addition, data collected from sewer line inspections, reservoir sediment deposition, and water quality risk assessments will be reviewed to determine what, if any, additional actions are necessary to reduce the threat to water quality from the Kensico watershed.

Implications for Watershed Management:

This project will pinpoint stormwater hotspots within the Kensico watershed, will identify practices that can be constructed to remediate these hotspots, and will develop biddable documents that can be used to construct these practices. At the end of this project, the DEP will have a better understanding of what stormwater concerns still exist within the Kensico watershed, and how they can be treated.

Problems Encountered:

The project kicked off in April, 2006. While it was intended to wrap up in April of 2007, additional time was necessary to allow for EPA/DOH/DEC review of selected management practices. The project is now expected to be completed in August, 2007.

2.2 Protection and Remediation Programs

2.2.1 Estimating Waterbird and Aquatic Mammal Nutrient Loads to Cannonsville Reservoir

Manager: Christopher A. Nadareski
Start & Completion Date: August 1, 2004 – November 30, 2006
Status: Completed
Project Cost: $124K

Objective and Justification:

The objective of this study was to estimate phosphorus and nitrogen loading to a New York City reservoir from Canada Geese *(Branta canadensis*), gulls (*Larus* spp.), other waterfowl, and water mammals (i.e., beaver). A total of 211 samples were collected and submitted for P and N analysis. Additionally, waterbird population surveys were conducted on a weekly basis from August 2004 to August 2005 to collect data on the number of birds utilizing the reservoir including their residence time. Nutrient loading was calculated using these data, a final report was prepared, and these results may be incorporated into DEP's Cannonsville Water Quality Model.

Implications for Watershed Management:

A sufficient roosting and foraging population of geese, gulls, other waterfowl, and water mammals could have the potential to impact the nutrient budget of a water supply reservoir by moving nutrients into the reservoir from the surrounding foraging areas, leading to enhanced cycling and loading of nutrients within the reservoir. This study will elucidate the role waterfowl play in the nutrient budget and was implemented to calculate P and N loadings via direct deposition by roosting birds and water mammals.

Problems Encountered:

Laboratory results from the contract laboratory were delayed.

2.2.2 Waterfowl Management at Kensico, West Branch, Rondout, Ashokan, Croton Falls, Cross River, Hillview, and Jerome Reservoirs

Manager: Christopher A. Nadareski
Start & Completion Date: 1993 - Ongoing
Status: Ongoing
Project Cost: Nearly 8.4M from 1995 to 2007

Objective and Justification:

The objective of the Waterfowl Management Program at Kensico Reservoir is to mitigate and quantify wildlife pollutant contributions. As part of DEP's Watershed Protection/Filtration Avoidance Program, a Waterfowl Management Program was established to measure the levels of bacteria and nutrients transported to reservoirs by waterfowl. Comprehensive wildlife surveys were conducted at Kensico to identify potential pollutant sources. Waterfowl species which

include most waterbirds were routinely surveyed to determine species richness (species diversity) and evenness (species population). Preliminary surveys conducted by DEP indicated that populations of several water bird species fluctuated daily (diurnal/nocturnal), seasonally, and spatially on the reservoirs. A relationship between avian populations and bacteria (fecal coliform) levels from untreated water samples revealed a positive correlation. As a result, DEP instituted a permanent Waterfowl Management Program through a contract to reduce or eliminate waterfowl activity in order to mitigate seasonal fecal coliform bacteria elevations, at source water intakes.

Implications for Watershed Management:

Since waterfowl were identified as a significant contributor of fecal coliform bacteria, a bird harassment program was developed to eliminate resident and migratory waterfowl populations from Kensico. The program was initially implemented in December of 1993 and has continued through the present resulting in a successful elimination of bird concentrations and corresponding lower bacteria levels. This has allowed DEP to consistently meet the requirements of the Catskill/Delaware System.

The basis for the Waterfowl Management Program Contract is to continue the success of waterfowl management at NYC's Kensico Reservoir (which resulted in the elimination of the seasonal fecal coliform bacteria elevations), and expand its waterfowl management operations (bird deterrence-harassment). EPA's Filtration Avoidance Determination in the November 2002 FAD (WMP) required DEP to expand the Waterfowl Management Program to include several reservoirs throughout the NYC Water Supply on an "As Needed" contingency. Each NYC reservoir has been categorized with a different level of mitigative intensity using similar waterfowl management techniques including a standard daily operation at Kensico and an "As Needed" program triggered by elevated waterfowl populations and increases in bacterial levels at several other reservoirs (West Branch, Rondout, Ashokan, Croton Falls, and Cross River). This standard program will be conducted annually from August through March and "As Needed" into mid-April. A supplemental program to monitor and curtail breeding populations of three waterfowl species (geese, cormorants, and swans) will be implemented annually from April through June.

Additional water bird surveys and bird deterrent measures have been instituted at Hillview and Jerome Reservoirs. Year-round populations of water birds have been recorded at both distribution reservoirs resulting in elevated fecal coliform bacteria counts (*E. coli*). Recommendations for overhead wires covering the surface water have been largely successful eliminating roosting and defecating birds.

Problems Encountered: None

2.2.3 Forest Ecosystem Health Assessment Phase II: Continuous Forest Inventory

Manager: Deborah Layton
Start & Completion Date: Long-term study began May 2002
Status (% Complete): ongoing, first round of measurements 60% complete
Project Cost: N/A

Objective and Justification:

Growing forests stabilize the landscape and contribute to good water quality. A large percentage of DEP's watershed is forest and its growth status is important. Its status has implications for development of forest management. The objective of this project is to establish permanent plots for the purpose of documenting long-term forest health and status of growth. This is measured by: average tree height, diameter and volume growth rates, mortality and recruitment, and general changes in species composition. Continuous Forest Inventory (CFI) plots will provide these data and track larger-scale changes in forests over time in a way that is similar to the Forest Service Forest Inventory and Analysis of Forest Health Monitoring plots, but at a scale that is better suited to management of City-owned lands.

The first season of plot establishment and data collection in the Ashokan basin in 2002 served as the pilot project for other CFI plots to follow. The plot measurement parameters were streamlined following the first year's work. Plots were established on City-owned lands in the Rondout and Neversink basins in 2003. In 2004 and 2005, plots were established in the Boyd Corners and West Branch basins EOH. CFI plot establishment began in the Schoharie basin during 2006 and will continue in 2007. Plots will be established in each major basin until plots are distributed across the watershed on City lands. Plots will be re-measured at approximately 10-year intervals in order to monitor stand dynamics.

Implications for Watershed Management:

Land managers on New York City watershed lands intend to manage the watershed's forests for ecosystem integrity and sustainability as existing literature indicates that higher water quality can be expected from lands that recover quickly from disturbance. Many kinds of information are needed to gain an overall picture of the health and sustainability of NYC-owned forests.

A substantial database and scientific study of local conditions is required to guide implementation of Basin Management Plans for City-owned lands and to offer guidance to local governments concerning land and forest management for water quality. This study will contribute to this database and will serve in the development of useful tools and equations that will expedite continuing inventory and management efforts throughout the watershed.

Problems Encountered: None.

2.2.4 Effects of Silvicultural Treatment on Forest Ecosystem Health

Manager: Deborah Layton
Start & Completion Date: April 1999 to May 2010
Status (% Complete): 60
Project Cost: N/A

Objective and Justification:

The objectives of the study are to determine what the effects of different silvicultural techniques will be and whether they provide effective tools for forest management. Specific objectives include experiments to determine:

- whether enhanced seedling germination, survival and growth, or other aspects of forest health are desirable to enhance water quality;
- whether recruitment of desirable species is increased and undesirable species decreased by application of current silvicultural methods on these lands and;
- whether observed improvements, if any, are adequate to ensure forest cover without further intervention.

Silvicultural treatments were applied to selected areas near reservoirs as part of dam rehabilitation projects. Work consisted of removal of hazardous trees (particularly along highways, utility corridors, and property boundaries); management of exotic shrubs and vines by cutting, removal, and cut-stem treatment with herbicide (as needed); and thinning of stands to encourage establishment and growth of native regeneration.

Baseline measurements were completed during the summers of 1999, 2000 and 2001 at West Branch, Bog Brook, East Branch, Amawalk, Titicus, Cross River, and Kensico Reservoirs. At Amawalk, Titicus, and Cross River Reservoirs, the silvicultural treatment had already taken place prior to plot installation, so an attempt was made to locate sites with similar species and conditions to serve as control plots to match with these treated sites. Control plots had to meet certain criteria to be suitable for statistical analysis.

Of the sites selected for possible side-by-side comparison, only one of the Amawalk sites met the necessary criteria for similarity between the treatment and control. The remaining sites were deleted from this study due to the inability to compare to a pre-treatment or non-treatment condition. At the other reservoirs, a before-and-after sampling scheme was initiated.

Pre-treatment plots were established at West Branch, Kensico, East Branch, and Bog Brook Reservoirs. Kensico received treatment during the winter of 2005-2006; however, a cursory examination of the study sites indicates that treatment did not occur where the plots were established. Silvicultural treatment work was completed at West Branch from early September 1999 through late April/early May 2000 and at Bog Brook and East Branch during 2004. As the sites require at least one growing season to recover from treatment, no measurements were taken in the summer immediately following cutting.

Initial post-cut measurements were completed at West Branch in the summer of 2001. A second round of measurements was completed there in 2003 and a third in 2005. The Amawalk 2 site was also measured for a third time in 2005. The first post-treatment measurements were done in the 2005 growing season for Bog Brook and East Branch.

Implications for Watershed Management:

On all study areas measured to date, there has been a slight to moderate decrease in numbers of saplings and shrubs in the midstory which appears to be due to removal of the exotic species component during treatment. Numbers of seedlings have generally improved on most sites. On both treated and untreated areas at the Amawalk site there has been a favorable reduction in overall coverage of exotic species in accordance with DEP's desire to promote native species, while total numbers of seedlings increased to levels consistent with forestry health objectives only on the treated plots. At both West Branch and Bog Brook, total seedling numbers increased but exotic species also increased. Increases in exotic species did not exceed 10% of total numbers, however. At East Branch, total numbers of seedlings decreased while numbers of exotic species increased. The cause of decreased seedling numbers could not readily be determined. The 2005 growing season was an exceptionally good seed year for many species which may have some impact on long-term results.

Measurement and reporting will occur at least one more time over the next 3 years before any recommendations can be made about continuing this treatment on other sites.

Problems Encountered:

One plot at Bog Brook could not be re-located due to flooding and change in vegetation since first measured and was deleted from the study. At East Branch, time constraints limited remeasurement to six of nine total plots. Two plots were destroyed by construction activities. Kensico plots are being measured in 2007; however, it is expected that these sites will be dropped from the study's analysis because it appears that treatments were not applied to areas where plots were established. Silvicultural treatments were not applied to study areas at Kensico because other areas were determined to be higher-priority at the time treatments were applied.

2.2.5 Deer Herbivory Impacts on Forest Regeneration: Deer Exclosure Study

Manager: Deborah Layton
Start & Completion Date: September 1999 to December 2008
Status (% Complete): 50
Project Cost: N/A

Objective and Justification:

The objective of this project is to obtain basic information on the impacts of deer on forest regeneration in the watershed. It is generally believed that locally high deer populations in the Croton watershed are adversely impacting forest tree seedling regeneration and overall plant ecosystem structure and diversity. Many researchers have used deer exclosures as a way of observing the direct impact of deer herbivory on the understory in forests.

Some very small (1 meter diameter) plots were previously established in the watershed to observe deer herbivory impacts. These showed increased numbers and sizes of tree seedlings within the small fences but findings were somewhat difficult to interpret due to the small size of the exclosures. For this reason, DEP constructed larger deer exclosures to further study local deer herbivory impacts.

In the spring of 2000 two large deer exclosures were constructed in the Croton watershed, one at Bog Brook Reservoir, and one at Kensico Reservoir. These consist of a 60 foot by 60 foot square chain-link fence eight feet high. Each exclosure plot has a companion plot nearby in the same forest stand. In the spring of 2001, a second deer exclosure was erected at Bog Brook Reservoir in a Norway spruce stand near the first exclosure. A companion control plot was also established in this stand. An additional deer exclosure was constructed at Titicus Reservoir in spring 2003.

Baseline measurements were taken one growing season following installation of the plots. Measurements have been repeated annually through the fall of 2004. Results to date have not shown any statistically significant difference between the fenced and unfenced areas. The Bog Brook site was thinned in 2003-4. The Titicus site is not scheduled for silvicultural treatment. The Kensico site was scheduled for thinning during the winter of 2005-2006; however, it appears that thinning did not occur on this area. It was expected that differences in herbivory would become more apparent following the thinning operation. As thinning occurred on only one site, it may be difficult to verify this thesis.

No measurements were taken in 2005. Sites were scheduled for re-measurement in 2006; however, only a portion of the sites could be measured before the end of the growing season. An attempt will be made to complete re-measurement in 2007.

Implications for Watershed Management:

This project will obtain basic information on the impacts of deer on forest ecosystem health to help guide decisions on proper forestry and deer management.

Problems Encountered:

DEP opened the area surrounding the Kensico deer exclosure to deer hunting in 2003. The control plot at this location, therefore, has a different treatment from other sites. Although measurements will continue to be taken at this site, it cannot be compared with the exclosures at Titicus and Bog Brook Reservoirs and will be used for observation purposes only.

2.2.6 Deer Herbivory Impacts on Forest Regeneration: Before and After Hunting on Watershed Lands

Manager: Deborah Layton

Start & Completion Date: Pilot study August to November 2002, Full Study July 2003 to December 2013

Status (% Complete): 45

Project Cost: N/A

Objective and Justification:

Deer herbivory has been noted in forested areas of New York City DEP lands both east and west of the Hudson River (EOH, WOH). This feeding activity is suspected to have reduced the quantity of desirable tree seedlings to sub-optimal levels. The U.S. Forest Service recommends a minimum of 10,000-15,000 desirable seedlings/acre in order to expect successful regeneration following a disturbance. It is thought that allowing deer hunting improves regeneration numbers and this method has been used successfully in other areas. DEP has begun allowing hunting on certain lands.

A pilot study was placed on a tract scheduled to open for hunting near Ashokan Reservoir in August 2002 to determine an appropriate sampling technique that would capture variability in sapling-size material and smaller across the landscape. The method devised places transects at 90-meter spacing across the topography with 3 meter by 10 meter plots placed along the transects, beginning at a random point zero to 90 meters from a starting point and with 90 meters between the plots. Additional plots were established during the summer of 2003 at areas that will not be opened for hunting at Ashokan Reservoir as well as hunted and non-hunted areas at Rondout and Boyd Corners Reservoirs. Baseline measurements were taken at all plots in 2003. The first measurements following establishment were taken in 2006. Additional measurements will follow approximately every 2 years through 2013.

Analysis of the first measurements following establishment were equivocal regarding changes in deer herbivory that may have resulted from opening areas to hunting. However, changes from similar deer management programs indicate that longer periods of time are required and statistically significant results were not anticipated only 3 years into the project.

Implications for Watershed Management:

This project will obtain basic information on the impacts of deer on forest ecosystem health in three basins as well as provide some information regarding success of hunting programs to reduce deer herbivory.

Problems Encountered: None.

2.2.7 Reference Wetlands Monitoring – Year 2

Manager: Laurie Machung /Michael Usai
Start & Completion Date: May 2005 to August 2006; Project complete
Status (% Complete): 100
Project Cost: $238K

Objective and Justification:

This project is the continuation of the Catskill/Delaware reference wetlands monitoring program established with Safe Drinking Water Act Funds to compare the baseline characteristics and water quality functions of wetlands among terrene and lotic landscape positions. Fieldwork for this two-year monitoring program was completed in 2005. Monthly baseflow sampling commenced at the reference wetlands in June 2004 and was completed in June 2005. A second season of water table level and pH, dissolved oxygen, specific conductance, and redox potential data were collected throughout the 2005 growing season. Vegetation sampling was completed at the remaining 19 sites during the 2005 growing season. A number of storms were sampled at four intensive sites during the summer and fall of 2005.

As the field work component of this project was completed in 2005, no field work was conducted in 2006. The final report on the results of this project was issued in 2006.

Implications for Watershed Management:

Results from this monitoring program will enable DEP to compare water quality functions of terrene and lotic wetland types. Water quality, vegetation, and soils data collected from wetlands among various landscape positions will also provide a framework for the development of wetland reference standards and assessment methodologies to guide both regulatory and non-regulatory wetland protection programs.

Problems Encountered: None

2.2.8 Hydroacoustics Monitoring Program (Fisheries)

Manager: Thomas P. Baudanza
Start & Completion Date: June 2003 - Ongoing
Status (% Complete): ongoing
Project Cost: $191K

Objective and Justification:

The objectives of the program are to assess fish population, biomass and distribution within the reservoirs, assess potential fisheries impacts (mortality, avoidance and recovery) associated with water quality problems or non-routine chemical treatment to control water quality, and determine fish distribution in relation to water intake structures to assist in selecting withdrawal elevations to minimize fish entrainment.

Hydroacoustic surveys use sound to estimate fish abundance and population density. A hydroacoustic system is placed on a boat and predetermined transects are surveyed, sampling fish as they pass through the acoustic beam. Targeted fish produce characteristic traces on chart recorder echograms. The returning signal is relayed to the computer-based echo processor to produce estimates of fish density, biomass and size. Gill nets are deployed during the surveys to validate species composition. A Biosonics Inc. 200 kHz Split-Beam Hydroacoustics System is used for these surveys.

The baseline monitoring of abundance is being carried out in two phases. Phase I is the development of a fisheries monitoring plan for Kensico Reservoir and is currently ongoing. Permanent GPS navigation transects were delineated to establish adequate survey coverage and allow for precise replication of follow-up surveys. Initial baseline surveys will be conducted to derive fish population and biomass estimates. Phase II will include program expansion to Rondout, West Branch, and New Croton Reservoirs. 2006 survey data will also be considered in the siting of the new Kensico Intake Chamber.

Equipment upgrades for program surface units and software were acquired in March 2005.

Implications for Watershed Management:

The implementation of Hydroacoustics Monitoring will provide several benefits for the NYCDEP's goals and mission. Initial surveys will provide baseline data for assessing impacts to reservoir fisheries and any impacts associated with water quality impairment. The determination of impacts to reservoir fisheries will also verify compliance with state regulations governing water quality treatment. In addition, acoustic survey information will allow NYCDEP to adjust intake elevations to minimize fish entrainment and subsequent increases in fecal coliforms from foraging birds. This problem occurs annually on the Catskill Aqueduct and insight into fish behavior will help operations to minimize entrainment.

Problems Encountered: None

2.2.9 Stream Reclassification Program (Fisheries)

Manager: Thomas P. Baudanza
Start & Completion Date: June 1996 to 2013 (projected)
Status (% Complete): 75
Project Cost: $14K

Objective and Justification:

The DWQC Stream Reclassification Program (Fisheries) began in 1996, as part of the DWQC Biological Monitoring Program. Streams in New York State are classified and regulated by NYSDEC based on existing or anticipated best use standards. The purpose of this program is to enhance the protection of water supply source tributaries under the New York State Codes, Rules, and Regulations (NYCRR) Title 6, by determining best use standards for trout and trout spawning. These standards strengthen compliance criteria currently permitted under any regulated action.

Reclassification surveys concentrate on likely trout habitat sections of stream including riffles, pools and undercut banks. Streams are electrofished using a Smith-Root Model 12 Electrofisher. All fish collected are held for processing (identification, length & weight) and examined for external anomalies prior to release. Presence of trout under 100mm (young-of-the-year) is used to indicate the occurrence of trout spawning. Physical and chemical stream data are collected and analytes measured include temperature, depth, width, DO, pH, conductivity, stream gradient and estimated discharge. Bottom substrate and land characteristics are also described. Collection reports and reclassification petitions are submitted to the NYSDEC on an annual basis.

To date, streams in the watersheds of the Kensico, West Branch, New Croton, Rondout, Neversink, Ashokan, Schoharie and Pepacton Reservoirs have been inventoried and petitions submitted to NYSDEC for final determination of classification upgrades. In 2007, inventories will be conducted in the Cannonsville Reservoir streams and are expected to last at least two more years.

Implications for Watershed Management:

Classification upgrades reflecting trout spawning function to ensure that regulatory criteria and standards for dissolved oxygen, ammonia, ammonium, temperature and volume for streams supporting trout and trout spawning are in place for the protection of fishery resources and overall water quality.

Problems Encountered: None

2.2.10 Total Phosphorus Tracking of Lawn Fertilizers

Manager: Vincent Giorgio & Charles Cutietta-Olson
Completion Date: June 2006
Status (% Complete): 100% complete
Project Cost: $50K

Objective and Justification:

The objective of this study was to obtain Croton System watershed-specific information on residential lawn care practices including types and frequency of fertilizer use, acreages of lawn managed, and whether or not the soil is sampled prior to applications of fertilizer. While many factors will affect the amount of phosphorus exported from managed turf, unnecessary fertilizer use may be among the more manageable factors.

This project surveyed homeowners and professional landscape maintenance personnel within the Croton System watersheds regarding their typical lawn care practices, and whether or not fertilizers are applied routinely or in response to an identified need. The survey was conducted with the Westchester and Putnam offices of the Cornell Cooperative Extension. The survey found that nearly 25% of 496 respondents have their lawns maintained by professional landscapers, and professional landscapers are more likely to regularly apply fertilizers. Eighty-five percent of the respondents indicated that they do not test their soil prior to fertilizer application.

Implications for Watershed Management:

Many of the Croton System reservoirs have elevated levels of phosphorus and require reductions in nonpoint sources of phosphorus in order to control eutrophication and meet water quality standards. Since low-density residential land is the largest land use in the Croton watershed, effective management options to reduce phosphorus loading from residential areas are desired. This survey indicated that residents would be responsive to a newsletter campaign that provided low-maintenance alternatives to the traditional homogeneous lawn. Cornell Cooperative staff intend to pursue this in the future.

Problems Encountered: None

2.3 Watershed Monitoring, Modeling, and GIS

2.3.1 Monitoring Crossroads Ventures Proposed Development of Belleayre Mountain

Manager: Tracy Lawrence
Start & Completion Date: August 2000 to August 2010
Status (% Complete): 40
Project Cost: N/A

Objective and Justification:

In response to the "Belleayre Resort at Catskill Park" development project proposed by Crossroads Ventures LLC (CRV), the Water Quality Impact Assessment group (WQIA) designed a program to monitor the water quality of area streams before, during, and after project construction. The project site straddles the watershed divide between the Ashokan and Pepacton Reservoirs near the Village of Pine Hill. The developer originally envisioned two 18-hole golf courses, a 17 lot residential subdivision, 700 hotel units, associated clubhouses, and maintenance and staff buildings disturbing 573 of the project's 1900 acres, making this one of the largest proposed land use changes in the Catskill Region in decades. DEP developed a Quality Assurance Project Plan (QAPP) with an objective to monitor the water quality of five tributaries in the vicinity of the proposed development area plus one nearby stream which will not be affected by this development. In 2006, Phase II Pre-Development Monitoring of the four-phase program continued with monthly routine sampling, automated monitoring of stream stage, and maintenance/development of stage-discharge rating curves for all sampling locations. Phase III is the construction monitoring phase, and Phase IV is the post-construction monitoring period during which DEP expects water quality to stabilize. Monitoring will be completed when either the resort has been built and water quality parameters stabilize or the developer abandons efforts to construct the resort. The draft EIS for the project was accepted by the NYSDEC; however, many issues were considered adjudicable and therefore must be resolved before the project can proceed. At this time the future of this development project is uncertain; however, monthly water quality monitoring continues at all stream sites.

Implications for Watershed Management:

Little information exists on the effects of large scale land use changes on water quality in the Catskill Mountains, or on the water quality of headwater streams. Headwater streams of the Catskills are major sources of high quality water to the NYC Catskill and Delaware Water Supplies. Information gained from this research will assist in the future management and review of development projects and land-use changes in the Catskill Region.

Problems Encountered: None

2.3.2 Storm Water Monitoring for Protozoa in NYC Watersheds (WRDA)

Manager: Paul LaFiandra, Jim Alair and Kerri Alderisio

Start & Completion Date: September 2005 to December 2007

Status (% complete): 70

Project cost: $250K

Objectives and Justification:

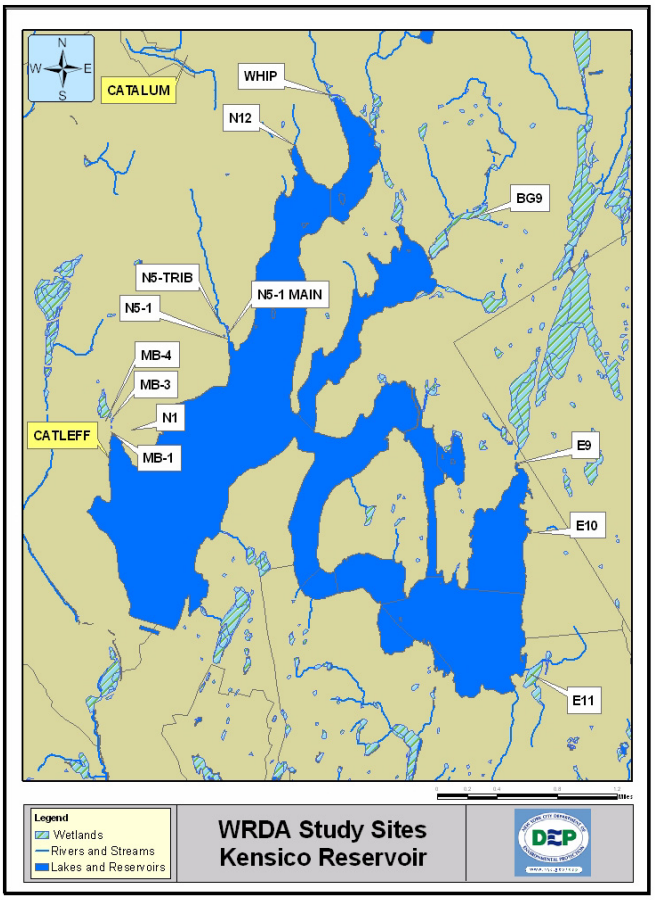

Figure 2.1 EOH WRDA study sites.

As part of a Water Resources Development Act (WRDA) grant awarded to the DEP Pathogen Program, storm event pathogen monitoring was to be performed at 6 West of Hudson (WOH) and 15 East of Hudson (EOH) sites (Figures 2.1, 2.2). The study was conducted in two phases; the first phase of this study, conducted over a one year period, involved the development and monitoring of two EOH sites to establish the methodology for the optimal sampling regimen (sampling duration and interval) to best assess the protozoan occurrence, concentration, and loading during storm events. This information will assist in reservoir operations and reservoir modeling.

The second phase of the project, spanning two years, involved expanding the number of sample stations to include WOH sites and to sample all the perennial streams in the Kensico basin based on the developed sample regimens. The first year of the second phase of this study involved the development and deployment of storm sampling equipment at 13 EOH stream sites (distributed along nine tributaries: E9, E10, E11, WHIP, BG-9, N-12, N-1, MB-1, N5-1), two keypoints entering Kensico Reservoir and 3 WOH sites along the Esopus Creek entering Ashokan Reservoir, to determine pathogen occurrence, concentration and loading during storm events. An additional objective was to determine the efficacy of BMPs at reducing protozoan loading into the reservoir. As part of evaluating BMP efficacy at reducing protozoan loading, three EOH streams had pre-existing, constructed BMPs, and two of them were sampled upstream and downstream of the BMP.

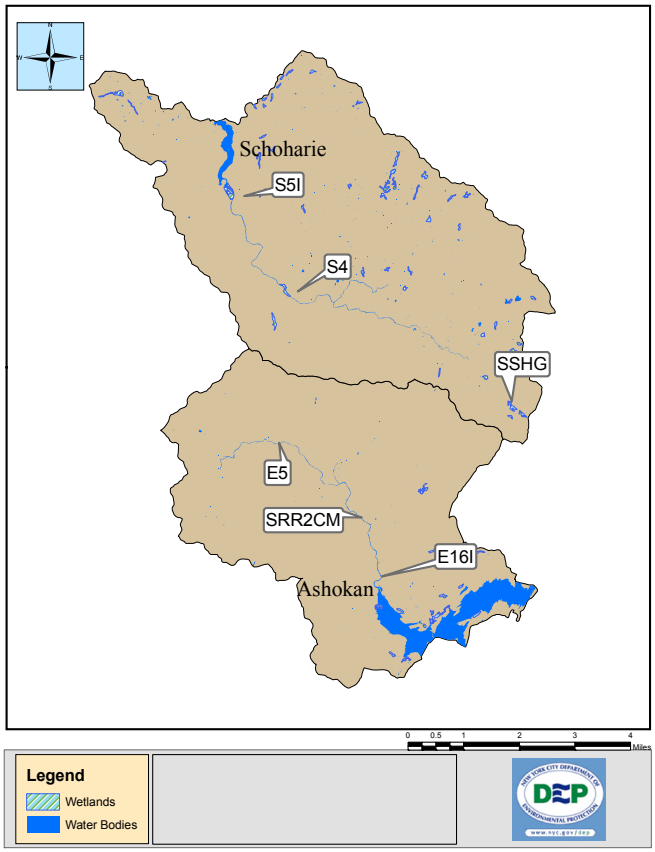

Figure 2.2 WOH WRDA study sites.

The second year of the second phase of this study involved storm monitoring of the EOH district streams with a more resolute sampling effort in order to determine the loading of streams during the different phases of a storm. This would allow DEP to determine if a particular portion of a storm is more important in terms of protozoan contribution to the water supply, and continue to evaluate any BMP removal efficiency. The WOH monitoring was completed for the Esopus Creek sites and shifted to three locations along Schoharie Creek.

As part of the data analysis, DEP may be able to determine seasonal pathogen concentration changes and how different types of storm events and different site characteristics may impact pathogen concentrations and loading into DEP reservoirs.

Project Timeline:

2005: Stream site development

Pilot study determining ideal sample size, flow trigger, interval, and duration for storm events at selected sites.

2006: Completion of stream site development

Monitoring of 12 storm events for all stream sites.

2007: Continued stream monitoring with increased resolution at the East of Hudson sites to further refine storm monitoring data.

2008: Final report due in the spring of 2008.

Project Update:

In 2005, DEP developed sample stations fitted with auto-samplers and flow gauges, linked to Campbell Dataloggers, which enabled a flow-based sample trigger for each storm event. DEP then ran a pilot study at selected sites, to determine the ideal sample sample size, flow trigger, interval, and duration for storm events at the selected sites. In 2006, DEP completed the development of the stream sample sites, and successfully sampled 10 storm events for the EOH and WOH sites. DEP analyzed data during the winter of 2007 in order to select sites for sampling at

increased resolution based on relative stream flow protozoan concentration and sites with BMPs. The EOH sites included E10, E11, MB-1, N5-1, N5-1 Trib, and N5-1 Main; whereas the WOH sites included SSHG, S4, and S5I. In the spring of 2007 the storm monitoring equipment at EOH and WOH sites was redeployed with new programming to reflect the new sampling regimen.

Implications for Watershed Management:

This data is expected to provide specific information on the protozoan load into the Kensico basin from all its perennial streams during storm events. DEP will also be able to assess the efficacy of BMPs at reducing protozoan loading. This will provide a more accurate picture of problem areas, if they exist, and allow for follow-up remediation.

Problems Encountered:

DEP fell short of the projected 12 storms due to some technical difficulties (i.e., power) in the beginning of the sampling program, as well as an extended dry period in the middle of the summer.

2.3.3 Occurrence and Partitioning of *Giardia* and *Cryptosporidium* (Oo)cysts within the Kensico Drainage Basin of the New York City Watershed (SDWA 5.5)

Managers: Kerri Alderisio, Steve Di Lonardo
Start & Completion Date: September 1, 2006 to August 31, 2007
Status (% complete): 70
Project cost: $250K

Objective and Justification:

The goal of this project is to characterize the partitioning behavior of protozoa and other microbes in association with suspended particulate matter in five Kensico watershed tributaries (Figure 2.3). Samples are collected just prior to entry into Kensico Reservoir during baseflow background conditions, as well as during storm events (which have the potential for increased transport across the reservoir as a result of increased flow). This project will help clarify if protozoa entering the reservoir coalesce with dense suspended particles and settle to the reservoir bottom, or if they remain unattached with the potential to float through the reservoir and into the distribution system.

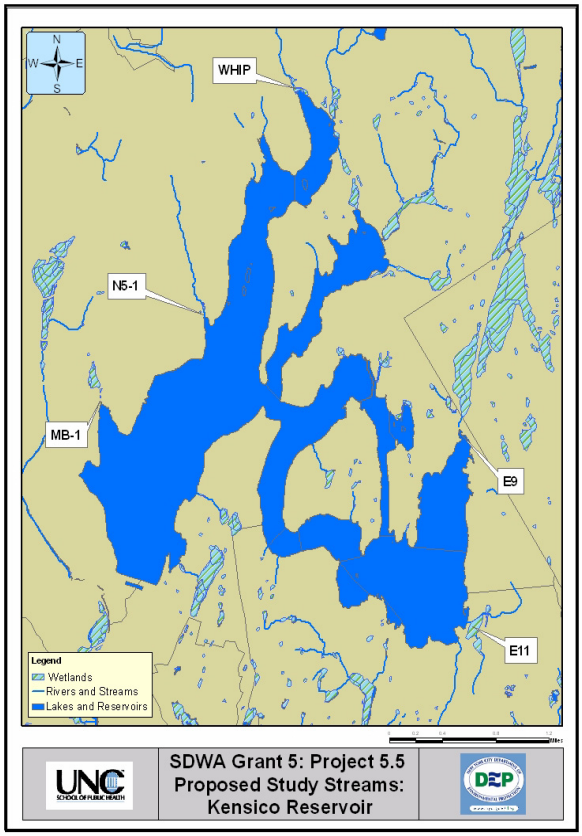

Figure 2.3 Kensico study streams for SDWA Project 5.5.

In the second phase of the project, DEP has been further refining this goal by analyzing the protozoan partitioning behavior for three of the five tributaries (selected based on pathogen concentration and relative stream flow) during the different hydrologic phases of a storm (Figure 2.4). This will help to dissect the influence of the different phases of each storm and to further focus management efforts.

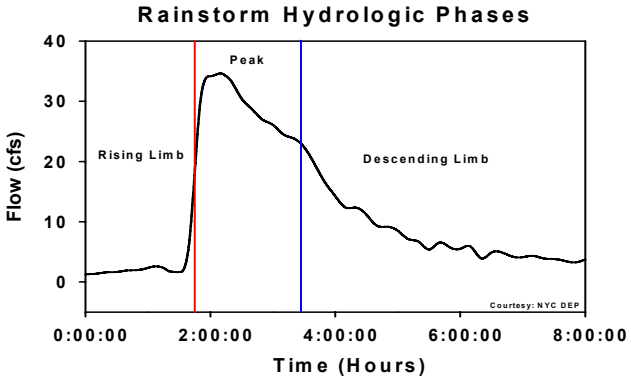

Figure 2.4 A typical depiction of the different hydrologic phases of a storm event

In addition, the contract laboratory is performing test case alum coagulation experiments with a few NYC aqueduct water samples to examine the suspended particle settling at different alum concentrations. DEP adds alum during high turbidity events to reduce the turbidity levels to those acceptable to a water supply. These few experiments will provide preliminary data to demonstrate the role of alum addition as it relates to particle settling and effective alum dosing.

Lastly, as a follow up to SDWA Grant 4, DEP has continued to perform genotyping of *Cryptosporidium* from wildlife feces in the NYC watershed, in order to increase the size of the reference library for identification of the specific sources.

Implications for Watershed Management:

Microbial particle attachment in the Kensico tributaries can have a direct influence on the impact those microbes may have on the receiving water. A comprehensive database documenting the behavior of targeted microbes entering Kensico Reservoir would be greatly beneficial to DEP in order to best estimate when, and with what likelihood, microbes entering the reservoir have the potential to enter distribution.

Project Schedule and Status:

Major Project Milestones Schedule (Timeline):

Months 1 to 3. Review existing Kensico reservoir and stream data and produce draft QAPP.

Months 2 to 5. Collect and analyze dry weather samples from five tributaries on three to four different occasions.

Months 2 to 5. Collect and analyze wet weather samples from five tributaries during three to four different storm events.

Months 3 to 10. Collect and analyze storm phase samples (three to four per storm) on two to three of the five tributaries for better resolution of data during event based sampling for three to four storms.

Months 6 to 8. Conduct bench scale coagulation and settling experiments.

Months 9 to 12. Data analysis, preparation of draft and final reports.

DEP has completed the first phase of the study, which included sampling four storm events and three background events for five streams (E9, E11, WHIP, MB-1, and N5-1) and determined (based on protozoan concentration and relative flow) that the second phase of the study should focus on WHIP, E9, and N5-1 locations. DEP has also sampled one of the four projected storm phase events. Preliminary test samples for the coagulation experiments have been analyzed, and the aqueduct is being monitored in order to collect a sample with an elevated number of particles. Many of the fecal samples for the genotyping portion of the study have been collected, and samples continue to be analyzed. Preliminary data analysis has begun for the final report due August 31, 2007.

Problems Encountered:

We are slightly behind schedule due to a long delay in getting the contract finalized and because of relatively dry conditions; however, we anticipate satisfying the goals set at the beginning of this project.

2.3.4 Monitoring of NYC's Reservoirs for Zebra Mussels

Manager: Sharon Neuman
Start & Completion Date: April through November, annually
Status: Ongoing
Project Cost: Approximately $37K per year

Objective and Justification:

The objective of this contract is to monitor all 19 of New York City's Reservoirs for the presence of zebra mussel larvae (veligers) and settlement on a monthly basis including April, May, June, October, and November, and on a bi-monthly basis during the warm months of July, August, and September. Sampling includes pump/plankton net sampling to monitor for veligers, and substrate sampling as well as bridal veil sampling to monitor for juveniles and adults. The contract lab analyzes these samples and provides a monthly report to the project manager as to whether or not zebra mussels have been detected. To date, zebra mussels have not been found within the NYC reservoir system.

Zebra mussels were first introduced to North America in the mid-1980s, and first identified on this continent in 1988. It is believed that they were transported by ships from Europe in their freshwater ballast, which was discharged into freshwater ports of the Great Lakes. Since their arrival in the United States, zebra mussels have been reproducing rapidly and migrating to other bodies of water at a much faster rate than any of our nation's scientists had predicted. They have been found as far west as California, as far south as Louisiana, as far east as New York State, and north well into Canada. They have been found in all of the Great Lakes and many major rivers in the Midwest and the South. In New York State, in addition to Lakes Erie and Ontario, zebra mussels have migrated throughout the Erie Canal, and are found in the Mohawk River, the St. Lawrence River, the Susquehanna River, and the Hudson River, as well as several lakes. DEP is concerned about infestation of New York City's reservoirs by this mollusk. Zebra mussels repro-

duce quickly and are capable of clogging pipes, which would seriously impair DEP's operations, preventing an adequate flow of water from the reservoirs to the City and those upstate communities dependent on the New York City water supply. As suppliers of water to over nine million people, it is DEP's responsibility to monitor New York City's water supply for zebra mussels, since early identification of a zebra mussel problem will allow us to gain control of the situation quickly and will save us money in the long run.

Implications for Watershed Management:

Monitoring for zebra mussels is critical for watershed management at this point in time. In addition to zebra mussels potentially preventing an adequate supply of water from reaching communities meant to use this system for drinking water, they also create taste and odor problems in the water. Early detection of zebra mussels would allow us to gain control of the problem quickly, as mentioned above, and would allow us to preserve the excellent water quality of this system, as well as save us money, in the long run.

Problems Encountered: None.

2.3.5 Development and Application of Watershed Loading Models for Evaluating Effects of Watershed Management, Land Use, and Climate Change on NYC Reservoir Water Quality

Manager: Elliot Schneiderman
Start & Completion Date: Ongoing
Status (% Complete): Ongoing
Project Cost: N/A

Objective and Justification:

The NYC DEP Modeling Program is engaged in ongoing research to develop, improve and apply watershed water quality models for simulating water, nutrient, and sediment loads to the NYC reservoirs under various land use, watershed management and climate scenarios. Loads simulated with the watershed water quality models are linked to reservoir receiving water models for evaluating the effects of land use, watershed management, and climate on reservoir trophic state. DEP has been working with and improving the VSLF (Variable Source Loading Functions) model which is a variant of the GWLF (Generalized Watershed Loading Functions) model. VSLF is a conceptual lumped-parameter model that simulates a daily water balance and partitions water among various pathways of the hydrologic cycle. The major difference between VSLF and GWLF is that VSLF simulates saturation-excess runoff from variable source areas (VSAs), while the traditional GWLF model assumes that runoff is produced by an infiltration excess process.

VSLF models have been developed for the Catskill and Delaware System reservoir watersheds. Model improvement and testing has been focused on refining the watershed hydrology and chemistry algorithms in VSLF, and on improved calibration of model parameters as additional data become available. Recent and ongoing model developments include further comparison of the VSA areas versus collected field data, refinement of the runoff curve number methods used to calculate direct runoff in the model, improvement of model calibration techniques and completed model calibration and validation for all Catskill/Delaware System watersheds. Model improvements are supported by continued collection of routine and storm event stream monitoring data.

Implications for Watershed Management:

Simulation modeling is a powerful tool for evaluating the effects of land use, watershed management, and climate on reservoir water quality. Evaluation of watershed land use management scenarios using models provides guidance to DEP and watershed management programs for most effective utilization of resources for maintaining and improving reservoir water quality. The DEP models have been used to evaluate the effects of land use change and watershed management programs on eutrophication in the Cannonsville and Pepacton Reservoirs for DEP's "2006 Watershed Protection Program Summary and Assessment" report. Future applications will also consider the effects of severe weather and climate change on the NYC water supply.

Problems Encountered: None.

2.3.6 Analysis of Nutrient and Sediment Loads at Beerston, Cannonsville Watershed

Manager: Don Kent
Start & Completion Date: October 1991 to September 2007
Status (% Complete): 98
Project Cost: $641K (based on the maximum number of allowable samples)

Objective and Justification:

The objective of this project is to provide continuous long term nutrient load data for the primary inflow to Cannonsville Reservoir. This data is needed to support the DEP's ongoing research of the Cannonsville watershed and reservoir models. Beginning in October of 1991 DEP has funded a series of 24 month contracts with Health Research, Inc. (HRI), to conduct storm event and routine sampling of the West Branch of the Delaware River at Beerston, NY. Under these contracts the NYS Department of Environmental Conservation (NYSDEC) collects storm event and routine samples which are analyzed by the NYS Department of Health (NYSDOH). To date, approximately 23,236 data points have been collected. After contract completion in September 2007, a total of 16 years of data will have been collected. An additional 24 month contract is currently being negotiated. The table below outlines the parameters measured.

Analyses of Water Samples	Number of Samples per Contract Period [1]
Total Phosphorus	750
Total Soluble Phosphorus	750
Soluble Reactive Phosphorus	750
Ammonia-N	750
Nitrate-Nitrite-N	750
Dissolved Organic Carbon	750
Particulate Organic Carbon	110
Chlorophyll *a*	110

[1] This is the maximum number of samples allowed under the current 24 month contract. The actual number of samples taken is subject to change based on the frequency and duration of storm event conditions during any contract period.

Implications for Watershed Management:

Accurate and continuous nutrient loads are a critical aspect of ongoing research designed to increase the reliability of and confidence in the Cannonsville Reservoir and Watershed Model simulations. As these models are used to evaluate the effects of watershed land use and management on reservoir water quality this monitoring needs to be continued so that reservoir responses to watershed management actions may be evaluated. Additionally, the information gained for Cannonsville in terms of data requirements for model testing and management action evaluation will be useful in assisting similar efforts on the other watersheds.

Problems Encountered: None

2.3.7 Suspended Sediment Dynamics in Ashokan West Basin

Manager: Allison Bennett
Start & Completion Date: April 1997 to December 2006 (changed from December 2005)
Status (% Complete): 90
Project Cost: N/A

Objective and Justification:

The objective of this study was to quantify the longitudinal and annual variations in sediment deposition in the Ashokan Reservoir and to potentially identify source or sink areas within the basin and to provide observational data for model development. High runoff events in the Catskill District periodically result in increased turbidity in the streams. Since the West Basin of the Ashokan Reservoir receives water directly from the Esopus Creek, it is susceptible to turbidity changes which occur in the creek. Sediment traps were deployed at a number of sites in the West

Basin of Ashokan Reservoir for a five year period to measure the downward flux of sediment over a range of hydrologic conditions. The placement of the sediment trap sites and the period of study will allow spatial and temporal resolution of the sediment flux throughout the Reservoir.

Implications for Watershed Management:

The study has identified spring and fall precipitation events to be the primary cause of elevated turbidity, with resuspension playing a much smaller role. With information about the sediment dynamics in the Ashokan West Basin, and information on how the Reservoir responds to periodic turbidity events, management will be able to make more informed decisions about operations to minimize effects of spring and fall storm events. Reservoir elevation plays a key role in how the West Basin will respond to high turbidity inflows. Low reservoir elevation will increase the amount of sediment resuspended within the reservoir due to wave action on the exposed shoreline. Low reservoir elevation will also increase bottom sediment resuspension by decreasing the water column depth, which will increase the effect of surface waves on the bottom. At higher elevations, the travel time through the reservoir is longer, which better enables the reservoir to buffer the effect of the inflow stream. Reservoir thermal structure also plays an important role in how a turbidity plume will travel across the basin. During stratified periods, a plume of turbid water will travel across the basin as an interflow, and reach the dividing weir much quicker than under isothermal conditions. Management can use this information to determine the best operational changes to make during an event depending on the reservoir elevation and thermal structure at the time of the event. Data collected from this study will also be incorporated into the turbidity model being developed by the Upstate Freshwater Institute, which will provide a useful management tool.

The Suspended Sediment Dynamics in Ashokan West Basin project has been incorporated into the Integrated Program of Measurements, Process Studies, and Modeling for the Turbidity Problem at Schoharie Reservoir and Esopus Creek (see section 2.3.15). DEP and Upstate Freshwater Institute (UFI) have collaborated on the data collection efforts, and UFI will incorporate the information into a turbidity model for the Ashokan Reservoir.

Problems Encountered: None.

2.3.8 Development of a Sediment-Nutrient Sub-model for EOH Reservoirs

Manager: Don Pierson
Start & Completion Date: 15 November 2005 to30 September 2006
Status (% Complete): 100
Project Cost: $70K

Objective and Justification:

In the EOH system, particularly the New Croton reservoir, major sediment releases of manganese (Mn), Fe, P, and color have been documented during the summer of multiple years. Therefore, water quality models in the EOH system, particularly New Croton Reservoir, should

have a mechanistic sediment sub-model that predicts sediment-water exchange in response to predicted redox conditions and deposition inputs of decomposable organic material (e.g., phytoplankton). The model should have the capability of predicting changes in sediment feedback from changes in the productivity of the overlying water column, and other ambient conditions. In contrast, the nutrient/phytoplankton models completed for the WOH reservoirs do not have sediment sub-models to quantify material exchange between the water column and underlying sediments. This added model complexity was unnecessary for those systems, as comprehensive monitoring established there was not substantial release of phosphorus (P) from the sediments of these reservoirs.

In this project a sediment sub-model was developed, set up, and initially tested, focusing on conditions typical of the near bottom water column in the New Croton Reservoir. The model was first developed and tested as a "stand alone" computer program, and was then incorporated within a one-dimensional hydrodynamic/hydrothermal model framework to eliminate hydrodynamic complexities and keep run times short. Both initial applications of the sediment model were judged as successful, and were able to reasonably predict variations in dissolved oxygen, iron, and soluble reactive phosphorus.

Implications for Reservoir Management:

The Croton System is typically shut down for several months in late summer to avoid sending highly-colored water into distribution. Color is due to anoxia and the release of Fe and Mn from the sediments. Models will assist operations by helping to predict when this will occur.

Future development of operational water quality models in the EOH system will require simulation of sediment-water nutrient exchange. The sub-model developed in this project will eventually be incorporated into the EOH water quality models. The approach taken here is consistent with that adopted in earlier model development and upgrades for WOH reservoirs; kinetic/water quality model advancements can be extended to the two-dimensional New Croton framework and the 1D water quality model frameworks for other EOH reservoirs in a subsequent phase. This work therefore, supports a consistent sequence of model development that will allow linking EOH water quality models to the 1D and 2D hydrothermal models.

Problems Encountered: None

2.3.9 Development of a Watershed Land Information System to Support the Management of New York City Water Supply Lands

Manager: Terry Spies

Start & Completion Date: Versions 1- 3: June 2001 to July 2006. Version 4: July 2006 to Spring 2008

Status (% Complete): Version 4: 70

Project Cost: Version 1-3: no cost to DEP (DEC SDWA funds used)
Version 4: $1.4 million in GIS FAD CP funds

Objective and Justification:

The Bureau of Water Supply is midway through the development of a sophisticated Watershed Land Information System (WaLIS) that currently operates on the workstations of approximately 130 registered DEP users, including the newly-formed group of Operations Regional Managers. WaLIS manages information about the watershed lands and resources owned by NYC and its neighbors. It uses Geographic Information System (GIS) data analyses and relational database reporting capabilities to support the WLCP Land Management and Land Acquisition Programs. WaLIS also leverages those same GIS and reporting capabilities to support other MOA program objectives and watershed management decisions. Until May 2006, federal Safe Drinking Water Act (SDWA) funds administered by the New York State Department of Environmental Conservation (DEC) were used to develop WaLIS in-house at DEP through DEC-contracted support with PAR Government Systems Corporation (PAR).

DEP now has a direct contract with PAR, which expires in January 2008, to continue to support and develop WaLIS, including upgrading to the next generation of enterprise hardware and software technology recommended by DEP's Office of Information Technology (OIT). Such an upgrade will resolve a myriad of issues with the current system, including long-term hardware, software, and database support and the ability to implement WaLIS at an "enterprise" level throughout DEP and other stakeholder agencies in the future. We strive to reduce the long-term maintenance of the system through the implementation of these new technologies. The goals of the upgrade include providing the user with an easier-to-use system, improving maintenance and support capability, providing a user-customizable interface, enhancing mapping capability, and implementing DEP-wide enterprise security standards.

Implications for Watershed Management:

Land conservation is one of the best methods for watershed protection, but only if the protected lands are subsequently well managed. A scattered and diverse land holding is difficult to keep track of and to harness for optimum source water protection. Inappropriate land use can lead to water quality impacts, inefficiencies in natural resource management, and increased long-term costs to repair neglected situations. This software product is resulting in innovative and advanced approaches to watershed land management in the areas of natural resource planning, forestry, pub-

lic access/recreation, road maintenance, granting of land use permissions, conservation easement stewardship, and the general administration of lands. This capability is of interest to a variety of other watershed programs.

Problems Encountered:

The development of the next generation of WaLIS, Version 4, is being managed by DEP WLCP GIS under the current DEP State contract with PAR funded by the GIS FAD CP. This was an expedited contract put in place to prevent a gap in services when DEC suddenly ended SDWA contracts on short notice in May 2006. Because of its stopgap nature, there is limited funding and a limited time period for work to be complete by the January 2008 contract end-date. There is a need to keep to a strict workplan with no change of scope to ensure that the necessary core functionality of WaLIS is migrated without problems to Version 4. The needs of Version 4, although primarily geared to LAP and LM, are also geared to extend functionality to a wider BWS use, including Operations, Engineering, and the DEP Police. This is possible by enhancing database security and defining user group roles to hide confidential information, such as Land Acquisition deals.

The main objective for the development of WaLIS Version 4 is to bring the system into OIT-standards for hardware, software, and database architecture, to streamline the code, and to clean up errors, not to add new functionality. Version 4 will be easier to use, easier to maintain and support, easier to customize, have better mapping capability, and will better adhere to enterprise security standards. Future development services beyond this contract will add additional functionality.

2.3.10 Upgrade of NYCDEP Reservoir Water Quality Model(s) to Simulate Functional Groups of Phytoplankton

Manager: Don Pierson
Start & Completion Date: 15 November 2006 to15 November 2008
Status (% Complete): 70
Project Cost: $270K

Objective and Justification:

This project will upgrade DEP's reservoir water quality modeling capability by integrating the desired features and capabilities of the PROTECH phytoplankton model into DEP's 1D reservoir models. PROTECH is documented in a manuscript by Reynolds *et al*. (2001; "The Ecological Basis for Simulating Phytoplankton Responses to Environmental Change (PROTECH). Ecol. Model. 140:271-291), and provides predictive capabilities for phytoplankton functional groups, but does not have the other attributes presently embedded in DEP's models.

Project Tasks:

- Compare present DEP phytoplankton identification/enumeration methodology to another widely used methodology. This will form the basis for any adjustments that may be needed in

order to use long-term DEP phytoplankton monitoring data for model calibration.
- Test the existing PROTECH model on Cannonsville Reservoir, including assessment of the ability to predict succession and biomass of functional groups. Compare PROTECH simulations of total phytoplankton biomass with predictions from the existing DEP model.
- Merge the best features of PROTECH (phytoplankton dynamics) and the existing DEP model(s) (hydrodynamics and nutrient cycling) to form the upgraded reservoir water quality model(s).
- Test the upgraded model for Cannonsville Reservoir.
- Develop recommendations for applying the upgraded composite model to other NYC reservoirs.

Work on this project is presently underway. All phytoplankton data has been collected. PROTECH algorithms have been incorporated into the 1D Cannonsville Reservoir model, and test of this model is underway. All project deliverables will be delivered on schedule.

Implications for Reservoir Management:

The capability to simulate algal functional groups can provide DEP with the ability to simulate algal blooms of groups (i.e., large colony forming cyanobacteria), and to anticipate problems in drinking water use and treatment. This will enhance our modeling capability, as presently we can only simulate total algal biomass (measured as chlorophyll *a*), but not algal types.

Problems Encountered: None.

2.3.11 Numerical Weather Prediction and Forecast Products as Input into Eutrophication Models

Manager: Don Pierson
Start & Completion Date: March 2005 to June 2005 (extended to May 2006)
Status (% Complete): 100
Project Cost: $10K

Objective and Justification:

There have been substantial advances in the accuracy of short-term (1-5 days), medium-range (two weeks), and longer-term (monthly to seasonal) atmospheric forecasting over the past two decades. Output from these forecasts, when used as input to hydrologic models, may improve forecasts of stream-flow and other derived parameters such as turbidity. The purpose of this project is to explore the feasibility of using the medium range (i.e., the Global Forecast System (GFS) model) and longer-term forecast products of the National Centers for Environmental Prediction (NCEP) for hydrologic predictions in the New York City watershed on time scales of up to eight weeks. This study will:

- Evaluate the systematic biases and the accuracy in predictions of precipitation and temperature over the NYC watershed domain and introduce procedures to improve raw GFS output through downscaling.

- Use the technique of model output statistics (MOS) to correct for systemic biases in the GFS output. MOS downscaling will develop empirical relations between gridpoint values of model output. Observed data will consist of historic Cooperative Observer network stations and the more recently deployed DEP meteorological network.
- Produce a test "hindcast" from a chosen subset of cases of interest to DEP with output including precipitation occurrence, precipitation amounts, maximum temperature, and minimum temperature for stations in the DEP network.
- Develop tool to incorporate real-time NCEP output into a daily updated 8-week forecast product that can be ingested by DEP hydrological models.

Implications for Watershed Management:

In order to make simulations that can support reservoir operational decision-making it is necessary to run the Nutrient Management Eutrophication Modeling System (NMEMS) up to the present and then into the future. This project investigated the possibility of using weather forecast information to provide a data set that can be used to drive NMEMS. The results of the project showed that GFS forecasts could be downscaled to the locations of meteorological stations within the NYC West of Hudson (WOH) Watershed area using MOS statistics. As a consequence of this downscaling, forecast predictions were shown (in retrospect) to be more accurate than the original GFS forecast. A tool to automatically download the GFS forecasts, and downscale them to the WOH meteorological station sites, was also developed.

Problems Encountered: None

2.3.12 Development of a Regional-Scale Future Climate Scenario for New York City Drinking Water Quality Modeling

Manager: Don Pierson

Start & Completion Date: January 2005 to August 2005 (original project)
May 2006 to July 2006 (extended project)

Status (% Complete): 100

Project Cost: $48K (original), $8.5K(extension)

Objective and Justification:

The objective of this project was to provide DEP with consistently developed present climate and future climate datasets, which can be used to drive DEP's Nutrient Management Eutrophication Modeling System (NMEMS), in order to evaluate possible effects of climate change on reservoir water quantity and quality. Columbia University Center for Climate Systems Research (CU-CCSR) was chosen as the contractor to develop these datasets. This project involved obtaining Global Climate Model (GCM) output, which out of necessity have a coarse spatial resolution, and downscaling these data using a regional climate model (RCM) to a 36 km grid resolution, which is more appropriate for modeling the NYC reservoir system.

Initial RCM modeling attempts, requiring significant computational resources, produced two datasets for the 1990 and 2050 decades. Verification of the 1990 control period against present meteorological measurements, however, suggested that the downscaling was not satisfactory and that the gridded data were not representative of present day conditions. A second phase of the project re-evaluated the downscaling methodology used during the first attempt, including aspects of the RCM parameterization and grid design. Tests of a new configuration of the RCM proved successful when the RCM was driven using a dataset derived from actual meteorological measurements, but were unsuccessful when driving the model with the output of the Goddard Institute of Space Studies (GISS) GCM. It was concluded that the RCM model was able to produce downscaled climate datasets encompassing the NYC reservoir watersheds, but that the GISS GCM was not a suitable driver for the RCM model. A preliminary analysis suggested more suitable GCM datasets.

Implications for Watershed Management:

It was hoped that data provided by this project would allow simulations with NMEMS under present and future climate conditions, so that the effects of climate change on reservoir water quantity and quality can be qualitatively assessed.

Problems Encountered:

This project was not successful in producing datasets that were acceptable for this application. CU-CCSR had previously been successful in downscaling summer period data using the same RCM methodology. Despite this, the demands of producing continuous 10 year RCM simulations led to unexpected problems that despite their best efforts prevented CU-CCSR from producing usable data. Follow up work has validated a working RCM approach and suggested future tests and GCM datasets. This will form a starting point for new climate change work that is now in the planning stages.

2.3.13 Croton System Hydrothermal Reservoir Models

Manager: Don Pierson
Start & Completion Date: 15 November 2005 to 30 September 2006
Status (% Complete): 100
Project Cost: $100K

Objective and Justification:

This project provided final verification of Croton System 1-D hydrothermal reservoir models that were calibrated, but not verified, under Phase I Croton System reservoir model development work (see Section 2.3.8 of 2005 report), and also completely developed a 2-D hydrothermal model for the New Croton Reservoir. This project consisted of two separate tasks based on model structure.

Task 1: In this task, one-dimensional models previously developed and calibrated for 6 EOH reservoirs were verified. The verification process involved a comparison of model predictions of reservoir thermal structure with measured data. Model verification was judged to be adequate, and as a result hydrothermal models are now completed for Muscoot, Titicus, Diverting, Croton Falls, Amawalk, and Cross River Reservoirs. Development of fully verified hydrothermal models is an important step in the process of developing operational Croton System reservoir models.

Task 2: In this task, a two dimensional hydrothermal model for the New Croton reservoirs was set up, calibrated and verified. The 2D model structure is the same (based on CE Qual W2) as used in 2D models in the WOH system. For the New Croton Reservoir the 2D structure is most appropriate for simulating water quality, which shows significant lateral variations due to the riverine nature of the reservoir.

Implications for Reservoir Management:

The hydrothermal models form the foundation of fully functioning water quality models and their development is an important step in the overall development of a system of water quality models similar to those presently available for West of Hudson (WOH) reservoirs. This project funded the continued development and testing of reservoir hydrothermal models for the East-of-Hudson (EOH) reservoir system. The models are compatible with the existing Catskill-Delaware reservoir models, with added functionality to accommodate Croton reservoir characteristics. The models will eventually serve as in-house management tools, and will contribute to the effective management of this reservoir system.

Problems Encountered: None.

2.3.14 Advancements of Croton System Reservoir Models for Water Quality Predictions

Manager: Don Pierson
Start & Completion Date: September 2006 to August 2007
Status (% Complete): 50%
Project Cost: $407K

Objective and Justification:

The purpose of this project is to add water quality algorithms to the now functioning EOH hydrothermal models, so that fully functioning reservoir water quality models are created. Work will be carried out on two separate tasks.

1. Water quality algorithms will be added to the models of EOH reservoirs for which 1D hydrothermal models are presently available. These operational water quality models will then be calibrated, and finally the performance of the calibrated models will be verified using an independent data set.
2. Water quality algorithms will be incorporated into the 2D New Croton Hydrothermal model.

As with the 1D models, the 2D water quality model will be fully calibrated and verified, but in addition to vertical variation in water quality, longitudinal variations will also be considered.

In the case of the New Croton Reservoir model, special emphasis will be placed on integrating the sediment-water nutrient exchange sub-model into the 2D model framework, since sediment-water processes are known to be of particular importance in influencing the water quality of the New Croton Reservoir.

Work on this project is presently underway, and the final models will be delivered on schedule.

Implications for Reservoir Management:

This project will provide the final development and testing of reservoir models for the EOH reservoir system. These models are to serve as in-house management tools for the DEP, and will contribute to the effective management of this reservoir system. The models will help to evaluate management alternatives to protect water quality, and will support analyses of related management goals. As a quantitative framework for examining information, and integrators of the data collected as part of ongoing monitoring programs, the models also improve our present understanding of the EOH reservoirs.

Problems Encountered: None.

2.3.15 Integrated Program of Measurements, Process Studies, and Modeling for the Turbidity Problem at Schoharie Reservoir and Esopus Creek

Manager: Don Pierson
Start & Completion Date: August 2003 to November 2006 (extended to December 2007)
Status (% Complete): 100
Project Cost: $2.5M + $0.5M (Change Order)

Objective and Justification:

The primary objective is to develop and test deterministic, dynamic, scientifically credible models for temperature and turbidity for Schoharie Reservoir and Esopus Creek (supported by the integrated programs of field measurements, sampling and laboratory analyses and process studies) that will be capable of supporting evaluation and design of rehabilitation technologies to abate the turbidity problems of these systems, and simultaneously meet specified temperature goals for Esopus Creek. A Change Order ($0.5M) is now included to extend this contract to December 2007 and will include additional modeling elements: development and application of a probabilistic model for turbidity and temperature in Schoharie Reservoir and Esopus Creek; application of a three-dimensional model to evaluate specified management options to reduce turbidity levels reaching the Schoharie Reservoir intake(s); development, testing and application of a turbidity model for Ashokan Reservoir, and integration with the model for upstream systems to

form a seamless Catskill System model; development of a near-real-time model that predicts time-of-travel and impacted depths of turbidity plumes in Schoharie Reservoir from runoff events.

Implications for Watershed Management:

This work is being conducted under contract to DEP, and requires extensive co-operation with other DEP consultants (a Joint Venture operating under a separate contract known as CAT-211 to the Bureau of Environmental Engineering. This JV is conducting engineering tasks related to the evaluation of alternatives and design of the selected technologies). These studies will assist DEP in the operation of the Shandaken Tunnel under the SPDES permit. The Upstate Freshwater Institute (UFI) is conducting integrated programs of field monitoring/laboratory analyses, process studies, development and testing of turbidity and temperature models, and application of models. These work elements are being used to support the evaluation and design of rehabilitation technologies for the turbidity problems in Schoharie Reservoir and Esopus Creek that will also continue to meet temperature requirements for fish populations in this creek. The Change Order enabled more refined and useful modeling and extended the study to Ashokan Reservoir. The models developed were valuable for evaluating the engineering structures to minimize the release of turbidity from Schoharie Reservoir, including multi-level intake structures and a turbidity curtain. Models were also used to develop an optimized release strategy in regards to water temperature and turbidity, in order to provide a low turbidity release and cold-water fish habitat in Esopus Creek. The use of model derived information to guide reservoir operations was shown to be an effective means of managing Catskill System reservoirs, and a valuable tool to mitigate the effect of elevated levels of reservoir turbidity. Consequently, a similar modeling effort is being undertaken at Ashokan and Kensico Reservoirs so that similar modeling capabilities will be available for all three of these reservoirs that are periodically subjected to elevated turbidity inputs.

Problems Encountered: None.

2.3.16 Modeling of Pathogen Fate and Transport in NYCDEP Reservoirs

Manager: Don Pierson and Kerri Alderisio
Start & Completion Date: 1 September 2006 to 31 August 2007
Status (% Complete): 20%
Project Cost: $160K

Objective and Justification:

This project will develop and test an approach for modeling the fate and transport of pathogens in water supply reservoirs, particularly pathogens that are present in low concentrations. In the Kensico Reservoir, as well as other surface waters, such pathogens would include *Giardia* cysts, *Cryptosporidium* oocysts, and human enteric viruses (HEV). This work would address conceptual and practical problems associated with the application of traditional water quality modeling techniques for these pathogens, and test a new modeling strategy for simulating the transport of pathogens through Kensico Reservoir. In a particle tracking model, the path of a

representative (relatively large) number of particles is determined, and the resulting spatial and/or temporal statistics of the distribution of particles (center of mass, variance) are used to quantify transport and the probability of a certain concentration. A particle tracking model would permit calculation of the statistical likelihood that a pathogen cell would reach a point of interest under specified environmental (weather, hydrology, reservoir operation) and loading conditions. The framework on which a particle tracking model is based is a hydrodynamic model which predicts water motion (advection) and mixing (diffusion/dispersion) processes. While the advection is treated as deterministic, the mixing processes have a random component.

In this project a particle transport model will be developed and coupled to an existing hydrodynamic model of Kensico Reservoir. A review of available pathogen data for Kensico Reservoir and its tributaries (streams and tunnels) will be done to select one or more pathogen types and historical periods to be used for model testing.

Implications for Watershed Management:

The particle tracking based approach of modeling pathogen transport will be evaluated and a series of recommendations will be made in regards to the value/validity of the modeling approach and the variability in pathogen transport that can be expected between Kensico influent and effluent locations.

Problems Encountered: None

2.3.17 Kensico Extended Detention Basin BMP Efficiency Assessment Project

Manager: Tracy Lawrence
Start & Completion Date: July 2006 to August 2007 (projected)
Status (% Complete): 10%
Project Cost: $80,000

Objective and Justification:

The objective of this project is to provide an independent review and analysis of the DEP's stormwater monitoring programs, including data review, on extended detention basins within the Kensico Reservoir watershed. The end product will be report(s) and an opportunity of publishing data to the international BMP monitoring database. A peer review of the data would benefit the DEP and other agencies by evaluating DEP's stormwater monitoring program; standardizing/ improving sampling protocols at the regional or national level; reducing costs associated with sample collection and analysis; and providing documentation for policy development, particularly in the EOH watershed.

Implications for Watershed Management:

The recommendations of the consultant may be used to improve cost effectiveness of the stormwater monitoring program while enhancing quality control and sampling procedures of influent and effluent water quality. Data may also be used to provide information to Stormwater Pollution Prevention Plan applicants.

Problems Encountered:

The start date for this contract was delayed until February 2007 as a result of DEP's contract bidding and registration process. However, the project is still planned to be completed in 2007.

3. Future BWS Research (Funded Proposals)

3.1 Climate Change Integrated Modeling Project – Phase I

Manager: Don Pierson

Start & Completion Date: January 2008 to June 2009 (Estimated – Exact dates depend upon contract implementation)

Status (% complete): 0

Project cost: $350K

Objectives and Justification:

Intergovernmental Panel on Climate Change (IPCC) is now agreement on the scientific basis of climate change, its anthropogenic elements, the reality of impacts, and the importance of adaptation and mitigation. With respect to water quantity and quality in the NYC watershed area, it is expected that, on the whole, precipitation will increase, which will bring more water and possibly more intense storms and lower water quality. Additionally, temperatures are expected to increase, bringing more evaporation, longer growing seasons and longer periods of low summer flow. Other potential impacts of climate change include earlier snowpack melting and changes in the timing of nutrient and sediment delivery to the reservoirs. The combination of these effects is likely to produce changes in water quantity and quality (turbidity in the Catskill System; eutrophication in the Delaware System). With these changes, it is necessary to examine the operation and reliability of the water supply system in the context of future climate change. This project is designed to use DEP's watershed, reservoir and system operations models in conjunction with estimates of future climate to investigate the potential impacts of climate change on water quantity and quality within the Catskill/Delaware System.

The project is planned in multiple phases. Phase I (18 months) is aimed at providing a first-cut evaluation of the effects of climate change on water quantity and quality, using the existing modeling system and data available from three Global Climate Models (GCMs). This first phase will be designed to provide initial testing of the resiliency of the NYC water supply system to different climatic regimes projected under climate change scenarios. Future phases will examine water quality as well as quantity on a system-wide basis, incorporate specific model enhancements, utilize refined climate predictions, and point to more specific recommendations for system operations and infrastructure.

Models currently employed that will be used for the integrated modeling project include: the Variable Source Loading Function watershed model (VSLF); a 1-dimensional reservoir eutrophication model; a 2-dimensional reservoir turbidity transport model; and the OASIS operating model for the overall water supply system. As part of Phase I these four models will be refined, partially integrated, and combined with future climate scenarios to make the proposed integrated assessment.

Implications for Watershed Management:

Given the complexity of future climate changes, the potential changes in quantity and quality of water available for use by NYC and other watershed interests unknown. This project aims to better ascertain how the water system supply will change, and in turn, how the future system infrastructure and operations might be adjusted to manage potential changes to supply optimal drinking water for the City.

3.2 Extension of the Schoharie Turbidity Monitoring and Modeling Program Through Ashokan and Kensico Reservoirs

Manager: Don Pierson
Start & Completion Date: Start date following contract registration. Project length 2.5 y
Status (% Complete): 0
Project Cost: $1,690K

Objective and Justification:

DEP designed and managed a contract with the Upstate Freshwater Institute (UFI) to conduct *integrated programs* of monitoring, process studies and modeling to provide scientific and quantitative (mathematical models) support to evaluate and design rehabilitation technologies to abate turbidity problems in the withdrawal from Schoharie Reservoir and the overall Catskill System. This broad task met a required deliverable of the November 2002 FAD and has provided invaluable support for the SPDES permit development for the Shandaken Tunnel discharge. An important result of DEP/UFI work to date has been to reveal that inputs from Esopus Creek and its tributaries are significant and outweigh the contribution of the Shandaken Tunnel to Ashokan Reservoir turbidity and "trigger" the need for alum treatment. Given this, models with the same level of scientific credibility are needed downstream for both Ashokan Reservoir and Kensico Reservoir. This project will develop turbidity transport models for Ashokan and Kensico Reservoirs that are calibrated and verified to the same high standard that has been applied at Schoharie Reservoir. The project will have the following elements: (1) conduct comprehensive monitoring in Ashokan and Kensico, (2) conduct extensive process studies in these reservoirs, (3) conduct extensive data analyses, (4) rigorous testing of the models, based on the information from the preceding three elements, and application of the models to support evaluation of management alternatives.

Implications for Watershed Management:

Turbidity generated in the Catskill system of reservoirs is a problem which ultimately manifests itself in Kensico Reservoir. Modeling to evaluate this turbidity problem, make predictions of future turbidity, or to suggest mitigating changes in reservoir operations requires a coupled system of reservoir models for the entire Catskill System and Kensico Reservoir. This project will develop all of the component models for such a coupled system.

Problems Encountered: None.

3.3 Evaluating the Effects of Climate Change on the NYC Water Supply Using an Integrated Modeling Approach

Manager: Don Pierson
Start & Completion Date: Initial Phase will be18 months following contract registration
Status (% Complete): 0
Project Cost: To be determined

Objective and Justification:

The goal of this project will be to estimate the effect of future climate change on the quantity and quality of water in the NYC water supply. Three issues of concern have been identified, and these will each be addressed by targeted simulations.

1. Effects on the overall quantity of water in the entire water supply, potential changes in the dynamics of the system (i.e. change in the timing of inputs, spill, and drawdown), and resultant changes in reservoir operations.
2. Effects on turbidity in the Catskill System of reservoirs, including Kensico reservoir. Changes in the frequency, timing and intensity of precipitation may lead to increases in turbidity loading to Catskill System reservoirs. Increased turbidity inputs could become a water quality concern that would limit the use of Catskill System water, and could also require treatment of Catskill System water with alum.
3. Effects on eutrophication of Delaware System reservoirs. Changes in the timing and magnitude of nutrient inputs to NYC reservoirs that have previously been impacted by eutrophication, could lead to further changes in reservoir trophic status. Reservoir trophic status, as measured by the long term distribution of water column chlorophyll and phosphorus, is one of the metrics by which DEP's FAD mandated watershed management and nutrient reduction programs have been judged. Increases in algal biomass could limit water use from some reservoirs, and increase the cost of water treatment.

This project will occur in multiple phases, with the first phase making an initial attempt to estimate the effects of climate change on the water supply within an 18 month time frame. During this phase DEP will work with available Global Climate Model (GCM) data, and models that are presently in use. Issues related to water quantity will be addressed for the West of Hudson System (WOH). Turbidity and eutrophication effects will be simulated for two upstream reservoirs where these problems have historically occurred, and where the effect of reservoir system operations will be relatively simple to specify. Subsequent phases of the project will involve improved downscaling of the GCM data, modifications to present watershed and reservoir models to make them more suitable for simulations of future climate change, and improved coupling of water quality models to the OASIS system model.

Implications for Watershed Management:

Climate change can potentially alter both the quantity and quality of water in the NYC drinking water supply. While it is easy to speculate on possible climate change effects, it is much more demanding to examine the potential effects of climate change in a quantitative framework

that is consistent with DEP's present water quality and system operations modeling framework. This project is the outcome of a series of meetings attended by members of the DEP Water Quality Modeling group, DEP Strategic Services group, DEP Bureau of Environmental Planning and Assessment, and the Columbia University Center for Climate Systems Research. The outcome of this project will be a collaborative effort to quantitatively evaluate the effects of climate change on the quantity and quality of water in the New York City Water Supply, as well as changes in the operation of the system that could occur as a result of climate change.

Problems Encountered: None

4. Review of Research Programs by Outside Agencies

4.1 Effectiveness of Whole Farm Planning and Implementation in Achieving Water Quality Improvement and Protection of New York City Water Supplies

Managers: Patricia L. Bishop[1], J. L. Lojpersberger[1], and M. R. Rafferty[2]
1: Bureau of Water Assessment and Management, NYS DEC
2: Water Resources Institute at Cornell University
Start & Completion Date: June 1993 to September 2006
Status (% Complete): 100%

This summary was excerpted from the September 2006 report, *Effectiveness Of Whole Farm Planning And Implementation In Achieving Water Quality Improvement And Protection Of New York City Water Supplies Final Report - September 2006*.

Objective and Justification:

As noted in the abstract of the report, *Effectiveness Of Whole Farm Planning And Implementation In Achieving Water Quality Improvement And Protection Of New York City Water Supplies Final Report - September 2006*, this research project "… documents reductions in nutrient and sediment loads resulting from agricultural best management practices (BMPs) implemented as part of an effort to control eutrophication of Cannonsville Reservoir, a drinking water supply for New York City. Dairy farms in the upstate New York reservoir basin were the target of BMPs designed to reduce P losses. A paired watershed study was established on one of these farms in 1993 to evaluate changes in pollutant loading attributable to implementation of BMPs that included manure management, rotational grazing, and improved infrastructure. Event-based stream water monitoring provided data to calculate loads from the 160-ha farm watershed for all runoff events during a two-year pre-treatment period and a nine-year post-treatment period. Statistical control for inter-annual climatic variability was provided by matched loads from a nearby 86-ha forested watershed, and by several event flow variables measured at the farm. Multivariate analysis of covariance (ANCOVA) provided estimates of both seasonal and overall event load reductions. Sampling during non-event periods and statistical analysis of pre- and post-BMP concentrations indicated significant changes in baseflow loadings as well. The results demonstrated overall farm load reductions of 64% for total ammonia, 53% for total dissolved phosphorus, 35% for particulate phosphorus, 28% for total suspended sediment, and 23% for nitrite+nitrate. Changes in farm management practices and physical infrastructure clearly produced decreases in farm losses measurable at the small watershed scale."

Implications for Management:

The report concludes that:

"Implementation of BMPs on the monitored farm resulted in a large number of changes to many aspects of the farm's infrastructure and management, and the observed reductions in nutrients and sediment loads are probably attributable to all of them. The small-scale watershed monitoring approach was an effective method for evaluating treatments that affected loading processes throughout the farm landscape. The results of the study quantitatively demonstrate that dairy farm BMPs can succeed in reducing losses during runoff events as well as baseflow periods. Overall, decreases in farm loads were estimated to be 64% for ammonia, 53% for dissolved phosphorus, 36% for particulate phosphorus, 28% for suspended sediment, and 23% for nitrite+nitrate. While the monitored farm has been more intensively managed, from an environmental perspective, than most other farms in the region that have adopted BMPs, our findings provide evidence that the Watershed Agricultural Program has reduced phosphorus and ammonia loading to one of New York City's water supplies, Cannonsville Reservoir. Presumably, initial decreases in phosphorus stream losses were a consequence of greater retention of P within the farm watershed, an outcome that could eventually lead to saturation of soil with P. Reductions in dissolved P occurring later in the study may be attributable [*sic*] to the implementation of precision feeding. Management programs that combine effective conservation and nutrient management measures with practices designed to improve farm P mass balance and slow net soil accumulation would appear to have the best chance of protecting water quality over the long term. The observed decreases in ammonia loads may be a result of both loss to the atmosphere through volatilization and conversion to nitrate in the soil with subsequent increases in loads of this nitrogen form during certain seasons. While nitrogen is not as important in this freshwater system as phosphorus, in ocean and estuarine systems where excess nitrogen is typically the nutrient of concern for eutrophication, other farm management practices that reduce inputs of N or utilize it more efficiently on the farm, may be of more value than the ones implemented in this project."

4.2 Water Quality Monitoring in the Source Water Areas for New York City: An Integrative Watershed Approach

Manager: Stroud Water Research Center, Avondale, PA.

Start & Completion Date: Phase II, Year 2 (2004) monitoring report was finalized in December, 2005.

Status (% Complete): The study is complete, except for a final report.

The Stroud Water Research Center's project was designed in two phases of three years each. During Phase I (2000-2002), 60 stream sites were monitored (30 EOH and 30 WOH); 50 sites were "target stations", which looked at particular watershed factors and 10 were "integrative stations" located on the larger tributaries. Eight source water reservoirs were also sampled in Phase I. The monitoring was primarily done synoptically. Phase II (2003-2005) built on the Phase I results by sampling other tributaries and conducting specific studies to clarify ambiguous results from the first phase. There were 62 sample sites in Phase II, most different from the Phase I sites. Fifty-two were "target stations" and 10 were "integrative stations." Seven reservoirs were

sampled as well (Muscoot, Amawalk, Titicus, Cross River, Neversink, Pepacton and Cannonsville Reservoirs). Thirty-five stream sites were WOH and 27 were EOH. Baseflow samples were collected at all sites and three sites were equipped with autosamplers to collect stormflow. Additional details and reports can be found on the project's website at http://www.stroudcenter.org/research/nyproject/index.htm.

Objective and Justification:

The goals of this monitoring program were to:

1. measure specific environmental variables that statistically relate aquatic ecosystem structure and function to land use, BMP implementation, and other watershed inputs or factors;
2. measure chemical, physical, and biological factors that can be used to evaluate or otherwise indicate the occurrence and/or source of selected chemical and biological aquatic contaminants and;
3. provide a baseline dataset of population, community, and ecosystem-level variables along with chemical, physical, and biological indicators for: (i) assessing the current status of water quality and aquatic ecosystem structure and function in response to ongoing and historical land use, BMP implementation, and other factors; and (ii) assessing future change of ecosystem function and water quality in response to changes in watershed activities and condition.

Management Implications:

In 2006 DEP scientists reviewed the latest project report (*Water Quality Monitoring in the Source Water Areas for New York City: An Integrative Watershed Approach. A Report on Year 5 (2004) Monitoring Activities*) produced by the Stroud Water Research Center in October 2005. This report presented data collected during 2004, but not much synthesis or analysis, and therefore few conclusions could be drawn. One of the primary goals of this project was to "measure specific environmental variables that statistically relate aquatic ecosystem structure and function to watershed factors. Unfortunately, some critical portions of the landscape, such as wetlands, were not studied. Wetlands were considered only as a land use variable in regression models without any investigation into the effects of the wetlands' function to ameliorate land use impacts (e.g., stormflow retention, nutrient transformation, streamflow maintenance, sediment retention) on the functioning of the downstream aquatic ecosystems. Wetlands are an important interface between the terrestrial and aquatic environments and this study is incomplete without their inclusion.

There does not appear to be much information reported that is new to DEP or that existing DEP monitoring programs are not monitoring. The general trend of greater impairment in the more urban and agriculturally influenced basins is to be expected and existing programs (land acquisition, conservation easements, tighter project reviews, Phosphorous Restricted Basin provisions, etc.) and the Watershed Rules and Regulations serve to help prevent these impacts from

becoming worse. Remedial programs, such as the WWTP and septic upgrades, will reverse some of the current degradation. Given the small sample size and sampling frequency in this study, it is clear that this data should be interpreted in the context of DEP's database. The one thing this report does illustrate clearly is the importance of comprehensive monitoring and research programs beyond the the aqueduct keypoint data. Monitoring must be conducted at the reservoirs and throughout the watershed in order to provide data for watershed management. DEP will review the final project report and incorporate useful findings or recommendations into our programs.

In 2006 the following articles covering the first three years of the project were published in the December 2006 issue of the Journal of the North American Benthological Society (http://www.stroudcenter.org/nyproj_pics/PDFs/SWRC2006_JNABS_NYProjectAllPapers.pdf):

Blaine, J. G., B. W. Sweeney, and D. B. Arscott. 2006. Enhanced source-water monitoring for New York City: historical framework, political context, and program design. Journal of the North American Benthological Society 25:851-866.

Arscott, D. B., C. L. Dow, and B. W. Sweeney. 2006. Landscape template of New York City's drinking-water-supply watersheds. Journal of the North American Benthological Society 25:867-886.

Dow, C. L., D. B. Arscott, and J. D. Newbold. 2006. Relating major ions and nutrients to watershed conditions across a mixed-use, water-supply watershed. Journal of the North American Benthological Society 25:887-911.

Kaplan, L. A., J. D. Newbold, D. J. Van Horn, C. L. Dow, A. K. Aufdenkampe, and J. K. Jackson. 2006. Organic matter transport in New York City drinking-water-supply watersheds. Journal of the North American Benthological Society 25:912-927.

Aufdenkampe, A. K., D. B. Arscott, C. L. Dow, and L. J. Standley. 2006. Molecular tracers of soot and sewage contamination in streams supplying New York City drinking water. Journal of the North American Benthological Society 25:928-953.

Kratzer, E. B., J. K. Jackson, D. B. Arscott, A. K. Aufdenkampe, C. L. Dow, L. A. Kaplan, J. D. Newbold, and B. W. Sweeney. 2006. Macroinvertebrate distribution in relation to land use and water chemistry in New York City drinking-water-supply watersheds. Journal of the North American Benthological Society 25:954-976.

Arscott, D. B., J. K. Jackson, and E. B. Kratzer. 2006. Role of rarity and taxonomic resolution in a regional and spatial analysis of stream macroinvertebrates. Journal of the North American Benthological Society 25:977-997.

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4.3 USGS Forest Health and Soil Nutrient Status

Manager: Peter Murdoch for USGS, James Porter for DEP

Start & Completion Date: April 2006 to March 2007

Status (% complete): This project is the continuation of over 10 years of research on the impacts of acidic deposition on surface water quality in the NYC water supply watersheds.

Project Cost: $534K for 2006. Project funded annually.

Objective and Justification:

The overall goal of this study is to learn to use forest harvesting to increase the retention of nutrients (mainly nitrogen and calcium) and decrease acidification and release of aluminum into surface waters in forested regions impacted by acidic deposition. As 75-80% of the West-of-Hudson water supply region is forested, this could be an extremely important tool. Specific objectives are: 1) Determine an approximate threshold of forest harvesting intensity above which nutrient release to surface waters is increased (degrading water quality), and below which nutrient release is reduced (improving water quality); 2) Determine how the availability of calcium and nitrogen affects the growth and health of, and nutrient release from, declining sugar maple stands; 3) Use forest growth models in conjunction with the results of Objectives 1 and 2 to predict the long-term (50-100 year) consequences of the interactions of nitrogen deposition, Ca depletion, and forest harvest, with obvious implications for long-term forest health and water quality; and 4) Develop a regional map of forest condition and sensitivity to logging with regard to surface water quality impacts. A secondary objective, developed during the course of this project, is the evaluation of a BMP designed to prevent leaching of dissolved nutrients following cutting. The slash left after logging has been chipped and applied to several small study plots. The hypothesis is that the high C:N ratio of the chips will drastically slow nitrification and reduce nutrient leaching from the plots.

Implications for Watershed Management:

This research will help managers develop scientifically-based land management plans aimed at maintaining and improving water quality. Such a tool has great significance for DEP. As part of the Watershed Agreement, DEP is spending at least $250 million on land acquisition within the watershed. Given that 75-80% of the West-of-Hudson water supply region is forested, much of the land being purchased is forested. DEP is developing management plans for all acquired lands. DEP also influences management of private forest land through the Watershed

Forestry Program, under which planners develop management plans for private landowners. To date, over 250 management plans have been developed, covering over 40,000 acres. There is also the potential to influence management of state-owned lands within the watershed.

Problems Encountered:

At this point funds will not be available beyond September 2007. Thus, data collection and analysis will end before the effects of the various treatments can be fully assessed based on the original work plan.

4.4 Operation and Maintenance for the Hydrological Monitoring Network Related to Streamflow

Manager: Gerard Butch for USGS, James Mayfield for DEP

Start & Completion Date: October 2006 to September 2009

Status (% complete): This project is the continuation of a series of agreements to develop, implement, operate, and maintain a network of gages to measure streamflow at 63 sites throughout the NYC watershed.

Project Cost: $2.54M.

Objective and Justification:

The operation and maintenance of the NYCDEP Division of Drinking Water Quality Control monitoring network is comprised of three major tasks. These tasks can be generally summarized as the (1) collection and interpretation of streamflow data, (2) the real-time or near-real time transmission of preliminary streamflow data, and (3) the electronic or written publication of the streamflow data. These tasks are applied in part or in whole at 63 stream sites within the Croton, Catskill, and Delaware Reservoir Systems.

Implications for Watershed Management:

The streamflow data retrieved from these gages are invaluable to the efforts of NYCDEP for a variety of projects, including making operational decisions on the management of the system and providing input and calibration/verification data for water quality models, and are necessary for the proper design of best management plans to control pollution in the watershed.

Problems Encountered: None.

4.5 Water Quality Operation and Maintenance and Assessment for the Hydrological Monitoring Network

Manager: Stephen Wolcott for USGS, James Mayfield for DEP

Start & Completion Date: October 2006 to September 2010

Status (% complete): This project is the continuation of a series of agreements to develop, implement, operate, maintain, and assess the results from a network of gages to measure water quality at 13 sites in the WOH System.

Project Cost: $1.37M.

Objective and Justification:

The purpose of this project is to evaluate the effects of land use and land cover on stream water quality and provide data to accurately assess potential sources of contamination in the Catskill and Delaware Reservoir Systems. There are 4 main tasks associated with the program: (1) collection of stream water-quality samples, (2) the analysis of stream water-quality samples, (3) the electronic dissemination of the stream water quality data, and (4) the evaluation of the effects of land use and land cover on stream water quality, identification of potential sources of contamination, and quantification of trends in water quality in the Catskill and Delaware Reservoir Systems. Although data collection, laboratory analysis, and data dissemination to NYCDEP are essential components of the project, the focus of the Water Quality Assessment Program is on interpretation and publication of project results that can be used for the Filtration Avoidance Determination.

Implications for Watershed Management:

The data collected in this program will provide necessary information on various land use impacts on water quality to support the development of Multi-Tiered Water Quality Models and may also provide useful information to DEP to support and assess protection and remediation programs, such as Land Acquisition, Watershed Agricultural Program, Watershed Forestry Program, Stream Management Program, Wetlands Protection Program, and Catskill Turbidity Control.

Problems Encountered: None.

In addition to the programs discussed above, the USGS conducts a number of projects with various cooperators in the NYC watershed that can provide useful information to DEP as well. The following items are brief descriptions of these projects from the U.S. Geological Survey in New York's website (http://ny.cf.er.usgs.gov/nyprojectsearch/search_nyprojects_results.cfm?SearchIn=Projects&SearchFor=All%20Projects).

4.6 Mercury Concentration in Water, Sediment, and Fish in the Neversink Watershed, New York

Cooperators - New York State Energy Research and Development Authority

The distribution of mercury (Hg) and sites of greatest Hg methylation are poorly understood in Catskill Mountain watersheds. Although concentrations of Hg in the water column are low, high concentrations of Hg in smallmouth bass and walleye have led to consumption advisories in most large New York City reservoirs in the Catskill Mountains. Mercury in natural waters can exist in many forms, including gaseous elemental mercury (Hg0), dissolved and particulate inorganic forms (Hg(II)), and dissolved and particulate methylmercury (MeHg). Most Hg in living organisms is MeHg, a highly neurotoxic form that bioaccumulates in aquatic food webs. The production of MeHg by methylation of inorganic Hg in the environment is a key process affecting the quantity of MeHg accumulated in fish. Small quantities of MeHg in the diet can adversely affect wildlife and humans, which are exposed to MeHg almost entirely through the consumption of fish.

This study was completed in 2002, but atmospheric mercury deposition monitoring at the Frost Valley YMCA Biscuit Brook National Atmospheric deposition station has continued and is planned for the foreseeable future. This has been the site of chemical deposition monitoring since 1983 and therefore is an excellent site to locate a Hg deposition collector because the long period of rainfall and atmospheric chemistry record will aid in the interpretation of Hg deposition data.

The Neversink watershed is a high relief, forested ecosystem that supplies part of New York City's drinking water supply. This watershed is in the general vicinity of some of the highest suspected atmospheric Hg deposition zones in the coterminous US, and as such the Hg problem here is likely not limited to the current supply of Hg in the watershed. Three water and sediment sampling surveys were conducted within the Neversink Reservoir watershed. The surveys were conducted (1) during dry, low water conditions, (2) during the period of increasing soil moisture in the fall, and (3) one month after fall rainstorms. Twenty sites were sampled. The data from this project is being compared to data from Hg research being conducted in the Adirondack Mountains of New York to identify differences in the way Hg is cycled in these different environments. As such, the data collected during this study will contribute to a regional understanding of mercury cycling.

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4.7 An Assessment of Forest Health and Soil Nutrient Status to Determine the Effects of Logging Practices on Water Quality in New York City's West-of-Hudson Watersheds

Cooperators - New York State Department of Environmental Conservation

The growth of temperate forests is typically limited by the availability of nitrogen. Elevated concentrations of nitrate in some Catskill Mountain streams, which are tributary to New York City's water-supply reservoirs west of the Hudson River, indicate that the forests of this region are at the early stages of nitrogen saturation. That is, nitrogen is available in excess of the amount utilized by vegetation and soil microorganisms in the forests. Nitrogen saturation is a concern because the mobile nitrate that moves through soil is accompanied by other nutrients such as the base cations calcium and magnesium that are necessary for forest growth but are present in short supply in some Catskill soils. And, nutrient cycling and forest health are directly related to water quality. For example, increased nitrogen concentrations in streams may, in combination with phosphorus, increase eutrophication to a greater extent than phosphorus alone in reservoirs.

Forest harvesting may provide a management tool for improving the retention of nitrogen and associated nutrients because a young forest grows faster and has a higher nitrogen demand than the 75-100 year-old forests typical of the Catskills. A preliminary assessment of Neversink soils indicates that calcium and magnesium availability is similar to that measured in dying sugar maple stands in Pennsylvania. If depletion of these base cations is limiting growth in the Catskill region, harvesting may not increase growth rates to a level sufficient to increase the retention of nitrogen. Furthermore, harvesting may worsen base cation depletion by removing the large supply stored in trees. Understanding the balance between nitrogen and base cation availability is therefore essential to the effective implementation of harvesting strategies.

The soil nutrient concerns mentioned above indicate that developing best management practices for forested watersheds should include harvesting practices that are designed with regard to soil nutrient status. To develop such practices, the nutrient cycling processes that control water quality in forested watersheds must be understood through scientific studies.

To develop such practices, the nutrient cycling processes that control water quality in forested watersheds must be understood through scientific studies. This study will involve the following work elements:

- Continued monitoring of nutrient release from watersheds logged during a previous USGS study.
- Monitoring of nutrient release from six treatment areas (duplicates of three treatments) that will be logged to remove about 30%, 50%, and 70% of forest biomass.

- Experiments in which nitrogen and calcium will be added to plots to determine how the availability of these nutrients affects growth, health, and nutrient release from declining sugar maple stands.
- A forest nutrient model will be developed, and will be used to predict the long-term (50-100 yr) consequences on forest growth of the interactions of nitrogen deposition and forest harvest.
- A survey will be conducted of the condition and chemistry of forests, soils, and water throughout the NYC water-supply watersheds in the West-of-Hudson region. A map will then be developed of the sensitivity of northern hardwood forests in Catskill watersheds to harvesting intensity with regard to the potential for soil-nutrient depletion and water-quality degradation.
- The research sites will be part of an environmental education program that will be coordinated by an educator who will be in frequent contact with the research scientists participating in the study.

Study participants include the U.S. Geological Survey, the U.S. Forest Service, State University of New York College of Environmental Science and Forestry, the Institute of Ecosystem Studies, and the Frost Valley YMCA.

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4.8 Potential Endocrine Disruption in Stream Waters and Fish of the New York City Watersheds

Cooperators - New York State Department of Environmental Conservation

Problem:

Almost 1900 public, private, and commercial wastewater treatment plants (WWTPs), many located upstream of drinking water intakes or within tributaries to water-supply reservoirs, are permitted to release effluents into surface- or ground-waters across New York State. More than 150 WWTPs are located within the New York City East of Hudson and West of Hudson Water Supply Watersheds (NYC Watersheds), which provide drinking water to nine million people in and around New York City. Some common WWTP contaminants (e.g., polycyclic musks, alkylphenols, and estradiol) can cause estrogenic or androgenic changes in the reproductive systems of exposed fish and wildlife. These and other compounds are generally referred to as endocrine-disrupting contaminants or endocrine disruptors. Recent investigations from across the country and within the NYC Watersheds indicate that many endocrine disruptors may pass through WWTPs in their original form or only partly altered, diluted, or strengthened. Changes in reproduction (endocrine) and histology (gonad) biomarkers of resident fish in streams receiving WWTP effluents have been documented in receiving waters worldwide and indicate that endocrine disruptors are a ubiquitous problem. More importantly, changes in fish may forecast possible effects within humans because their endocrine systems integrate infrequent and/or long-term exposures to low-level steroid hormones in stream waters. The extent to which NYC Watershed streams may be affected by natural and synthetic hormones and the threat that these hormones pose to fish populations or human consumers remain largely unknown, however, because comprehensive estrogenicity surveys have not been done across the region.

Objectives:

The United States Geological Survey (USGS) and the New York State Department of Environmental Conservation (NYS DEC) in collaboration with the New York City Department of Environmental Protection (NYC DEP) and the New York Department of Health (NY DOH) have proposed herein a preliminary study to (a) appraise the spatial extent to which fish in streams of New York State, and specifically in the NYC Watersheds, are potentially affected by natural and synthetic hormones from WWTPs, and (b) develop a study plan to document potential endocrine-disruption issues in stream waters and fish of the NYC Watersheds.

Approach:

This preliminary study is the first phase of a five-part investigation. Phase 1 will characterize the spatial extent of potential estrogenicity issues across New York State and develop/propose a strategy (work plan) to document potential endocrine-disruption issues in surface waters of the NYC Watersheds. These materials will be made available to the NYS DEC and the public through a project-summary web page and as a USGS web-only published report. Study phases 2, 3, 4, and 5 propose to: (2) conduct a screening survey of estrogenicity within some fraction of

WWTPs (effluents and/or receiving streams) in the NYC Watersheds using a combination of in vitro estrogenicity assays and water-chemistry analyses, (3) conduct a seasonal (spring, summer, and fall) survey of reproductive biomarkers from one or more game-fish species (e.g., brown trout) at two NYC Watershed streams, (4) conduct a one-time (spring, summer, or fall) survey of reproductive biomarkers from one or more game-fish species at 15 to 20 representative streams in the NYC Watersheds, and (5) inventory fish populations that are possibly affected by endocrine disruption at the same 15 to 20 streams to evaluate possible population and community level effects. Progress on phases 2 through 5 will proceed only if additional funding is secured. Additional statewide estrogenicity screening, fish-biomarker, and fish-population surveys may be considered at a later date depending upon the levels of estrogenicity found in waters and fish of the NYC Watersheds.

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4.9 An Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Precipitation in the Catskill and Adirondack Regions, New York

Cooperators - New York State Energy Research and Development Authority

Problem:

Acidic precipitation has affected forested and aquatic ecosystems in New York, particularly in the Adirondack and Catskill regions. Acidification of surface waters and deleterious effects on fish and other biota have been well documented in both these regions. Despite reduced levels of acidity in atmospheric deposition over the past 20 years across New York and the northeastern United States, the most acid-sensitive streams and lakes have not yet begun to recover, and many show continued declines in acid-neutralizing capacity, an indicator acid-base status.

Many studies have documented the effects of acid precipitation in New York, but thus far, there has been no comprehensive effort to synthesize and compare data and results from the Adirondack and Catskill regions. This shortcoming will be addressed by bringing together researchers from five research institutes who have collected data on the effects of acidic precipitation in the Adirondacks and Catskills during the past two decades.

Objectives:

The principal goal of this study is to synthesize data on the chemistry of streams, lakes, soil, and atmospheric deposition in the Adirondacks and Catskills, and to analyze these data to detect patterns and trends in recovery from reduced levels of acid deposition. Time trends in key chemical indicators of acid-base status will be identified using Seasonal Kendall Tau analysis of at least 5 monitored lake-outlet sites in the Adirondacks and 5 intensively monitored stream sites in the Catskills. Changes in the retention of atmospheric nitrogen deposition over time will be analyzed for these sites as well. Predictions of likely changes in acid-base status of these waters will be made using a biogeochemical model using various future projections of atmospheric nitrogen and sulfur deposition. All data used in the study will be compiled and stored in linked databases that will be made available to the public through a web site. Results will be published in peer-reviewed journals and communicated to the New York State Energy Research and Development Authority and invited guests at two annual meetings. The results of this study will be of interest to air pollution policy makers at the state and national level.

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4.10 Development and Implementation of a Baseflow (ground water) Monitoring Network for the Pepacton Watershed

Cooperators - New York State Department of Environmental Conservation

The Pepacton watershed is an integral part of New York City's public-water supply system. Most of the watershed is within Delaware County with headwaters of some of its eastern tributary streams originating in Greene and Ulster Counties. Land use varies from dairy farms in the northern portion of the watershed to extensive forested areas in the south, with small rural communities interspersed throughout the watershed. Sound management of the water resources in the region necessitates development of hydrologic data networks that will document current water-quality conditions in relation to watershed characteristics such as land use. Groundwater discharge to streams accounts for most of the water reaching the New York City reservoirs during periods of little or no rainfall (baseflow conditions), and a large proportion (60-70 percent) of total annual streamflow. Baseflow samples from carefully selected drainage areas provide a com-

posite or integrated groundwater discharge sample that is a reflection of the most active part of the shallow groundwater flow system. The study addresses groundwater quality (major ions, nutrients, selected pesticides and their metabolites) through development of a monitoring network of baseflow sites that characterize spatial (land use, physical basin characteristics) and temporal water-quality variations within the Pepacton watershed.

Objectives:

- Development of a groundwater (baseflow) monitoring network that will provide water-quality data that are representative of upland and valley shallow groundwater flow systems and the spatial variations in the type or intensity of land use in each sampled basin.
- Identification of temporal water-quality variations in baseflow.
- Interpretation of initial water-quality data on the basis of hydrogeologic setting, land-use type, distribution, and intensity.

Related Publications:

Heisig, P.M. and Phillips, P.J., 2004, Stream base-flow chemistry responses to hydrogeology and nonpoint sources, Pepacton Reservoir watershed, New York [abs.], in Compendium of Abstracts, 2d Annual New York City Watershed Science and Technical Conference, Sept. 21-22, 2004, Fishkill, New York, p.16.

Phillips, P.J. and Heisig, P.M., 2004, Hydrogeology and water quality of the Pepacton Reservoir Watershed in Southeastern New York. Part 1. Concentrations of pesticides and their degradates in stream baseflow, 2000-2001: U.S. Geological Survey Water-Resources Investigations Report 03-4137, 13 p.

Reynolds, R.J., 2004, Hydrogeology and water quality of the Pepacton Reservoir Watershed in Southeastern New York. Part 2. Hydrogeology, stream base flow, and ground-water recharge: U.S. Geological Survey Scientific Investigations Report 2004-5134, 31 p.

Heisig, P.M., 2004, Hydrogeology and water quality of the Pepacton Reservoir Watershed in Southeastern New York. Part 4. Quantity and quality of ground-water and tributary contributions to stream base flow in selected main-valley reaches: U.S. Geological Survey Scientific Investigations Report 2004-5018, 21 p.

Heisig, P.M. and Phillips, P.J., 2004, Hydrogeology and water quality of the Pepacton Reservoir Watershed in Southeastern New York. Part 3. Responses of stream base-flow chemistry to hydrogeologic factors and nonpoint-sources of contamination: U.S. Geological Survey Scientific Investigations Report 2004-5008, 31 p.

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4.11 Pesticide Monitoring at Keypoints in the New York City Reservoir System

Cooperators - New York State Department of Environmental Conservation

Problem:

Samples were collected from 10 keypoint sites in the New York City Reservoir system between 1999-2000 as part of the cooperative USGS-New York State Department of Environmental Conservation (NYSDEC) statewide pesticide monitoring project (Phillips and others, 2000). Ten pesticides were detected in the keypoint samples collected between January 1999 and September 2000--the herbicides atrazine, metolachlor, simazine and prometon, the herbicide degradates deethylatrazine, hydroxyatrazine, alachlor ethanesulfonic acid (ESA), metolachlor ESA, and metolachlor oxanilic acid (OA), and the insecticide diazinon. Concentrations for most of these detections were generally low (between 0.001 and 0.05 µg/L), with the exception of concentrations of alachlor and metolachlor degradates, which frequently exceeded 0.1 µg/L.

Objectives and Approach:

The objective of this project is to continue ongoing monitoring to establish a long-term trends network for pesticides at keypoints within the New York City reservoir system. This project will use a large number of analytes, all of which will be analyzed at the trace level (submicrogram per liter) detection limits. Some of the analytes are degradates of commonly used herbicides, which until recently were widely analyzed. Samples will be collected three times during the year at each of 10 keypoint sites within the NYC reservoir system. The 10 sites are:

Delaware System:

- •Cannonsville Reservoir , USGS Station ID 01423900
- •Pepacton Reservoir, USGS Station ID 01415200
- •Neversink Reservoir, USGS Station ID 01435800
- •Rondout Reservoir, USGS Station ID 01366399

Catskill System:

- •Schoharie Reservoir, USGS Station ID 01362230
- •Ashokan Reservoir, USGS Station ID 01363400

Receiving Reservoirs:

- •West Branch Reservoir, USGS Station ID 01374620
- •New Croton Reservoir, USGS Station ID 01374995
- •Kensico-Delaware Aqueduct, USGS Station ID 01301900A
- •Kensico-Catskill Aqueduct, USGS Station ID 01301900B

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4.12 Potential Recovery of Water Chemistry and Stream Biota from Reduced Levels of Acid Deposition at a Sensitive Watershed in the Catskill Mountains, New York

Cooperators - New York State Energy Research and Development Authority

The Catskill Mountains of southeastern New York receive among the highest loads of acid deposition in New York and the northeastern U.S. Additionally, the Catskills are underlain by sandstone and conglomerate, which is base poor and weathers slowly. Thus, the Catskills contain numerous streams with low (< 50 µeq/L) acid-neutralizing capacity (ANC) and are sensitive to impacts from atmospheric acid deposition. Since at least 1983, however, the levels of acidity in atmospheric deposition (primarily sulfuric acid) have been declining in the Catskills and throughout New York. While widespread recovery of streams in the Catskills has not yet been confirmed, recent data suggest that recovery in waters with ANC values in the range of 30 - 70 µeq/L may be starting. This early recovery of stream chemistry may eventually result in the recovery of acid-intolerant biota in affected streams.

The Neversink River in southeastern New York is the most acid-sensitive watershed in the Catskill Mountain region, and among the most acid-sensitive watersheds in the state. Numerous tributaries of this river, and upper reaches of its East and West Branches, have base flow pH values of less than 5.2 and ANC values of less than 0 µeq/L. These acidic conditions and high aluminum concentrations mobilized at low pH have affected fish populations within the Neversink Watershed.

A dataset collected by the New York State Department of Environmental Conservation and U.S. Geological Survey in 1987 indicates that the number of mayfly species in the Neversink River watershed is strongly related to stream pH and ANC values. During the 1987 study, a sharp transition zone was sampled, where the pH of the East Branch Neversink River increased by 0.5 units and mayfly species increased from 1 to 4 within about a 1-km reach. These data suggest that mayfly species diversity may be a good indicator of increases in pH and ANC and of recovery from reduced levels of acid deposition. Data collected by the U.S. Geological Survey since the 1987 study has identified a similar pH transition zone in the West Branch Neversink River. In this study, the sites that were first sampled in 1987 will be resampled to evaluate current stream chemistry and species composition of aquatic macroinvertebrates, fish, and algae. An additional 3-4 stream reaches in the two zones of sharp pH transition will also be sampled.

Objectives:

The principal objective of this study is to determine whether the spatial patterns in species composition of aquatic macroinvertebrates, fish, and periphyton have changed as a function of altered spatial patterns in surface-water chemistry since 1987 in the Neversink River upstream of the Claryville stream flow gage. Emphasis will be an examination of the relations of biota with

pH, ANC, and aluminum concentrations in light of declines in the acidity of precipitation since 1987. These data will also provide a basis for comparison with future changes in the acidity of precipitation and the acid-base status of surface waters in the Neversink basin.

Results:

A paper and report documenting study results were completed in 2006. The paper is in press at the journal, Ecological Indicators, and the report is in press and to be published by NYSERDA. When published, the report will be available for downloading and printing on the USGS New York Water Science Center web site. Figures and tables of data that were developed in this project and are the basis for the paper and report are available at the link http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-ARV-1.pdf.

Further information on this project can be found at the following link:

Environmental Monitoring, Evaluation, and Protection (EMEP) program at the New York State Energy Research and Development Authority (NYSERDA)

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4.13 Define Existing Water Quality in UPDE Streams for Development of Special Protection Waters Standards

Problem:

In 1992, the Delaware River Basin Commission (DRBC) designated 112 miles of the mainstem Delaware River within the Upper and Middle Delaware Scenic and Recreational River segments, including the Delaware Water Gap National Recreation Area (DEWA), as "Outstanding Basin Waters" and enacted "Special Protection Waters Regulations" for these river reaches after defining their existing water quality. These "Special Protection Waters Regulations" (SPWR) are strict "anti-degradation" regulations that prohibit human development from causing any "measurable change" in water quality (DRBC 1996). To date, "existing water quality" for the tributaries and mainstem waters of the Upper Delaware Scenic and Recreational River (UPDE) has not been adequately defined by monitoring data to enable the establishment of "Special Protection Waters Regulations" for the UPDE corridor. Nearly all existing monitoring data has been collected between April and October of each year, while the majority of river export in the northeast occurs during spring snowmelt and fall rainstorms from November through March.

Objectives:

Intensive tributary monitoring performed at the DEWA is not a workable strategy in the UPDE. Similar protective measures are needed in the rapidly developing watersheds on both sides of the river, but the large number of tributaries to account for would be prohibitively expensive to intensively sample. A strategy of load measurements for segments of the Upper Delaware River, coupled with regional surveys of tributary water quality, load estimates on selected high-priority tributaries, and focused surveys on tributaries of the most polluted reaches will be tested as a means to provide an adequate description of UPDE water quality at a manageable expense.

Benefits:

This project will integrate the creation of high water quality standards, GIS-based land use mapping, and research and monitoring performed by leading land use and aquatic scientists. The UPDE results will further our understanding of the effects of forest fragmentation, suburbanization, and agriculture on water quality, test new methods of interpreting remote sensing coverages for land-use classification, and refine our predictions of thresholds of land disturbance above which water quality degradation occurs. Application of the multi-scale CEMRI study design to develop cost-effective monitoring strategies will have significant transfer value to other Park Service lands where water quality standards need to be established. The study will be made available through a report to the NPS, a journal article in the peer-reviewed literature, and presentations at symposia and/or local management meetings.

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4.14 Forest Health and Stream and Soil Chemistry in the Catskill Mountains, NY

Problem:

A major adverse effect of acid rain on forest health and productivity is a reduction in the available supply of calcium (Ca) and other base cations (positively charged ions) in soil that are needed for forest growth. The Catskill Mountain region of NYS has among the highest rates of sulfur and nitrogen deposition in the state and the lowest values for soil calcium availability. Significantly, the forested watersheds of this region provide the New York City water supply.

Objectives:

Building on three years of research on the correlation between depleted soil calcium, forest health, and runoff water quality, the USGS and USFS will further develop existing remote-sensing methods for mapping the condition of forests. These improvements will make it possible to assess regional changes in forest health (e.g., levels of foliar calcium and nitrogen, tree decline) on a much

finer scale across the landscape. The result will be an integrated picture of the sensitivity of the landscape to disturbance as well as a better understanding of the spatial variability in potential forest and surface water responses to decreased or increased levels of acidic deposition.

Benefits:

This project will develop forest health and sensitivity indicators and first-generation maps of potential sensitivity to disturbance for the Catskill Mountain region. The methodologies and data layers created will help reveal the extent and magnitude of terrestrial and aquatic responses to acidic deposition. The information will provide resource managers with useful information and tools that will benefit the development of sound management strategies, in particular those addressing critical loads of acidic deposition in the watersheds of the New York City water supply. In addition, the project will allow future assessments of forest conditions and more detailed forest sensitivity maps to be made at reduced cost.

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4.15 Surface-Water Data Collection in New York

Cooperators - Various Federal, State, and local agencies

Problem:

Surface-water information is needed for planning, design, hazard warning, and operation and management in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood plain management, and water-resources development. Appropriate historical and real-time surface-water data, such as stream flow and stage, reservoir levels, and water temperature, are necessary to properly assess, manage and protect water resources.

Objectives:

Collect timely and high quality surface-water data for (1) assessment of water resources; (2) operation of reservoirs or industries; (3) forecasting flow; (4) disposal of wastes and pollution controls; (5) discharge data to accompany water-quality measurement; (6) compact and legal requirements; and (7) research or special studies. Collect data necessary for analytical studies to define the statistical properties of, and trends in, the occurrence of water in streams, lakes, and estuaries for use in planning and design.

Benefits:

An important part of the USGS mission is to continually assess the surface-water resources of the nation. To do this effectively, the USGS operates more than 7,000 stream, lake, and reservoir gages nationally, makes periodic flow measurements on rivers and streams using standardized methods, maintains the data from these gages in a national data base, makes these data available on the worldwide web (WWW) at http://ny.usgs.gov, and publishes the data for each state annually. Continuous records of discharge are defined using stage-discharge relations in conjunction with recorded stage records. Flow data from about 82 percent of the gage sites are delivered on a real-time basis to customers and the public on the WWW, which is critical to the most effective management of the nation's vital resources. These data are needed to develop information about flow characteristics that can be used for overall planning and managing of water-resources projects and regulatory programs, such as flood warning and assessment, reservoir operations, setting and monitoring water-quality standards, designing bridges and culverts, evaluating the effects of changing land use, detecting long-term changes in climate, and administering compacts, decrees, and/or treaties on interstate and international bodies of water. The stream, lake, and reservoir gages operated in this state are an integral part of the national surface-water network.

Approach:

Standard methods of data collection will be used as described in the series "Techniques of Water-Resources Investigations of the U.S. Geological Survey". Partial-record gaging is used instead of continuous-record gaging where it serves the required purpose.

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4.16 Geomorphology, Biology, & Stability of Catskill Mountain Streams, New York

Cooperators - New York City Department of Environmental Protection

Problem:

The New York City Department of Environmental Protection (NYCDEP) Stream Management Program, in cooperation with local Soil and Water Conservation Districts, is implementing stream-restoration demonstration projects to decrease channel bed and bank erosion and improve water quality (lower suspended sediment and turbidity) in several priority streams of the Catskill Mountain Region. A variety of issues relating to (a) the hydraulic geometry of stable and unstable stream channels, (b) validation of underlying assumptions used to characterize channel stability

and design, and (c) the effects of restoration on stream-channel geomorphology, stability, biota, and sediment transport have not been addressed previously in the region. Restoration of streams in the region provides an opportunity for the USGS, the NYCDEP, and other collaborating agencies to conduct research, test assumptions, and monitor and assess the responses of interrelated elements to changes in stream-channel stability that should result from channel restorations.

Objectives:

Primary objectives of this project are to document the effects that stream-channel restoration efforts have on stream channel geomorphology, stream habitat, and fish assemblages. The project consists of four general tasks that intend to: (1) augment work being done by the NYCDEP to develop models of the relations between drainage area and hydraulic-geometry parameters at bankfull flows in the region, (2) develop a database of hydraulic, geomorphic, and biologic characteristics for reference-stream reaches in the region, which is needed to identify, classify, and assess geomorphic stability of similar reaches, (3) develop and refine methods to model the relations among stream discharge, stream type, channel geometry, bed-sediment size distribution, and bed-sediment transport in stable reference reaches, and (4) determine whether channel and bank stability, habitat, and fish and macroinvertebrate communities are significantly affected by restoration of streams in the Catskill Mountain Region. Hydrologic and geomorphic data will be provided to the cooperators and the public through conventional USGS annual reports. The response of stream habitat and fish populations and communities to stream restoration will be evaluated and published as three or more peer-reviewed journal articles and also presented at local, regional, and national meetings. Additional information on habitat and fish assemblages in reference reaches of the region will be published as a USGS peer-reviewed Science Investigative Report (SIR).

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4.17 Regionalization of Channel Geomorphology Characteristics for Streams of New York State, Excluding Long Island

Cooperators -New York State Department of Environmental Conservation
New York State Department of Transportation
New York State Department of State
New York City Department of Environmental Protection

Problem:

Geomorphologic techniques for stream channel and bank restoration are fast becoming the techniques of choice among federal, state, county, and local agencies to reduce suspended sediment loads, reduce flood damage, improve aquatic habitat, and generally stabilize stream channels. One reason for this upswing in use is that appropriate application of these techniques has been shown to reduce the need for repetitive visits to a reach to remove sediments or repair stream banks, and thus reduce long-term channel maintenance expenses. Geomorphologic restoration projects require data that define what a stable stream channel should look like in a given region. Regional hydrologic curves and regional channel-geomorphologic characteristics are critical data needed to design geomorphologic restoration projects. These regional data have not been compiled or analyzed for New York. This project will begin to address this information gap.

Objectives:

The primary objective of this project is to develop regional hydrologic curves and regional channel-geomorphologic characteristics at bankfull discharge by hydro-physiographic region and by Rosgen stream type for streams of New York State. These data will be used to confirm bankfull hydraulic-geometry characteristics at ungaged reference streams and verify designs for stream-channel restoration projects. The project is a collaboration between the United States Geological Survey (USGS), New York State Department of Environmental Conservation (NYSDEC), New York State Department of Transportation (NYSDOT), New York State Department of State (NYSDOS), New York City Department of Environmental Protection (NYCDEP), local Soil and Water Conservation Districts, and other interested agencies. An advisory committee reviews work and helps determine strategies to best implement collaborative efforts.

Products for this study will include protocols for collection and interpretation of data, summaries of channel-geometry and hydrologic data for selected sites, and regional channel-geomorphologic characteristics for each hydro-physiographic region.

Related Links

Natural Resources Conservation Service (NRCS)
Federal Interagency handbook on Stream Corridor Restoration
North Carolina State University Stream Restoration Institute
Greene County Soil and Water Conservation District (GCSWCD)
New York City Department of Environmental Protection (NYCDEP) Stream Management

Related Publications:

Miller, S.J., and Davis, D., 2003, Optimizing Catskill Mountain Regional Bankfull Discharge and Hydraulic Geometry Relationships: in Proceedings of AWRA 2003 International Congress, June 29-July 2, 2003, New York City, 10 p.

Powell, R.O., Miller, S.J., Westergard, B.E., Mulvihill, C.I., Baldigo, B.P., Gallagher, A.S., and Starr, R.R., 2004, Guidelines for Surveying Bankfull Channel Geometry and Developing Regional Hydraulic-Geometry Relations for Streams of New York State: U.S. Geological Survey Open-File Report 03-092, 20 p., online only

Westergard, B.E., Mulvihill, C.I., Ernst, A.G., and Baldigo, B.P., 2005, Regionalized Equations for Bankfull-Discharge and Channel Characteristics of Streams in New York State: Hydrologic Region 5 in Central New York: U.S. Geological Survey Scientific Investigations Report 2004-5247, 16 p., online only.

Mulvihill, C.I., Ernst, A.G., and Baldigo, B.P., 2005, Regionalized Equations for Bankfull-Discharge and Channel Characteristics of Streams in New York State: Hydrologic Region 6 in the Southern Tier of New York: U.S. Geological Survey Scientific Investigations Report 2005-5100, 14 p., online only.

Mulvihill, C.I., Ernst, A.G., and Baldigo, B.P., 2006, Regionalized Equations for Bankfull-Discharge and Channel Characteristics of Streams in New York State: Hydrologic Region 7 in Western New York: U.S. Geological Survey Scientific Investigations Report 2006-5075, 14 p., online only.

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4.18 Flood Investigations in New York

Cooperators - New York State Department of Transportation

Problem:

Flooding can be a serious problem in many parts of New York State. Information on floods and analyses of flood data are needed to aid in the design of bridges, culverts, dams, highways, and buildings, and for the prudent management of flood-prone areas. Documentation of floods and a more thorough understanding of flood hydrology and hydraulics will result in more effective management of flood plains and design of structures.

Objectives:

(1) To provide information on the magnitude and frequency of floods to agencies and individuals involved in flood-protection, planning, and design. (2) To develop regional flood-frequency relations for streams in New York to allow flood-frequency determinations at locations without stream gages. (3) To make local site studies using hydrologic and hydraulic analyses.

Approach:

(1) Collect flood data at crest-stage gage stations and publish annual peak discharges. (2) Document notable floods through flood-discharge calculations at miscellaneous measurement sites, by determination of flood profiles, and from flood data collected at long-term continuous record gaging stations. Prepare reports detailing individual floods. (3) Periodically update flood-frequencies at individual stream gaging stations. Use these values in conjunction with GIS-based basin characteristics for each gage to develop regional flood-frequency relations for rural, unregulated streams in New York. These relations can be used to estimate the magnitude and frequency of floods at any ungaged stream location in the State. (4) Study other factors affected by or which affect floods such as bridge scour, channel roughness coefficients, rainfall-runoff analyses, ice jams at bridges, and several other hydrologic and hydraulic processes.

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4.19 Regional Long-Term Monitoring (RLTM) of Stream Discharge and Water Quality in the Catskill Mountains of New York

Cooperators - United States Environmental Protection Agency

Recent trend analyses have shown that it is important to identify changes in the environment caused by human activity so management strategies can be developed to address those changes. The TIME (Temporally-integrated monitoring of the environment) project is a US Environmental Protection Agency (USEPA) program designed to monitor regional trends in surface water quality by nesting a few intensively-monitored stations within a network of more numerous but less frequently sampled stations. The intensively monitored stations (the Regional Long-Term Monitoring Stations or RLTM), have been providing monthly discharge and water-quality data since 1983.

Continuous discharge and storm-event water-quality sampling were added to these stations in the late 1980s. One of the major objectives of the Clean Air Act Amendments (CAAA) was to establish a network of stations for long-term monitoring of surface-water quality and to determine its relation to changes in atmospheric deposition. The Catskill RLTM program has been integrated with a local monitoring network sponsored by the New York City Department of Environmental Protection (NYCDEP), and with ongoing watershed research programs in the Catskills. To help manage the quality of water entering the New York City reservoirs, the NYCDEP has enhanced their network of stream monitoring stations. From a network of 55

stream-discharge monitoring stations representing a range of land uses, 13 stations have been equipped to monitor water temperature, air temperature, and stream water specific conductance, and automated samplers have been installed to collect stream water during storms.

Three of the RLTM stations have been incorporated into the NYCDEP network to offset operating expenses for the RLTM program and to provide additional stream water quality data at those sites. This combined network greatly enhances the capability of the TIME program to detect and interpret trends in stream water quality, interpret regional survey data, and integrate the data into the environmental monitoring framework for the Mid-Atlantic region. The design of the new RLTM network allows analysis of temporal trends in surface water quality during base-flow and peak-flow conditions.

Water-quality sampling includes periodic manual sample collection and discharge measurements, electronic measurement of stream stage, air temperature, water temperature, and specific conductance every fifteen minutes, and stream-water sampling using automated samplers during changes in streamflow related to storms and snowmelt. Including discharge and storm water-quality sampling to the RLTM program during the 1990s has made it possible to identify trends in concentration-discharge relations and to describe concentration-discharge relations at each site. The processes that affect stream-water chemical responses to reductions of atmospheric emissions are beginning to be better understood because the RLTM network and the integration of the RLTM with the NYCDEP stream monitoring network, the deposition-monitoring network, and the USGS watershed research programs have enhanced the interpretive power of the RLTM program in the Catskill Mountain region. Data reports of data collected during the previous year are submitted to the USEPA each year. These data have been the basis of several scientific journal articles about trends in acid deposition in the northeastern United States.

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4.20 Implementation of the USGS Hydrologic Benchmark Network (HBN) Post-Characterization Sampling Program

The Hydrologic Benchmark Network is a group of stream discharge and water-quality monitoring stations first established by USGS in the mid-1960s to track long-term changes in the hydrology and water quality of natural landscapes. The HBN is the only established network in the world of non-developed, medium-size watersheds (50-250 square miles in area) where tracking of long-term trends in water quality has been done. The network slowly diminished over

time, and the program was suspended in 1997 to re-evaluate its mission and protocols. In 2003 the USGS initiated a re-vitalization of the HBN program that will allow assessment of (1) Trends in discharge and baseflow stream chemistry over time, (2) Changes in the slope of the concentration-discharge relationship for specific constituents over time, and (3) Changes in the relation between atmospheric-deposition chemistry and stream chemistry over time.

The new network includes 30 gaging stations of which 15 are sampled for water quality, 7 rivers in the eastern US and 8 rivers in the western US. Many of the HBN stations are equipped with refrigerated automated samplers and remote communication equipment. All stations are equipped with continuous monitors for stream conductance and water temperature. Samplers are programmed to collect baseflow and storm samples.

The HBN is the only national network suitable for tracking the health of ecosystems in mid-size, undisturbed basins in the United States. The HBN basins are of appropriate size for detecting changes in ecosystem processes at the landscape scale caused by acidic deposition, excess nutrient deposition, and climate change. They are larger than typical research watersheds where most process-oriented work has been done (making them more relevant to resource managers), but are small enough to be responsive to regional anthropogenic effects. The HBN provides a background frame of reference for evaluating changes in chemistry and hydrology at larger scales, such as those found in the USGS NAWQA and NASQAN networks, which have been affected by land-use changes and water diversions.

The Hydrologic Benchmark basins provide a unique opportunity for collaboration between federal agencies. The National Park Service needs the type of information provided by HBN to evaluate possible effects of climate change and atmospheric deposition of pollutants on National Park land and will rely on HBN data to serve as a foundation for their Inventory and Monitoring Program. In Yosemite and Glacier National Parks the National Park Service is working with the USGS by providing personnel and physical resources critical for ongoing sample collection activities.

The US Forest Service will use HBN data to help evaluate and track forest health, allowing the agency to better manage National Forests for sustainable development and use. The Forest Service and the environmental community will use HBN data to establish background conditions for the National Forests prior to increased logging that is expected as a result of the Healthy Forests Initiative.

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Appendix - Abstracts Produced by NYC-DEP BWS Staff for 2007 NYC Watershed Science & Technical Conference

(Hotel Thayer, West Point), 10/11 September

Linking Water Supply Protection and Recreation: Management of Boat Fishing on New York City Water Supply Reservoirs and Lakes

Jennifer Cairo

The New York City Water Supply features 19 reservoirs and controlled lakes that are popular fishing destinations for anglers, nearly 11,000 of whom keep rowboats on site in concentrated storage areas for their use. DEP is committed to provide for boat fishing by law and requires on-site storage to prevent water supply contamination from substances and organisms, including zebra mussels. DEP's strategy for boat fishing is to maintain a plan and supporting policies that will minimize negative water supply protection issues related to fishing by boat while providing safe, managed, high-quality public deep water fishing opportunities. This strategy includes 1) boat storage area clean up, 2) outreach and feedback, including user surveys, 3) creation and application of a *Boat Area Rapid Assessment* (BARA) procedure incorporating GIS mapping, inventory, natural resources assessment (e.g., soil compaction, vegetation loss, erosion), aesthetics, and evaluation, 4) improvement of existing boat areas, and 5) creation and implementation of a long-term approach and policies within the context of DEP's water supply land management plans.

Watershed Land Information System

Paul Lenz

A Watershed Land Information System (WaLIS) is being used by the Natural Resource Management group within the Bureau of Water Supply to manage land and conservation easements owned by the City. WaLIS continues to be developed with the help and support of the New York State Department of Environmental Conservation's Division of Water, the US Environmental Protection Agency, and PAR Government Systems Corporation.

WaLIS is a cutting-edge database that incorporates mapping capabilities similar to Geographic Information Systems and empowers "non-technical users" to access data, prepare maps and reports, track conversations, record and view documents and pictures, and communicate among internal staff. The primary goals for the WaLIS application include: the ability to collect, manage, and store vast amounts and types of data that are available to "desk-top" users, improving the consistency and equity of decisions regarding management of City water supply lands, improving the accuracy, consistency, and security of land information assets, improving employee satisfaction with the work environment and ability to effectively schedule tasks, increasing productivity and reducing cycle time for completion of business processes related to land management, eliminating redundant data and processes, and improving the accountability and ability to report the status of land management activities both internally and externally.

At the time of this presentation, WaLIS 4 will be presented which is the latest version and incorporates a new look and many updated features and functionalities. This presentation will take the audience through the many features of WaLIS using real-world scenarios and illustrate how land managers at DEP use this system for the effective management of City land and easements.

A GIS-Based Prioritization of Land Parcels for Watershed Protection
Matt Schwab

The Land Acquisition Program (LAP), a key component of the City's Watershed Protection Plan, has the mission of acquiring environmentally-sensitive watershed land to prevent future degradation of the water supply. Under the MOA and the two FADs issued in 1997 and 2002, the City agreed to solicit the owners of 355,050 acres in the Catskill-Delaware System regarding their respective willingness to sell fee simple or conservation easement interests in their land.

LAP employed a geographic information system (GIS) to prioritize land parcels for solicitation based on a parcel's size, slope characteristics and proximity to surface water features (streams, ponds, floodplains and wetlands). A parcel ranking system was developed to provide an effective screening tool to identify parcels of interest to NYC. The land protection goals embodied in the ranking system will be explored, as well as a discussion of the limitations of this approach and success to date. It is hoped that some of the strategies and techniques developed by NYC DEP can be exported and/or adapted to enhance other watershed protection programs.

Incidence of Enteric Viruses in Surface Water from New York City's Catskill and Delaware Watersheds
Gerald Pratt and Kerri A. Alderisio

Surface water samples from aqueduct monitoring locations representing New York City's Catskill and Delaware Watersheds, as well as effluent samples from 10 waste water treatment plants (WWTP) located within these watersheds, were collected for Human Enteric Viruses (HEV) over a five year period, 2002 through 2006. The weekly surface water samples and quarterly plant samples were collected and analyzed using the Total Culturable Virus Assay (TCVA) according to the USEPA Information Collection Rule (ICR). Aqueduct monitoring occurred at influent and effluent locations of a surface water reservoir in Westchester County, New York. The WWTPs monitored were located in Delaware, Ulster, Sullivan, and Greene Counties and were upgraded just prior to sampling. Surface water samples ranged from 66% to 80% non-detect of HEV at influent locations and 84% to 87% at effluent locations. Average HEV concentrations from influent locations ranged from 0.61 to 1.8 MPN/100L, while average virus concentrations of water samples from effluent locations were 0.28 to 0.48 MPN/100L respectively. WWTP effluent samples had a 99% non-detection rate. Of the 170 samples collected, only 2 tested positive for viruses, each about 1MPN/100L, suggesting that plant upgrades were adequate to mitigate virus

loads to either minimal concentrations, or to eliminate them from final effluent. Results suggest a reduction of virus occurrence during transport through the reservoir, and that any local input of viruses is similarly reduced by the reservoir.

The Effect of Two Different Approved Stains on Pathogen Results for the New York City Water Supply

Kerri Ann Alderisio and Lisa Anne Blancero

Protozoan pathogens, namely *Giardia* cysts and *Cryptosporidium* oocysts have realized a prominent role in the water industry due to their potential to cause human disease by transmission through drinking water. National research studies have taken place (Information Collection Rule –ICR) and are currently underway (Long Term 2 Enhanced Surface Water Treatment Rule – LT2) in order to provide insight as to the occurrence of these organisms throughout the country's water supplies. The NYC DEP has been sampling for these protozoa for over 15 years in its watershed, and guidelines for these organisms have been established between the water supply managers and regulators in order to provide guiding principles in the event a course of action is warranted in the interest of public health. Although many water quality factors are considered in the decision tree, the triggers for initial action are based on numbers of organisms discovered in water samples at specific locations. As a result, the number of cysts or oocysts recovered from a sample can have a direct impact on resources and management decisions. In the interest of improving methodology and efficiency NYC DEP evaluated the use of a second US EPA approved stain for use with Method 1623 (EasyStain, BTF Inc.) and compared results with DEP's routine stain (Merifluor, Meridian Bioscience Inc.). Samples were collected at both stream and key point locations and analyzed in duplicate for over one year. Results indicate a significant difference between the recovery of *Giardia,* and a notable quality difference for *Cryptosporidium*. These results have implications for the evaluation of any national studies, as well as for utilities and regulators alike, when these different stains are used. Additionally, this work emphasizes the need to advance the science of water quality pathogen assessment to include technologies that provide more detailed information, such as genotyping, in order to more accurately predict potential risk to public health.

Whitetail Deer Browsing Effects on Watershed Forests and DEP's Assessments and Management Strategies

Fred Gleising

Watershed forests require structural and species diversity in order to effectively control nutrient releases and respond to major disturbances to minimize impacts to water quality. Browsing by whitetail deer can have a detrimental effect on forest structure and diversity. DEP has initiated several assessment methods to evaluate deer impacts and densities, including the use of forward looking infrared radar (FLIR). Through the data derived from FLIR and other methods, we have implemented forest and deer management strategies and supported regional deer management initiatives to promote watershed forest regeneration. This presentation will focus on the efforts the DEP Natural Resources Management group has taken to address deer impacts on City

watershed lands. This includes the deer impact management strategy (DIMS), forest management project strategies, implementation of deer herd management strategies on selected sites, technical support for regional deer task forces, and cooperative management initiatives programs with the NYSDEC and local sporting organizations.

Challenges of the NYCDEP Wastewater Treatment Plant Upgrade Program
Robert Ravallo

As part of the MOA, the City agreed to fund the eligible costs of designing, permitting and constructing upgrades of all non-City-owned wastewater treatment plants (WWTPs) in the watershed. For the purposes of this program, "Upgrades" means equipment and methods of operation that are required solely by the WR&R, and not by federal or State law. The City further agreed to pay the annual costs of operation and maintenance of the upgraded facilities. The task of coordinating these complex projects with the 106 different owners in the watershed is enormous. Virtually all of the WWTP owners are restaurateurs, hoteliers, camp operators, homeowners' associations, school administrators, managers of recreational facilities and the like – not professional WWTP operators and construction specialists. DEP has proceeded diligently with this vast undertaking and provided step-by-step guidance on a host of legal, engineering, contracting and regulatory issues.

Settling Characteristics of *Giardia* Cysts and *Cryptosporidium* oocysts in Storm Water Flow to a New York City Drinking Water Reservoir
Steve S. Di Lonardo, Kerri A. Alderisio, and Greg Characklis of the Department of Environmental Sciences and Engineering, Chapel Hill, NC 27599

Giardia and *Cryptosporidium* are significant causes of waterborne enteric disease throughout the world. We identified whether *Giardia* cysts and *Cryptosporidium* oocysts attached to suspended particulate matter and further, whether this particle association was based on size class. In the first phase of our study, we synchronously sampled five tributaries of Kensico Reservoir (Westchester County, New York), just prior to the stream-reservoir interface, for *Giardia* cysts and *Cryptosporidium* oocysts during storm events (using auto-samplers), and base flow conditions (grab samples) over one year. The streams were selected based on the flow weight and sub-basin physical characteristics (i.e., flowing from a wetland or man-made retention pond). For the second phase of the study, we selected three of the five streams for resolved storm sampling, which involved sampling dissected phases of a storm, based on the storm's hydrological characteristics (e.g., rising limb, peak, descending limb). The samples were analyzed in the laboratory for *Giardia* cyst and *Cryptosporidium* oocyst abundance as well as particle size and density attachment. Our results suggest differences in pathogen settling and loading between base flow and storm conditions, as well as within the different phases of a storm. Similarly, we analyzed differences in pathogen loading and loading rates as well as differences in suspended particulate matter concentrations between streams, for base flow and storm conditions and within the differ-

ent phases of a storm. This study will ultimately aid in the modeling of transport across the reservoir and into aqueducts supplying water to New York City residents and eventually be useful in attempts to reduce transport of pathogens into drinking water supplies.

Storm Water Loading of *Giardia* spp. and *Cryptosporidium* spp. in Perennial Streams of a New York City Reservoir

Christian Pace, Kerri A. Alderisio, James Alair, and Steve Di Lonardo

The loading of waterborne pathogens and particulate matter increases significantly during the elevated stream flow of storm events. Recognizing its potential implications for water quality, the New York City Department of Environmental Protection constructed several storm water attenuation basins (BMPs) around Kensico Reservoir to help minimize the effects of storm water on reservoir water quality. We previously reported the development of integrated monitoring stations for event-based sampling. In the second phase of this project, we sampled nine perennial tributary streams to Kensico Reservoir (Westchester, New York), to estimate *Cryptosporidium* oocyst and *Giardia* cyst loading of each stream over the course of 10 storms (0.36 – 2.76 in) in 2006. Sampling was performed with automated samplers at 13 stations with continuous flow monitoring. Two composite samples representing the hydrologic phases of a storm (rising and descending limbs), were obtained by sampling 24 aliquots at 30 min intervals from the nine streams. Five streams contained BMPs, two of which were monitored upstream and downstream to examine whether a reduction in pathogen loading was realized. Loading was calculated for each sampling period using the composite sample concentration and sum of the flow over the course of the sampling period. Each stream was ranked according to storm flow, and compared against a ranking for pathogen loading. We found that BMPs delayed pathogen loading into the reservoir; however, loading was not significantly reduced. This study suggests that the efficacy of existing BMPs, initially designed for the reduction of turbidity and fecal coliform bacteria, may not be as effective in reducing pathogens as previously assumed, and this information should ultimately be considered in future BMP designs.

Storm Event Monitoring for Pathogens on the Esopus Creek in 2006

Paul A. LaFiandra

As part of a Water Resources Development Act (WRDA) grant awarded to NYCDEP by the United States Army Corps of Engineers, pathogen monitoring during storm events was performed on the Esopus Creek from April to December 2006. Monitoring was performed at stream sites E5 (representing the mid-upper headwaters of the Esopus Creek) and E16I (representing the mainstem of the Esopus). Pathogen monitoring was also performed at site SRR2CM which represents a major contribution to the Esopus Creek flow between the two stream sites being monitored for pathogens. This water source is the diversion from the Schoharie Reservoir and can represent over 50% of the base stream flow below E5 and above E16I. Flow volume from this Schoharie Diversion can be highly variable thus impacting the flow at the downstream site E16I signifi-

cantly. A total of ten events were monitored with two pathogen (*Giardia* spp. and *Cryptosporidium* spp.) samples collected per event at the stream sites and one per event at the SRR2CM diversion site.

All of the equipment met and exceeded design expectations and a great deal of experience was realized in terms of the equipment programming and storm monitoring logistics.

Mean storm event pathogen concentrations at the headwaters site (E5) were found to be 1.5X the mean baseline *Giardia* concentrations and 2X the mean baseline *Cryptosporidium* concentrations in 2006. Mean storm event pathogen concentrations at the mainstem site (E16I) were found to be 3X the mean baseline *Giardia* concentrations and 4X the mean *Cryptosporidium* concentrations for 2006. Mean pathogen concentrations at the Schoharie Reservoir diversion site (SRR2CM) were much higher than expected given the fact that this water source was not under storm influence at the time of sampling. Mean *Giardia* concentrations here were 2X the mean baseline and mean *Cryptosporidium* concentrations were 25X the baseline for 2006. Storm event concentrations were similarly higher when compared to baseline data for 2003 to 2006 also. Seasonal trends in pathogen concentration and loading were not observed.

Pathogen loading calculations were also performed which indicated that pathogen loadings were the highest at the mainstem monitoring site. This type of result was expected given the significant increases in flow at the two stream sites during storm events.