NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER SUPPLY

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.

May 15, 2004

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

FINAL VERSION

Prepared by: Division of Drinking Water Quality Control
Bureau of Water Supply

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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 that 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 need for conducting a watershed monitoring seminar to disseminate data in the upcoming year and. 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 current research and future research, still in the developmental stage, and research programs on the watershed conducted by outside agencies.

The Research Objectives Report is laid out parallel to the structure of the FAD. The order of studies described is under 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 Filtration Avoidance Determination (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, fisheries studies, and work carried out under the Croton Process Studies contract.

Periodic seminars on watershed monitoring are part of the City's efforts to foster communication on NYC's watershed. 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 21, & 22, 2004, the Second Annual New York City Watershed Science and Technical Conference will take place in Kingston, N.Y. It is expected that there will be approximately 25 papers presented, with DEP staff contributing approximately 15 papers for consideration. The abstracts from DEP submissions are presented in the Appendix of this report.

2. Current BWS Research

2.1 Environmental Infrastructure

2.1.1 Stormwater Management Practices Monitoring Demonstration Project

Managers: James Benson/Eve Bocca
Start & Completion Date: February 2001 & October 2005
Status (% Complete): 40
Project Cost: $313K
Objective and Justification:

The objective of this project is to 1) assess watershed conditions, monitor water quality and evaluate sampling data, and identify incidences of improperly controlled stormwater that result in the discharge of pollutants to the water supply, and 2) through the design, construction and monitoring of stormwater management practices, eliminate nonpoint sources of pollution in the water supply watersheds and generate important data concerning the effectiveness of different stormwater management practices in reducing stormwater related pollution. Sites where stormwater practices will be implemented will be selected based upon the availability of water quality data, watershed condition and land use data, and the affected waterbody's classification on the DEC's Priority Waterbody List (PWL). The proposed program is consistent with both the New York State Nonpoint Source Management Plan and the applicable County Water Quality Strategies, which prioritize watershed assessment and remediation programs. The project is also consistent with the federal and state Unified Watershed Assessment, developed under the Clean Water Action Plan to integrate the protection and restoration of water-related natural resources.

Implications for Watershed Management:

Numerous stormwater management control facilities are being installed throughout the New York City drinking water supply watershed to remediate nonpoint sources of water pollution and minimize the impact of new and existing development on water quality. The New York City Watershed Regulations require that the stormwater management facilities meet certain design and performance standards. While not mandated by EPA, these types of management practices are recommended to treat stormwater runoff from land use development projects. Within the East of Hudson watersheds of the New York City drinking water supply watershed, stormwater pollution prevention plans that include SMPs such as these are required to reduce total phosphorus and total suspended solids from stormwater runoff to pre-construction levels.

The information gained in this study will be directly applied to DEP's regulatory and non-regulatory stormwater and nonpoint source management programs. This study will provide critical site-specific information on facility performance, design standards and maintenance needs. This project is particularly important because little site specific information is available concern-

ing the treatment abilities of SMPs as they relate to New York City's drinking water quality goals, SMP performance standards and programs.

Following an initial monitoring period, DEP will implement retrofits on two existing Stormwater Management Practices (SMPs) in the West Branch and Croton Falls reservoir drainage basins, in the Town of Carmel, New York. The objectives of this program are:

To initiate and provide high runoff (storm event) monitoring in a manner that is sufficient to compare the percent removal of two wetland extended detention basins to the design pollutant removal efficiencies for wetland extended detention basins, as specified in the New York State Department of Environmental Conservation's (DEC's) "Reducing Impacts of Runoff from New Development (NYSDEC, 1992).

To quantify the effectiveness of the retrofitted wetland extended detention basins by comparing pre and post retrofit monitoring data as well as comparing the monitoring data from the retrofitted inlet and outlet structures. Specifically, an annual load reduction of Total Phosphorus (TP), Total Suspended Solids (TSS), and Dissolved Organic Carbon (DOC), will be calculated.

Problems Encountered:

DEP was awarded two grants; a Water Resources Development Act (WRDA) grant, for the construction of two wetland extended detention basins and a Safe Drinking Water Act (SDWA) grant, for the associated monitoring stations, that will allow DEP to assess how well these facilities reduce TP, TSS, and DOC loads in stormwater. On 8/7/01, DEP provided the United States Army Corps of Engineers (Corps) with additional information that was identified as being necessary for the Corps to prepare the Project Management Plan for the WRDA portion of the project. Final Corps approval of the Project Management Plan has been suspended pending a determination of funds that the Corps will provide. A construction contract to build the wetland extended detention basins has been awarded and registered by the City Comptroller however, and construction will proceed in June 2004 according to the established schedule, and in order to comply with a FAD mandate.

2.1.2 Stormwater BMP Retrofit Effectiveness Monitoring

Manager: Tracy Lawrence
Start Date: September 2003
Completion Date: December 2005
Status (% Complete): 25%
Project Cost: $60K (DEP) + $60K Laboratory Analysis Contract (CWC)
Objectives and Justification:

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. The Water Quality Impact Assessment group of DEP is developing and implementing

this stormwater BMP monitoring program to determine the effectiveness of retrofitted BMPs to improve water quality. In a partnership role with DEP, the Catskill Watershed Corporation (CWC) is funding a contract to provide for the analyses of all of the project's samples by a commercial laboratory. WQIA has drafted a Quality Assurance Project Plan (QAPP) detailing this stormwater monitoring project which has subsequently been reviewed and approved by the DEC, CWC and DEP. Monitoring will begin in 2004 with the goal of sampling 35 events over a two year period. Stormwater samples will be collected at four retrofits located in the WOH villages of Walton (2), Roxbury and Margaretville. Three different BMP technologies Stormfilter® chambers, Vortechnic® device and an infiltration bed will be investigated as part of this project. This project was previously titled the "WOH Stormwater BMP Retrofit Effectiveness Monitoring Project" and its name was changed in 2004 to better reflect the project's collaborative nature.

Implications for Watershed Management:

This research will determine which stormwater BMP technologies perform best at meeting DEP's water quality objectives and ultimately help quantify the success of the BMP retrofit program. It is hoped that results from this research will be used to help guide the selection of future stormwater BMP practices by identifying those that provide the greatest benefit in water quality.

Problems Encountered: The reduction in DEP staff and overtime has required this to be extended from a 1-year project to a 2-year project.

2.1.3 Kensico Streams Best Management Practices Monitoring Project

Manager: Dale Borchert
Start & Completion Date: January 1, 2000 through December 31, 2010
Status (% Complete): 25
Project Cost: N/A
Objectives and Justification:

The objective of this project is to evaluate the effectiveness of Kensico BMPs at reducing storm loads of fecal coliform, total suspended solids, turbidity and total phosphorus.

During 1998 - 2004, ten extended detention basin Best Management Practices were installed on streams discharging to Kensico Reservoir. 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 basins BMPs are constructed to address these analytes.

The monitoring plan intended to rotate among the constructed BMPs over a 7-year period, monitoring up to 2 BMPs for a period of 1 year, until all 10 BMPs were monitored. This rota-

tional schedule intended to allow sufficient time for the collection of data that would be necessary to evaluate the effectiveness of each BMP. Based on work completed to date, DEP has determined that the original schedule is not achievable as sample collection under the QAPP was too restrictive to yield the best results. DEP has developed a revised proposed project schedule that has been shared with EPA. DEP anticipates discussing the matter further with EPA prior to finalizing schedule revisions.

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 applicants.

Problems Encountered:

During the first four years of monitoring, we learned that our original monitoring time frame was too ambitious, considering the logistics of collecting sufficient data for the analysis of each BMP. Specifically, fecal coliform monitoring has required the adherence to strict holding times. This has limited our ability to coordinate sampling and laboratory analysis, reducing the number of storm events that can be satisfactorily monitored during one year, and delaying our ability to monitor every BMP. In addition, a delay in the instituting of a contract to construct flow control structures at the inlets and outlets of several BMPs has eliminated our ability to monitor these structures.

2.1.4 Red Falls Monitoring Project

Manager: James Porter

Start & Completion Dates:

Monitoring start date: Spring, 1998

Monitoring end date: 12/31/05 per current QAPP, but this will likely be revised to at least 12/31/07 due to delays in BMP implementation

Report due date: currently 12/31/07, but this will likely be revised to at least 12/31/09 due to delays in BMP implementation

Status (% Complete): 50%

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 the Stream Management Program of DEP's Division of Watershed Lands and Community Planning (WLCP), Greene County Soil and Water Conservation District will design and implement BMPs to reduce the sediment and turbidity originating in the Red Falls area. DWQC's Hydrology Program has

been monitoring several sites on the Batavia Kill prior to BMP implementation, and will continue to do so for several years after implementation (currently scheduled for 2005). As turbidity and suspended sediment are one of the most important water quality issues facing DEP in the Schoharie watershed, evaluating 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 be more effective and cost-efficient in reducing sediment and turbidity in watershed streams.

Problems Encountered: None

2.2 Protection and Remediation Programs

2.2.1 Identify Watershed Sources of *E. coli* Found in the Water Supply and Estimate Nutrient Contributions from Waterfowl Fecal Matter.

Manager: Neil deLuca, Christopher A. Nadareski
Start & Completion Date: Part I started in November 2003
Status (% Complete): Part I = 12%; Part 2
Project Cost - $323K
Objective and Justification:
Part I:

The objective is to attempt to link *E. coli* isolates from our water supply to potential sources of contamination within the watershed, through the comparison of ribotypes (RT). DEP has been collecting *E. coli* from water samples with elevated fecal coliform counts, geese and gull feces, human feces, wild and domestic animals feces and other potential sources of pollution since 1991. This collection of approximately 2500 *E. coli* has been serotyped and is being stored at the Penn State University, Gastroenteric Disease Center. For this project, DEP's collection of these 2500 *E. coli* will be ribotyped with the DEP RiboPrinter from Qualicon.

The RiboPrinter Microbial Characterization System is an automated ribotyping system that generates restriction-cut DNA fragments containing RNA sequences that, after processing through algorithms, produce a genetic fingerprint (RiboPrint pattern) of each isolate. These genetic fingerprints are normalized digital representations of the genetic data for each sample. They serve as a stable, reproducible depictions of the genetic data for each isolate analyzed with the RiboPrinter system.

We have ribotyped only a small portion of this collection to date using *Eco*R1 restriction enzyme and have had very mixed results. For this current project, we are proposing using *Hin*d III

restriction enzyme instead of *Eco*R1 because of its superior discriminatory ability with *E. coli*. This decision was made after reviewing research performed by Dr. Charles Tseng, et al. In a comparison involving combinations and single restriction enzymes for *E. coli* using a RiboPrinter, Dr. Tseng concluded that H*ind* III was the best single restriction enzyme when ribotyping *E. coli* (Tseng, C.C., et al. "Automated Ribotyping of *Escherichia coli* Isolates from Humans and Animals", American Society for Microbiology General Meeting. 2001).

A temporary staff member has been hired, whose responsibilities will include reconciling DEP's *E. coli* archived at Penn State University with DEP's dataset. This will be completed before any request for isolates are sent. Then the archived *E. coli* will be processed through the RiboPrinter along with QC samples. In addition, the staff will maintain the RiboPrinter and assist with data analysis.

DEP has received the 1st group of *E. coli* from Penn State University, which are currently being ribotyped. The 2nd group *E. coli* has also been received from the Penn State and is being matched against our dataset for accuracy before being ribotyped. When each group of *E. coli* has been ribotyped, the data will be placed into newly created source libraries and also into BioNumerics data analysis program.

Part II:

The objective of this study will be to estimate phosphorus and nitrogen loading to reservoir from Canada Geese *(Branta canadensis*), gulls (*Larus spp.*) other waterfowl, and beavers.Up to 200 fecal samples will be collected and submitted for P and N analysis. Additionally, waterbird population surveys will be conducted to collect data on the number of birds utilizing the reservoir and their residency time. Nutrient loading will be calculated using these data, and these results may be incorporated into DEP's Cannonsville Water Quality Model. In combination with Part I of this project, approximately 200 *E. coli* isolates from these fecal samples will ribotyped using *Hin*d III restriction enzyme. Since waterfowl do contribute fecal coliforms to DEP reservoirs, the addition of the *E. coli* from upstate birds to our RiboGroup libraries will increase our confidence in making decisions on Bacterial Source Tracking.

A sufficient roosting and foraging population of geese, gulls and other waterfowl have the potential to impact the nutrient budget of a water supply reservoir by moving nutrients into the reservoir from the surrounding foraging areas and cycling nutrients within the reservoir. To elucidate the role waterfowl play in the nutrient balance, this study is being implemented to calculate P and N loadings via direct deposition by roosting birds.

Implications for Watershed Management:

Once DEP has expanded the ribotyping (RT) library at the conclusion of this project, DEP will have an increased confidence in the conclusions found in this analysis. This capability to help identify the sources of *E. coli* in the watershed and allow management to apply remedial measures in the appropriate locations. The RT library will aid in identifying whether coliforms are form

anthropogenic or non-anthropogenic sources. This is important in defining coliform –restricted basins.

The transport of nutrients from foraging areas to the reservoir can have implications for water quality if the loading is high enough. Increases in nutrient levels can negatively impact water quality by increasing the rate of eutrophication, increasing primary production and as a result decrease the reservoir's capacity to improve water quality. Waterfowl may be one of several sources of nutrient inputs and are easily manageable if shown to be a major contributor of P and N, or *E. coli*.

Problems Encountered:

Procurement delays in obtaining the sufficient ribotyping supplies are adversely affecting the time table for this project.

2.2.2 Reference Wetlands Monitoring – Year 1

Manager: Laurie Machung/Kimberlee Kane

Start & Completion Date: October 2003 – April 2005

Status (% Complete): 25

Project Cost: $262K

Objective and Justification:

The objectives of the reference wetland monitoring program are to compare the baseline characteristics and water quality functions of wetlands among the various hydrogeomorphic settings described by the USFWS in the Watershed-based Preliminary Assessment of Wetland Functions. In 2003, a two-year monitoring program was initiated in the Catskill and Delaware Watersheds through Safe Drinking Water Act funds. In the first year of the Catskill/Delaware Monitoring Program, 22 reference wetlands occupying terrene and lentic landscape positions throughout the Catskill and Delaware Watersheds will be selected. Baseflow sampling of the 22 reference sites will be initiated in year 1. Water quality samples will be collected from the wetland outflows and analyzed for dissolved major cations, pH, specific conductance, total alkalinity, Cl, TN, TP, and DOC. Storm and groundwater sampling will be conducted at a subset of the study sites in order to develop rudimentary mass balances. Vegetation and soil sampling will also be completed at 11 of the 22 sites in year 1.

As of January 2004, significant progress has been made: the contract for water quality monitoring by SUNYESF was registered, a Quality Assurance Project Plan was prepared and approved by DEC and EPA, site selection continued to make progress with additional fieldwork. DEP is currently working with the consultants to finalize the selection of 22 wetland sites for the study, including the 4 intensive sites. Monitoring of the study sites will start in the spring of 2004 and continue through 2005.

Implications for Watershed Management:

Results from this monitoring program will enable DEP to compare water quality functions of terrene and lotic wetland types. Analysis of reference wetland water quality and vegetation data in a hydrogeomorphic context will also provide a framework for the development of wetland assessment methodologies to guide both regulatory and non-regulatory wetland protection programs.

Problems Encountered: None

2.2.3 Forest Ecosystem Health: Phase I

Manager: Deborah Layton
Start & Completion Date: April 1999 to December 2005
Status (% Complete): 98
Project Cost: N/A
Objective and Justification:

This pilot project tests a systematic method for gathering information on NYC-owned forest lands, as well as performs an initial inventory of EOH forest conditions. This inventory will be used:

- To ground-truth GIS data that will be used by several disciplines within DEP.
- To quantify forest ecosystem health and determine further research needs for its management as it relates to nutrient and sediment retention, and therefore water quality.
- To assess the sampling protocol and sample size needed for adequate capture of stand variability.

The initial phase of the study is to be short-term and will lay the groundwork, in consultation with Land Acquisition and Stewardship Program personnel, for further forest inventory and research work to be carried out both EOH and WOH.

Sixteen sites were chosen in the West Branch, Bog Brook, East Branch, Amawalk, Titicus, Cross River, Middle Branch, Muscoot, and Kensico Reservoir watersheds and 235 plots established.

Implications for Watershed Management:

The sampling regime used in this project was found to adequately represent vegetation in the overstory and at the sapling/shrub level of the stand for all sites. At the herbaceous/seedling level of vegetation, however, where four meter-square plots were sampled per acre, species present were not adequately represented in samples from larger study areas with more variable terrain, soils, etc. In smaller, more homogeneous study sites, though, this sampling strategy worked well. Plots up to four times larger did not capture more variability than the size used (meter squared). The additional time required to sample these much larger plots, therefore, does not appear to be justified.

The presence of exotic/invasive species is believed to have a negative net effect on forest resilience and sustainability. This, in turn, has the potential for changing nutrient outflows from forested areas. A preliminary data analysis indicates that exotic and invasive plant species make up approximately 14% of the sapling/shrub level, 37.5% of the seedling level, and 24% of vines, throughout the EOH watershed. Percentages of exotics, overall, were lowest in the West Branch basin and highest at Cross River Reservoir. Based on these data, further study and inventory may allow prioritization and determination of the need for managing exotic/invasive species.

Vegetation complexity contributes to water quality protection by providing many layers through which precipitation may be intercepted and evaporated. Where complexity is reduced, there is greater potential for forest disturbances to have a greater immediate impact on water quality. Total percent vegetative cover at ground level ranged from 13% to 63% at the various research sites. These data can assist land managers in determining whether some forest stands require the application of various silvicultural practices to encourage more complexity.

Some initial data analysis has resulted in negative findings that also bear on watershed management concerns. For example, surface soil pH values had no statistical correlation with dominant overstory species. No correlation was found between overstory species richness and occurrence of either native or exotic species in the understory. Other interrelationships in parameters in all vegetation levels will be further explored through additional data analysis.

Problems Encountered:

Final plot measurements are complete; the data analysis and final report for this project are anticipated in 2005.

2.2.4 Effects of Silvicultural Treatment on Forest Ecosystem Health

Manager: Deborah Layton
Start & Completion Date: April 1999 to May 2010
Status (% Complete): 30
Project Cost: N/A
Objective and Justification:

The objectives of the study are:

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

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 (when feasible), 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, Middle Branch, Muscoot, 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. To determine whether the treated and untreated areas could be used for statistical analysis, the following conditions must be met:

- The treated site must have a lower average basal area than the untreated site,
- The overstory species must be similar with evidence that undesirable species, if any, were partially or completely removed from the canopy in the treated area and still exist in at least a portion of the plots in the untreated area and
- The understory species must be similar with evidence that any exotic/invasive species were removed from the treated area and continue to exist on at least a portion of the untreated area.

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. At the other reservoirs, a before-and-after sampling scheme was initiated.

Pre-treatment plots were established at West Branch, Kensico, and Bog Brook Reservoirs. Neither Kensico nor Bog Brook has yet received treatment. Silvicultural treatment work was completed at West Branch from early September 1999 through late April/early May 2000. As the sites required 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 in the summer of 2001. A second round of measurements was completed at West Branch in 2003.

Implications for Watershed Management:

On the Amawalk site there has been a favorable reduction in overall coverage of exotic species in accordance with DEP's policy to promote native species but, to date, the number of tree seedlings has not reached a number consistent with forestry health objectives.

The study will be measured and reported at least two more times over the next 5 years before any recommendations can be made about continuing this treatment on other sites.

Problems Encountered: None.

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): 40
Project Cost: N/A
Objective and Justification:

The objective of this project is to obtain basic information on the impacts of deer on 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 as the small exclosures tended to collect large quantities of leaves that may have improved microsite conditions (increased moisture and nutrients, improved protection from cold) beyond that of simply removing deer herbivory. For this reason, DWQC's Natural Resources Division constructed larger deer exclosures to further study local deer herbivory impacts.

In the spring of 2000 two large deer exclosures were constructed on 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, with a locked gate at one corner of the fence for researcher access. Each exclosure plot has a companion plot nearby in the same forest stand. The Bog Brook 1 site primarily has a red pine overstory while the Louden Cove 1 site is primarily hardwood. In the spring of 2001, a second deer exclosure was erected at Bog Brook Reservoir in a Norway spruce stand nearby the first exclosure. A companion control plot was also established in this stand. An additional deer exclosure was constructed at Titicus Reservoir, using different fence materials, in spring 2003.

Baseline measurements were taken one growing season following installation of the plots. Measurements have been repeated annually through the fall 2003. Results to date have not shown any statistically significant difference between the fenced and unfenced areas. The Bog Brook site was thinned in 2003. The Titicus site is not scheduled for silvicultural treatment. The Kensico site is scheduled for thinning within the next few years. It is expected that differences in herbivory will become more apparent following the thinning operation.

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 management.

Problems Encountered: None.

2.2.6 Forest Ecosystem Health Assessment Phase II: Continuous Forest Inventory West of Hudson

Manager: Deborah Layton
Start & Completion Date: Long-term study begun May 2002
Status (% Complete): ongoing, first round of measurements 25% complete
Project Cost: N/A
Objective and Justification:

The objective of this project is to establish permanent plots for the purpose of gathering information about longer-term forest processes, such as 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 or 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 performed in the Ashokan basin in 2002 serves 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, work will continue in the Boyd's Corner basin EOH to cover the large land area acquired in recent years. CFI plots will continue to be established in each major basin in the WOH region each year after this until plots are distributed on all basins. Plots will be re-measured at approximately 10-year intervals in order to monitor overall 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 write 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.

2.2.7 New York State Freshwater Wetlands Remapping Program

Managers: Laurie Machung, Kimberlee Kane, James Benson
Start & Completion Date: August 2002 through December 2004
Status (% Complete): 50
Project Cost: N/A
Objective and Justification:

At DEP's request, DEC is currently examining existing data sources and conducting field work to revise the NYS Freshwater Maps for the EOH watersheds. Specifically, DEC is verifying the boundaries of existing regulatory wetlands, locating additional wetlands that meet the regulatory threshold of 12.4 acres, and identifying smaller wetlands of Unusual Local Importance (ULIs) that are adjacent to the reservoirs.

In December 2003, public hearings were held on the proposed amendments to the Westchester County NYS Freshwater Wetland Maps. In the NYC watershed, the draft maps include a total of 36 new State wetlands and 75 ULIs (primarily around the reservoirs). DEP staff conducted extensive field investigations for this effort, and identified over 90 acres of wetlands in addition to those identified by the DEC contractors. Field work for Putnam County map revisions started in 2003 and will continue in 2004. Public hearings for the proposed amendments to the Putnam County NYS Freshwater Wetland Maps are anticipated in October 2004.

Implications for Watershed Management:

When adopted, these amendments would increase the area of wetlands subject to both DEC regulations and the WR&R. Regulated acres would increase from 5338 acres to 7731 acres in Westchester County alone. A similar increase is anticipated for Putnam County.

2.2.8 Wetland Characterization and Preliminary Functional Assessment

Manager: Laurie Machung
Start & Completion Date: March 1 2002 through October 1 2004
Status (% Complete): 70
Project Cost: $83,900
Objective and Justification:

To better understand the distribution, types, and functions of wetlands in the NYC watershed, DEP has contracted the U.S. Fish and Wildlife Service to conduct a "Watershed-based Preliminary Assessment of Wetland Functions" (W-PAWF). For the W-PAWF, the USFWS attaches hydrogeomorphic modifiers to each wetland polygon in the National Wetlands Inventory (NWI) database to support preliminary, basin-wide assessments of eight wetland functions: surface water detention, streamflow maintenance, nutrient cycling, sediment and particulate retention, shoreline stabilization, fish habitat, waterfowl and waterbird habitat, and other wildlife habitat. Pilot W-PAWF projects were first completed in the West Branch and Boyd Corners Reservoir Basins in 1999 and in the Neversink and Cannonsville Reservoir Basins in 2002. By the end of 2004, the

USFWS is scheduled to complete a W-PAWF for the entire Croton, Catskill, and Delaware watersheds.

Implications for Watershed Management:

In its current state, the NWI provides information on the cover types and other general characteristics of wetlands. The addition of hydrogeomorphic features to this database will provide further information about individual wetlands, such as their landscape settings and hydrologic connectivity, that will enable a watershed-scale functional assessment. The hydrogeomorphic characterization will also enable DEP to quantify the abundance of wetlands among various landscape settings. This type of analysis has already proven beneficial for DEP to quantify the acreage of isolated wetlands that were potentially removed from federal jurisdiction in 2002. Thus, the W-PAWF will enable DEP to focus its wetland programs by identifying functionally significant wetlands in need of protection.

Problems Encountered: None.

2.2.9 Mapping Update of Watershed Wetlands and Wetland Trend Analysis in EOH Watershed Wetlands

Manager: Barbara Dibeler

Start & Completion Date: Start date-September 2003; estimated completion date-July 2005 (USFWS contract registered in September 2003)

Status (% Complete): 50

Project Cost: $99,300

Objective and Justification:

I. NWI Mapping Update in WOH and EOH Watersheds

This project involves a contract with USFWS to update the National Wetland Inventory (NWI) through the analysis of spring leaf-off, 1:40,000 scale color infrared aerial photography. The original NWI was completed by USFWS in 1995 using medium scale color infrared (CIR) photography dating from 1982-1987.

The NWI update will improve knowledge of present wetland resources by mapping recently constructed ponds and identifying filled or altered wetlands, as well as small wetlands that may have been omitted from the original NWI because of the scale and quality of the source photography. For WOH, information on wetland changes and causes of change for the period from 1980s-2003 will be mapped. The project is scheduled for completion by June 2004.

II. Wetland Trend Analysis in EOH Watershed Wetlands

This project extends the analysis of EOH wetland trends from 1968 through 2004; the extent and causes of EOH wetland losses and changes since 1994 will be identified. The first USFWS EOH wetland trends project analyzed wetland trends for a 26-year period (1968-1984-

1994). Spring 2004 aerial photography will be used to map and assess the causes of recent changes in EOH NWI wetland cover type, distribution, and extent.

The project will support EOH wetland protection efforts by providing current information on the types and causes of wetland change and loss for a 36 year period. The project is scheduled for completion by July 2005.

Implications for Watershed Management:

Results from the two mapping projects will support wetland protection program goals, inform regulatory permit decisions, and provide water quality modeling inputs.

Problems Encountered:

Projects I and II are expected be completed on time (by June 2004 and July 2005, respectively) despite early contractual delays and the need to repeat the EOH flyover in 2004 because of the failure of the 2003 photography to meet technical specifications.

2.2.10 Hydroacoustics Monitoring Program (Fisheries)

Manager: Tom Baudanza
Start Date: June 2003
Completion Date: Ongoing
Project Cost: $191K (for capital equipment); (in-house for on-going component)
Objective and Justification:

Hydroacoustic surveys of reservoir fish populations will be conducted to assess potential impacts associated with chemical treatments. The purpose of this program is to work with DEC to run pilot projects that will assess mitigation of potential fish impacts associated with entrainment at the intakes and evaluate fish behavioral response (potential avoidance) to changes in intake levels. The monitoring will include baseline stock assessments at Rondout, West Branch, New Croton and Kensico Reservoirs to determine annual population levels and distribution patterns. Permanent transects (open water and shoreline) will be established with a Geographic Positioning System (GPS) to precisely determine data point locations and allow for conducting identical follow-up surveys.

Hydroacoustic surveys involve placing a hydroacoustic system on a boat, traversing predetermined GPS transects of the reservoir and 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 echo processor to produce estimates of fish density, biomass and size.

Total biomass for each area is then calculated as numeric fish estimate times the mean weight/fish. Gill nets will be deployed during the hydroacoustic surveys to validate species composition. Training in the use of the hydroacoustic gear was completed in June 2003.

Implications for Watershed Management:

Acoustic survey information will allow DEP Operations to adjust intake elevations to minimize fish entrainment and mortality, and subsequent elevations in fecal coliforms due to foraging birds.

Problems Encountered: None.

2.2.11 Stream Reclassification Program (Fisheries)

Manager: Tom Baudanza
Start Date: June 1996
Completion Date: projected 2013
Status (% Complete): 33%
Project Cost: N/A
Objective and Justification:

Streams in New York State are classified and regulated based on existing or anticipated best use standards. The objective of this program is to enhance the protection of watershed tributaries under New York State Environmental Conservation Law by determining the presence of trout and trout spawning in streams. Trout and trout spawning waters have stricter water quality standards and receive additional consideration during SEQRA reviews of proposed land use changes.

Reclassification surveys concentrate on likely trout habitat sections of stream including riffles, pools and undercut banks. 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 collected includes temperature, depth, width, DO, pH, conductivity, stream gradient and estimated discharge. Bottom substrate and landscape topography are also described. Collection reports and reclassification petitions are submitted to DEC annually. To date, streams in the watersheds of the Kensico, West Branch, New Croton, Rondout, Ashokan, Schoharie and Neversink Reservoirs have been inventoried and petitions submitted to NYSDEC for classification upgrades.

Implications for Watershed Management:

Identification of trout and trout spawning habitats in streams heighten agency review and public awareness of potential impacts from proposed land use changes.

Problems Encountered: None.

2.3 Watershed Monitoring, Modeling, and GIS

2.3.1 New York City's Ambient Surface Water Monitoring

Manager: Dale Borchert

Start & Completion Date: January 1, 2004 through December 31, 2004

Status (% Complete): 25

Project Cost: $187K

Objective and Justification:

The project objectives are:

- To quantify the analyte load removal efficiency of best management practices that can be determined through high runoff monitoring;
- To quantify the changes in analyte loads from selected catchments that can be observed through high runoff monitoring before, during and following land development activities;
- To provide high runoff monitoring input data for the Reservoir Modeling Program.

During this phase of the study the objectives and accomplishments have been:

- Continue storm event monitoring at the two impact sites and one control site identified and monitored under previous funding awarded for the first two years of this project. The initial proposal involved monitoring two small watersheds, approximately 100-200 acres in area, where a land use change is expected to occur sometime in the next few years. High Runoff monitoring would occur for approximately 10 years, allowing for approximately 2 years of pre-development monitoring, 2 years of monitoring during construction and 6 years of post-development monitoring. The analytes collected at the site will be Total Phosphorus, Total Dissolved Phosphorus, Nitrite-Nitrate, Dissolved Organic Carbon and Total Suspended Solids. Approximately eight (8) storm events will be sampled each year. Samples will be collected and analyzed based on their location along the hydrograph. Approximately 10 samples will be collected from each sampling location during each storm event. During 2003, at least 8 storm events were samples at all three sampling locations, with an average of 10 samples collected from each site, during each event.
- Extend for one year the contract for laboratory services that was obtained with the funding for the first three years of this project. This contract has been awarded to Aqua-Pro Tech Laboratories in New Jersey.
- Extend for one year funding for temporary staff, whose responsibilities will be the collection and processing of data from these sites.
- Purchase small parts or accessories that become necessary for the maintenance of previously purchased equipment.

Implications for Watershed Management:

The results of this project have the potential to guide the Department's regulatory section in their application of the City's Watershed Rules and Regulations. This project could identify whether stormwater pollution prevention plans required under the City's watershed regulations are effective at reducing the water quality impacts associated with land use development. It could

also identify the change in pollutant loads associated with land use development. This study could contribute to a revision of the Department's expectations of stormwater pollution prevention plans, providing a way to quantify the impact DEP's Regulations have on water quality.

Problems Encountered:

This project is for one year of a study that expects to monitor land use changes over an extended period. Monitoring equipment needed to be installed on catchments where land use changes were expected to occur, but had not yet received their approvals. For one study site, the landowner did not receive an approval on his application to construct a golf course. He has indicated that he will instead construct a residential subdivision on this location. This change in plans would still provide a suitable study area, but at this time, plans for a subdivision have not yet been prepared. At the second study site, the applicant received his approvals and began construction earlier than expected, reducing the amount of pre-construction data available for this study.

2.3.2 Occurrence and Transport of *Giardia* and *Cryptosporidium* within the New York City Watershed (Year 1)

Manager: Patrick O'Brien

Start and Completion Date: A "conditional" start date has been granted by NYSDEC and USEPA for May 3rd, 2004. The project will be completed about 13 months from the "conditional" start date.

Status (% complete): 0

Project Cost: $440K

Objective and Justification:

The objectives of this project are to (a) validate the use of ColorSeed™ as the QC spiking material using USEPA Method 1623 for the detection and enumeration of *Giardia* cysts and *Cryptosporidium* oocysts, (b) determine differences in the spatial distribution of (oo)cysts within the watershed through a synoptic "range finding" effort while locating potential "hot spots" for (oo)cyst occurrence, and (c) perform targeted, pair-wise (upstream and downstream), sampling in response to elevated (oo)cyst occurrence to determine areas of non-point source (oo)cyst contamination.

DEP's pathogen monitoring program has developed since 1992 an extensive database on the protozoan pathogen concentrations at our keypoints, as well as in various streams within the watershed through a substantive fixed frequency, fixed location sampling network. Moreover, the pathogen group has a substantial database on the temporal changes in pathogen concentrations in streams resulting from storm events. These data are being used to correlate pathogen concentration data with differences in surrounding land-use, and other factors in order to identify potential sources of pathogens in the watershed. Ultimately, it is DEP's goal to obtain data not only on the sources of pathogens but also on transport properties. This information is needed for both watershed and risk management purposes. However, due to the sampling constraints, DEP has been unable to systematically monitor and assess the many different small scale projects or locations

that might be potential sources or sinks of protozoan pathogens. This type of monitoring should be done in and near the project site, with a sampling approach that is flexible and that can respond to immediate concerns (e.g. an overflowing sewer). Locations of potential interest include, for example, areas of potentially failing septic system, housing developments, wetlands, industrial parks, shopping centers, stormwater outfalls, BMPs, etc.

Since the original submission of the proposal, the first year of this two-year study has been divided into three tasks.

Task1: The first task is to complete a validation study of ColorSeed™ for use with USEPA Method 1623. ColorSeed™ is a killed, dyed, preparation of *Giardia* cysts and *Cryptosporidium* oocysts that is designed to be differentiated from intrinsic (oo)cysts in an environmental sample. This allows both the enumeration of environmental (oo)cysts and the determination of matrix recovery percentages with one sample. Full approval of the project QAPP will be granted upon completion of this validation study.

Task 2: The second task is to conduct the synoptic "range finding" study to determine differences in (oo)cyst occurrence throughout the watershed by sampling a large number of sites that are not currently sampled for pathogens. Based upon historical data and the results from this portion of the study, "hot spots" within the watershed that present with high (oo)cyst occurrence will also be determined.

Task 3: The third task of this study will utilize the results from Task 2 to conduct targeted follow-up sampling in areas of the watershed that contain "hot spots." Pair- wise (upstream and downstream) sampling will be conducted in response to high (oo)cyst occurrence in an attempt to determine non-point sources of (oo)cyst contamination (i.e. wildlife dwellings, failing septic systems, etc.).

Implications for Watershed Management:

The understanding of transport of pathogens (*Cryptosporidium* spp. and *Giardia* spp.) from source points to reservoirs is very important because the data is needed for both watershed and risk management purposes. The proposed work scope will leverage existing DEP resources and will be integrated with other DEP monitoring programs.

The identification of sampling sites with elevated (oo)cysts within the watershed will provide opportunities to investigate the land use types affecting the sampling sites and remediate anthropogenic sources. The development of protocols for in-reservoir sampling will also assist with the monitoring of sewage spills.

Problems Encountered:

There has been a lengthy QAPP review and approval process that has delayed the start of the project. NYSDEC and USEPA have granted "conditional" approval to start the project so that the September 2005 deadline for Final Reports and Reimbursement Submissions can be met.

2.3.3 Stream Biomonitoring

Manager: Martin Rosenfeld
Start Date: August 1994
Completion Date: ongoing
Status (% Complete): ongoing
Project Cost: N/A
Objective and Justification:

The primary objective of the program is the assessment of water quality for the purpose of supporting healthy biotic communities in watershed streams and rivers, through the sampling and identification of benthic macroinvertebrates. Other objectives include trend analysis at sites with a sufficiently long assessment record (>5 years), the assessment of impacts from point sources using the NYSDEC's "Biological Impairment Criteria for Flowing Waters", and the development of descriptions of benthic communities that correspond to DEP's water quality goals.

Biological monitoring is an aspect of water quality monitoring originally called for in the Clean Water Act of 1972. The DEC's Stream Biomonitoring Unit has established clear protocols for documenting impacts to aquatic macroinvertebrate communities in streams, and these protocols have been incorporated into Addendum E of the Memorandum of Understanding between the DEC and the DEP. Since 1994, WQIA has been following these protocols to conduct stream benthic macroinvertebrate biomonitoring in the watersheds of the New York City water supply system.

Implications for Watershed Management:

In addition to providing ongoing evaluation of the biotic health of watershed streams, data generated by the stream biomonitoring program have proved useful in a variety of contexts where the assessment of impacts to aquatic biota from anthropogenic sources has been required. These include water quality assessment at the site of a fish kill, assessment of impacts from WWTP discharges, and assessment of stream biotic integrity below the Shandaken Tunnel discharge to Esopus Creek. Stream biomonitoring data have been used to nominate waterbodies within NYC's water supply watershed for inclusion on NYS's Priority Waterbody List, and have been reported in the FAD Annual Report. DEP is using multivariate statistical methods to develop descriptions of attainable ecological goals for streams that might currently suffer from sub-optimal conditions.

Problems Encountered: None.

2.3.4 Monitoring Crossroads Ventures Proposed Development of Belleayre Mountain

Manager: Tracy Lawrence
Start Date: August 2001
Completion Date: August 2011
Status (% Complete): 20
Project Cost: N/A
Objectives 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 envisions 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 six tributaries in the vicinity of proposed development area. The monitoring plan was designed as a 4-phase program with an anticipated duration of approximately 10 years. Phase II of this program, currently underway, includes the installation of automated monitoring equipment to continuously monitor stream stage and includes the development of stream discharge rating curves for all sampling locations. Storm-event monitoring was also an added component of Phase II monitoring. Phase III is the construction monitoring phase, and Phase IV is the post-construction monitoring period during which DEP expects water quality to stabilize. This development project has yet to complete the SEQRA process therefore construction has not begun. The Developer has issued a draft EIS to the NYS DEC for formal public review and comment. DEP's review of the DEIS included a rebuttal of phosphorus export coefficients used by the Developer based on the data generated by this program which leads to estimates approximately one-tenth those reported in the DEIS. If this project progresses, WQIA will implement Phases III and IV of the monitoring program.

Implications for Watershed Management:

Little information exists on the affects of large scale land use changes on water quality in the Catskills 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:

No problems have been encountered so far. This project is on schedule with adequate staff and resources to meet program objectives.

2.3.5 Pesticide and Toxic Compound Monitoring Program

Manager: Tracy Lawrence
Start Date: ongoing
Completion Date: ongoing
Status (% Complete): ongoing
Project Cost: $120,000 to start (2001-2); $25,000 annually
Objectives and Justification:

The objectives of the Pesticide and Toxic Chemical Monitoring Program are:

- to identify potential source areas using available data,
- to attempt to detect toxic contaminants in watershed streams,
- to infer the threat to the water supply of any compounds detected,
- to make recommendations for any future pesticide and toxic compound monitoring programs, and
- to collect samples for toxics and/or pesticides as needed in response to environmental incidents such as spills, fish kills, or the presence of unknown organic compounds ("sheens") on waterbodies.

The initial phase of this project, a spatially extensive watershed-wide survey targeting potential source areas, is complete. WQIA continues seasonal targeted monitoring for toxic compounds within the watershed and maintains a commitment to sample aqueduct keypoints annually in the fall. The initial extensive monitoring effort found no significant concentrations of target analytes with sample results exceeding any NYS AWQS. In fact, the vast majority of sample analyses were reported as non-detect for all monitored compounds despite the fact that source areas were targeted. A complete report of the project's findings is in progress.

Implications for Watershed Management:

Identifying pollution sources and determining the risk they pose to the water supply are the first steps in the watershed management process. By implementing a source-targeted sampling program and including a review of other agencies' work in a final report, WQIA intends to evaluate the water supply's risk of exposure to pesticides and toxic compounds. With the implementation of ongoing watershed management and monitoring programs, this baseline condition is not expected to change in the foreseeable future.

Problems Encountered: None.

2.3.6 Development and Application of Watershed Loading Models for Evaluating Effects of Watershed Management on NYC Reservoir Water Quality

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

The DEP Modeling Program is engaged in ongoing research to develop, improve and apply Watershed Loading Models for simulating water, nutrient, and sediment loads to the NYC reservoirs under various watershed management and climate scenarios. Watershed Loading Models are linked to Reservoir Receiving Water Models for evaluating the effects of watershed management on reservoir trophic state. GWLF models have been developed for Catskill and Delaware system reservoir watersheds. GWLF model improvement and testing is focused on improved calibration of model parameters as additional data become available. A SWAT model is being developed for the Cannonsville Watershed, through a collaboration between USDA-ARS (the developers of SWAT) and DEP. Both SWAT and GWLF have valuable features not found in the other model. SWAT features dynamic calculation of phosphorus (P) loading coefficients as a function of soil P levels, and the explicit simulation of effects of agricultural management practices on nutrient loads. GWLF simulates nutrients from failing septic systems, and utilizes sediment rating curves for improved estimation of suspended sediment loads. Current plans are to conduct concurrent model development and testing of the two models so that the best features of these models can be incorporated into DEP's modeling system, to provide increased reliability and confidence in model simulation of watershed processes that effect water quality.

Implications for Watershed Management:

Simulation modeling is a powerful tool for evaluating the effects of watershed land use and management on reservoir water quality. Evaluation of watershed management scenarios using models provides guidance to DEP and watershed management programs for most effective utilization of resources for improving reservoir water quality. The DEP models have been used for a preliminary evaluation of the effectiveness of watershed management programs to control eutrophication in the Cannonsville and Pepacton Reservoirs (NYC 2001 Watershed Protection Summary, Assessment, and Long-term Plan 12/01). This application involves analyses of long-term scenarios, and will be revisited, using updated and improved models and data, in the next five-year Comprehensive Water Quality/Program Evaluation Report due to EPA 3/31/06.

Problems Encountered: None.

2.3.7 Analysis of Nutrient and Sediment Loads at Beerston –Cannonsville Watershed

Manager: Don Kent

Start & Completion Date: October 1991 – September 2005

Status (% Complete): 86

Project Cost: $520,780 (based on the maximum number of samples analyzed)

Objective and Justification:

The objective of this project is to provide continuous long term nutrient load data needed to support the DEP's ongoing research of the Cannonsville Watershed and Reservoir Models. Beginning in October of 1991 the DEP has funded, under a contract with Health Research, Inc. (HRI), the storm event and routine sampling of the West Branch of the Delaware River at Beerston, NY. Under this contract 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 5,200 water samples have been collected during each of the six and half previous 24-month contract periods. A seventh 24-month contract has been renewed which, after contract completion, will result in a total of 14 years of data from all the contracts combined. The table below outlines the parameters measured.

Analyses of Water Samples	Number of Samples per Contract Period [1]
Total Phosphorus	800
Total Soluble Phosphorus	800
Soluble Reactive Phosphorus	800
Ammonia-N	800
Nitrate-Nitrite-N	800
Particulate Organic Carbon	400
Soluble Organic Carbon	400
Chlorophyll *a*	400

[1.] This is an approximate number of samples which is subject to change based on the frequency and duration of storm event conditions during any 24 month 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

2.3.8 Assessing Management Alternatives for Achieving Phosphorus TMDLs to Control Eutrophication in NYC Reservoirs.

Manager: Mark Zion

Start & Completion Date: Jan. 02 – Dec. 04

Status (% Complete): 50

Project Cost: N/A

Objective and Justification:

Phase II total phosphorus TMDLs for New York City's Reservoirs are implemented to minimize water quality issues associated with eutrophication for the water supply. The TMDLs are expressed as an annual load of total phosphorus into each reservoir that will result in a target in-lake phosphorus concentration. The objectives of this study are to use DEP's Nutrient Management Eutrophication Modeling System to (1) further understand the implication of the annual phosphorus TMDL using more complex modeling tools such as the NMEMS and (2) to assess how different phosphorus reduction strategies, consistent with the annual TMDL, affect reservoir trophic state as indicated by growing season chlorophyll-*a* concentrations in the reservoirs.

For the Catskill/Delaware System Reservoirs currently above the Phase II TMDL, phosphorus loading reductions can be obtained using a number of different watershed management programs. Each of the programs targets phosphorus loading from different sources including waste water treatment plants, agricultural runoff, on-site septic systems and urban stormwater. Depending on the mix of watershed management programs, loading reductions can affect the proportions of different types of phosphorus (dissolved versus particulate) and the timing of the loads reaching the reservoir, while achieving similar annual total phosphorus loads. The timing and type of phosphorus entering the reservoir have a large effect on the resulting reservoir trophic status as indicated by in-lake growing season chlorophyll-*a* concentration. Hence, loading reductions targeted on different sources have similar reductions in annual total phosphorus load with differing impacts on reservoir water quality and trophic state. The NMEMS system is used to investigate these differences.

Implications for Watershed Management:

This research project is part of a series of FAD requirements to use DEP's water quality models to investigate Phase II TMDLs. Additionally, results of the project may highlight watershed management programs and strategies with the greatest effects on reservoir trophic status.

Problems Encountered: None.

2.3.9 Monitoring of NYC's Reservoirs for Zebra Mussels

Manager: Sharon Neuman
Start & Completion Date: April through November, annually
Status: On-going
Project Cost: Approximately $37,060 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 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 Oklahoma, 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 reproduce 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.

2.3.10 Initial testing of CE-QUAL-W2 Model in the Croton System

Manager: Todd Echelman
Start & Completion Date: 06/03 - 08/04
Status (% Complete): 95%
Project Cost: $5K
Objective and Justification:

This project will make preliminary tests of Version 3.1 of the CE-QUAL-W2 model New Croton and Muscoot reservoirs, and provide the setup and parameterization files for the two reservoirs. The project compliments the work described in section ??? by providing some initial tests of the two dimensional hydrothermal framework in Croton System reservoirs. A feature of this version of CE-QUAL-W2 is the ability to combine multiple reservoirs and river reaches into a single application consisting of two water bodies. Therefore, a third setup will be provided to DEP that combines Muscoot and New Croton reservoirs. This setup requires modification of the bathymetry files and a renumbering of all segment references.

Implications for Watershed Management:

The Croton reservoirs are smaller and shallower than the Catskill and Delaware system reservoirs and due to different physical conditions react to external loadings differently than deeper and larger reservoirs. Problems that DEP faces in the Croton System include eutrophication, seasonally high color, oxygen depletion and release of hydrogen sulfide and metals (i.e. Fe and Mn) from the sediments, and bacterial contamination from wildlife or spills. Monitoring suggests that the New Croton and Muscoot reservoirs can show distinct spatial gradients in water quality, suggesting that 2 dimensional models will be useful for managing these reservoirs.

Problems Encountered: None.

2.3.11 Update of 3-D Kensico Reservoir Model

Manager: Todd Echelman
Start & Completion Date: 06/03 - 12/04
Status (% Complete): 50%
Project Cost: $5K
Objective and Justification:

This project will make use of the most recent FORTRAN code available for RMA-10V and RMA-10Q These programs are successors to the 1995 versions of the RMA-10 model that form the foundation of Kensico 3-D Water Quality Model. The Kensico model will be reviewed and updated as needed for compatibility with present versions of the Microsoft Windows operating system, and assistance will be provided in re-compiling and installing the model on a com-

puter at DEP's Valhalla offices. DEP will be assisted in testing the new installation using existing input data files to validate the success of the transfer process.

Implications for Watershed Management:

The present Kensico water quality model is not operational under the Windows operating system. This project is intended to provide interim 3-D Kensico model capability while future 3D modeling capability is investigated as part the Kensico tunnel 3 project.

Problems Encountered: None.

2.3.12 Weather Generator Development

Manager: Don Pierson
Start & Completion Date: 06/03 - 12/04
Status (% Complete): 20%
Project Cost: $10K
Objective and Justification:

Weather generators are programs which provide realistic time series of synthetic weather data – data that are randomly generated, but retain key stochastic characteristics of the historical weather record. This project will undertake research to identify the most suitable weather generator program(s) available that meets the requirement to provide driving data for DEP's eutrophication modeling system and to provide DEP with a working weather generator program, calibrated to generating synthetic weather sequences at the locations of present day national weather service (NWS) climate stations in the WOH watersheds.

To as great an extent as possible, the simulations of weather will retain realistic relationships between variables, and. a means of maintaining realistic spatial correlations between the NWS stations will be investigated and implemented. Each synthetic data series will have a length of 30 years and a daily time step. The weather generator will be calibrated using the measured data from the NWS climate stations used by the eutrophication modeling system

Implications for Watershed Management:

This project is intended as an enhancement for the 1-D reservoir management system by providing stochastically variable weather data, which serves as input to the models. Such variability can be used to further assess the role of variations in the weather in influencing the variability of model predictions.

Problems Encountered: None.

2.3.13 Catskill/Delaware resuspension upgrade for 1-D reservoir models

Manager: Don Pierson

Start & Completion Date: 06/03 - 12/04

Status (% Complete): 5

Project Cost: $10K

Objective and Justification:

The project will undertake the following four tasks:

1. Replace the empirical resuspension approach used in the earlier Catskill-Delaware 1-D models, with that of the Cannonsville program, which mechanistically simulates resuspension of particles and the cycling of phosphorus between the water column and reservoir bottom associated with resuspension and settling.
2. Complete preliminary testing of this enhanced framework for one year of historical conditions for each of the six reservoirs (Pepacton, Neversink, Rondout, Ashokan East, Ashokan West, and West Branch).
3. Deliver an upgraded version of DEP's 1-D models for the above six reservoirs.
4. Provide a brief report documenting the manner in which the enhanced model was applied to these reservoirs, comparing model predictions (with and without resuspension upgrade) with measurements for the single test year, for each reservoir.

Implications for Watershed Management:

This project is intended as an enhancement for the 1-D and 2-D Catskill-Delaware reservoir models (see Section 2.3.12 of the 2002 report), and will make recommendations for the additional effort required to implement the enhanced resuspension and phosphorus cycling approach into final versions of DEP's "Hindcasting" and "Management" one- and two-dimensional models.

Problems Encountered: None.

2.4 Data and Methods Development

2.4.1 Communication of Water Quality Data Analyses and Model Applications

Manager: David Smith

Start & Completion Date:10/00 - 10/04

Status (% Complete): 55

Project Cost: $646K

Objective and Justification:

Task I. Automation of DWQC's Routine Reports: Water Quality Annual and Long-term Trend Reports.

This task consists of the design and production of two related reports. The first report is an annual report (i.e., covers the time period of one year). It will be formulated in such a way that some of the basic tables and figures will be readily repeatable. The second report design focuses on analysis of long-term trends; this will carried out at five year intervals with the data base expanded by five years each time. The "Trends" report is intended to highlight any long-term changes that occur in the watershed and will contribute to evaluation of the effectiveness of the MOA on an on-going basis. LakeWatch and WQStatPlus are examples of the software that will be used for trends analysis. For the latter, the software will require customization specific to DEP needs so that 24 data points per annum can be incorporated. This is required to take advantage of twice-monthly sampling at key river sites for key analytes so that higher power and trend analysis confidence can be obtained.

Greater automation of reports is required to allow timely reporting of water quality data. In the current situation, little staff time is available for report production. DEP is only staffed sufficiently to carry out the field and laboratory activities required for the ongoing programs, but is insufficiently staffed to address some complex data analysis and reporting needs. This hinders the use of the data and ultimate reason for its collection, i.e., the use of analyses that lead to informed decision-making for watershed management. Greater automation of the process may remedy this staffing shortfall to some extent. Routine production of specific analyses will allow DEP to ensure that information such as phosphorus- or coliform-restricted basin status is conveyed to the public in a timely fashion. Annual Report layout must be efficiently designed, text must be written and edited, then sent to a printer for high quality, color reproduction. Reports can then be posted on the DEP website in addition to the production of hard copies. Completion of this task will greatly enhance DEP's in-house report production capabilities and communication with others.

II. Condensed Version of the Report on Effectiveness of DEP's MOA Programs.

DEP produced a 1998 Supplemental Annual Report to describe how the effectiveness of the MOA would be evaluated in preparation for the next EPA Determination (April 2002.) This report indicated, in principle, the types of information and modeling capability available for such an evaluation, however, the analysis itself is being planned in much greater detail and will result

in an extensive technical document. This document will need to be condensed and simplified in order to convey the essence of this report to the public and partners of the Watershed MOA. At the present, the scope of the report will include: i) a comparison of current water quality to benchmarks (regulatory limits) and an evaluation of long-term trends, ii) description of program implementation since the signing of the MOA in 1997 and quantification of effects to date, iii) projection of future effects of programs in each reservoir basin. This last item will require modeling work to estimate the balance between the increasing pressures of 'build-out' with the anti-degradation effects of the Watershed Rules and Regulations and MOA Programs. This balance will affect future pollutant loadings to the water supply and projections of these loads will be used to project how reservoirs will respond. Several comparative scenarios will be developed, including projections for water quality both with and without MOA programs to highlight MOA effectiveness and expectations for the long-term.

This task can be considered a limited prototype and specific application of the work that will be conducted under the Par Government Systems Corp. proposal entitled "NYC Watershed Data Management and Software Tool Development." It will be an analysis based on existing data that will be completed at the end of 2001 and will provide valuable practical guidance for the development of the more broadly scoped, data management and analytical system that Par Tech has proposed for DEP and DEC's long-term use.

This project is complex and requires significant time and expertise for project management, that will be provided by DEP, at a high level of technical difficulty. Although much of the individual analysis and modeling work is in progress, substantial effort must be devoted to the integration and documentation of results. The subsequent presentation of this material in an accessible and easily understood format is a major goal of this effort. The report layout must be designed, compiled, edited, and submitted to a printer for reproduction. The document that will be produced under this task will be one that is essentially a condensed version of the detailed technical "evaluation of the effectiveness of the MOA" report that DEP will submit to EPA in Dec. 2001. It will be designed for widespread distribution and posting on DEP's website.

III. Bureau-wide, long-term development and implementation of comprehensive Water Quality Information System. (This task now combines the original Tasks III and V.)

The goal of this task is to meet information demands and to improve the availability of data, and hence information, for decision makers. DEP has developed, and will continue development of, internet and intranet websites with basic descriptive information about the Department, reports, and periodic updates of current information about water quality and Cryptosporidium. However, there are increasing demands for water quality data to be made more readily available, for instance via a browser, and for some users to have this data linked to GIS data. The mechanism for such data availability needs to be developed.

This task will be accomplished through the development of the architecture (via PAR), the

purchase of hardware (server and workstations), web application software, conversion of DEP's SAS database to ORACLE (consistent with DEP's GIS data), and purchase of specialist hydrometric software (e.g., HYDSTRA or WISKI). This necessarily complex architecture will likely involve "thin client" use (i.e., a simple Wide Area Network browser-based desk-top system), more complex hydrologic and limnologic use (via specialist hydrometric software), and "power" users (via ARCGIS tools). A user-based Questionnaire will be developed to assist in the development of the architecture so that the requirements of all potential WQIS users are taken into account

IV. Media Conversion of Historical Water Quality Data

The objective of this contract is to make DWQC's historical water quality data more accessible. Microfiche copies of original handwritten lab books will be converted to digital format. The data is currently contained on seventy-one 16 mm micro-cartridges that require an optical reader. The lab books contain the results of chemical, biological and physical examinations made at the Mt. Prospect, Mt. Pleasant, Mt. Kisco, Kensico, Ben Nesin, Grahamsville and Central Laboratories between 1897-1985. These records are essential for preservation of DEP's historic data, and conversion to digital format will make this feasible.

Implications for Watershed Management:

Better communication with the public, both lay and professional, about the breadth and depth of the City's watershed research and protection programs serves the interests of all involved. Using the medium of the internet puts the facts and many facets of the City's extensive efforts at the fingertips of millions of individuals who consume the water supply being protected as well as thousands of people who live near the supply's sources. These constituents can learn of their own stakes in these programs and the ways in which they are linked to each other, upstate and down. Many of the programs are the first of their kinds. Written documentation and a website will make this information more available. Increased accessibility can also help the City and its partners build support for new programs and innovations that may be needed in the future.

Within the Bureau and the Division, this project will make water quality data more accessible to scientific and managerial personnel. Increased data accessibility will result in quicker and more efficient conversions of data into knowledge-based, operational and policy decisions.

Problems Encountered: None

2.4.2 DEP and National Weather Service (NWS) Data Coordination Project

Manager: James Porter

Start & Completion Date: 4/30/02 – ongoing

Status (% Complete): Ongoing indefinitely. Will be modified as data users' needs change, and with changes in technology.

Project Cost: N/A

Objective and Justification:

The are two main objectives of this project: 1) DEP receives specially-designed, Internet-accessible, hydrometeorological products from the National Weather Service and associated River Forecast Centers (e.g., probabilistic forecasts of inflow to reservoirs, used by DEP Division of Operations for reservoir balancing, and additional locations for river stage forecasts used in operating the storm event program; and 2) NWS receives near-real-time (NRT) data from the Hydrology Meteorological Network, which they use for numerous purposes including flood forecasting, emergency management, and calibration of Doppler radar areal precipitation estimates. NWS will also add DEP rainfall data to the Integrated Flood Observing and Warning System (IFLOWS) Internet page of NRT precipitation data, which will be a benefit to both agencies (by providing easy access to rainfall data from any Internet connection) and to Emergency Managers in watershed communities. Several types of historical data are also being shared between agencies for various and sundry research purposes.

This project is based on Recommendations S-1 and G-6 of the report "Recommendations to Address Flood Warning Deficiencies in the Delaware River Basin" (Delaware River Basin Commission, Flood Advisory Committee, April 2001). It was specifically requested by the Chair of the DRBC Flood Advisory Committee via a letter to DEP. The project is being formally tracked by the DRBC.

Implications for Watershed Management:

Specialized products from the NWS will allow DEP Division of Operations to better operate and balance the reservoirs, and will assist DWQC with storm event sampling. This project has also opened useful channels of communication with NWS and River Forecast Center staff that DEP now uses to obtain even more detailed and timely information (beyond what is available on the Internet) in planning for, and during, major storm events, snowmelt, etc. Through acquisition of NRT data from DEP, NWS greatly improves their ability to make highly localized and timely forecasts of floods and other dangerous weather-related situations. This benefits local communities, in the spirit of the Watershed Agreement, and also benefits DEP staff and facilities located in the watershed. As part of this initiative, the Northeast Regional Climate Center has agreed to provide climate data to the DWQC Modeling Program for free (saving DEP approximately $1,500 per year) in exchange for receiving our NRT meteorological data. Additional benefits and management implications will surely arise in the future as this collaboration continues.

Problems Encountered: None

2.4.3 Ribotyping of *E. coli* from Sewage Treatment Plants

Manager: Neil deLuca
Start & Completion Date: November 2002 - November 2004
Status (% Complete): 30%
Project Cost: $16K
Objective and Justification:

The objective is to provide links between *E. coli* in the water supply to *E. coli* from possible sources of contamination. DEP has been ribotyping *E. coli* isolates from the watershed from a variety of sources since December 1999. These sources included geese, gulls, dogs, wildlife and water samples. The addition of sewage treatment plant (STP) *E. coli* to our ribotype database will allow DEP to make a more comprehensive comparison of possible contaminants to NYC source water supply, by adding *E. coli* most likely from humans to the library. The inclusion of human *E. coli* will increase the size and versatility of our data set, since there has been a limited set of human *E. coli* in the library.

All samples have been collected and ribotyping has commenced. All finalized ribotyping data will be entered into our source library and BioNumerics program. The restriction enzyme *Hin*d III will be used for the ribotyping phase of this project, with the use of an additional enzyme if necessary.

The *E. coli* ribotyped for this project are likely mostly of human origin. These ribotypes will either create or be added to an existing RiboGroup. Identification of individual host sources of fecal *E. coli* is our goal and a prerequisite for remedial action by DEP management. The comparison of RiboGroups will be made by two methods. First we will compare RiboGroups obtained from STPs to RiboGroups in our existing library. Secondly, data will be analyzed by BioNumerics (Applied Maths) which is a powerful statistical tool using a mathematical program, that analyzes datasets to produce correlations for tree and cluster figures.

Implications for Watershed Management:

One of DEP's priorities is to maintain and deliver drinking water of the highest quality to the residents of New York City and the surrounding areas. By the end of this project, we hope to provide management with the information to identify areas by source. Armed with this knowledge, management will be able to take remedial action to assess and correct these situations. It will also provide information important for the identification of coliform-restricted basins.

Problems Encountered: None

2.4.4 Comparison of the Distribution of *Cryptosporidium* Genotypes in Storm Water Samples from Three Watershed Sub-basins

Manager: Kerri Ann Alderisio
Start & Completion Date: 2001 – November 2004
Status: (% Complete): 85%
Project Cost: N/A
Objective and Justification:

The objective of this study is to assess the source and public health significance of *Cryptosporidium* oocyst contamination in storm water within three New York City Watershed sub-basins. A PCR-RFLP technique based on the small subunit rRNA gene was used in the analysis of storm water samples collected from the Ashokan Brook, a tributary to Ashokan Reservoir, and Malcolm Brook and the N5 Stream, tributaries to Kensico Reservoir, over several years. All samples have been collected and sampling just ended last week at the N5 location. The distribution of *Cryptosporidium* spp. and genotypes in storm water samples collected at N5 will be compared with the data obtained from 29 storm water samples from the Ashokan Brook, and 40 samples collected at Malcolm Brook in previous sampling done by the New York City Department of Environmental Protection. Preliminary results demonstrate some shared genotypes between the watersheds; however, there were also genotypes recovered that were specific to each site.

The Malcolm Brook catchment is approximately 108 acres in area. It consists of sewered, relatively high-density suburban residential lots (approximately 4 lots per acre), corporate office parks and forested areas. The Ashokan Brook drainage basin, in contrast, is mostly undisturbed and forested, and differs in topography, fauna and flora. Both of these watersheds were studied and compared to determine if there were any differences in the sources identified as contributors of *Cryptosporidium* oocysts, given the varied land use of these areas. (Jiang, et al. 2003) The N5 basin will be characterized as well, and oocysts types will be compared to the other two locations for a final assessment of the data.

Implications for Watershed Management:

Finding different types of oocysts in different land use areas may help to shape the future design of sampling efforts for *Cryptosporidium* oocysts. This information may be helpful in qualifying the public health risk of different watershed categories with respect to the potential contribution from different sources, since not all *Cryptosporidium* species or subspecies are infectious to humans. Water samples (60 of 69) from the first two watersheds were positive for *Cryptosporidium* oocysts by PCR, almost all of which belonged to species and genotypes that have never been seen in humans or domestic animals before. Of the 60 positive samples analyzed from both watersheds, 54 (90%) were linked to either known or unknown animal sources. In addition, the detection of *C. hominis*, along with animal types, was noted in several samples collected from the Malcolm Brook over a two-week period in March of 2002. The fact that 90% of samples from both watersheds yielded types from animal species, rather than from humans, significantly helps

qualify the risk of infection to humans, and allows management to concentrate more effort on areas impacted by human sources. Altogether, 18 *Cryptosporidium* parasites were found in storm water samples from these watersheds, only 10 of which could be attributed to known species/ groups of animals. Additional work is needed in this area to help identify the sources of these other 8 subspecies.

Problems Encountered: None

2.4.5 Pressure as a Potential Indicator for the Need to Apply Method Modifications for Improved Recovery of *Cryptosporidium* spp. oocysts and *Giardia* spp. cysts in Water Samples Using Method 1623HV

Manager: Kerri Ann Alderisio
Start & Completion Date: June 2002 – February 2005
Status (% Complete): 85%
Project Cost: N/A
Objective and Justification:

The objective of this study is to determine if the recovery efficiency of *Giardia* cysts and *Cryptosporidium* oocysts varies when samples are collected at different filter pressures. Investigators challenged protozoan collection filters (Envirocheck HV) at three different pressures with a matrix created in the laboratory using local Catskill clay. Laboratory created matrix samples were spiked with equal amounts of (oo)cysts and filtered at three different pressures: 10psi, 25psi and greater than 50psi. Percent recovery of the target organisms has been recorded for each pressure.

The most current US EPA method for the analysis of protozoan samples from surface waters (Method 1623HV) recommends performing a matrix spike sample along with the first sample collected at a particular site, with a follow up frequency of every twenty samples. The method does not currently require the monitoring and recording of pressure throughout the filtration process, only that the procedure maintains a flow rate of two liters per minute. Water quality and matrix quality vary within watersheds, as well as across the country, and these differences have the potential to affect the quality of the sample result. Some sample matrices may have high turbidity, but not raise filter pressure; whereas others may have relatively low turbidity yet increase filter pressure dramatically.

Implications for Watershed Management

Preliminary data analysis of field filter pressure and the frequency of the detection of *Cryptosporidium* and *Giardia* indicates a signal of decreased recovery at increased filter pressures. Since there are distinctly different components within the matrices throughout the New York City watershed, the results of this study may have a great impact on the way samples are collected in the future. Results support that samples filtered at the lower pressure had greater (oo)cyst recovery than those filtered at higher pressure – a result of pressure, or increased processing per 50L. These data indicate the importance of monitoring and recording pressure while col-

lecting samples for protozoan analysis, as well as the need to be very familiar with the matrix in a sample in order to appropriately analyze samples and qualify the data produced at each collection site. This is true for samples collected in house, as well as those collected for national databases such as the upcoming LT2.

Problems Encountered: The data analysis and write up required to finalize this study has been delayed due to other priorities.

2.4.6 Improved Recovery of *Cryptosporidium* oocysts in High Turbidity Matrix Spike Samples Using a Dual Immunomagnetic Separation and a Sodium Hexametaphosphate Procedure with Method 1623HV

Manager: Kerri Ann Alderisio
Start & Completion Date: October 2002 – December 2004
Status (% Complete): 90%
Project Cost: N/A
Objective and Justification:

The objective of this work was to apply two method modifications to US EPA Method 1623HV to determine their effectiveness in improving the recovery of *Giardia* cysts and *Cryptosporidium* oocysts from high turbidity matrices. Sample filtration data resulted in high turbidity and high filter pressure mimicking local storm event measurements. Cyst and oocyst recoveries from these samples were significantly low compared to (oo)cyst recovery from less turbid samples. A dual IMS procedure and sodium hexametaphosphate wash were introduced, both independently and in combination, to attempt to improve the recovery of the (oo)cysts.

Researchers have endeavored to improve the recovery of protozoa from water samples for several years. As a result, there has been much emphasis on both laboratory analytical procedure and field sample collection. With the improved time saving steps of US EPA Method 1623 compared to the ASTM and ICR methodologies there has been increased focus on the ability to process more quality control samples in a protozoan laboratory than ever before. This is particularly true in the area of matrix spike testing. Although the methods have not yet reached 100 % recovery of *Giardia* cysts and *Cryptosporidium* oocysts, laboratories are able to qualify data with the addition of more matrix spike samples in their quality assurance sampling plans. This information is helpful when performing data analysis and when comparing occurrence data for these pathogenic protozoa at different locations throughout various watersheds.

Implications for Watershed Management:

The initial average oocyst percent recovery using the 1623HV method (12%) was increased by the dual IMS procedure (58%), and the sodium hexametaphosphate wash (66%). Results from two trials combining both method improvements demonstrated the most significant *Cryptosporidium* oocyst recovery (81%). The recovery of *Giardia* cysts did not improve significantly with either of the tested methods. Data suggest that these procedures may also improve the

recovery of *Cryptosporidium* oocysts from other difficult matrix samples. This information is extremely valuable to the sample collector and sample analyst, since these two techniques have been shown to improve recovery compared to samples analyzed not using these techniques. Triggers can be established in the field (turbidity/ pressure) that can identify the need to introduce analytical improvements back at the laboratory in order to improve (oo)cyst recovery from certain matrices.

Problems Encountered: The project ended and the contract expired on 4/30/04, therefore a no-cost time extension was granted to August 30, 2004. The project is 99% complete and DEP awaits the remainder of the monitoring data as well as minor revisions to the final report for the terestrial component.

2.4.7 Croton Process Study

Manager: Kimberlee Kane
Start & Completion Date: 4/1/99 – 8/30/04
Status (% Complete): 99
Project Cost: $6.03M
Objective and Justification:

The objective of this contract is to provide basic scientific information into the hydrological and biogeochemical processes that link land use and geographic sources to water quality. This project is conducted by a research consortium consisting of SUNY-ESF, UFI, USGS, and Syracuse University. The research focuses on the problems of cultural eutrophication and its impacts, as well as problems associated with naturally occurring organic carbon.

The project contains both a terrestrial component and a reservoir component. The terrestrial component included three "intensive sites" that spanned a range of development from pristine to high density residential, "broad brush sites" that sampled a broad range of land uses, wetland studies and an integrative modeling component. The reservoir component included specialized monitoring of all the Croton reservoirs, with a special emphasis on New Croton and Muscoot Reservoirs. The reservoir investigations focused on the sources, spatial/temporal variations, and key physical, chemical and biological processes within the reservoirs related to nutrients, organic carbon and color.

Implications for Watershed Management:

This project will provide a strong scientific basis for many management decisions in the Croton System, especially the design of mitigation programs to address problems such as disinfection by-products and phosphorus.

Problems Encountered: None.

2.4.8 Croton Watershed Strategy

Manager: Kimberlee Kane
Start & Completion Date: 12/5/00 – 7/6/04
Status (% Complete): 90
Project Cost: $2.64M
Objective and Justification:

The Croton Watershed Strategy project started in December 2000. The primary goal of this project was to develop an integrated watershed management plan for the Croton System which would allow DEP to optimize management efforts and focus limited resources on critical areas to achieve maximum water quality benefit. This was achieved by:

- conducting a subbasin watershed assessment for four critical indicator variables: total phosphorus, total suspended solids, pathogens, and toxic chemicals;
- implementing the methodology in a Decision Support Tool, and
- recommending watershed management alternatives for DEP's consideration.

The watershed assessment examined both existing and full build-out conditions in the watershed for 74 subbasins. The methodology focuses on impairment from point and nonpoint watershed sources to identify each subbasin's relative potential to impair water quality. The results were compiled in a series of documents and released in March 2003.

Basin Reports: Individual reports were developed for each of the reservoir basins which provide: potential point and nonpoint water quality impairment sources for each variable ("Areas of Concern"); subbasin scores that indicate the relative potential for water quality impairment from each source and each subbasin; and basin-specific management recommendations. Background information on the physical, environmental, and demographic characteristics of each basin are also included in the reports.

Watershed Reports: A watershed-wide analysis of the individual basin results was also conducted as part of the project. The analysis compares subbasins and Areas of Concern across the watershed objectively, prioritizing the recommendations based on several factors including: reservoir operations, 60-day travel time, phosphorus restricted basins, trout streams, and wetlands/sensitive environments. Management recommendations were grouped into five general areas: wastewater, stormwater, open space preservation, road drainage improvement and agricultural.

During the remainder of 2003, the project continued with development of a Project Tracking Tool, an additional management tool linked with the Decision Support System. This tool will track implementation of projects by basin (remedial, protective and new development), estimate reductions of phosphorus based on existing or proposed implementation projects, estimate increases of phosphorus based on new development, and generate basin status reports. The

Project Tracking Tool will primarily be utilized to track implementation of the phosphorus TMDLs.

In addition to the Project Tracking Tool, several other tasks were initiated in 2003:

- Stakeholder Reports, summarizing the watershed assessment results, were developed for the counties and municipalities;
- Impervious surface analysis, comparing the mapped impervious data to literature values and examining the results by land use category and by subbasin.
- Water quality analysis, comparing the watershed assessment results to monitoring data at select sites.

These supplemental reports are expected to be finalized during 2004.

Implications for Watershed Management:

The Croton Watershed Strategy project has provided a more detailed and comprehensive watershed analysis than was previously available. It will be valuable in a wide variety of DEP activities such as: prioritization of mitigation projects, guidance for field investigations and water quality monitoring, and SEQRA review of new development projects. The Decision Support Tool will also allow DEP to update this analysis as new data is developed.

Problems Encountered: None

3. Future BWS Research (Funded Proposals)

3.1 Protection and Remediation Programs

3.1.1 USGS Forest Health and Soil Nutrient Status

Manager: Peter Murdoch (James Porter for DEP)

Start & Completion Date: 4/1/03 – 3/31/04

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. The current work is just one funding cycle of an on-going project expected to last several years into the future.

Project Cost: $785K

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.

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, in 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: None.

3.1.2 Reference Wetlands Monitoring – Year 2

Manager: Laurie Machung/Kimberlee Kane

Start & Completion Date: October 2004 – October 2005

Status (% Complete): 0

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 terrene and lotic wetlands. In year 2, water quality, vegetation, and soil sampling will be completed at the 22 reference sites. Storm and groundwater sampling will be completed and rudimentary mass balances will be developed to assess nitrogen and phosphorus budgets for a subset of terrene and lotic wetlands. A final report summarizing the findings of the monitoring program will be produced.

Implications for Watershed Management:

Results from this monitoring program will enable DEP to compare water quality functions of terrene and lotic wetland types. Analysis of reference wetland water quality and vegetation data in a hydrogeomorphic context will also provide a framework for the development of wetland assessment methodologies to guide both regulatory and non-regulatory wetland protection programs.

Problems Encountered: None

3.2 Watershed Monitoring, Modeling and GIS

3.2.1 Ambient Surface Water Quality Monitoring

Manager: Dale Borchert

Start & Completion Date: January 1, 2005 through December 31, 2005

Status (% Complete): 0

Project Cost: $200K

Objective and Justification:

This proposal is a continuation of the work described in section 2.3.1. The project objectives are:

- Continue storm event monitoring at the two impact sites and one control site identified and monitored under previous funding awarded for the first four years of this project. The initial proposal involved monitoring two small watersheds, approximately 100-200 acres in area, where a land use change is expected to occur sometime in the next few years. High Runoff monitoring would occur for approximately 10 years, allowing for approximately 2 years of pre-development monitoring, 2 years of monitoring during construction and 6 years of post-development monitoring. The analytes collected at the site will be Total Phosphorus, Total Dissolved Phosphorus, Nitrite-Nitrate, Dissolved Organic Carbon and Total Suspended Sol-

ids. Approximately eight (8) storm events will be sampled each year. Samples will be collected and analyzed based on their location along the hydrograph. Approximately 10 samples will be collected from each sampling location during each storm event.
- Extend the contract for laboratory services that was obtained with the funding for the first three years of this project.
- Extend the funding for temporary staff, whose responsibilities will be the collection and processing of data from these two sites, as well as report writing.
- Purchase small parts or accessories that become necessary for the maintenance of previously purchased equipment.

Implications for Watershed Management:

The results of this project have the potential to guide the Department's regulatory section in their application of the City's Watershed Rules and Regulations. This project could identify whether stormwater pollution prevention plans required under the City's watershed regulations are effective at reducing the water quality impacts associated with land use development. It could also identify the change in pollutant loads associated with land use development. This study could contribute to a revision of the Department's expectations of stormwater pollution prevention plans, providing a realistic look at the impact our Regulations have on water quality.

Problems Encountered: None.

3.2.2 Occurrence and Transport of *Giardia* and *Cryptosporidium* within the New York City Watershed (Year 2)

Manager: Patrick O'Brien

Start & Completion Date: This project will start at the completion of the Year 1 study (Project 2.3.2)

Status (% Complete): 0

Project Cost: $200K

Objective and Justification:

Objective 1: Targeted sampling program follow-up. DEP will conduct data analysis from Year 1 results and select sites with positive findings, continue monitoring at these primary sites, identify and monitor intermediate sites between primary sites and reservoir, and evaluate pathogens transport.

Objective 2: Role of reservoirs. Results from the first year sampling may suggest that more intensive sampling is warranted at sites within reservoirs following storm events. Multiple data sets will be required to compensate for uncontrollable parameters (i.e., variability between storm events and laboratory holding times). Sampling will be conducted based upon the finding of the Year 1 study.

Implications for Watershed Management:

Data collected will provide information on land-based sources of pathogens and pathogen transport into the reservoirs. This information is needed for both watershed and risk management purposes.

Problems Encountered:

Start of the Year 1 study has been delayed to May 2004. Year 2 will begin upon the completion of the Year 1 study.

3.2.3 Distribution and Seasonality of HAA Sources in the Croton System

Manager: Gerard Marzec

Start & Completion Date: SDWA proposal: pending approval of funding - April 2005

Status (% Complete):0%

Project Cost - $150,000 (Projected)

Objective and Justification:

The City of New York's New Croton Reservoir provides high quality drinking water that has occasionally exceeded the SDWA standard for HAAs. This study is designed to assess the temporal and spatial distribution of the precursor sources of HAAs (HAA Formation Potential), and to incorporate a monitoring system that enables the City to better manage the reservoir to minimize disinfection byproducts (DBP) precursors in the water withdrawn for distribution. The objectives include:

1) Compare THMFP to HAAFP and confirm that HAAFP behaves similarly to THMFP with regard to sources, seasonality, spatial distribution (i.e. do we get the same attenuation through the reservoir as THMFP, and the same decrease with depth).
2) Determine whether the tributaries are major sources of HAAFP, as is the case with THMFP.
3) Use ΔA_{272} to compare to THMFP and HAAFP for temporal and spatial relationships. ΔA_{272} is the difference between the absorption at 272 nm of the raw water sample and the absorption at 272 nm of a sample that has been chlorinated and incubated for a set time (Li et al. 1998). Should correlate very well and we hope to use ΔA_{272} to predict when DBPs may be elevated in the distribution system. In this regard, this measurement should be considered a tool for long-term use.
4) Establish a system for continuous monitoring of ΔA_{272} on the Croton System to enable some management for HAAs.
5) Tie reservoir concentrations and temporal-spatial distributions to the current distribution system study. In the 1999 study (DEP 1999), 25% of the THMFP levels in the reservoir were found to result in THMs at BX32. It would be beneficial to establish such a relationship for HAAs.

Implications for Watershed Management:

1) Ability to link HAAFP sources with previous understanding of THMFP sources.
2) Easy method to provide monitoring and a predictive tool for DBPs. This method allows for an almost immediate determination of DBP formation potential as compared to other methods that take up to a week. By monitoring on a long-term basis, trends could be determined and management decisions could be made quickly if there was a sudden increase in ΔA_{272} .

Problems Encountered: None

3.2.4 EOH Reservoir Bathymetry

Manager: Gerard Marzec

Start & Completion Date: Fall 2004 - Spring 2006

Status (% Complete):0%

Project Cost - (Approved NYC Capital project funding)

Objective and Justification:

The purpose of this contract is to produce accurate bathymetry and detailed physical and chemical characterization of bottom sediments for 11 reservoirs in NYC's Croton System. The bathymetry and sediment classification information generated from this contract will be utilized by DEP managers to develop new hypsographic curves relating volume to reservoir elevation, by DEP limnologists in assessing reservoir processes and the identification of appropriate monitoring stations, and by outside consultants in the development of the hydrodynamic component for various modeling efforts.

Reservoir geometry can have a major influence on its eutrophication and hydrology, thus detailed digital maps of the reservoirs, which indicate bathymetric contours, bottom profiles, and shoreline features, are essential for understanding reservoir processes. The reservoirs of the Croton System range in age between 87 and 128 years, and the bathymetric features may have changed since original construction. The development of new bathymetric contour maps will greatly enhance the DEP's Geographic Information System database, and will improve the hypsographic relationships currently used by water supply managers. The current contract will, therefore help to create methodologically uniform, updated information for selected reservoirs.

Bottom sediment mapping and characterization is important in defining the area, types, and amounts of sediment in each reservoir. This contract will investigate numerous sediment analytes (e.g., particle size distribution, organic content, nutrient and metals content). From this information such issues as sediment sources (e.g., external vs. internal, biologic vs. inorganic) and relationships to overlying water quality can be determined. This preliminary information is crucial in determining and modeling the type and extent of water quality problems that are present in Croton System reservoirs.

This project must be handled through a contract because DEP does not have the personnel, expertise, or equipment to provide this type of service in a timely manner.

Implications for Watershed Management:

In summary, this contract will provide reservoir bathymetric and sediment data to improve water supply hypsographic information, enhance limnological water quality monitoring, and support reservoir hydrodynamic and eutrophication modeling efforts, in order to accurately assess the sources and fate of pollution in the Croton watershed of the City's drinking water supply.

Problems Encountered: None

3.2.5 Croton System Reservoir Models

Manager: Don Pierson and Todd Echelman

Start & Completion Date: pending contract registration

Status (% Complete): 0 Pending SDWA funding

Project Cost: $100K

Objective and Justification:

This project consists of two separate tasks based on model structure. The first task will provide final verification of Croton system 1-D hydrothermal reservoir models calibrated, but not verified, under Phase I Croton system reservoir model development work (see Section 2.3.10 of 2002 report). This task will result in a group of seven models which are fully calibrated and verified. In the second task a two-dimensional (2D) hydrothermal models for the New Croton and Muscoot reservoirs will be setup and calibrated, building upon the preliminary 2D setups described in Section 2.x.x of this report.

Task 1 In this task one dimensional models previously developed and calibrated for 5 EOH reservoirs will be verified. The verification process will involve comparison of model predictions of reservoir thermal structure with measured data. The verification process is important step needed to ready the models for operational use.

Task 2. In this task a two dimensional hydrothermal model for the New Croton and Muscoot reservoirs will be set up, calibrated and verified. As a result of this work operational 2D hydrothermal models of these reservoirs will be delivered to DEP. The 2D model structure will be the same (based on CE Qual W2) used in 2D models in the WOH system

Implications for Watershed Management:

This project will fund the continued development and testing of reservoir hydrothermal models for the East-of-Hudson (EOH) reservoir system. The models are planned to have compatibility 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. 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.

Problems Encountered: None.

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

Manager: : Don Pierson and Todd Echelman

Start & Completion Date: pending SDWA funding

Status (% Complete): 0

Project Cost: $70K

Objective and Justification:

The nutrient/phytoplankton models completed for the WOH reservoirs do not have sediment sub-models to quantify exchange processes 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. While anoxia was encountered (e.g., Cannonsville), the redox potential does not drop low enough to mobilize solid phase iron (Fe) - P associations. In the EOH system, particularly the New Croton reservoir, major sediment releases of manganese (Mn), Fe, P, and color were documented in summer in multiple years. Therefore, water quality models in the EOH system should have a mechanistic sediment sub-model that predicts sediment-water exchange in response to redox (predicted) conditions and deposition inputs of decomposable organic material (e.g., phytoplankton). The model would have the capability of predicting changes in sediment feedback from changes in the productivity of the overlying water column, and other ambient conditions. It would require the addition of at least one more model state variable (Fe), and probably also a second state variable for Mn.

In this project a sediment sub-model will be developed, setup, and initially tested (focusing on near bottom water column). This will be done within the one-dimensional hydrodynamic/hydrothermal model framework to eliminate hydrodynamic complexities and keep run times short. This is consistent with the approach 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 that will be completed in Project 3.2.5.

Implications for Watershed Management:

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.

Problems Encountered: none

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

Manager: David Smith

Start & Completion Date: August 2003 – November 2006

Status (% Complete): 15

Project Cost: $2.5M

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.

Implications for Watershed Management:

The Upstate Freshwater Institute (UFI) will conduct integrated programs of field monitoring/laboratory analyses, process studies, development and testing of turbidity and temperature models, and application of models. These work elements will support evaluation and design of rehabilitation technologies for the turbidity problems in Schoharie Reservoir and Esopus Creek that will continue to meet temperature requirements for specified fish populations in this creek. [This work will be conducted under contract to DEP, and will require extensive co-operation with consultants selected by DEP (operating under a separate contract) who will conduct engineering tasks related to the evaluation of alternatives and design of the selected technology(ies)]. Further, these studies will assist DEP in the operation of the Shandaken Tunnel SPDES permit.

Problems Encountered: None.

3.3 Data and Methods Development

3.3.1 Total Phosphorus Tracking of Lawn Fertilizers

Manager: Vincent Giorgio & Charles Cutietta-Olson

Start & Completion Date: June 2004

Status (% Complete): 0

Project Cost: $50K

Objective and Justification:

The objective of this study is to obtain watershed-specific information on lawn care practices, types of fertilizer used and the frequency of application. While many factors will affect the amount of phosphorus exported from managed lawns, lawn care practices, particularly fertilizer use, is likely the most manageable.

This project will survey homeowners and professional landscape maintenance personnel within the EOH watersheds regarding their typical lawn care practices, and whether or not fertilizers are applied routinely or in response to an identified need. The survey may also ask for information on other potential sources of phosphorus (e.g. automatic dishwashing detergent). The grant money will be used to contract with the Westchester office of Cornell Cooperative Extension to conduct the survey. The information obtained will be used to assess: percent of homeowners who fertilize, percent of homeowners who use landscaper services, phosphorus content of the fertilizer used, extent of routine versus "as needed" 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 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 type of watershed-specific data is necessary to develop effective non-point source management plans for phosphorus in the Croton watershed and for estimating the impact of such management plans using the Watershed Strategies Project tracking tool.

Problems Encountered: None

3.3.2 Ribotyping Using a Second or Third Restriction Enzyme and a Test Application On Sewers and Septic Systems

Manager: Neil deLuca / Kerri Alderisio

Start & Completion Date: None at this time

Status (% Complete): 0

Project Cost: $138K

Objective and Justification:

The objective in the first phase of this project will be to analyze the data from the previous SDWA project, " Identify Watershed Sources of *E. coli* found in the Water Supply and Estimate Nutrient Contributions from Waterfowl Fecal Matter". This will consist of 2500 archived *E. coli,* ribotyped with *Hin*d III restriction enzyme together with approximately 1200 *E.coli* isolates already run by DEP with *Eco*R1. This analysis will determine if the use of this second restriction enzyme can differentiate origin type (Bacterial Source Tracking – BST) better than one single enzyme. If the use of a second enzyme (*Eco*R1) is determined to be beneficial, then the remaining

isolates not yet analyzed using *Eco*R1 will be ribotyped under the second phase to result in a dataset of approximately 2500 *E. coli*, each ribotyped with both enzymes for improved subset discrimination.

The objective in the second phase of this project will be to ribotype 700 isolates with *Eco*R1, based on the findings from the first phase and to increase the size of the potential human sources of contamination in our ribotyped library of archived *E. coli*. This portion also consists of isolating approximately 340 *E. coli* from sewers, septic systems and water bodies and ribotyping using *Hin*d III restriction enzyme. Depending on the analysis in phase I of this project, DEP will determine if additional ribotyping of these 340 *E. coli* with *Eco*R1 is warranted. If the use of *Eco*R1 restriction enzymes is not of any value, a third enzyme, MLU I, will be tried in its place. It is much more cost effective to use a single restriction enzyme when ribotyping, but if two restriction enzymes produce the desired goal, this will become our protocol.

The RiboPrinter Microbial Characterization System is an automated ribotyping system that generates restriction-cut DNA fragments containing RNA sequences that, after processing through algorithms, produce a genetic fingerprint (RiboPrint pattern) of each isolate. These genetic fingerprints are normalized digital representations of the genetic data for each sample. They serve as a stable, reproducible depictions of the genetic data for each isolate analyzed with the RiboPrinter system.

Implication for Watershed Management:

As a result of this project, we hope to be able to better discriminate human fecal contamination from other sources of fecal contamination. If successful, this would allow watershed managers to identify sources of fecal contamination with increased confidence, and to take appropriate remedial action as well as aid in the identification of coliform-restricted basins.

Problems Encountered: None.

4. Review of Research Programs by Outside Agencies

4.1 Protection and Remediation Program

4.1.1 Effectiveness of Whole Farm Planning and Implementation in Achieving Water Quality Improvement and Protection of New York City Water Supplies. Analysis of Fifth Year of Monitoring Data.

Authors Patricia L. Bishop, M. R. Rafferty, and J. L. Lojpersberger, Bureau of Water Assessment and Management, NYS DEC.

Date: Oct 2003.

Executive Summary:

This report presents the fifth year of monitoring data from the paired watershed study of the R Farm and Shaw Road sites. The R Farm was one of the original pilot farms selected to demonstrate Whole Farm Planning (WFP) under the New York City Watershed Agricultural Program. In order to evaluate the effect of the WFP approach for water quality protection and improvement, the farm has been monitored intensively for the past 10 years. Using a modified paired watershed study design, with the R farm as the treatment watershed and the forested Shaw Road watershed as the control, monitoring has included continuous measurement of stream flow, precipitation, phosphorus, nitrogen, organic carbon, and suspended sediment. In addition, records of farm activities before and after BMP implementation have been kept.

The farm and control sites were monitored for two years from June 1993 through May 1995, prior to BMP implementation at the farm in 1995-1996. Monitoring resumed in late 1996 and has continued until present. Sampling effort have largely been event-based. Samples are also collected on a routine basis during baseflow periods, at least one per week.

Additional implementation of BMPs has occurred since the original practices were installed in the mid-nineties. Specifically, a high-contributing source area just upstream of the monitoring station was improved in autumn 2001 and precision feeding of the dairy herd was initiated in January of 2001.

Both of these improvements on the R farm should lead to additional reductions in nutrient losses and improved water quality that would be evident in future monitoring results. Preliminary data and analysis for the fifth year of POST-BMP monitoring are presented in this report.

Description of Data Collected:

Approximately 1300 water samples were collected during the two years of pre-implementation monitoring; the vast majority of which represented runoff event periods. In the five years of post-implementation monitoring, approximately 2,900 samples have been collected. The bulk of samples each year were collected during runoff events. Sample numbers generally varied in relation to the amount of runoff each year, with more samples collected in higher runoff years.

Chemical Analyses	Biological Analyses	Covariates
Total Phosphorus (TP)	Cryptosporidium	Runoff
Total Dissolved Phosphorus (TDP)	Giardia	Precipitation
Soluble Reactive Phosphorus (SRP)	Macroinvertebrates	
Particulate Phosphorus (PP)		
Nitrate + Nitrite (NOx)		
Total Ammonia (T-NH3)		
Total Kjedahl Nitrogen (TKN)		
Total Organic Carbon (TOC)		
Total Suspended Solids (TSS)		
pH, Alkalinity		

Study Evaluation:

This is an ongoing study whose results show that between pre and post BMP implementation, a statistically significant decrease in loads was achieved at the farm site.

With only one additional year beyond Post-4, it is likely too soon to tell if the BMPs implemented in 2001 have further reduced the loads from the farm. Analysis of the next year of data may start to show some trends.

Unfortunately the effectiveness of each individual BMP in decreasing the total farm load cannot be ascertained. This limits the applicability of these results in any modeling attempt to scale these results up to the Cannonsville Reservoir watershed scale.

4.2 Watershed Monitoring, Modeling and GIS

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

Author: Stroud Water Research Center, Avondale, PA.

Date: November 2002.

The summary below was compiled from portions of the introduction and Chapter 11 of the draft Year 3 Final Report.

"The principal objectives of The Stroud Water Research Center's monitoring program are:

- To provide dependent variables for statistical analyses relating aquatic ecosystem structure and function to land use, best management practice (BMP) implementation and other watershed inputs or factors.
- To provide chemical, physical, and biological indicators for evaluating the occurrence and

source of selected chemical and biological aquatic communities.

- To provide a baseline data set of populations, community, and ecosystem-level parameters, as well as chemical, physical, and biological indicators of contaminants, that will enable us to assess changes in land use.

Measurements made across sites representing a gradient of watershed conditions in the study area can also provide insight into the potential effects on a given sites of changes in watershed condition."

"One of the primary purposes of our enhanced monitoring program is to create, over a three year period, a baseline of information for each study watershed and hence for the entire NYC watershed area. This baseline will serve as reference points for determining whether the environmental quality of a given site is improving, deteriorating, or remains unchanged over time."

Study Evaluation:

It is too soon to evaluate how DEP will use the results of this study.

4.2.2 Watershed Modeling of the Cannonsville Basin using SWAT2000: Model Development, Calibration, and Validation for the Prediction of Flow, Sediment and Phosphorus Transport to the Cannonsville Reservoir. Version 1.0.

Author: Bryan Tolson and Christine Shoemaker, Cornell University

Date: Feb 2004

Executive Summary:

A watershed model of the Cannonsville Basin has been developed using SWAT2000 (Neitsch et al. 2001a) to describe phosphorus transport to the Cannonsville Reservoir. A SWAT2000 parameter set representative of the basin has been developed and tested against measured flow and water quality data. The model will eventually be used to evaluate the performance of a wide range of phosphorus management options in order to help local decision-makers allocate resources and efficiently reduce phosphorus loading to the reservoir.

Description of Data Collected:

The SWAT2000 model application used previously collected land use, soils, climate, point sources, groundwater phosphorus, agricultural phosphorus sources and management practice data.

Study Evaluation:

Delaware County and Cornell University researchers, as part of the Delaware County Action Plan (DCAP), developed, calibrated, and validated a SWAT2000 model applied to the Cannonsville Reservoir watershed. The SWAT model simulates flow, nutrients, and sediment loads from non-point sources. SWAT has several advantages over the GWLF model (which DEP has been using for this purpose), including dynamic calculation of phosphorus (P) loading coeffi-

cients as a function of soil P levels, and the explicit simulation of effects of agricultural management practices on nutrient loads. These features make SWAT a potentially valuable tool for evaluating the effects of land use and watershed management on reservoir eutrophication.

As a preliminary model, the DCAP SWAT application is a useful starting point towards the ultimate goal of developing a SWAT model application for Cannonsville. The study shows the value of SWAT modeling and has many excellent data analysis for deriving inputs and parameters. However, the DCAP SWAT model application that DEP reviewed has the following significant shortcomings which should be addressed, given SWAT's capabilities:

A. Critical Agricultural Management Practices Not Represented:

Crop Rotations: Crop rotation is one of the longest-standing and effective agricultural practices for erosion and nutrient management. One of SWAT's strengths is the ability to simulate crop rotations. The DCAP SWAT application fails to utilize this capability. Instead, rotated corn and hay are treated as continuous crops. Corn as a simulated continuous crop is tilled year after year without a break.

Barnyards and Milkhouse Wastes: These concentrated sources of nutrients are important elements of whole farm planning. Significant resources are expended by the WAP to manage them. They are not represented in the DCAP SWAT application.

Grazing: Grazing is a primary dairy farming management practice. Grazing practices can have significant effects on erosion and nutrient loading. SWAT has the ability to simulate grazing. This feature is not utilized in the DCAP SWAT application, and grazing is not represented.

Cows in Streams: Cows in streams may significantly load nutrients directly into the stream, based on preliminary investigations by USDA-ARS in Town Brook watershed. These are not accounted for in the DCAP SWAT application.

Manure Spreading on Snow: Manure spread on snow may results in significantly elevated nutrient concentrations in snowmelt runoff. This is not accounted for in the DCAP SWAT application.

B. Non-Agricultural Nutrient and Sediment Sources Not Represented:

Septic Systems: Septic system failure and nutrient loading from failing septic systems my not be uncommon in Cannonsville watershed, where sub-optimal soil and slope conditions for on-site waste disposal exists. DEP is expending significant resources on septic system remediation and replacement. Septic system failure is not represented in the DCAP SWAT application.

Rural Roads: Rural roads represent a significant fraction of the impervious surface area in the Cannonsville watershed, and an important potential source of nutrient loading via wash-off. Rural roads are not represented in the DCAP SWAT application.

C. Critical Watershed Processes Not or Poorly Represented:

In-Stream Nutrient Reactions: In-stream transformation of P between soluble and particulate phases may significantly effect loading predictions at the outlet of the watershed. This is particularly important during low-flows, when soluble P from Waste Water Treatment Plants can be assimilated by the stream bed. This has implications for model calibration and for estimating non-point vs. point source loading contributions. In-stream nutrient reactions are not represented in the DCAP SWAT application.

Partitioning of Streamflow into Surface Runoff, Lateral Flow, and Baseflow Components: Accurate simulation of streamflow components is a prerequisite for simulating chemical loads from a watershed and for evaluating the effects of landuse and climate on watershed loads. The DCAP SWAT application underestimates the baseflow component and overestimates the lateral flow component when compared to baseflow-separated streamflow data.

Lateral Flow Soluble P: Soluble P in lateral flow is not accounted for in the DCAP SWAT application. In this application, lateral flow is the biggest component (approaching 50%) of streamflow. Thus, P associated with up to half of streamflow is unaccounted for. A P concentration of 0.0 associated with lateral flow is unrealistically low, resulting in overestimation of P associated with other flow components.

Baseflow Soluble P Concentrations Varying as a Function of Landuse and Season: Soluble P concentrations in baseflow may vary significantly with landuse and season. The DCAP SWAT application assumes a constant concentration. The data analysis of monitoring data to estimate baseflow soluble P concentrations needs to be extended to derive loading functions for baseflow soluble P concentrations as a function of landuse and season.

Spatial Variability of Soil Properties: The methodology used in the DCAP SWAT application to assign soil properties to the STATGO soil map units based on SSURGO soil data fails to account for spatial variability in soil properties across STATGO map units, which may be significant.

Repeated Over-Prediction of TDP and Under-Prediction of PP: The DCAP SWAT application over-predicts Total Dissolved P and under-predicts Particulate P. This partitioning is critically important to eutrophication dynamics in the reservoir, where algal growth is sensitive to TDP loads.

Repeated Under-Prediction of TSS during High Flows: The DCAP SWAT application consistently under-predicts TSS during high flows, with implications for particulate P as well as sediment yield predictions.

Daily Air Temperature Adjustments: Daily air temperature data is manipulated in the DCAP SWAT application to force the model to simulate snow vs. rain based on snow records. However, by manipulating air temperature data, other variables in the model are also affected. The implications of using manipulated temperature data to drive the model have not been adequately investigated.

These shortcomings should be addressed before linking the DCAP SWAT model to the Cannonsville Reservoir model to evaluate watershed management. DEP and USDA-ARS are collaborating to address these issues in SWAT, and has invited Delaware County to participate in NYCDEP/USDA-ARS SWAT model research and development.

4.3 Data and Methods Development

4.3.1 Assessment of Mercury, PCB and Organ Chlorine Pesticide Residues in Indicator Fish Species in the NYC Reservoir System

Author: Jefferey Loukmas, NYSDEC

Date: 2001 - 2004

Executive Summary:

The New York State Department of Environmental Conservation (DEC) was awarded

SDWA funding to assess contaminant levels in fish collected from NYC reservoirs. In the SDWA grant application, DEP was listed as a cooperating agency for collecting fish for this study.

Description of Data Collected:

The study collected fish for analysis of mercury, PCBs/pesticides, and dioxins/furans.

Samples are collected by electrofishing, gill netting, trap netting, and angling. Six indicator species were targeted for collection and include smallmouth bass, largemouth bass, walleye, brown trout, lake trout, and yellow perch. Other species are substituted when indicator species are not collected.

In 2003, fish were collected from the following waters for contaminants analyses: Schoharie and Pepacton Reservoirs. Additional DOH consumption advisories are forthcoming.

Study Evaluation:

DEP will continue to track fish consumption advisories and examine water quality data for indications of a relationship between the advisories and the quality of the water supply. Currently, DEP has not identified such a relationship.

The full list of waterbodies with fish consumption advisories is available at http://www.dec.state.ny.us/website/dfwmr/fish/fishregs/fishadvisories.html.

References

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Tseng, C.C., et al. "Automated Ribotyping of *Escherichia coli* Isolates from Humans and Animals", American Society for Microbiology General Meeting. 2001

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Appendix

List of Abstracts

2004 New York City Watershed Science and Technical Conference

Croton Session:

Overview of the Croton Reservoir System
by Michael A. Principe, Ph.D.

Croton System Watershed Management
by Michael A. Principe, Ph.D.

Limnological and Kinetic Process Studies for EOH Reservoirs: Integration into Water Quality Models
by S.W. Effler, R. Gelda and S. O'Donnell

Effects of Suburban Land Use on Water Quality in the Croton Watershed
by Douglas Burns, James Hassett, Paul Heisig, Tomas Vitvar

Modeling Session:

Modeling of Turbidity and a Pathogen Surrogate in Kensico Reservoir
by Todd Echelman

Improving GWLF Models for NYC Watersheds Using the USDA SWAT Model
by Elliot M. Schneiderman, Mark S. Zion, and Guillermo Mendoza

Modeling Streamflow Components in NYC Cannonsville Reservoir Watershed with SWAT2000 Model
by Guillermo Mendoza, Elliot M. Schneiderman, and Mark S. Zion

Use of SWAT Watershed Model to Investigate Seasonal and Inter-Annual Variability of Dissolved Phosphorus Concentrations in Overland Flow
by Mark S. Zion, Elliot M. Schneiderman and Guillermo Mendoza

Pathogens Session:

Genotypes of *Cryptosporidium* Oocysts in New York City Storm Water
by Kerri Ann Alderisio and Lihua Xiao

Seasonal Variations in *Cryptosporidium* and *Giardia* Concentrations in New York City Watersheds
by Yves B. Mikol, Gerry Pratt, Kerri Alderisio, and Lisa Blancero

Climate Session:

Impacts of Projected Climate Change on Phosphorus and Sediment Loadings and Phytoplankton Growth Response for Cannonsville Reservoir

by Moore, K., Pierson, D.C., Rosenzweig, C. , Goldberg, R., Pettersson, K., Schneiderman, E.M., Zion, M.S., Lounsbury, D.G.

Comparisons of Hydrological Simulations for Water Quality Modeling in Different Climatic Regions

by Pierson, D.C., Moore, K., Pettersson, K., Naden, P., Allott, N., Jennings, E. Tamm, T., Järvet, A., Nickus, U., Thies, H., Arvola, L., Järvinen, M., Schneiderman, E.,Zion, M., Lounsbury, D.

Water Supply Issues Related to Climate Change

by Lorraine L. Janus**,** Kerri Alerisio, Dale Borchert, Christopher Nadareski

Monitoring Session:

Early Warning Surveillance Systems for Watersheds, From Streams to Source Water

by Yves B. Mikol and William Richardson

DWQC's Meteorological Network: History, Current Status, and Future Direction

by Glenn D. Horton and James H. Porter

Stormwater Session:

Quantifying the Effect of Best Management Practices on Turbidity and Total Suspended Solids in the Batavia Kill

by Francis Huber and James H. Porter

Extended Detention Basin Storm Monitoring

by Dale L. Borchert, James D. Mayfield and David G. Smith

Development of a Stormwater BMP Monitoring Program

by Tracy Lawrence

Forestry Session:

Forest Regeneration Issues in the NYC Water Supply Watershed

by Deborah Layton

Overview of the Croton Reservoir System

by Michael A. Principe, Ph.D.

The Croton Reservoir System, with twelve reservoirs and three controlled lakes located in Westchester, Putnam and Dutchess Counties, provides essential flexibility and vital redundancy for the New York City water supply. The smallest of the City's three reservoir systems, the Croton ordinarily provides about 10% of New York City's total daily water needs. But in times of drought or during maintenance shutdowns or other system outages, the Croton supply can be relied upon for up to 30% of the City's total water supply.

But over the past ten or fifteen years, the Croton system has been less reliable, with eutrophic conditions in many of its reservoirs and other problems necessitating that the system be shut down for months at a time, often during the peak periods of water demand -- the summer and fall. Under present conditions, Croton water consumers may sometimes receive lower quality water then consumers receiving Catskill/Delaware water.

A discussion of the history of the Croton system and an overview of the water quality concerns facing the City will be presented.

New York City Department of Environmental Protection, Bureau of Water Supply, 465 Columbus Avenue, Valhalla NY 10595, 914-742-2001, Fax 914-741-0348, Email: mprincipe@dep.nyc.gov

Croton System Watershed Management

by Michael A. Principe, Ph.D.

In advancing filtration of the Croton System, New York City has no intention of cutting back on watershed protection efforts in the Croton. Watershed protection is a critical component of the multiple barrier approach for protection of the water supply. A multiple barrier approach uses several lines of defense to ensure a high quality water supply. By optimizing raw water quality, watershed protection can minimize the risks of pathogens and other contaminants entering the distribution system. Indeed, DEP has had an extensive watershed management program in the Croton System, consisting of regulatory and non-regulatory components DEP believes that a strong watershed protection program will continue to be an essential part of safeguarding the Croton supply for future generations. The following ongoing Croton Watershed protection efforts will be discussed:

- Wastewater Treatment Plant Upgrades and Diversion
- Land Acquisition
- East-of-Hudson Nonpoint Source Program
- East-of-Hudson Watershed Agricultural Program
- East-of-Hudson Reservoir and Terrestrial Models
- Croton Watershed Strategy
- Wetland Programs
- DEP Source Water Monitoring Program
- Phosphorus Total Maximum Daily Loads
- Croton Planning and Water Quality Investment
- Regulatory Enforcement

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Limnological and Kinetic Process Studies for EOH Reservoirs: Integration into Water Quality Models

by S.W. Effler, R. Gelda and S. O'Donnell
Upstate Freshwater Institute

Interdisciplinary limnological and kinetic/process studies were conducted for the East of Hudson (EOH) reservoirs over the 1999 - 2002 interval, with the primary objective to support development and testing of water quality management models for nutrients/eutrophication and color. The scope of these studies is described within the context of the following five categories: (1) development and specification of model forcing conditions, (2) limnological characterization and analysis, (3) process and specialty studies, (4) optics, and (5) water, material and heat budget calculations. The role such information plays in an **integrated** modeling approach is reviewed. The results of the EOH studies will serve to: (1) specify limnological conditions (e.g., model state variables) and thereby form a basis to test model performance, (2) guide identification of model needs with respect to physical and biochemical structure and capabilities, and (3) specify necessary model forcing conditions, such as hydrologic and material loadings, reservoir operations, and meteorological conditions, that drive the observed water quality. A phased water quality modeling program, that is now underway and utilizes the data from the EOH limnological and kinetic/process studies, is preliminarily described. An example of the integration of results from the studies into the modeling process is presented.

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Effects of Suburban Land Use on Water Quality in the Croton Watershed

Douglas Burns[1], James Hassett[2], Paul Heisig[1], Tomas Vitvar[3]

About 10% of the New York City water supply originates in the Croton Watershed located east of the Hudson River and about 50 – 80 km north of the city. This water supply region includes extensive suburban/urban land development; about 180,000 people reside within the drainage area of the 11 reservoirs that make up the water supply system. We studied the effects of land use on water quality during 2001-02 at two temporal/spatial scales in the Croton Watershed: (1) 3 intensively-monitored small watersheds (< 0.1 km^2 each) with a range of population density (0, 450, and 1080 houses/km^2), and (2) 22 small watersheds that encompass a broad range of land use and hydrologic settings. Overall, housing density was strongly related to concentrations of inorganic nitrogen (N) and phosphorus (P) species, but was only weakly related to dissolved organic carbon (DOC) and associated disinfection by-product (DBP) concentrations; DOC and DBP concentrations were strongly related to watershed hydrologic setting, wetland type, and wetland area. Here, we highlight four results from this study that are of significance to researchers interested in land use effects on water quality as well as planners and managers with responsibilities for maintaining water of high quality. First, groundwater discharge from septic systems in unsewered watersheds contributed to enhanced baseflow and poor water quality relative to the undeveloped reference watershed. This result is counter to the prevailing concept that human land use and associated impermeable area decrease groundwater recharge and baseflow. Baseflow during a dry period was about 0.25 mm/day greater in a suburban-density residential watershed than in the nearby undeveloped watershed. Some water-quality constituents such as nitrate (NO_3^-) were highest during low flow and diluted during storms in the suburban watersheds, the opposite of that observed in small watersheds in the Catskill and Delaware watersheds where the highest NO_3^- concentrations are observed during rainstorms and snowmelt when NO_3^- is flushed from the shallow soil into streams. Second, sewered watersheds had higher concentrations of Total P, DOC, and some DBP species than unsewered watersheds in equivalent hydrologic settings; this suggests that sewer mains that often parallel streams are leaking water of poor quality into adjacent streams. Third, salt pollution is widespread in the Croton watershed. Previous work indicated that road salt is the major contributor to high sodium and chloride concentrations in the Croton Watershed, but we have identified flushing of accumulated salt from water softeners as an important source of salt as well in areas where water supply is derived from groundwater. Finally, while DBP concentrations are generally related to DOC concentrations and to wetland type, DBP species that contain bromine are associated with medium- and high-density residential development, where likely sources of bromine include fertilizer and human waste. The results of this study have important implications for the management of future land use and water quality in the Croton Watershed.

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Modeling of Turbidity and a Pathogen Surrogate in Kensico Reservoir

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Kensico reservoir, located in southern Westchester County of New York state, is an important component of the New York City water supply, where an average of about 90% of the City's potable water flows through it. With a storage capacity of about 30 billion gallons and average outflows of more than a billion gallons a day, the reservoir has an average retention time of about a month. Turbidity and pathogen water quality levels have been monitored in this important reservoir for at least 20 years. Ten years ago New York City began a water quality modeling program for this reservoir, with the development of a three-dimensional model (RMA based). Subsequently, in 2001, New York City began a two-dimensional modeling program (CE-QUAL-W2 based). Although both two- and three-dimensional models have been adapted to address management strategies for reservoir operations, in recent times the two-dimensional CE-QUAL-W2 model has been more widely used. Here, two-dimensional modeling studies have evaluated the transport and dilution of turbidity loads entering the reservoir. Systematic analyses examine the effects of varying the turbidity and inflow discharges from the two aqueducts entering the reservoir during stratified and non-stratified conditions. This will provide water managers with guidelines to minimize turbidity entering the distribution system and insight into particle (as a surrogate for pathogen) transport through the reservoir.

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Improving GWLF Models for NYC Watersheds Using the USDA SWAT Model

Elliot M. Schneiderman, Mark S. Zion, and Guillermo Mendoza *

DEP has developed and tested GWLF watershed models for simulating stream flow, nutrient, and sediment loads to NYC Reservoirs. The models have been used for preliminary evaluation of the effectiveness of watershed management programs, and are being used to investigate the potential effects of future climate change on NYC water supply. Efforts are ongoing to improve and test GWLF models as more data and research results become available.

To support these improvements and to enhance the robustness of its watershed modeling applications, DEP is currently developing, in collaboration with USDA-ARS, a SWAT model application for the Cannonsville Reservoir watershed. GWLF and SWAT share a basic hydrologic formulation, but also differ in significant ways. We focus on two major differences: the method for applying runoff curve numbers in the calculation of runoff and infiltration; and the determination of dissolved nutrient concentrations in runoff. Comparison of the two models applied to the Cannonsville Watershed yields insights into watershed processes, and provide the basis for improving GWLF hydrologic partitioning, dissolved nutrient loading estimates, and the effects of watershed management practices on loads.

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Modeling Streamflow Components in NYC Cannonsville Reservoir Watershed with SWAT2000 Model

Guillermo Mendoza, Elliot M. Schneiderman, and Mark S. Zion*

The Soil Water Assessment Tool (SWAT) is a model that simulates hydrology, nutrient dynamics in the soil, and landscape processes in a watershed. All these processes are integrated to simulate water quality in streams. A first step in developing a SWAT model application is to accurately simulate the streamflow components because these control the timing and quantities of chemical loads from a watershed. Given the complexity of interdependent functions modeled by SWAT it is appropriate to establish a methodology to adequately represent individual hydrologic processes. The approach is to constrain simulated output to adequately represent our best expectations of streamflow components from analysis of data. We developed and applied such a methodology to systematically analyze streamflow components and capture the key hydrological processes.

SWAT2000 model parameters that control quantity and timing of the runoff and baseflow components of streamflow were estimated from streamflow records for NYC Reservoir watershed streams in the Catskill Mountains, NY. Daily streamflow records were separated into direct runoff and baseflow time series. These time series were analyzed to determine respective lag parameters in the model, and were used to calibrate flow partitioning parameters by optimization methods. Model calibration and performance were greatly improved by a model revision allowing vertical movement of water in frozen soils. The revised SWAT model simulates streamflow components well in Catskill Mountain streams, providing a firm hydrologic basis for water quality modeling in the NYC water supply watersheds.

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Use of SWAT Watershed Model to Investigate Seasonal and Inter-Annual Variability of Dissolved Phosphorus Concentrations in Overland Flow

Mark S. Zion, Elliot M. Schneiderman and Guillermo Mendoza*

A major pathway for dissolved phosphorus to enter streams and reservoirs is via the overland flow component of runoff. Rain or snow melt washing over the ground surface carries dissolved phosphorus from the soil and transports these constituents downstream. The concentration of dissolved phosphorus in the overland flow is dependent mainly on the phosphorus concentration in the soil which, in turn, is dependent on multiple factors including the land cover and agricultural or urban management options such as spreading of fertilizer or manure, tillage alternatives, grazing, crop rotations and street sweeping.

To obtain an appropriate dissolved phosphorus concentration for overland flow, many existing water quality models use either calibration to existing data or literature based values. Alternatively, the Soil and Water Assessment Tool (SWAT) model, developed by the U.S. Department of Agriculture, integrates theories behind how phosphorus moves into, out of and within the soil column to maintain a soil phosphorus mass balance, and in turn, calculates concentrations of dissolved phosphorus in overland flow. This method enables the simulation of feedbacks on overland flow dissolved phosphorus concentrations due to and land management practices and climatic variability.

The purpose of this study is to use the SWAT model to investigate the sensitivity of dissolved phosphorus concentrations in overland flow due to land management options and climatic variability. A SWAT model calibrated for hydrology in the western Catskills of New York is implemented for each land use. By varying the management options, the model, based on the underlying integrated theory, predicts appropriate dissolved phosphorus concentration in overland flow. Changes in the concentrations based on seasonal patterns and inter-annual variability is investigated. The seasonal patterns are compared to data collected at the Town Brook Research Watershed, located within the Cannonsville Reservoir Watershed. These resulting concentrations can then be used further to inform less sophisticated models that currently use calibrated or literature based values for dissolved phosphorus concentrations in overland flow.

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Genotypes of *Cryptosporidium* Oocysts in New York City Storm Water

Kerri Ann Alderisio* and Lihua Xiao**

To compare the sources and public health significance of *Cryptosporidium* oocysts found in different storm waters in the New York City watershed, samples were collected from two distinctly different streams and analyzed using a small-subunit rRNA-based PCR RFLP technique. Forty samples were collected from Malcolm Brook in Westchester county N.Y., and compared with 29 samples collected and analyzed previously from Ashokan Brook in Ashokan, N.Y. Most samples were positive for the recovery of *Cryptosporidium* oocysts, and nearly all of those recovered were determined to have originated from wildlife sources rather than types recovered from humans or domestic animals. An exception was the recovery of *C. hominus* from Malcolm Brook during a two week period in March 2002; however, the brook was sampled repeatedly since that time and *C. hominus* was not recovered again. The predominant sources of oocysts in both watersheds were determined to be deer and muskrats, as well as an unknown genotype (W1). Some *Cryptosporidium* types were found at Malcolm Brook and not Ashokan Brook, including two additional unknown types as well as a likely fox genotype. Conversely, there were a few types recovered from the Ashokan brook that were not recovered at Malcolm brook, such as *C. baileyi*, and two 2 opossum genotypes. In all, 12 genotypes were recovered from these storm waters that can be attributed to known species/ groups of animals, while 6 genotypes are unique and the sources are yet unknown. Results from this study indicate that molecular techniques can be used to compliment current enumeration techniques used in water sample analysis to identify sources of contamination in the watershed. These results are significant since oocyst source identification can help determine the human infective potential and health risks associated with *Cryptosporidium* oocysts found in storm water.

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Seasonal Variations in *Cryptosporidium* and *Giardia* Concentrations in New York City Watersheds

Yves B. Mikol*, Gerry Pratt*, Kerri Alderisio** and Lisa Blancero**

DEP began weekly monitoring of *Cryptosporidium* and *Giardia* at its source water in 1992 and extended monitoring to the entire watershed in 1993. In 2003 911 samples collected at 152 sites were analyzed. Additionally, DEP conducts research and participates in validation studies sponsored by USEPA for the development of improved analytical methods. Over the past 12 years DEP has used three different methods for routine analyses of *Cryptosporidium* oocysts and *Giardia* cysts. The current method, Method 1623 HV used since October 2001, has improved recoveries of these organisms. While water quality has not changed, the number of oocysts and cysts recovered is higher than with previous methods. In the past, the number of "no detect" prevented simple statistical analyses. The number of *Giardia* cysts detected can now be used in statistical analyses. Data from source waters and other keypoints show seasonal variations. Increases are observed during high flow periods ("winter months"). Many sites throughout the watersheds show similar trends. *Cryptosporidium* appear to present a similar seasonality but the effect is not as visible because detections are less frequent and concentrations are lower than these of *Giardia*. Of interest, is the comparison of the seasonality of *Cryptosporidium* and *Giardia* observed in the watershed ("winter months") with the seasonality of cases of cryptosporidiosis and giardiasis cases observed in New York City ("summer months") suggesting that these seasonal increases, occurring at different time of the year, are unlikely to be related.

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Impacts of Projected Climate Change on Phosphorus and Sediment Loadings and Phytoplankton Growth Response for Cannonsville Reservoir

Moore, K. [1], Pierson, D.C. [2], Rosenzweig, C. [3], Goldberg, R. [3], Pettersson, K. [1], Schneiderman, E.M. [2], Zion, M.S. [2], Lounsbury, D.G. [2]

Water quality models were used to evaluate the possible impacts of climate change on the NYC water supply. As a first step in developing the modeling approach, output from a global climate model (GISS-GCM, the Goddard Institute of Space Studies global climate model) was used as input to a watershed model (GWLF, the Generalized Watershed Loading Functions Model). Nutrient loading estimates for N and P from the watershed model were then used to drive a reservoir model for phytoplankton growth. The development of the methods, their limitations, and recommendations for future refinement to this approach are discussed. Modeling is used as a tool for gaining a better understanding of watershed responses to climatic variability.

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Comparisons of Hydrological Simulations for Water Quality Modeling in Different Climatic Regions

Pierson, D.C. [1], Moore, K. [2], Pettersson, K. [2], Naden, P. [3], Allott, N. [4], Jennings, E. [4], Tamm, T. [5], Järvet, A. [6], Nickus, U. [7], Thies, H. [8], Arvola, L. [9], Järvinen, M. [9], Schneiderman, E. [1], Zion, M. [1], Lounsbury, D. [1]

ABSTRACT We are applying the GWLF watershed model in the EU CLIME (Climate and Lake Impacts in Europe) project to evaluate the effects of weather on seasonal and annual delivery of N, P, and DOC to lakes. Model calibration is based on long-term records of weather and water quality data collected from sites in different climatic regions spread across Europe and in the US for the NYC water supply area. The overall aim of the CLIME project is to develop methods and models to support lake and catchment management under current climate conditions and make predictions for future climate scenarios. Scientists from 10 partner countries are collaborating on developing a consistent approach to defining model parameters for the Generalized Watershed Loading Functions (GWLF) model. A model optimization approach for the hydrological sub-model of GWLF will be presented. Model coefficients obtained for different climatic regions in Europe are compared with coefficients used for simulations in the NYC water supply region.

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Water Supply Issues related to Climate Change

by Lorraine L. Janus, Kerri Alerisio, Dale Borchert, Christopher Nadareski

Changes in climate are expected to have a major effect on the dynamics of precipitation, streams, lakes, and reservoirs. In order to plan for water resources management (including new policy and infrastructure), models must be developed to predict future water quality and quantity conditions. Potential impacts must be estimated through modeling work since many trade-offs exist in the future conditions that will affect water quality. DEP is in the process of developing a suite of linked models that can predict responses of streams, lakes, and reservoirs to future changes in climate. Key water quality and quantity issues for the upstate watershed include drought, flood, turbidity, stormwater (nutrients and bacteria), eutrophication (algal blooms, taste and odor, and THM precursors), temperature effects (such as coliform bacteria related to water-fowl migration, Giardia seasonality inversely correlated with temperature), BMP efficacy, and dam safety. Next steps include the development of future climate scenarios for the watershed at a regional or watershed scale to estimate the severity of more extreme weather conditions. These in turn will be used to predict future hydraulic and nutrient loadings to reservoirs, to determine the impacts of eutrophication (such as THM levels or taste and odor problems), and to allow a re-evaluation of current watershed protection programs, Watershed Rules and Regulations, and recent dam safety upgrades in the context of new future conditions.

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Early Warning Surveillance Systems for Watersheds, From Streams to Source Water

Yves B. Mikol and William Richardson

Early warning surveillance (EWS) has been used in Europe for over 20 years following accidental contamination and non-point source pollution of surface water used for water supplies. The terrorists' attacks of September 11th increased the need for information on systems that can be easily deployed at source waters and upstream from water intakes. Early warning surveillance programs should also be designed to identify common and potential accidental contaminations. DEP initiated an EWS pilot program in 1999 and has increased resources allocated to this program. The objectives of this presentation are to outline (a) the need for watershed assessment to identify potential accidental sources, (b) the components of an EWS system; (c) on-line real-time instrumentation commercially available; (c) strategies for developing a program based on watershed activities and other possible threats; (d) strategies to confirm events and rule out false alarms; and (e) other planning required.

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DWQC's Meteorological Network: History, Current Status, and Future Direction

Glenn D. Horton and James H. Porter

In 1994, recognizing that meteorological data were valuable in meeting its mission of providing high-quality drinking water through environmental monitoring and research, DWQC installed a pair of Remote Automated Weather Stations (RAWS) in the Delaware District watershed. Subsequently, the need for meteorological ("met") data became critical when the DWQC Modeling Program identified them as required input for the models they were developing as Filtration Avoidance Deliverables. Thus, the network was expanded to its current configuration of 26 stations, covering both the East- and West-of-Hudson watersheds. Most of the stations utilize radio telemetry to transmit data in near-real-time. In addition to being used by the Modeling Program, these data are shared with the National Weather Service to help them make more accurate and timely severe weather warnings for watershed communities, and they assist Hydrology staff monitoring water quality during storm events. This presentation will explain the rationale of network development, detail the current configuration of the network, and discuss plans for planned upgrades and expansion of the network.

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Quantifying the Effect of Best Management Practices on Turbidity and Total Suspended Solids in the Batavia Kill

Francis Huber and James H. Porter

Observations and preliminary 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 the Stream Management Program of DEP's Division of Watershed Lands and Community Planning (WLCP), Greene County Soil and Water Conservation District will design and implement best management practices (BMPs) to reduce the sediment and turbidity originating in the Red Falls area. The geomorphic approach will be used, in which the stream channel will be modified to create a "stable" reach that will minimize the erosion of its bed and banks. DWQC's Hydrology Program has been monitoring several sites on the Batavia Kill prior to BMP implementation, and will continue to do so for several years after implementation (currently scheduled for 2005). The objective of the project is to quantify the effectiveness of the various BMPs at reducing suspended sediment and turbidity. This presentation will discuss the monitoring design and show some of the pre-BMP data from extensive storm event monitoring done in the Batavia Kill Basin.

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Extended Detention Basin Storm Monitoring

Dale L. Borchert, James D. Mayfield and David G. Smith,

ABSTRACT: As part of its Filtration Avoidance Determination, the New York City's Department of Environmental Protection has developed a comprehensive storm water management plan for the Kensico Reservoir watershed, a key terminal reservoir in the New York City system. Part of that plan required the construction of extended detention basins on several streams draining into the reservoir, to reduce fecal coliform bacteria and turbidity. Storm monitoring has been carried out at two of the extended detention basins to determine their efficiency at reducing loads and peak values of fecal coliform, turbidity (quasi-load), suspended solids and total phosphorus. For each storm, an average of 15 discrete samples are collected from each monitoring location. A regression of loads analysis technique is used to determine each basin's load reduction efficiency. Results from the first BMP have been previously presented. This presentation will examine the preliminary results from the second BMP. Using this technique, we preliminarily estimate that based on two years of data, one of the extended detention basins reduced stream loads by an average of 59% for fecal coliform, 72% for turbidity (quasi-load), 71% for total suspended solids and 40% for total phosphorus. Monitoring data will be collected at the second BMP throughout 2004, and results to date will be presented.

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Development of a Stormwater BMP Monitoring Program

Tracy Lawrence*

The Water Quality Impact Assessment Group (WQIA) of the New York City Department of Environmental Protection (DEP) in partnership with the Catskill Watershed Corporation (CWC) has developed and implemented a water quality monitoring project to measure the efficiency of stormwater best management practice (BMP) retrofits to remove pollutants. Three different types of structural BMP devices were selected to be monitored for this project; an infiltration bed, a Stormceptor™ filter chamber and a Vortechnic™ water swirling chamber. Each of these BMPs was newly installed in West-of-Hudson towns as part of the NYC Watershed Agreement's Stormwater Retrofit Program. The objectives of this monitoring program are to quantify the removal of pollutants from stormwater runoff, mainly total suspended solids and nutrients, and to compare pollutant removal rates among different BMP types. This 2-year project began in the spring of 2004 and will end in the fall of 2005. Plans are to sample up to 35 storms at each BMP. WQIA is providing the study design and field sample collection expertise while the CWC is funding the cost of sample analyses by a NELAP certified laboratory.

Implementing a scientifically sound stormwater BMP monitoring program that can be used to compare the ability of a variety of different BMP types to remove pollutants requires skill, patience, and a bit of luck. Representative sampling of rain event-based runoff relies in part on accurate weather prediction to provide foreknowledge of the timing, amount, intensity and duration of expected rainfall. In addition to collecting representative water samples for each event, the volume of stormwater flowing into and out of each BMP must also be measured. This requires the installation and calibration of flow measuring devices and data logging equipment. Finally, collected field data and reported laboratory results must be analyzed using appropriate statistical methods and reported in a comprehensive manner.

The presentation of this monitoring program will begin with a description of the development of the project's objectives and carry through with a discussion on how the project is being implemented in the field using automated monitoring equipment. Project design issues discussed will include determining data quality objectives, sample size estimation, composite sample procedures and the estimation of event mean concentrations (EMCs) along with the calculating of BMP efficiency ratios and their statistical confidence. Project implementation issues will include the programming of automated sampling equipment to obtain flow weighted composite samples, techniques for estimating and recording flow measurements within BMP structures, and responses to unforeseen field conditions.

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Forest Regeneration Issues in the NYC Water Supply Watershed

Deborah Layton, Forest Scientist

DEP's Natural Resources Section of the Division of Drinking Water Quality Control provides the scientific basis for management of wetlands, fisheries and forests on New York City water supply lands. Since the 1990's there have been some efforts to inventory and study terrestrial ecosystems to provide better management and, where necessary, protection of critical areas in order to maximize the potential for high water quality.

The forestry studies can be categorized in four major areas: 1) Forest Ecosystem Health Assessment, 2) Effects of Silvicultural Treatment on Forest Ecosystem Health, 3) Forest Regeneration Assessment Following Salvage Cutting, and 4) Effects of Deer Herbivory on Forest Regeneration. After 2 to 5 years of gathering data on various studies, several pieces of information are coming to light.

In the East of Hudson region, there is a gradient from the north to the south for deer impacts on forest regeneration. Impacts become more severe moving from north to south. Across the watershed, most forests, particularly planted conifers, are of a relatively even age (around 70 years on average) and approaching maturity. Invasive exotic plant species, combined with deer herbivory and possibly other factors, have created a situation in the southern end of the EOH watershed where native tree regeneration is unlikely to occur without intervention. Silvicultural treatments meant to control invasive species and encourage growth of native seedlings have some success but more frequent treatment of invasives along with deer management may be required. Deer exclosure fences are only beginning to show some positive results three or more years into the study and more time is required to determine whether ecosystems can recover after excluding deer. Baseline information has been gathered for a couple of areas that have been opened to deer hunting West of Hudson to determine whether hunting alone will help forest regeneration. West of Hudson there are significant differences among the forests in the three basins inventoried to date. Differences in tree size, growth and vigor are likely related to variation in underlying rock, soils, elevation, aspect, climate, past history, and other factors. Hemlock woolly adelgid and beech bark disease are likely to impact the basins to different degrees, based on species occurrence and existing advanced regeneration.

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