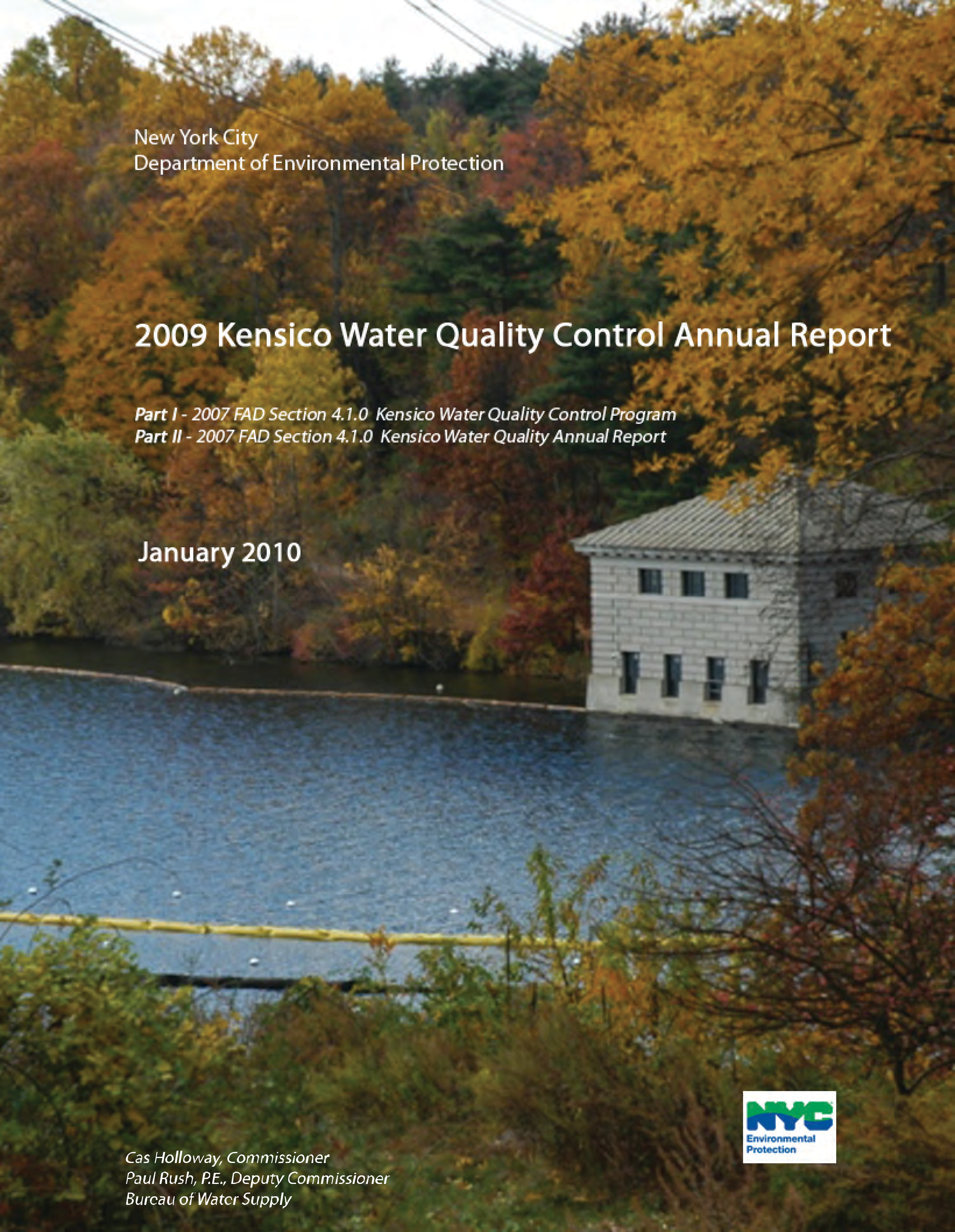

New York City
Department of Environmental Protection

2009 Kensico Water Quality Control Annual Report

Part I *- 2007 FAD Section 4.1.0 Kensico Water Quality Control Program*
Part II *- 2007 FAD Section 4.1.0 Kensico Water Quality Annual Report*

January 2010

NYC Environmental Protection

Cas Holloway, Commissioner
Paul Rush, P.E., Deputy Commissioner
Bureau of Water Supply

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List of Acronyms

BMP	Best Management Practice
BWS	Bureau of Water Supply
CATALUM	Catskill Alum Chamber
CATIC	Catskill Influent Chamber
CATLEFF	Catskill Lower Effluent Chamber
CATUEC	Catskill Upper Effluent Chamber
CFPS	Croton Falls Pumping Station
CFU	Colony Forming Units
DEL17	Delaware Aqueduct Shaft Building 17
DEL18	Delaware Aqueduct Shaft Building 18
DEC	New York State Department of Environmental Conservation
DEP	New York City Department of Environmental Protection
DMR	Discharge Monitoring Report
DOH	New York State Department of Health
DOT	Department of Transportation
EOH	East of Hudson
USEPA	United States Environmental Protection Agency
FAD	Filtration Avoidance Determination
FC	Fecal Coliforms
HEV	Human Enteric Virus
ICR	Information Collection Rule
IMR	Inter-Municipal Agreement
MGD	Million Gallons per Day
MPN	Most Probable Number
NYWEA	New York Water Environment Association, Inc.
NTU	Nephelometric Turbidity Units
NYC	New York City
RWBT	Rondout-West Branch Tunnel
SEQR	State Environmental Quality Review
SPDES	State Pollution Discharge Elimination System
SVOC	Semivolatile Organic Compound
SWTR	Surface Water Treatment Rule
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
VOC	Volatile Organic Compound

WMP	Waterfowl Management Program
WQD	Water Quality Directorate
WRDA	Water Resources Development Act
WWQMP	Watershed Water Quality Monitoring Plan

Acknowledgements

The Deputy Commissioner of the Bureau of Water Supply, Mr. Paul Rush, the Director of the Water Quality Directorate (WQD), Mr. Steven Schindler, and the Assistant Commissioner of the Bureau of Water Supply, Mr. Dave Warne, continued to provide general direction for operation of Kensico Reservoir and watershed activities throughout 2009. The reservoir undergoes continuously changing conditions that affect water quality in a variety of ways and this requires their constant attention. This report is intended to provide an accurate description of the water quality of Kensico Reservoir, the watershed events which have affected water quality, and the scientific investigations and monitoring programs conducted by DEP that allow the staff to operate Kensico Reservoir to ensure delivery of a safe water supply to NYC consumers.

The members of the Watershed Protection and Planning Division were responsible for development and implementation of the projects within Part I - Kensico Water Quality Control Program. They include: Mr. Michael Meyer (Program Coordinator), Mr. Matt Warne, Ms. Maria Mandarino, Mr. Matt Giannetta, Mr. Andrew Stor, Mr. Vincent Giorgio, Mr. Richard Wilhelm, Mr. Jose Nieves, Mr. Joseph Ziminsky, Mr. Daniel Shedlo, Ms. Patricia Grogan, and Mr. Tom Baremore. Ms. Cathy Durso contributed to the completion of program reporting.

The members of the Watershed Water Quality Science and Research Division were responsible for coordination, data analysis, and primary authorship roles for Part II - 2009 Kensico Water Quality Annual Report. They include: Dr. Lorraine Janus, Mr. James Mayfield, Mr. Gerard Marzec, Mr. Steve DiLonardo, Mr. David Quentin, Mr. Ray Homolac, Dr. Yucel Tokuz, Ms. Kerri Alderisio, Mr. Christian Pace, Dr. Don Pierson, Dr. Elliot Schneiderman, Mr. Mark Zion, Mr. David Lounsbury, and Mr. Don Kent. Ms. Pat Girard and Mr. Martin Rosenfeld were responsible for desktop publishing of the report. Mr. Martin Rosenfeld also applied his editing and proofreading skills to finalize the document.

The members of Watershed Water Quality Operations, directed by Ms. Lori Emery, provided the watershed field and laboratory work and resulting database for Part II of this report. The Waterfowl Management Program (WMP) directed by Mr. Chris Nadareski, the East of Hudson Operations directed by Mr. Charles Cutietta-Olsen, and the Pathogen Laboratory directed by Ms. Lisa Blancero, and their staff members, were important contributors. Mr. Nadareski contributed the written section on the WMP.

Mr. Tracy Lawrence, of WQD, provided the description of the October 2009 taste and odor event and operational response. Ms. Diane McGowan, of the East of Hudson Operations staff, contributed the update on plans for dredging for alum removal at the Catskill Upper Influent Cove, and Mr. Steven Adamec, of the Upstate Office of Information Technology (OIT), provided many of the photos included in this report.

Thanks are also due to the many people behind the scenes. These include the administrative, information technology, health and safety, and quality assurance staff who support the DEP programs. Although we could not name everyone, thanks go to all those who contributed directly and indirectly to this report.

Erratum

The 2009 Kensico Annual Report contained erroneous results in Section 4.1 – Groundwater. The correct information for the 2009 section is provided below.

Groundwater

The Kensico Groundwater Monitoring Program began in 1995 to determine whether groundwater could be contributing significant levels of pollutants to Kensico Reservoir. Results of this program were included in subsequent Kensico reports. By agreement with EPA, as of 2007, DEP ended its routine groundwater monitoring program because groundwater quality was excellent and showed no signs of contamination. However, a stipulation of this agreement was that DEP would continue to receive and review results from the Westchester County Airport voluntary groundwater monitoring program. Groundwater samples are collected twice yearly (usually May and November) at 57 wells, and data are shared with DEP. Reports are generated biannually by the consultant for the airport, SAIC, Inc. Sampling was in fact conducted in May and November of 2009, and those data are discussed below.

Analytical Methodologies

The groundwater samples were analyzed for volatile organic compounds (VOCs) by United States Environmental Protection Agency (USEPA) Method 8260, modified to include methyl tertiary-butyl ether (MTBE); semi-volatile organic compounds (SVOCs) by EPA Method 8270; ethylene and propylene glycol by EPA Method 8015; and Target Analyte List (TAL) total metals and TAL dissolved metals by Methods SW-846 6010 and 7470. The quality control samples were analyzed for VOCs by EPA Method 8260, modified to include MTBE, SVOCs by Method SW-846 8270, ethylene and propylene glycol by EPA Method 8015, and TAL total metals by Methods SW-846 6010 and 7470.

Results

The groundwater analytical results were tabulated and compared to the New York State Department of Environmental Conservation (NYSDEC) Technical and Operational Guidance Series (TOGS) 1.1.1 Ambient Water Quality Standards and Guidance Values for GA water class for groundwater.

According to the consultant, SAIC, Inc., due to the elevated turbidity in the groundwater, water samples were also collected for dissolved metals since the higher turbidity tends to bias the results of a total metals analysis. For this reason, the results from TAL dissolved metals analysis was compared to the TOGS Guidance Values. The TAL dissolved metals were detected above TOGS Guidance Values in 38 wells surrounding Westchester County Airport. The dissolved metals which were detected above TOGS Guidance Values were iron, manganese, magnesium, zinc, and sodium. The groundwater samples also contained elevated dissolved concentrations of aluminum, calcium, and potassium, for which there is no guidance value, but the concentrations were relatively above the method detection limit. The dissolved metals that were detected above TOGS Guidance Values and the dissolved metals with elevated concentrations with no guidance value are also the primary elements that comprise the underlying bedrock in and around the airport.

Saprolite, which is a silt/ clay-rich weathered bedrock, overlies the competent bedrock and is most likely the reason for the occurrences of elevated concentrations of both total and dissolved metals in the groundwater. After the consultant reviewed the boring logs for the monitored wells, it was determined that the boring for each well was terminated at the top of the bedrock contact, but within the saprolitic material. This explains the highly turbid water samples and elevated concentrations of total and dissolved metals in the groundwater samples collected. Based on the data reviewed and the nature of the rocks underlying the airport, it is believed that the occurrences of metals observed in the groundwater samples are naturally occurring.

Organics

Listed in the following table (Table 4.1) are outstanding results of organic constituents (e.g. VOCs) for wells located within the Kensico Reservoir drainage basin. Outstanding results can be defined as those that are at or above the concentration for the principal organic contaminant standard of 5.0 μgL^{-1}. This standard can be found in the NYSDEC Part 703.5 Regulations. Ethylene glycol and propylene glycol were not detected in any of the samples analyzed.

Table 4.1. Principal Organic Contaminant Detection at Westchester County Airport wells within the Kensico Reservoir Drainage basin; standard is 5.0 μgL^{-1}.

Well Name	Compound Name	CAS No.	Concentration (μgL^{-1})
FMW-14	Chlorobenzene	108-90-7	8.2
FMW-14	4- Isopropyltoluene (p-Cymene)	99-87-6	7.5

Note: Chlorobenzene is a chlorinated solvent, found as a constituent in adhesives, paints and polishes, and tar and grease removers. 4- Isopropyltoluene is an industrial chemical used in the manufacture of paint, furniture and other consumer goods; it has also been found in sewage sludge

Part I - 2009 Kensico Water Quality Control Program Annual Report

Prepared in accordance with Section 4.10 of the New York City Filtration Avoidance Determination, July 2007

This report discusses the status of the components of the Kensico Water Quality Control Program and the results of water quality monitoring in the Kensico Reservoir and its watershed for 2009.

1. Introduction to Kensico Watershed Programs

Kensico Reservoir, located in Westchester County, is the terminal reservoir for the City's Catskill/Delaware water supply system. Because it provides the last impoundment of Catskill/Delaware water prior to entering the City's distribution system, DEP has prioritized watershed protection in the Kensico basin to ensure the continued success of past efforts while providing for new source water protection initiatives that are specifically targeted toward stormwater and wastewater pollution sources.

1.1 Stormwater Management and Erosion Abatement Facilities

1.1.1 BMP Construction, Operation, and Maintenance

DEP constructed 45 stormwater management and erosion abatement facilities throughout the watershed in order to reduce pollutant loads conveyed to the reservoir by stormwater. The facilities, shown in Figure 1.1, were routinely inspected and maintained as needed throughout the year. Maintenance was completed in accordance with the Operation and Maintenance Guidelines (DEP 2000, revised 2003), which require regular inspections. Table 1.1 identifies the inspection requirements and maintenance needs.

Table 1.1. Inspection checklist for extended detention basins.

Inspection Guidelines	Minimum Inspection Frequency	Maintenance Guidelines
Access routes, basin structures, including riprap stabilized outlet, emergency spillway, headwalls, riser boxes, embankments, weirs, handrails and trash racks for cracks, seepage, and settling of embankment.	Four times a year and after heavy storm events for erosion, structural damage, debris accumulation, and vegetative growth.	Report access obstructions, damage to access route, damaged structures, and erosion to Project Manager and repair as advised. Remove debris, clogs, and vegetative growth promptly. Replace or remove debris and sediment accumulation from riprap when clogging becomes apparent. Replace filter fabric when riprap is replaced. Maintain clear access to manholes, gate valves, and catch basins.
Inlet/outlets, basins, and maintenance access roads for debris and trash accumulation, obstructions, and clogging.	Monthly and after heavy rain or snowmelt for clogging.	Remove debris, trash, and obstructions promptly using hand tools if tools are needed.

Table 1.1. (Continued) Inspection checklist for extended detention basins.

Inspection Guidelines	Minimum Inspection Frequency	Maintenance Guidelines
Vegetation - health of planted vegetation (wetland, embankment, coconut rolls, and seeded areas), erosion of planted areas.	Monthly during growing season. Quarterly during non-growing season.	Replace dead and dying wetland and planted vegetation, repair erosion, and prevent future erosion and reseed and mulch bare areas. Maintain/mow/prune embankment vegetation and remove tree growth from embankment bi-annually. Do not mow wetland vegetation.
Nuisances: odors, burrowing pests.	Monthly.	Identify source and remove nuisance. Report nuisances to Project Manager and address as advised.
Gate Valve.	Yearly.	Check integrity of the valve by fully opening and closing the valve to ensure it is functioning properly.
Dams for structural integrity (seepage, settling, and erosion).	Annually.	Report damage to Project Manager and repair structures as advised.
Sediment depth in forebay and detention basin. Measure sediment depth with marked measuring stick. Once a year, drain pond to measure sediment depth.	Once a year and after significant storms.	Remove sediment from forebay every 5 years and from main basin every 15 years or when depth >50% of the basin depth. If basin does not contain a forebay, remove sediment at least every 15 years. A backhoe will be required to clean out the sediment. Dispose of the removed material in accordance with federal, state, and local regulations.

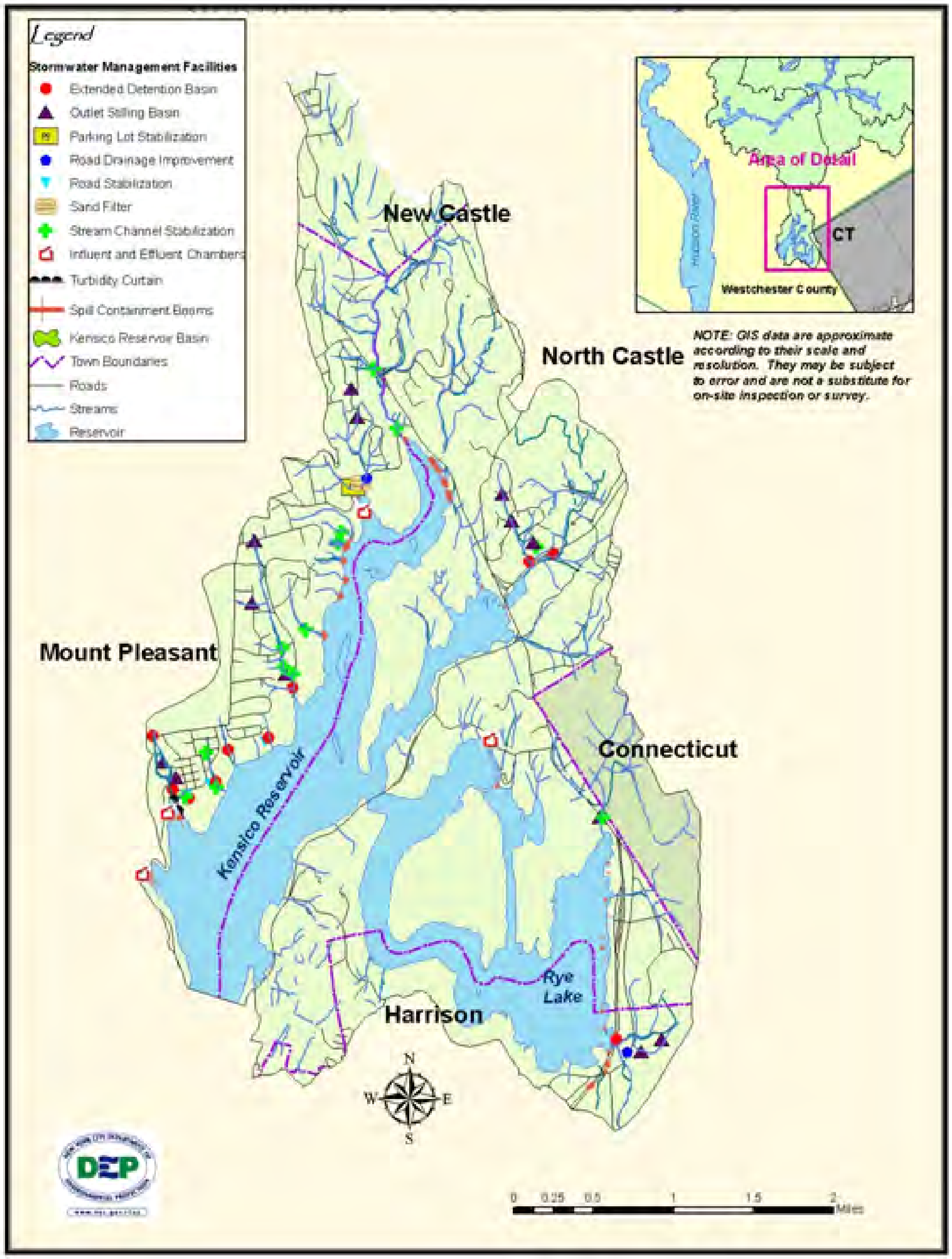

Figure 1.1 Location of stormwater management facilities in Kensico Reservoir.

DEP updated the scope of the next 3-year maintenance contract and the new contract was in place in August 2008. Repairs and maintenance activities during 2009 are described in Table 1.2.

Table 1.2. Kensico stormwater and erosion abatement facility construction and completion schedules and maintenance activities.

Basin	Facility Number and Type	Construction Dates	2009 Maintenance Activities
Malcolm Brook	2, extended detention basin	11/21/00	Weed whacked , debris removal, sediment removal forebay (2CY), seed and hay
	4, stilling basins	8/31/99 9/13/99	
	8, drop pipe, velocity dissipation box, outlet stabilization	6/14/99 8/20/99	Remove/dispose of unwanted vegetation
	12, extended detention basin	4/12/99 11/5/99	Weed whacked 3 trees removed Sediment removal upstream (110CY)
Young Brook	13, extended detention basin	3/29/99 11/5/99	Sediment removal (1CY), debris removal (1CY), weed whacked
Young Brook	14, 15 Road, outlet, and channel stabilization	3/29/99 11/5/99	
N2	16, outlet stabilization	10/27/99 10/27/99	
N2	18, 19, 20, extended detention basin, and road, outlet, and channel stabilization	9/28/99 9/14/00	Weed whacked
N3	2A, extended detention basin	10/12/99 9/14/00	Weed whacked
N4	23, 24, extended detention basin and road stabilization	12/22/99 9/14/00	Weed whacked, debris removal, sediment removal (42CY), remove clog in outlet pipe
N5	37, 39, and 40, extended detention basin, road stabilization, and channel stabilization	3/27/00 9/14/00	Weed whacked, BMP 40 sediment removal (1CY) BMP 37 – Debris removal multiple times, sediment removal forebay (40CY)
N5	5A, drop pipe, manhole and stabilized outlet	3/27/00 4/25/00	
N5	35, outlet stabilization	5/24/00 5/25/00	
N5	34, stream channel stabilization	5/23/00 5/23/00	
N5	31, stream channel stabilization	10/25/99 11/22/99	
N5 tributary	28, outlet and stream channel stabilization	10/25/99 10/25/99	Weed whacked, debris removal (13CY), seed and mulch

Table 1.2. (Continued) Kensico stormwater and erosion abatement facility construction and completion schedules and maintenance activities.

Basin	Facility Number and Type	Construction Dates	2009 Maintenance Activities
N5	25, outlet stabilization	10/25/99 11/12/99	
N6	41, stream channel stabilization	12/8/99 12/28/99	Sediment removal (1CY), debris removal (1CY)
Bear Gutter	63, outlet stabilization	4/5/00 4/5/00	
Bear Gutter	64, outlet stabilization	5/26/00 5/26/00	
Bear Gutter	65, outlet stabilization	5/27/00 5/27/00	Debris removal (1CY)
Bear Gutter	66, extended detention basin	4/24/00 9/14/00	Weed whacked
Bear Gutter	67, extended detention basin	6/7/00 11/8/00	Weed whacked
Bear Gutter	8A, stream channel stabilization	4/18/00 4/20/00	
N8	43, stream channel stabilization	12/3/99 4/3/99	
N9	44, stream channel stabilization	4/18/00 4/18/00	
N12	7A, outlet stabilization	11/16/99 11/17/99	Sediment removal (4 CY)
N12	47, outlet stabilization	11/17/99 11/18/99	Sediment removal (3CY)
N12	57, sand filter 58, road drainage improvements 59, parking area stabilization	1/11/00 12/15/00 (57) 8/2002 (58 & 59)	Weed whacked, debris removal (4CY) Sand filter – sediment removal (8CY)
Whip	60, stream channel stabilization	12/1/99 12/3/99	
Whip	61, stream channel stabilization	11/29/99 12/3/99	
E9	68	4/10/00 4/10/00	Sediment removal (5CY), debris removal
E9	68A	5/1/04 11/28/04	
E11	70, outlet stabilization	4/6/00 4/7/00	

Table 1.2. (Continued) Kensico stormwater and erosion abatement facility construction and completion schedules and maintenance activities.

Basin	Facility Number and Type	Construction Dates	2009 Maintenance Activities
E11	71, outlet stabilization	4/7/00 4/7/00	Sediment removal (1CY)
E11	74, 75	11/6/00 11/28/04	Weed whacked, sediment removal (6CY)
Turbidity curtains			New curtain sections added from station 0+00 through 5+50, new anchors and cable added. New 1,000 ft. secondary turbidity curtain

Figure 1.2 Accumulated sediment being removed at BMP 37.

1.1.2 Spill Containment Facilities

DEP installed, and now maintains, spill containment facilities around Kensico Reservoir (see Figure 1.3). The facilities improve spill response, cleanup, and recovery, thereby minimizing water quality impacts in the event of a spill. In 2009, DEP continued to maintain the 39 spill containment facilities installed at the outlets of 26 storm drains along Interstate 684 and Route 120 (see Figure 1.4).

Although no spills have been reported on Interstate 684 or the roads surrounding Kensico since the booms were installed, the booms have functioned as designed. Temporary booms were located at the end of the boat ramp that can encircle the ramp in the event of a spill. No spills or discharges occurred, nor was boom deployment required.

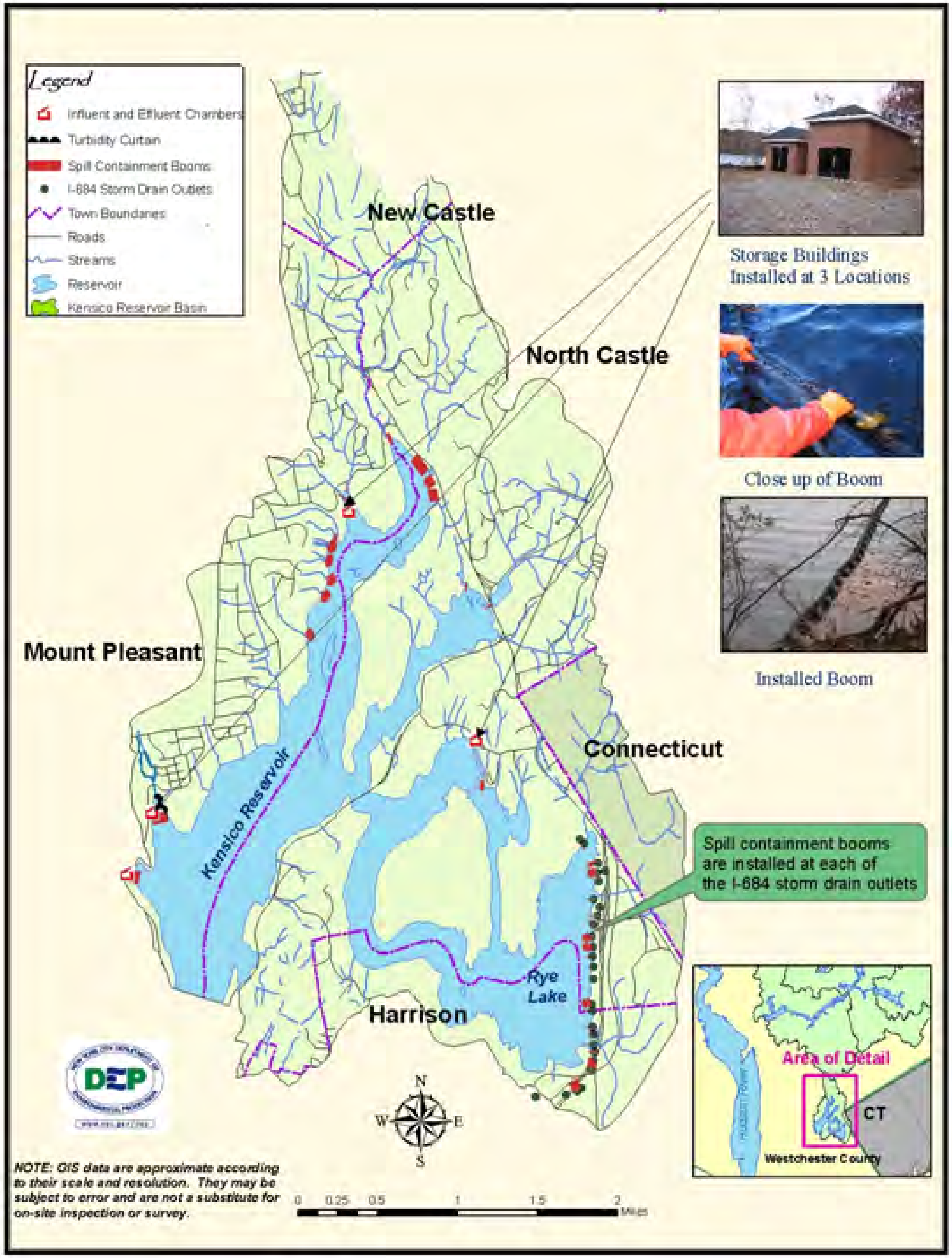

Figure 1.3 Spill containment facilities in Kensico Reservoir.

Figure 1.4 Kensico spill boom - Site 11.

1.1.3 Turbidity Curtain

Along with the existing 1100-foot-long turbidity curtain in the reservoir between the Catskill Upper Effluent Chamber and Malcolm and Young Brooks, a new 1000-foot -long turbidity curtain was installed as a backup. This primary and secondary turbidity curtain system has effectively deflected discharges from the two watercourses away from the effluent chamber. In 2009, DEP monitored the extended turbidity curtain, and performed the following maintenance tasks:

- November 2009 – A diving inspection was performed which generated a list of curtain sections requiring removal and replacement.
- November 2009 – 11 degraded curtain sections were removed and 11 new replacement curtain sections added. In addition, new stainless steel cables were added to the turbidity curtain.

1.1.4 BMP Monitoring

DEP has conducted sampling at selected Kensico BMPs. The goal of the monitoring was to quantify the fecal coliform, total suspended solids, and total phosphorus load reductions that can be attributed to four extended detention basins and one sand filter constructed within Kensico catchments. Sampling began in 2000 and was continued through 2007. Detailed findings of the BMP monitoring can be found in Section 4.6 of this report.

1.2 Kensico Action Plan

In early 2006, DEP initiated the development of the Kensico Action Plan in an effort to build on the successful watershed management and protection strategies within the Kensico basin. In March 2006, DEP retained HDR/LMS Engineering Inc. to complete the Kensico Action Plan.

Following submittal of the Kensico Action Plan in August 2007, DEP evaluated the four proposed pollution remediation practices: 1) a pipeline system and engineering stormwater practice at N7, 2) an extended detention basin at N12, 3) stream stabilization at Whippoorwill, and 4) drainage improvements along West Lake Drive in order to enhance the performance of BMPs 12 and 13. Based on the evaluation of the projects, DEP determined in December 2007 to move forward with the implementation of all four of the projects and provided an implementation schedule.

During 2008, DEP reviewed the completed project specifications that were submitted by the design consultant. Design and contract documents were finalized and received legal review and approval. The first bid opening occurred in January 2009. However, the project needed to be re-bid due to inadequate bids. DEP re-bid the project in April 2009 and selected a contractor. The selected contractor withdrew his bid in July 2009. DEP will bid the construction contract again once all permits are secured.

DEP secured all the necessary town permits in 2009. DEP was required to submit a separate permit application for each of the four sites. Additionally, the Whippoorwill site required permitting from the Town of Mt. Pleasant and the Town of North Castle. DEP submitted the necessary permit applications to the U.S. Army Corps of Engineers in October 2009. The approval of these permits will complete the permitting process.

1.3 West Lake Sewer

The Westlake Sewer Trunk Line, owned and maintained by the Westchester County Department of Environmental Facilities (WCDEF), conveys untreated wastewater to treatment facilities located elsewhere in the county. Given the proximity of the collection system to Kensico Reservoir, potential defects or abnormal conditions within the sewer line and its components could lead to exfiltration or overflows of wastewater. The intent of this program is to work with the County to mitigate risks posed by the line while maintaining the collection system's location and gravity flow.

1.3.1 Sanitary Sewer Remote Monitoring System

DEP has proposed a sanitary sewer remote monitoring system for the West Lake Trunk Sewer, the purpose of which is to provide a real-time detection of problem events such as leaks or system breaks, overflows and blockages, which allows for a quick response to such problems. During the reporting period, DEP, the Director of Maintenance for the Westchester County Department of Environmental Facilities (WCDEF) and Westchester County legal counsel established a project scope of work and a draft inter-municipal agreement (IMA). The IMA contains language that requires WCDEF to provide the contracting services for installation, monitoring, and maintenance of the system. The IMA will establish a procurement process for reimbursement of capital expenses to Westchester County.

1.3.2 Sewer Line Visual Inspection

DEP conducts an annual visual inspection of the trunk line in order to assess the condition of exposed infrastructure, including manholes, for irregularities. The annual full inspection was performed in November 2009. Partial inspections were conducted throughout the year in association with ongoing routine maintenance of Kensico stormwater best management practices in the vicinity of the line. No defects or abnormalities were noted.

1.4 Video Inspection of Sanitary Sewers

Under the 2007 FAD, DEP will establish a recurring inspection program for select portions of the sanitary sewer system located within the Kensico basin. This effort will be completed under the same contract for the inspection and cleaning of the sanitary infrastructure contained within the EOH Cat/Del reservoir basins. The area that will be targeted includes several possible areas of concern that were identified during the prior video inspection of sanitary infrastructure in the Kensico basin.

1.5 Septic Rehabilitation Reimbursement Program

DEP initiated the Kensico Septic System Rehabilitation Reimbursement Program in order to reduce the potential water quality impacts that might occur through failing septic systems. The program provides funding to reimburse a portion of the costs to rehabilitate eligible failing septic systems or connect those systems to an existing sewage collection system. The program is voluntary, with the goal of encouraging property owners to have their septic systems inspected, and if failing, rehabilitated. DEP is rolling out the program in three priority phases, with those properties located closest to Kensico Reservoir and watercourses given higher priority (see Figure 1.5).

In 2008, DEP entered into an agreement with the New York State Environmental Facilities Corporation (EFC) to assist in implementing the program. In April 2009, EFC sent mailings to the 178 residents located in the Phase I priority area, which includes all residential properties thought to be served by an on-site wastewater system and located within 500 feet of a reservoir or reservoir stem or 100 feet of a watercourse. The letters notified residents of their eligibility for funding and provided a brief program overview. The mailing also included a response card that provides DEP with additional information on the status of the on-site wastewater system.

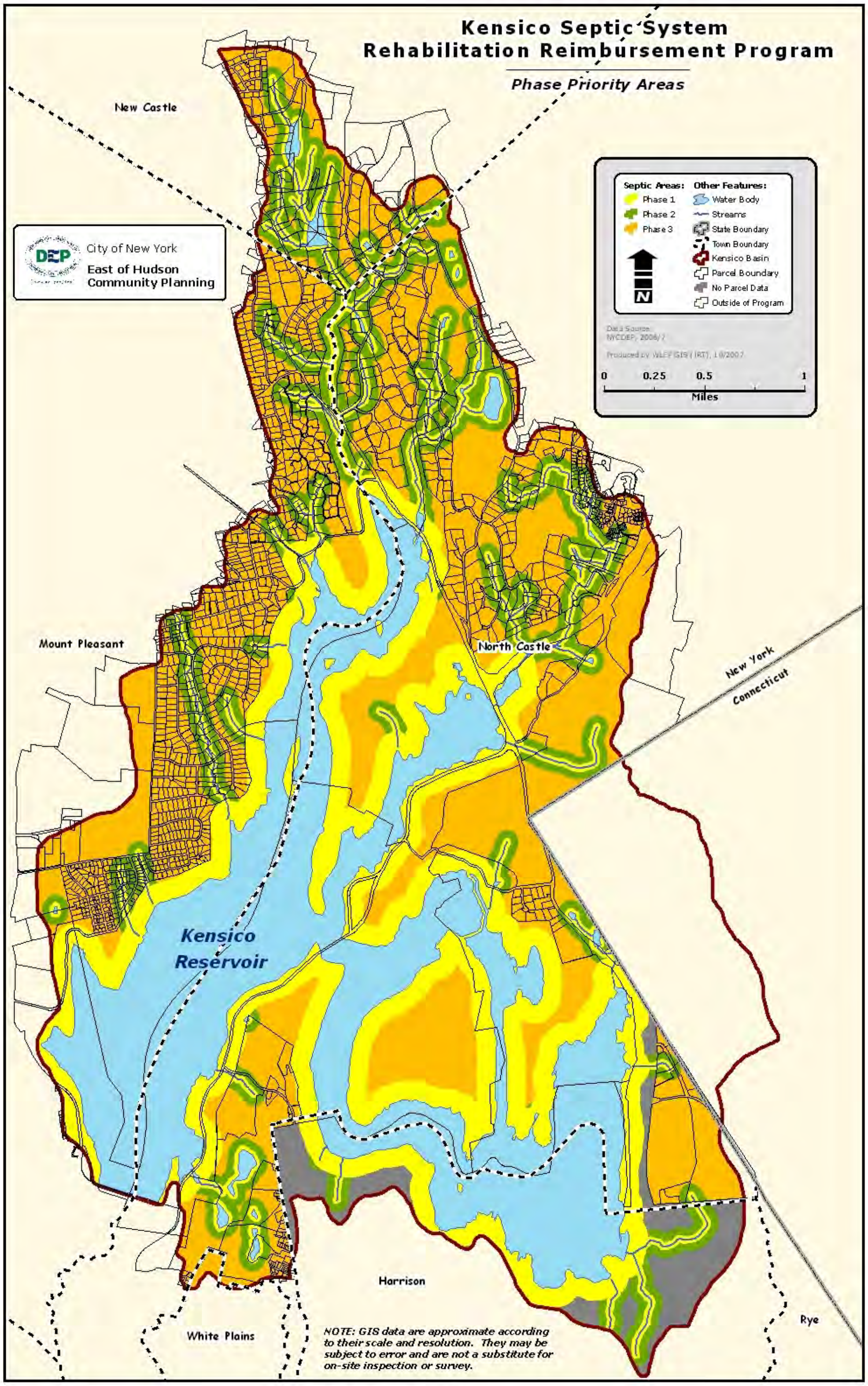

Figure 1.5 Kensico Reservoir Septic Program priority areas.

In October 2009, EFC mailed initial notification letters and response cards to 147 residents located in the Phase II priority area, which includes all residential properties located between 100 feet and 300 feet from a watercourse. At that time, EFC also mailed a follow-up notification to Phase I residents that did not respond to the April mailing.

Using data received from the mailing responses, DEP updated its database of parcels that are served by a municipal sewer system and not an on-site wastewater system. Additionally, several residents requested additional information about the program. For those residents that indicated they did not know the status of their system and/or requested additional information, EFC followed up with a telephone call and forwarded additional program information via mail.

DEP intends to mail initial notification letters to those residents in the Phase III priority area in Spring 2010. This priority area includes all the remaining residential properties in the Kensico basin that are thought to be served by on-site wastewater treatment systems. In addition, DEP continues to update its GIS database of sewage service status based on the responses received by residents.

1.6 Turbidity Reduction

The Catskill Upper Effluent Chamber (CATUEC) is situated along the shore of a cove in the southwest section of Kensico Reservoir. The shoreline of this cove trends north to south, so that CATUEC faces east into the cove. The cove then extends south and east into the main basin of the reservoir. Water from Kensico Reservoir enters CATUEC and is transported to the Catskill Lower Effluent Chamber (CATLEC) where Kensico Reservoir's Catskill Lower Effluent Chamber (CATLEFF) monitoring site is located. When wind velocities are sufficient to create wave action on the shoreline in the cove near CATUEC, sediment in this area may become resuspended and entrained into the Kensico Reservoir effluent that enters CATUEC, resulting in a short-term rise in turbidity values measured at CATLEFF.

DEP determined that a shoreline stabilization project south of the chamber would be implemented to mitigate the erosion and possible resuspension of near-shore materials that may contribute to turbidity at CATUEC during wind events. Design of the shoreline stabilization project has been assigned to Malcolm Pirnie and Gannett Fleming. Design work commenced in the first half of 2008.

DEP considered several options for implementing the stabilization project, including combinations of geotextiles, rip rap, and proprietary products. After review of each alternative, DEP determined that rip rap would be the best material for stabilization and that a coffer dam would be the best means to dewater the work area adjacent to the shoreline during installation. The final design was completed in December 2008.

During the reporting period, DEP spent significant time securing the necessary permits for the installation of the project. The Site Plan Approval package and Stormwater Pollution Prevention Plan were submitted to the Town of Mt. Pleasant in August 2009. All Town permitting approvals are dependent on the SEQRA Negative Declaration, which is dependent upon the USACE's approval of the Wetland Mitigation Plan. The Wetland Mitigation Plan for the shoreline stabilization has been incorporated under the KAP Wetland Mitigation Plan. The joint permit application was submitted in August 2009 and a Conceptual Wetland Mitigation Plan was submitted in December 2009.

1.7 Route 120

During the 2009 reporting period, there was no activity on the New York State Department of Transportation proposal for resurfacing I-684 and constructing stormwater treatment basins in the I-684 median from just south of the new Lake Street overpass in New York northward to the bridge over Tamarack Swamp in Connecticut. Due to a pending permit requirement from Connecticut, it is now anticipated that this project, which is a portion of the overall corridor project known as Routes 120 and 22/Exits 2 and 3 on I-684/Old Post Road, will begin in 2010.

1.8 Westchester County Airport

The Westchester County Airport is located east of Kensico Reservoir in close proximity to Rye Lake. As such, DEP continues to review any activities that are being proposed at the airport. Two projects were still pending in 2008. At this time, DEP has not identified serious concerns with the proposals. The activities include the following:

- The relocation of the north perimeter road away from the northern end of Runway 16-34, and the removal of a portion of the existing north perimeter road. The north perimeter road will be relocated to increase safety at the north end of the runway, pursuant to FAA runway safety requirements. This project received Stormwater Pollution Prevention Plan approval in October 2009.
- Proposed improvements to the existing terminal area aircraft deicing system and related improvements. This proposal was initially part of a larger overall Airport Layout Plan modification, now being considered a separate project as requested by the Westchester County Planning Department. There was no new activity in 2009. A delay in obtaining federal grants to fund this project is contributing to project delays.

Part II - 2009 Kensico Water Quality Annual Report

Prepared in accordance with Section 4.1.0 Kensico Water Quality Control Program of the New York City Filtration Avoidance Determination, July 2007 and New York City's December 2006 Long-term Watershed Protection Program

This report fulfills the FAD requirement to provide water quality data to complement the information on program implementation.

Executive Summary

The 2007 Filtration Avoidance Determination (Section 4.10 Kensico Water Quality Control Program) requires DEP to produce an annual report that includes a presentation, discussion, and analysis of monitoring data (e.g., keypoint, reservoir, stream, BMPs). For the 2009 report, DEP must also report on the findings of the Stormwater BMP Monitoring Study that occurred from 2000-2007. This part of the report satisfies that requirement by analyzing and discussing ongoing water quality data collections as well as any departures from routine operations. Compliance with the Safe Drinking Water Act's Surface Water Treatment Rule is of paramount importance to DEP for maintaining Filtration Avoidance; therefore, fecal coliform and turbidity are focal points of the discussion. DEP's ongoing Waterfowl Management Program, which has been instrumental in keeping coliform bacteria concentrations low, is also described. Other sections include information regarding the protozoan pathogens *Cryptosporidium* and *Giardia*, and human enteric viruses.

The Waterfowl Management Program (WMP) continued to maintain a high level of success during 2009. This was demonstrated by full compliance with the SWTR requirements for fecal coliform bacteria in raw water samples, which is only possible when resident and migratory waterfowl populations are minimized. Low levels of fecal coliform bacteria have been consistently achieved since 1993. The implementation of the WMP continues to be the most cost-effective way to achieve compliance with the SWTR.

In 2009, Kensico Reservoir experienced a taste and odor event. Taste complaints began in early October 2009, and it was determined that the alga *Chrysosphaerella* in Kensico was the likely source of this taste problem. All water quality testing confirmed that, despite the unusual taste, the water was safe to drink. The Delaware Aqueduct was changed from its normal reservoir mode to float mode on Oct. 8, 2009, sending water from Rondout Reservoir directly to distribution. On November 19, 2009, Kensico Reservoir water began to be blended back into the Delaware Aqueduct as the bloom subsided. The aqueduct was put back on full reservoir mode on November 30, 2009.

DEP continued to meet its reporting obligations for engineering and scientific reports as specified in the SPDES permit for the use of alum. In addition, DEP has provided DEC and DOH with a monthly progress report, since October 2005, on the investigations conducted to finalize the construction contract for the project. In 2009, DEC responded to DEP with a request for a joint habitat assessment/evaluation to identify unidentified potential impacts to fisheries and the status of the reservoir's aquatic ecosystems and factors which are affecting it.

As in the past, DEP conducted visual inspections of the turbidity curtain at the Catskill Upper Effluent Chamber cove in 2009. The boom only required one instance of maintenance on September 10, 2009, and this was promptly performed.

There was one special investigation conducted within the Kensico Reservoir watershed during 2009. On June 3, 2009, a tractor trailer travelling southbound on Interstate 684 jackknifed and spilled 55 gallons of diesel fuel near the reservoir. DEP determined that the spill was well contained and reservoir water quality was not endangered. DEP HazMat reported that Tri-State Environmental removed the contaminated soil and replaced it with fresh topsoil. The investigation was then closed without incident.

Con Edison ("ConEd") maintains an electric transmission corridor that traverses 2.1 miles of land in the Kensico Reservoir drainage basin along the western shore of the reservoir. ConEd approached DEP in the summer of 2009 to request permission to remove trees along the corridor to increase the reliability of the electric system per their maintenance plan filed with the New York State Public Service Commission. DEP granted approval to ConEd, and tree removal work began in December 2009, with completion scheduled for the first quarter of 2010.

Kensico Reservoir water quality monitoring that was conducted in 2009 included approximately 6600 samples collected at 74 sites throughout the basin, with the highest intensity of monitoring at the effluent keypoint sites. The next most intensely sampled sites were those located throughout the reservoir itself. Grab samples were taken at the effluent keypoint sites 730 times and in the reservoir 468 times. In addition, 310 pathogen samples were analyzed for *Cryptosporidium* and *Giardia*, and another 212 samples were collected for human enteric viruses (HEV).

In 2009, DEP continued to receive and review results of ongoing sampling of Westchester County Airport groundwater monitoring wells by Westchester County DOT as a matter of routine surveillance. The parameters analyzed were volatile, semivolatile, and non-halogenated organic compounds, and metals. In general, most analytes were below their respective detection limits, except for propylene glycol in the winter months only. One of the uses of propylene glycol is deicing of airplanes. Given that these sampling locations are within the vicinity of the airport, airplane deicing activities are the likely source of this chemical in groundwater.

The annual surveillance of Kensico Reservoir keypoints DEL18 and CATLEFF for 67 volatile organic compounds (VOCs) and 68 semivolatile organic compounds (SVOCs) resulted in no compounds being detected.

DEP continues to monitor the hydrology of the Kensico watershed. Samples were collected monthly at eight fixed sampling sites to quantify water quality at each of the perennial streams (BG9, E10, E11, E9, MB-1, N12, N5-1, WHIP). All Kensico streams had median fecal coliform values less than 200 CFU $100mL^{-1}$. For total coliform bacteria, five values of more than 5000 CFU $100mL^{-1}$ all occurred when at least 0.75 inches of precipitation had fallen within the week before the sample date. This was the fewest number of exceedances for a year above the 5000 CFU $100mL^{-1}$ benchmark that have been reported for the Kensico streams. The median turbidity data for all stream sites was less than 5 NTU, except E9 (median = 5.6 NTU).

In 2009, 366 total coliform and 373 fecal coliform bacteria samples were collected throughout Kensico Reservoir for total and fecal coliform analyses. The medians for total and fecal coliform samples were below their respective DEP guidelines of 100 CFU 100mL^{-1} and 20 CFU 100mL^{-1}, respectively. As in previous years, there were several times when total coliform concentrations exceeded the guideline, typically in late summer and autumn when most reservoirs experience an increase in bacteria counts. There were no instances where fecal coliform samples exceeded the DEP guideline. Turbidity did not exceed 5 NTU in any of the 418 samples collected. As in the past, Site 5 near the Catskill Influent had the highest median turbidity (1.7 NTU) of the eight sites. At the sites closest to the effluent chambers (sites 2 and 3), the turbidity was less than 2.0 NTU for all routine samples.

Additional limnological surveys conducted in 2009 were related to a shutdown of the Catskill Aqueduct on April 20, and during two Rondout-West Branch Tunnel shutdowns (November 5-15 and December 4-16), including the associated operation of the Croton Falls Pump Station (CFPS). Additional surveys were also conducted in response to taste complaints by drinking water consumers. One special survey for turbidity was conducted when a storm caused increased turbidity levels in the Ashokan Reservoir and the Catskill Aqueduct. Consequently, water with high turbidity was observed at CATUEC and CATLEFF on April 20 and 21. The Catskill Aqueduct was shut down and Kensico effluent water quality was closely monitored during this turbidity alert.

DEP routinely conducts water quality compliance monitoring at the four aqueduct keypoints at Kensico Reservoir. The CATALUM and DEL17 influent keypoints represent water entering Kensico Reservoir from the NYC upstate reservoirs via the Catskill and Delaware Aqueducts, respectively. The CATLEFF and DEL18 effluent keypoints represent Kensico Reservoir water entering the Catskill and Delaware Aqueducts, respectively, at points just prior to disinfection, and are the sites which must meet SWTR regulations.

The 2009 median fecal coliform level for 2009 at the Kensico influents (CATALUM and DEL 17) and the effluents (CATLEFF and DEL18) was 1 CFU 100mL^{-1} for all four Kensico keypoint sites. In 2009 there was only one reported value at the effluent sites that exceeded the 20 CFU 100mL^{-1}guideline. A value of 30 CFU 100 mL^{-1} was reported at DEL18 on April 27, following three successive days of rain. At the influent sites, median turbidity for 2009 was 2.00 NTU at CATALUM and 0.80 NTU at DEL17. At the effluent sites, median turbidity for 2009 was 0.80 NTU at CATLEFF and 0.90 NTU at DEL18. The maximum 4-hour turbidity measurements were 3.60 NTU at CATLEFF and 3.10 NTU at DEL18. Thus, the SWTR limit of 5 NTU was consistently met at both effluent keypoints.

In addition to coliform bacteria, turbidity, and pathogens, DEP also monitors the perennial streams for other analytes, including temperature, pH, specific conductivity, alkalinity, dissolved oxygen, chloride, total suspended solids, and nutrients. Descriptive statistics of the 2009 results for these analytes are presented.

DEP is responsible for performing compliance and surveillance monitoring of protozoan pathogens (*Cryptosporidium* and *Giardia*) and human enteric viruses (HEV) in the New York City Watershed. In 2009, 304 samples were collected and analyzed for *Giardia* and *Cryptosporidium* in the Kensico Reservoir watershed. This includes 208 fixed frequency samples collected at the two influents and two effluents, as well as 96 fixed frequency samples collected at eight perennial tributaries. In addition, 212 samples were collected and analyzed for human enteric viruses (HEV). In general, 2009 results were consistent with past data in that *Cryptosporidium* was found infrequently and at low concentrations, and *Giardia* were found more frequently and at higher concentrations than *Cryptosporidium.* Although some of the volumes varied per sample, no more than 3 oocysts were detected in any of the streams, no more than 2 oocysts were detected at the influents, and no more than 1 oocyst was detected at either of the effluent sites in 2009. *Giardia* was more variable and found at higher levels, with a reservoir influent maximum of 7 cysts $50L^{-1}$ and an effluent maximum of 8 cysts $50L^{-1}$.

The findings for the sampling of the BMPs installed on streams tributary to Kensico Reservoir are presented. The sampling began in 2000 and concluded in 2007. The results of this study suggest that the BMPs do indeed provide a reduction in total suspended solids, turbidity, and total phosphorus load, according to their design, hence providing an improvement to water quality compared to what would be the case were BMPs not present. In addition, the loading results indicate some degree of reduction in fecal coliform loads, depending on initial load and size and intensity of the storm, provided it is a storm within the design of the BMP.

Finally, 2009 was the first year of a three-year effort, performed under contract by the Upstate Freshwater Institute (UFI), to deploy, operate, and maintain a robotic monitoring network on portions of the NYC system of reservoirs, including Kensico Reservoir. In Kensico, the robotic network consists of a profiling buoy manufactured by YSI, Inc. and two fixed-depth buoys developed by UFI. The profiling buoy is located in the Catskill influent arm of the reservoir. The fixed-depth buoys are located near the Delaware (Station 2) and Catskill (Station 3) effluent chambers. Data are automatically downloaded at least every three hours. Once the robotic monitoring equipment has been thoroughly tested, it is expected to provide new insights and water quality management opportunities based on high frequency measurements that are not otherwise available. These data will be used as model input (initial conditions) and to evaluate reservoir water quality model performance.

1. Introduction to Kensico Streams, Reservoir, and Keypoint Monitoring Data

Section 4.10 (Kensico Water Quality Control Program) of the 2007 Filtration Avoidance Determination calls for semiannual reporting on the implementation of Kensico protection programs. On an annual basis, a report must also be prepared that includes a presentation, discussion, and analysis of water quality monitoring data (e.g., data relating to keypoints, reservoirs, streams, BMPs) as well as the status and application of the Kensico Reservoir model. Part II of this report fulfills that requirement.

The role of Part II of the report is to analyze and discuss ongoing water quality data collections in order to assess the efficacy of protection programs and improve management operations if possible. Compliance with the Safe Drinking Water Act's Surface Water Treatment Rule is of paramount importance to DEP for maintaining Filtration Avoidance; therefore, fecal coliform and turbidity are focal points of the discussion. DEP's ongoing Waterfowl Management Program, which has been instrumental in keeping coliform bacteria concentrations low, is also described. Other sections include information regarding the protozoan pathogens *Cryptosporidium* and *Giardia*, and human enteric viruses. The Kensico Water Quality Control Program is designed to reduce fecal coliform, toxic chemicals, and turbidity in Kensico Reservoir.

When operated in its normal "on-reservoir" mode, water enters Kensico Reservoir at the Catskill Influent Chamber (CATIC) and at Delaware Shaft 17 (DEL17), and leaves the reservoir at the Catskill Upper Effluent Chamber (CATUEC) and Delaware Shaft 18 (DEL18). Water can also be diverted through bypass tunnels for water quality or maintenance purposes. In 2009, normal operations were interrupted on several occasions, as described below.

Taste complaints that began in early October 2009 were traced to an algal bloom in Kensico Reservoir (see section 2.2 for more details). The Delaware Aqueduct was changed from its normal reservoir mode to float mode on October 8, 2009, sending water from Rondout Reservoir directly to distribution. On November 19, 2009, Kensico Reservoir water began to be blended back into the Delaware Aqueduct as the bloom subsided. The aqueduct was put back on full reservoir mode on November 30, 2009.

The Rondout-West Branch section (RWBT) of the Delaware Aqueduct was shut down for repairs at Shaft 6 from November 5–15 and again from December 4–16, 2009. To supplement the water supply during the shutdown of the RWBT, the Croton Falls Pumping Station was activated from December 5–28, 2009.

Finally, there were several nighttime shutdowns of the Delaware Aqueduct between Kensico Reservoir and Hillview for maintenance. The periods were May 5–12, May 19–23, May 26–30, June 2–6, September 21–26, and September 28–October 8, 2009. The Catskill Aqueduct between Kensico and Hillview was shut down for inspections on June 10 and September 16.

It should also be noted that the SPDES permit for DEL17, which took effect March 1, 2005, and sets the requirements for DEP to discharge waters from the Delaware Aqueduct into Kensico Reservoir, was revised on September 17, 2009, to incorporate a total phosphorus (TP) load limit to comply with the Kensico TMDL.

2. Water Quality Management

2.1 Waterfowl Management

Figure 2.1 Daily waterbird dispersal activities.

DEP's Wildlife Studies Section is responsible for oversight of the Waterfowl Management Program (WMP), while program implementation is the responsibility of a consultant, Henningson, Durham, and Richardson, P.C. The most recent Waterfowl Management Program Contract (WMP-08) was awarded and commenced on August 1, 2007, and is expected to continue through the end of July 2010. For a more detailed account of the WMP, refer to the annual FAD report on this topic dated July 31, 2009 (required under section 4.1 of the FAD).

The objectives of the WMP are:

- Survey and record daily waterbird counts from 0500 to 0800 hours, including spatial and temporal distribution of roosting waterbirds, and document behavioral changes of the birds from August 1 through March 31. Survey frequency is decreased to weekly from April 1 through July 31. All morning surveys are conducted from a boat and/or the shoreline. The morning survey data are used to evaluate the success of the previous day's bird harassment efforts. The bird data are also compared with reservoir water quality data to assess the impacts of birds on fecal coliform bacteria levels, which are monitored for the Surface Water Treatment Rule (SWTR).
- Conduct daily waterbird dispersal activities from 0800 hours until 1.5 hours past sunset from August 1 through March 31. Dispersal activities include harassment via motorboat, Husky Airboat, pyrotechnics, and broadcasting of bird distress tapes where needed.
- Record daily surveillance of water influent facilities for alewives (*Alosa pseudoharengus*), a baitfish. Dead and dying alewives transported through the NYC aqueducts from upstream reservoirs to Kensico attract waterbird foraging. To eliminate this feeding attraction, containment booms are used to collect the fish. Baitfish deterrent measures are being investigated to prevent the transport of alewives from Ashokan Reservoir to Kensico.
- Install avian deterrent netting at Delaware Shaft 18 to deter cliff swallows and barn swallows from nesting near the water intake. This was completed during the spring of 2009.

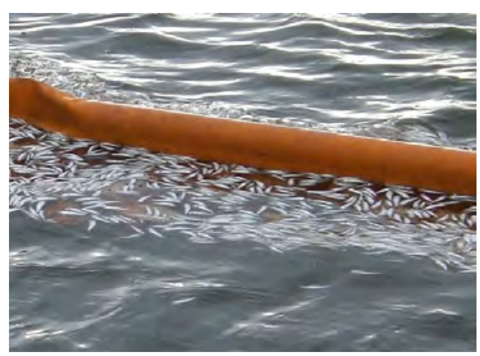

Figure 2.2 Dead alewives collected by boom at Kensico Reservoir.

Additional waterbird management measures employed annually during spring months include the following:

- Depredation of eggs and nests of Canada Geese (*Branta canadensis*) and Mute Swans (*Cygnus olor*), shown in photos below (Figure 2.3), under federal and state permits, from April through June annually.

Figure 2.3 Depredation of eggs and nests of Canada Geese (*Branta canadensis*) and Mute Swans (*Cygnus olor*).

- Meadow management, including maintenance of shoreline fencing to discourage nesting geese from occupying the area around Delaware Shaft 18, as well as maintenance of a meadow-like field to eliminate mowed lawns, which attract goose foraging.
- Annual banding activities conducted with DEC. These activities involve placing identification bands on Canada Geese and Double-crested Cormorants (*Phalacrocorax auritus*) in order to monitor local movements to and from the reservoirs.
- Use of similar management measures at six additional reservoirs on an "as needed" basis as outlined in the 2007 FAD. These additional reservoirs include five which are upstream source waters (or potential source waters) to Kensico (Rondout, West Branch, Ashokan, Croton Falls, and Cross River), and one downstream reservoir (Hillview), which receives water from Kensico.

The WMP continued to maintain a high level of success during 2009. This was demonstrated by full compliance with the SWTR requirements for fecal coliform bacteria in raw water samples, which is only possible when resident and migratory waterbird populations are kept at low levels. These low levels of fecal coliform bacteria have been consistently achieved since 1993. The implementation of the WMP continues to be the most cost-effective way to achieve compliance with the SWTR.

2.2 *Chrysosphaerella* Taste and Odor Management

DEP began to receive complaints from NYC residents of a metallic taste in the drinking water on October 2, 2009. Initial investigations by Distribution Water Quality Operations and by Watershed Water Quality Operations determined that the alga *Chrysosphaerella* in Kensico Reservoir was the likely source of this taste problem. All water quality testing confirmed that, despite the unusual taste, the water was safe to drink. The Bureau of Water Supply (BWS) responded to this taste issue by placing the Delaware Aqueduct in a partial by-pass mode, thereby operationally circumventing Kensico Reservoir and delivering mostly Rondout Reservoir and West Branch Reservoir water directly to the distribution system. This by-pass operation began on October 8, 2009, and continued for 52 days until November 29, 2009, when BWS began to bring Kensico Reservoir back on-line. Kensico Reservoir and its aqueduct keypoints were intensively monitored during this period to assist in managing this water quality issue. The report, "Response to an Increase in Metallic Taste Complaints in New York City Drinking Water" (DEP 2010a, in progress), provides a full description of BWS's investigation, enhanced monitoring, and response actions to this increase in water taste complaints from NYC consumers.

2.3 Alum Dredging Status

In April 2005, several heavy rain events were experienced in upstate New York, creating record flooding which in turn led to extensive erosion of streambanks and channels throughout the Catskill System and a significant increase in turbidity in water entering the Catskill Aqueduct at Ashokan Reservoir. DEC issued a SPDES permit to allow DEP to add aluminum sulfate (alum) to coagulate the suspended solids in Catskill water entering Kensico Reservoir during this period of high turbidity. The SPDES permit, issued on December 20, 2006, includes a condition that DEP remove the resulting alum floc, including the entrained solids, from Kensico Reservoir. Through competitive bidding, DEP will procure the services of a dredging contractor to remove the floc from the reservoir in the vicinity of the Catskill Influent Chamber (CATIC), where water from the Catskill Aqueduct enters Kensico Reservoir.

Hydraulic dredging and mechanical dewatering, with disposal of the resultant concentrated cake at an offsite location, has been determined to be the best method at this time. The scientific investigations of the area of floc deposition were completed in 2007. DEP and the design consultants at Malcolm Pirnie, Inc., submitted reports to DEC in October 2007 detailing the bathymetric, benthic, core sampling, computer modeling, and flow study findings.

After reviewing all of the scientific data, DEC requested additional clarification. DEP submitted a supplemental report to DEC dated December 2007 on the "Extent and Depth of Alum Floc in Kensico Reservoir". In June 2008 DEC requested modifications to the DEP Dredging Plan and clarification. DEP and Malcolm Pirnie procured the services of an independent third party expert to review all scientific data collected during the investigation of the alum floc deposition in Kensico Reservoir. In September 2008 DEC was sent a supplemental technical report on the “Impacts of Dredging the Estimated Area of Alum Floc Deposition in Kensico Reservoir”. This report included the conclusions of the independent third party expert. In July 2009 DEC responded to DEP with a request for a joint habitat assessment/evaluation to identify unidentified potential impacts to fisheries and the status of the reservoir’s aquatic ecosystems and factors which are affecting it. A decision on next steps is pending further discussion between DEP and DEC. DEP, Malcolm Pirnie, and Arcadis US, Inc., have initiated a Constructability Analysis for the proposed dredging.

In addition to the engineering and scientific reports specified in the SPDES permit, DEP has provided DEC and DOH with a monthly progress report, since October 2005, on the investigations conducted to finalize the construction contract for the project. The Environmental Review for SEQR and the required permitting process have also been initiated. Contract documents were completed in 2007 and have undergone NYC legal review.

2.4 Turbidity Curtain Monitoring

DEP’s Water Quality Directorate conducts visual inspections of the turbidity curtain at the Catskill Upper Effluent Chamber cove (Figure 2.4). Table 2.1 lists the dates and results of the turbidity curtain inspections carried out in 2009. If an observation indicated that maintenance was required, Systems Operations was notified and conducted appropriate repairs or adjustments. In addition to the inspections carried out by the Water Quality Directorate, Systems Operations performs its own routine inspections and maintenance of the turbidity curtain.

Figure 2.4 Catskill Upper Effluent Chamber turbidity curtain.

Table 2.1. 2009 visual inspections of the Catskill Upper Effluent Chamber turbidity curtain.

Inspection Date	Observations
01/09/09	The main boom and the deflecting boom are intact and anchored.
01/21/09	Boom appears in good condition from shore, frozen in.
02/05/09	Boom appears in good condition from shore, frozen in.
02/18/09	Boom appears in good condition from shore, frozen in.
03/04/09	Boom appears intact from shore, partially frozen in.
03/19/09	Boom appears intact from shore, no ice.
04/01/09	Boom appears in good condition from shore.
04/15/09	Boom appears in good condition from shore.
04/29/09	Boom appears in good condition from shore.
05/13/09	Boom appears in good condition as is the shore boom south of the UEC.

Table 2.1. (Continued) 2009 visual inspections of the Catskill Upper Effluent Chamber turbidity

Inspection Date	Observations
05/27/09	Boom appears in good condition as is the shore boom south of the UEC.
06/11/09	Boom appears in good condition from shore.
06/24/09	All booms appear to be in good condition.
07/09/09	All booms appear to be in good condition.
07/27/09	All booms appear to be in good condition.
08/05/09	All booms appear to be in good condition. Contractor working in cove.
08/19/09	All booms appear to be in good condition. Contractor working in cove.
09/03/09	All booms appear to be in good condition. Contractor working in cove.
09/10/09	UEC shoreline boom came apart; compromised. Maintenance required.
09/17/09	All booms appear to be in good condition.
10/01/09	All booms appear to be in good condition.
10/15/09	All booms appear to be in good condition.
10/28/09	All booms appear to be in good condition.
11/12/09	All booms appear to be in good condition.
11/25/09	All booms appear to be in good condition.
12/10/09	All booms appear to be in good condition.
12/23/09	All booms appear to be in good condition.

2.5 Power Line Right-of-Way Management

In 1915, the City granted a right-of-way to Con Edison (“ConEd”) to establish and maintain an electric transmission corridor along City land from Yonkers to Millwood. The transmission corridor traverses 2.1 miles of land in the Kensico Reservoir drainage basin along the western shore of the reservoir. ConEd approached DEP in the summer of 2009 to request permission to remove trees along the corridor to increase the reliability of the electric system per their maintenance plan filed with the New York State Public Service Commission. DEP granted approval to ConEd, with restrictions, to remove trees along the corridor that were currently tall enough, or would grow tall enough in the next three years, to pose a hazard to the transmission system. Prior to the work, the corridor had an average width of 150 feet and occupied approximately 40 acres of land in the Kensico basin. Upon completion of the work, it is estimated that the corridor will have an average width of 175 feet and occupy approximately 45 acres of land. Tree removal work began in December 2009 with completion scheduled for the first quarter of 2010. Restrictions placed on ConEd by DEP include measures to minimize the potential for the work to cause erosion through equipment choice and operating area, debris reduction and placement, and soil stabilization efforts. All equipment used was approved by DEP Operations for travel over the Catskill Aqueduct.

2.6 Special Investigations

There was one special investigation conducted within the Kensico Reservoir watershed during 2009.

On June 3, 2009, a tractor trailer travelling southbound on Interstate 684 jackknifed and spilled 55 gallons of diesel fuel near the reservoir. Responders included the Armonk Fire Department, Westchester County Department of Health, DEP Police, DEP Haz Mat, and Tri-State Environmental, DEP's remediation consultant. DEP determined that because the spill was well contained and reservoir water quality was not endangered, samples were not necessary. DEP Haz Mat reported that Tri-State Environmental removed the contaminated soil and replaced it with fresh topsoil. The investigation was then closed without incident.

3. Routine Sampling Strategy

The overall water quality sampling effort within the Kensico basin is summarized in Table 3.1 and the results from these samples are discussed throughout the remainder of this report. A map of routine sampling sites is shown in Figure 3.1. Kensico Reservoir water quality monitoring that was conducted in 2009 included samples at 74 sites throughout the basin, with the highest intensity of monitoring at the effluent keypoint sites. These keypoint sites receive the highest level of scrutiny because this is where raw water compliance samples are taken to track quality just prior to chlorination and entry into the distribution system. The next most intensely sampled sites were those located throughout the reservoir itself. Grab samples were taken at the effluent keypoint sites 730 times and in the reservoir 468 times. In addition, 310 pathogen samples were sampled for *Cryptosporidium* and *Giardia*, and another 212 samples were collected for HEV. Supplementary information (not included in the summary table) is collected by probes that provide continuous readings. Continuous monitoring of turbidity is recorded on circular charts (Figure 3.2) and sampled manually at 4-hour intervals. Other parameters that are monitored continuously are pH, temperature, and conductivity.

The outlets of the Delaware and Catskill Aqueducts into Kensico Reservoir are regulated by SPDES permits #NY-026-4652 (CATIC) and NY-026-8224 (DEL17), respectively. These permits require a number of analyses to be reported in monthly DMRs. Additionally, these monitoring dataare used to inform operational decisions. The nutrient data collected by the Water Quality Directorate are transmitted to Operations staff via monthly memo and are combined with data collected by Operations to develop and submit the DMR to DEC as required by the permit.

Table 3.1. Summary of Kensico Reservoir water quality monitoring conducted in 2009.

Kensico Sampling Programs	Number of Sites	Parameters	Routine Frequency	Sampling Agency	Number of samples collected in 2009
Streams	8	bacteria, turbidity, physicals, nutrients[1], other chemistry[1]	monthly	DEP	96[2]
Reservoir	8	bacteria, turbidity, physicals, nutrients[3], other chemistry[3]	2x monthly, Apr-Dec only	DEP	468[4]
Keypoints at effluents	2	bacteria, turbidity, physicals	5x/week	DEP	260
		nutrients[5], other chemistry[5]	monthly	DEP	24
Keypoints at influents	2	bacteria, turbidity, physicals, nutrients, other chemistry	daily	DEP	730

Table 3.1. (Continued) Summary of Kensico Reservoir water quality monitoring conducted in

Kensico Sampling Programs	Number of Sites	Parameters	Routine Frequency	Sampling Agency	Number of samples collected in 2009
Toxic Chemicals at effluents	2	VOCs, SVOCs	annually	DEP	2
Groundwater at county airport	57	VOCs, SVOCs, NOCs, metals	semi-annually	Westchester Co. DOT	114
Pathogens		*Cryptosporidium*, *Giardia*	4 keypoints weekly, 7 streams bi-monthly, and monthly at Malcolm Brook		310
		HEV	4 keypoints weekly		212
SWTR Compliance	2	turbidity	every 4 hours	DEP (operators)	4380
Total	74	-	-	-	6596

[1] At 6 sites only.

[2] Monthly and at 6 sites only.

[3] 72 samples for nutrients and chemistry.

[4] 252 samples for nutrients and chemistry.

[5] TP weekly at CATALUM, DO daily at DEL17.

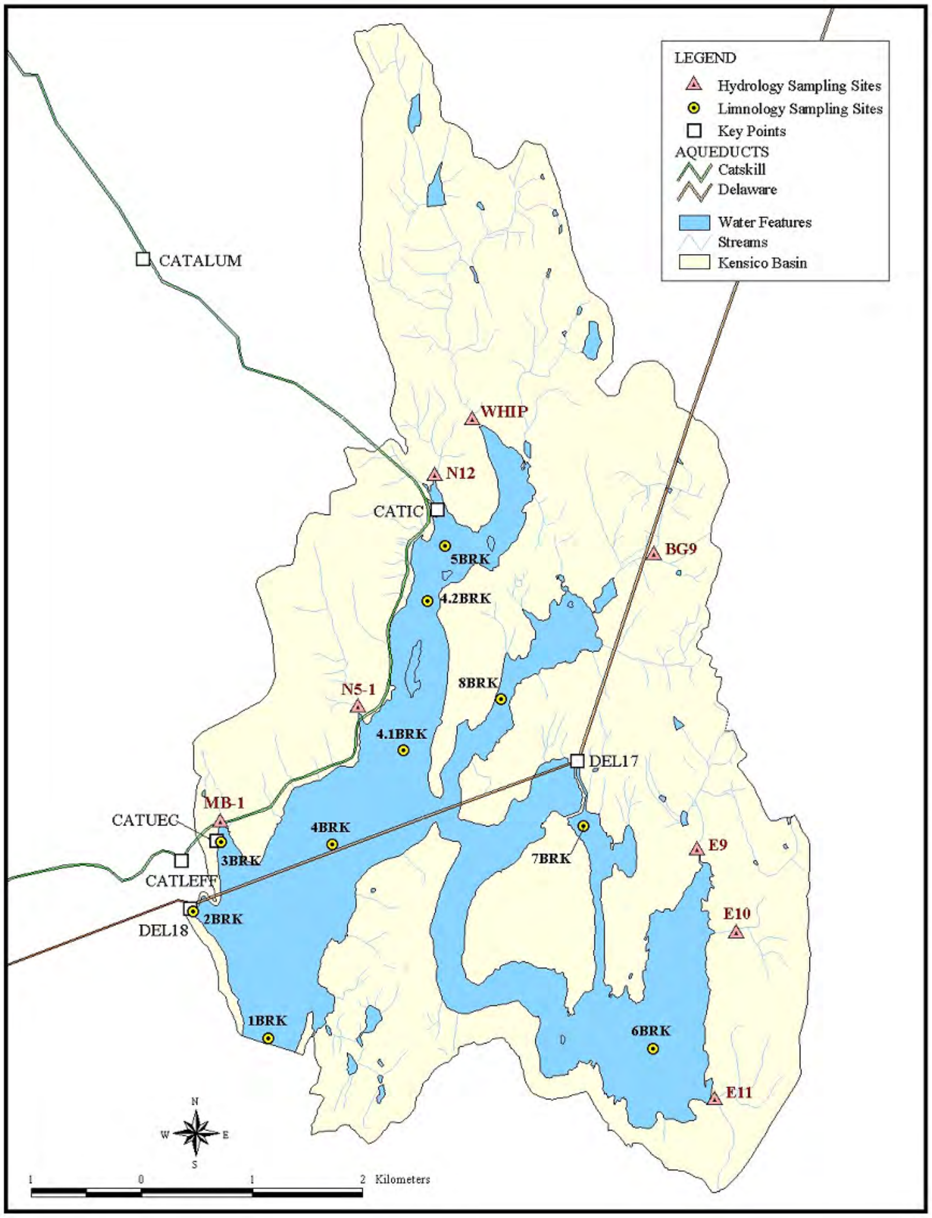

Figure 3.1 Kensico Reservoir, showing limnological and hydrological sampling sites, keypoints, and aqueducts. There is a meteorological station at DEL18.

3.1 Groundwater (DOT data)

The Kensico Groundwater Monitoring Program began in 1995 to determine whether groundwater could be contributing significant levels of coliform bacteria to Kensico Reservoir. Results of this program were included in subsequent Kensico reports. By agreement with EPA, as of 2007, DEP ended the routine groundwater monitoring program because groundwater quality was excellent and showed no signs of contamination. However, DEP continues to receive and review results of ongoing sampling of Westchester County Airport groundwater monitoring wells by Westchester County DOT as a matter of routine surveillance. These wells are monitored for flow rate, pH, 5-day biological oxygen demand (BOD_5), volatile, semivolatile, non-halogenated organic compounds, and metals.

3.2 Toxic Chemical Surveillance

On October 28, 2009, Kensico Reservoir keypoints were sampled for volatile compounds and semivolatile compounds. All keypoints are sampled on an annual basis at this time of the year as part of a watershed-wide keypoint toxics monitoring program. Volatile compounds were analyzed by potable water method USEPA Method 524.2; semivolatile compounds were analyzed by potable water method 525.2. Kensico Reservoir keypoints sampled were DEL18 and CATLEFF.

A volatile organic compound is one that produces vapors readily at room temperature and normal atmospheric pressure, such as benzene, toluene, xylene, and ethylene (BTEX). Although ubiquitous in nature and modern industrial society, they may also be harmful or toxic. Inhalation effects represent an acute toxic exposure and groundwater contamination represents a route of chronic exposure, with the potential to affect the kidneys, nervous system, heart, and lungs.

A semivolatile compound has a low to moderate vapor pressure compared to a volatile compound. Examples of semivolatile compounds are benzo[a] pyrene, phenol, and the pesticide pentachlorophenol. Some polyaromatic hydrocarbons, phthalates, and phenols are probable human carcinogens and endocrine disruptors. The primary routes of human exposure to SVOCs are ingestion of contaminated food and inhalation of contaminated air, rather than via drinking water. The toxics monitoring program is conducted to determine whether these compounds are absent from the drinking water supply.

3.3 Streams

DEP continues to monitor the hydrology of the Kensico watershed. Samples are collected at eight fixed sampling sites to quantify water quality at each of the perennial streams (BG9, E10, E11, E9, MB-1, N12, N5-1, WHIP) as shown in Figure 3.1. Routine sampling of these streams was conducted monthly in 2009. Also in 2009, continuous flow measurements were maintained at six of the eight perennial Kensico tributaries: Malcolm Brook, N5, N12, E9, E10, and E11. Plans are also being developed to re-establish this capability at Whippoorwill Creek and Bear Gutter Creek.

3.4 Reservoir

DEP monitors Kensico Reservoir water quality by routine limnological surveys for a series of physical, chemical, and microbiological parameters. Samples are collected at different depths throughout the water column at fixed sampling locations as shown in Figure 3.1. During the reporting period, routine limnological and supplementary survey monitoring of Kensico Reservoir was conducted twice each month from March 17 through November 24, 2009.

In addition to the routine surveys, special sampling may be required when a water quality issue or concern develops. These additional surveys involve more frequent sampling, sampling at different locations within the reservoir, and/or sampling for additional analytes, as needed. Additional surveys conducted in 2009 were related to a shutdown of the Catskill Aqueduct on April 20, and during two Rondout-West Branch Tunnel shutdowns (November 5-15 and December 4-16) including the associated operation of the Croton Falls Pumping Station (CFPS). Additional surveys were also conducted in response to taste complaints by drinking water consumers which were determined to be likely caused by an algal bloom of the golden alga *Chrysosphaerella* in Kensico Reservoir. All routine and additional data collected during the sampling period were distributed through weekly water quality reports, source water briefs, and after action reports.

The "Croton Falls Pumping Station Operation After Action Report" (DEP 2010b, in progress) contains details of the monitoring required for this operation. DEP submitted a request to DOH to operate the CFPS and this request was approved on December 3, 2009. Approval included specific, intensified monitoring (prior to and during the operation) and reporting requirements, all of which were met by DEP. Operation of the CFPS began on December 5, 2009, and pumping was continuous for 23 days, ending on December 28, 2009. No water quality or operational issues were encountered throughout the entire period of operation of the CFPS.

The "Response to an Increase in Metallic Taste Complaints in New York City Drinking Water" after action report (DEP 2010a, in progress) provides a full description of the Bureau of Water Supply's (BWS's) investigation, enhanced monitoring, and response actions to an increase in water taste complaints from water consumers. DEP began to receive complaints of a metallic taste in the drinking water on October 2, 2009. An initial investigation determined that the alga *Chrysosphaerella* in Kensico Reservoir was the likely source of this problem. BWS responded to this taste issue by placing the Delaware Aqueduct in a partial by-pass mode, thereby operationally circumventing Kensico Reservoir and delivering mostly Rondout Reservoir and West Branch Reservoir water directly to distribution. By-pass operations began on October 8, 2009, and continued for 52 days until November 29, 2009, when BWS began to bring Kensico Reservoir back on-line. Kensico Reservoir and keypoints were intensively monitored during this period to assist in managing this water quality issue. (A more detailed description of this water quality event is included in Section 2.2 of this report.)

3.5 Keypoints

DEP routinely conducts water quality compliance monitoring at the four aqueduct keypoints at Kensico Reservoir. The CATALUM and DEL17 influent keypoints represent water entering Kensico Reservoir from the NYC upstate reservoirs via the Catskill and Delaware Aqueducts, respectively. The CATLEFF and DEL18 effluent keypoints represent Kensico Reservoir water entering the Catskill and Delaware Aqueducts, respectively, at points just prior to disinfection (Figure 3.2); this water ultimately travels down to distribution. The CATALUM and DEL17 influent keypoints are monitored via grab samples for fecal coliforms (5D/week), turbidity (5D/week), and nutrients (monthly, except TP is collected weekly at CATALUM as one of the monitoring requirements of the Catskill Influent Chamber (CATIC) SPDES Permit) as part of DEP operations. The information is used as an indicator of water quality entering Kensico Reservoir, which is in turn used to optimize operational strategies to provide the best possible water exiting the reservoir. The CATLEFF and DEL18 effluent keypoints are monitored via grab samples for fecal coliforms (daily), turbidity (every four hours, in accordance with SWTR regulations), and nutrients (monthly). All four keypoint sites are also equipped with continuous monitoring of temperature, pH, conductivity, and turbidity. The exceptional importance of these keypoints (for optimal operations (influents) and as source water compliance monitoring sites (effluents)) warrants this high intensity monitoring.

Figure 3.2 Continuous monitoring instrumentation at Kensico Reservoir (Catskill Lower Effluent Chamber).

3.6 Protozoa and Human Enteric Viruses

DEP is responsible for performing compliance and surveillance monitoring of protozoan pathogens (*Cryptosporidium* and *Giardia*) and human enteric viruses (HEV) in the New York City Watershed. In 2009, 304 samples were collected and analyzed for *Cryptosporidium* and *Giardia* within the Kensico Reservoir watershed between January 1 and December 31, 2009. This sample set includes 208 routine fixed-frequency samples from four keypoints (Kensico Reservoir influent and effluent aqueducts), and 96 fixed-frequency samples at the eight perennial Kensico tributaries. In addition, 212 samples were collected for HEV at the Kensico Reservoir influent and effluent aqueducts.

Cryptosporidium and *Giardia* monitoring involved the collection of 50 L samples filtered in the field and analysis according to Method 1623 (USEPA 2001). HEV monitoring involved the collection of 200-300 L field-filtered samples and laboratory analysis as per the Information Collection Rule (ICR) method (USEPA 1996). All HEV samples were analyzed by Environmental Associates Limited (EAL) in Ithaca, NY.

Occasionally (i.e., after storm events or at some stream sites), samples have elevated turbidity which can result in filter clogging. When this occurs, sample volumes do not always reach the targeted value. As in the past, rather than only extrapolating results to the targeted sample volume, the actual sample volume obtained is also reported with the data.

4. Results and Discussion

4.1 Groundwater

DEP reviews results of ongoing sampling of Westchester County Airport groundwater monitoring wells by the Westchester County Department of Transportation (DOT) as a matter of routine surveillance. Westchester County Airport lies within the Croton and Blind Brook watersheds; however, it is in relatively close proximity to Kensico Reservoir and groundwater is not necessarily limited by watershed boundaries. The parameters analyzed are volatile, semivolatile, and non-halogenated organic compounds, and metals. In general, most analytes are below their respective detection limits, except for propylene glycol in the winter months only. One of the uses of propylene glycol is deicing of airplanes. Given that these sampling locations are within the vicinity of the airport, airplane deicing activities are the likely source of this chemical in groundwater.

The highest result obtained for a well sample in 2009 was 223.80 mg L^{-1} (in January), followed by 89 mg L^{-1} (in February), and 80 mg L^{-1} (in March). Though propylene glycol is not currently listed as a hazardous material by any federal or state agencies, an allowable discharge standard of 50 µg L^{-1} total glycols has been established by the New York State Department of Health (DOH) for discharge to the Croton watershed. If this concentration were used as a benchmark for monitoring Westchester County DOT monitoring wells, the sample results would greatly exceed the benchmark. However, the amount of water that these wells represent is only a fraction of the total water budget. Moreover, according to Miller (1979), who summarized the literature concerning the fate and persistence of glycols in the environment, glycols are capable of being degraded by a variety of soil, water, and sewage organisms. Complete degradation, depending on testing conditions, occurred in Miller's study within 3 to 20 days. Therefore, even if propylene glycol could reach Kensico Reservoir, the travel time might exceed its persistence in the environment. Also, propylene glycol appears in samples in the winter months only, which supports the theory that it does not persist or bioaccumulate in the environment.

The principal concern regarding the environmental impacts of deicing activities relates to oxygen consumed during the decomposition of deicing materials, principally glycol (Switzenbaum et al. 1999). Oxygen consumption occurs when bacteria decompose organic materials (including deicing chemicals) and use oxygen in the process. This phenomenon can reduce or deplete dissolved oxygen concentrations in water if the rate of decomposition is greater than the rate of re-aeration. For the Westchester County DOT data, oxygen consumption is expressed as carbonaceous biochemical oxygen demand exerted over 5 days ($CBOD_5$). The Westchester County data do indeed confirm measurable increases in $CBOD_5$ for the DOT sampling during the winter months, but the levels do not exceed the 34 mg L^{-1} threshold set by DEC (maximum during winter months: 8.6 mg L^{-1}).

Given the relatively high rate of degradation, $CBOD_5$ measurements well within regulatory limits, the amount of water these measurements represent relative to the Kensico Reservoir water budget, and the fact that the Westchester County Airport is not within the Kensico watershed, it is unlikely that propylene glycol levels would affect Kensico Reservoir's water quality, though DEP will continue to closely monitor the results.

4.2 Toxic Chemical Surveillance

Annual surveillance monitoring of Kensico Reservoir effluent keypoints DEL18 and CATLEFF on October 28, 2009 for 67 VOCs and 68 SVOCs resulted in no compounds being detected; this duplicates the results from last year.

4.3 Coliform Bacteria

4.3.1 Streams

The routine fecal coliform data for the period January 2009 through December 2009 are plotted in Figure 4.1. Box plots are used to display data which contain censored data (i.e., nondetects, where the data are either less than a detection limit, or, in some cases, greater than a maximum detection limit). Coliform data often contain censored data, and while box plots can be used to display these data, a modification is needed. A horizontal line is drawn at the maximum detection limit (Max DL), and the portions of the box plot below this limit are unspecified. By doing this, all of the detected values are correctly distributed; however, the data below the maximum detection limit are not displayed.

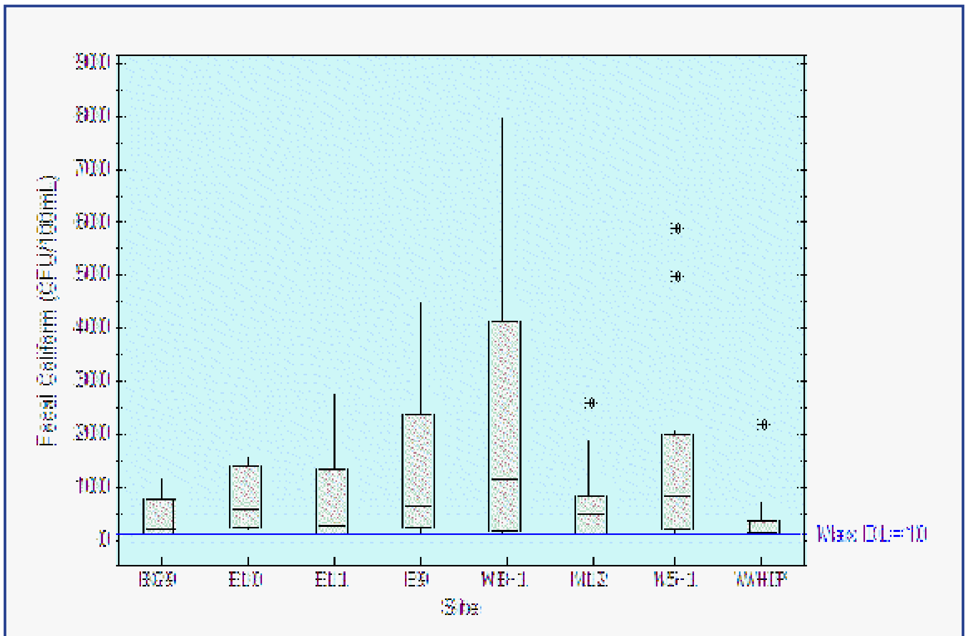

Figure 4.1 Fecal coliform plots for routine Kensico streams monitoring data, January–December, 2009.

All Kensico streams had median values less than 200 CFU 100mL^{-1}. Malcolm Brook (MB-1) had the highest median value at 115 CFU 100mL^{-1}, while Whippoorwill Creek (WHIP) had the lowest at 14.5 CFU 100mL^{-1}. Fecal coliform values this year were consistent with previous years. The highest values were generally seen when rain on the order of 0.5 inches or more occurred during the week prior to the sample date.

Total coliform samples are also collected monthly from the eight Kensico stream sites. As with fecal coliform data, the total coliform data contain censored data, so a non-parametric statistic technique, a Turnbull estimate, which is similar to a Kaplan-Meier method but can accommodate both right and left-censored data, was used to estimate the medians. E10 had the highest median total coliform value (2538 CFU 100mL^{-1}), while Bear Gutter Creek (BG-9) had the lowest median value (460 CFU 100mL^{-1}). NYSDEC Part 703 water quality standards for total coliform have been used as a guideline for the comparison of stream water quality, based on DEP's monthly fixed frequency monitoring program. The 2009 data indicate that some of the streams have an occasional occurrence above 5000 CFU 100mL^{-1}, which are generally associated with a fixed frequency sample being collected during or immediately following wet weather. The five reported values of more than 5000 CFU 100mL^{-1} all occurred when at least 0.75 inches of precipitation had fallen within the week before the sample date. This is the fewest number of exceedances for a year above the 5000 CFU 100mL^{-1} benchmark that has been reported for the Kensico streams.

4.3.2 Reservoir

The routine bacteria samples collected from Kensico Reservoir provided 366 total coliform and 373 fecal coliform data points during the period April through November 2009. Box plots for these data are shown in Figures 4.2a,b. The results are compared with Surface Water Treatment Rule (SWTR) drinking water limits of 100 CFU 100mL^{-1} for total coliforms and 20 CFU 100mL^{-1} for fecal coliforms. Although the SWTR limits apply to raw water quality at the effluent chambers, DEP uses these limits as a guideline to identify potential reservoir water quality impacts before they reach the effluent chambers.

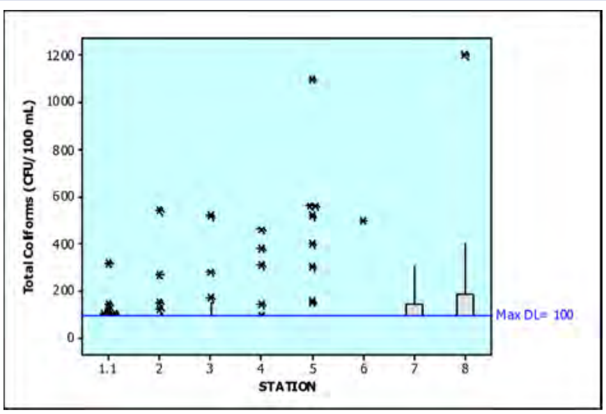

Figure 4.2a Total coliform plots for routine Kensico Reservoir monitoring data, April–November, 2009.

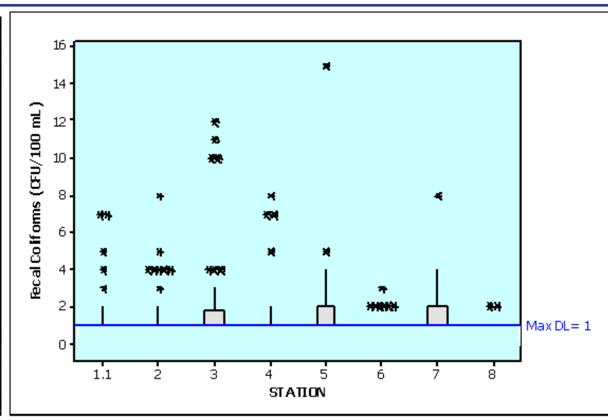

Figure 4.2b Fecal coliform plots for routine Kensico Reservoir monitoring data, April–November, 2009.

During this reporting period all sites had estimated median total coliform values less than 100 CFU 100mL^{-1}. There were three sites where the box plots extended above the Max DL. These were Sites 3, 7, and 8, and the median values were estimated as 17, 36, and 33 CFU 100mL^{-1}, respectively. At all the sites there were several occasions where the total coliform exceeded the guidance value. These higher levels were typically observed in late summer and autumn. Seasonality of total coliform levels is a routine observation in many of the NYC reservoirs.

During the reporting period all sites from routine surveys had a median fecal coliform level below 20 CFU 100mL^{-1}. Median values were 0.4 CFU 100mL^{-1} for Site 1.1, 0.5 CFU 100mL^{-1} for Site 4, 0.6 CFU 100mL^{-1} for Sites 2 and 5, and 1 CFU 100mL^{-1} for Sites 3 and 7. There were no instances where the fecal coliform levels from discrete samples were above the DEP guideline (20 CFU 100mL^{-1}). The highest fecal coliform values of 11 and 12 CFU 100mL^{-1} occurred at Site 3 on June 16 (samples from a depth of 3 and 5 feet, respectively) and 15 CFU 100mL^{-1} at Site 5 on August 25.

4.3.3 Keypoints

The keypoints monitored were the Kensico influents (CATALUM and DEL17) and effluents (CATLEFF and DEL 18). The effluents are subject to the SWTR and, as such, are monitored daily for fecal coliforms. The influents are monitored for fecal coliforms five days per week. Monitoring the quality of water entering Kensico Reservoir makes it possible to adjust operational strategies to optimize water quality at the effluents.

Coliform bacteria, like many other environmental parameters, has measurement thresholds (usually limited by instrumentation sensitivity), below which the measured value has a degree of uncertainty (i.e., < 1 unit of measurement). The incorporation of this uncertainty into the calculation of basic statistics such as the mean and median has resulted in the development of alternative methods of calculation to correctly represent the mean or median. (For the case of coliform bacteria, the Kaplan-Meier median calculates the median by calculating the median of medians of 1000 or more iterations of the median using a bootstrapping technique.)

For the fecal coliform concentrations measured at the Kensico influents from December 1, 2008 to November 30, 2009, medians of 1 CFU 100mL^{-1} at CATALUM and 1 CFU 100mL^{-1} at DEL17 were calculated. Similarly, the Kaplan-Meier mean values (calculated in a similar way) were 1.19 CFU 100mL^{-1} at CATALUM and 1.42 CFU 100mL^{-1} at DEL17. The maximum fecal coliform concentrations were 7 CFU 100mL^{-1} at CATALUM and 34 CFU 100mL^{-1}at DEL17 (Figure 4.3a,b). These data demonstrate that the fecal coliform levels of the aqueducts flowing into Kensico were typically very low.

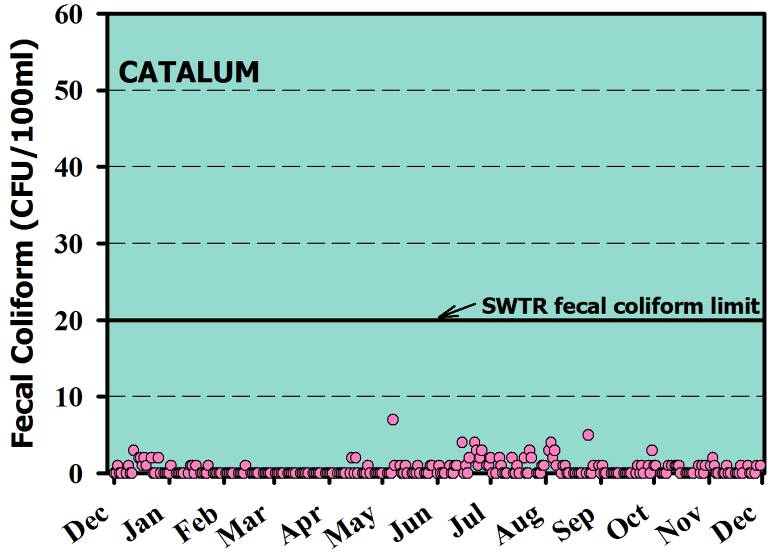

Figure 4.3a Five day per week fecal coliform grab sample results at the Catskill Aqueduct Kensico influent keypoint (CATALUM). Note: While the SWTR fecal coliform limit is indicated as a reference point, the influent keypoint is not subject to the SWTR. It is monitored in operational support of the effluent keypoint, which is subject to the SWTR.

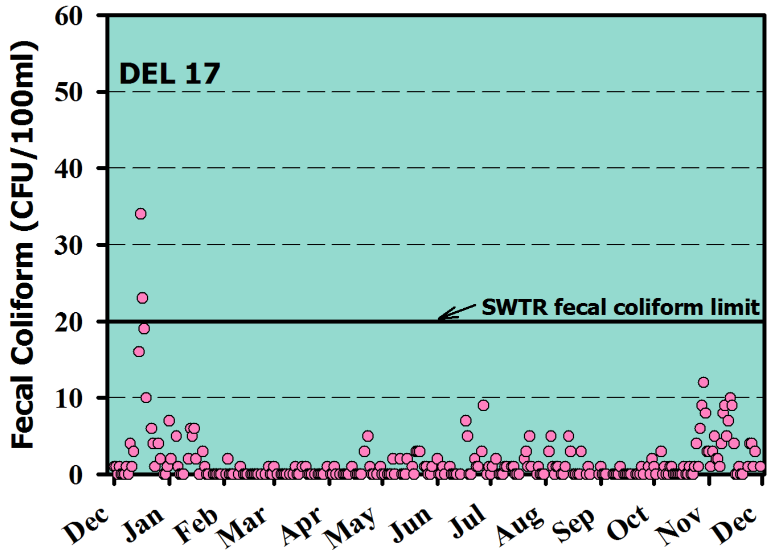

Figure 4.3b Five day per week fecal coliform grab sample results at the Delaware Aqueduct Kensico influent keypoint (DEL17). Note: While the SWTR fecal coliform limit is indicated as a reference point, the influent keypoint is not subject to the SWTR. It is monitored in operational support of the effluent keypoint, which is subject to the SWTR.

For the fecal coliform concentrations measured at the Kensico effluents from December 1, 2008 to November 30, 2009, medians of 1 CFU 100mL^{-1} at CATLEFF and 1 CFU 100mL^{-1} at DEL18 were calculated. Similarly, the Kaplan-Meier mean values (calculated in a similar way) were 1.05 CFU 100mL^{-1} at CATLEFF and 1.81 CFU 100mL^{-1}at DEL18. During the same period, values above the regulatory benchmark of 20 CFU 100mL^{-1} were only observed once (at DEL18) (Figure 4.4a,b). For reference, the 2008 fecal coliform data indicated two exceedances at CATLEFF and 4 exceedances at DEL18. Hence, 2009 had fewer fecal coliform exceedances than 2008. According to the regulations, 18 values above 20 CFU 100mL^{-1} are permitted within any 6-month period at each keypoint. DEP's source water at Kensico is therefore well within the SWTR limits for fecal coliforms.

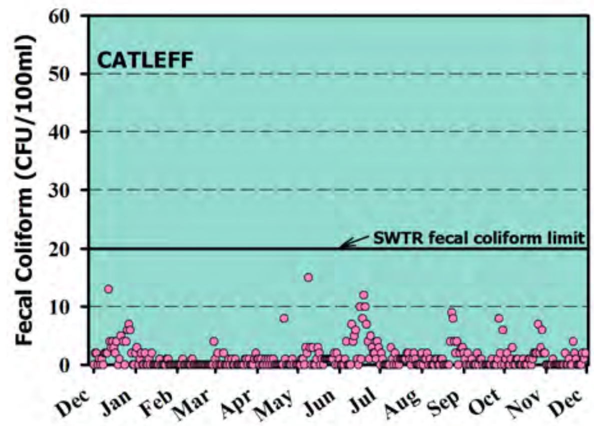

Figure 4.4a Daily monitoring fecal coliform grab sample results, as per the SWTR, at the Delaware Aqueduct Kensico effluent keypoint (CATLEFF).

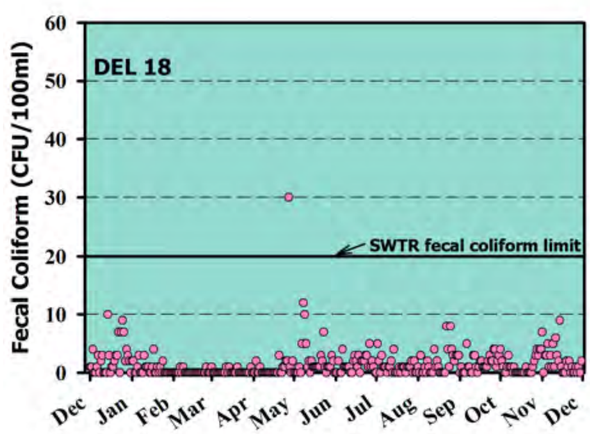

Figure 4.4b Daily monitoring fecal coliform grab sample results, as per the SWTR, at the Delaware Aqueduct Kensico effluent keypoint (DEL18).

The single exceedance in 2009—30 CFU 100mL^{-1}—occurred on April 27, following three successive days of rain on April 21, 22, and 23, totaling about 1.39 inches (Figure 4.5). This supports the conclusions of previous DEP studies, which have indicated that, since the inception of DEP's Waterfowl Management Program (See Section 2.1), elevated fecal coliform levels have generally coincided with precipitation events occurring within a few days before the elevated fecal coliform conditions were observed.

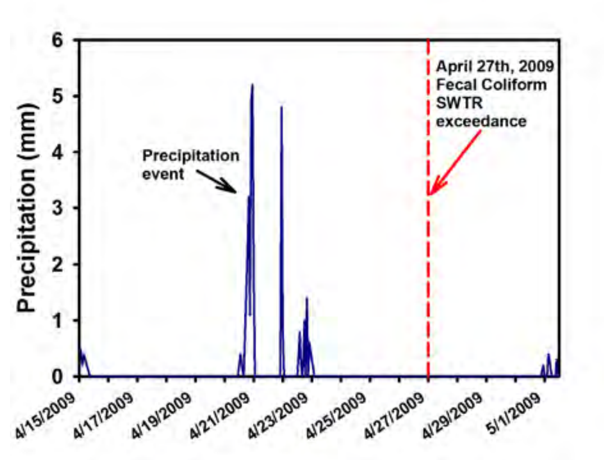

Figure 4.5 Precipitation event preceding a fecal coliform SWTR exceedance.

4.4 Turbidity

4.4.1 Streams

The routine turbidity data for the period January 2009 through December 2009 are plotted in Figure 4.6. The median turbidity for all sites is less than 5 NTU, except E9 (median = 5.6 NTU). Turbidity values in 2009 were generally consistent with data from previous years, with a maximum value of 11 NTU at E9. Notably, the local streams within the Kensico basin are only a small percentage of the total inflow volume and these values are greatly diluted by the aqueduct inputs.

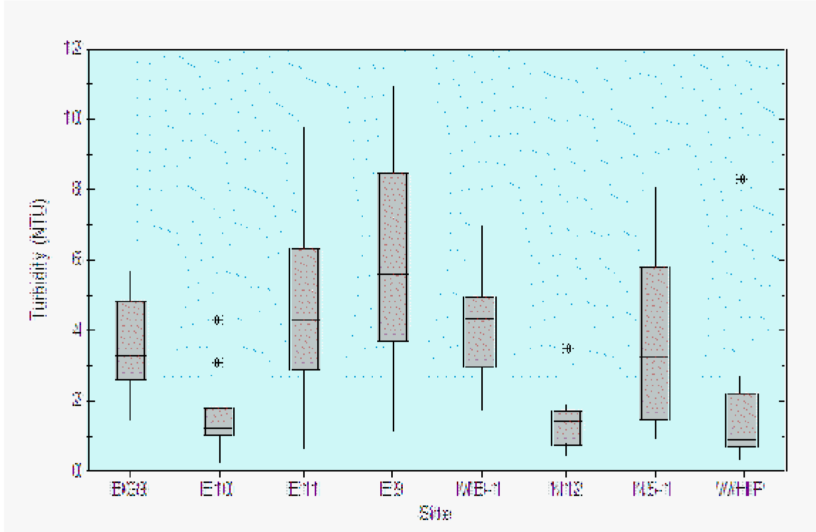

Figure 4.6 Turbidity plots for routine Kensico stream monitoring data, January-December, 2009.

4.4.2 Reservoir

The routine monitoring of Kensico Reservoir during the April 2009 through November 2009 period yielded 418 turbidity samples. A box plot constructed using these data is presented in Figure 4.7. As in the past, Site 5 showed the highest median turbidity (1.7 NTU) and entries for this site exceeded 2.0 NTU nine times. At the other sites the turbidity was below 2.0 NTU with the exception of the following observations for Site 6: 2.4 NTU, 2.4 NTU, and 2.3 NTU on November 2, November 9, and October 27, respectively.

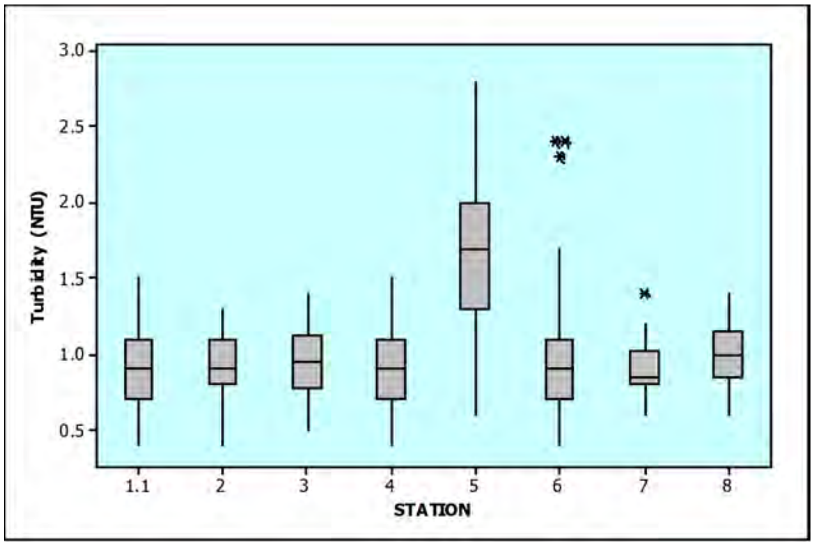

Figure 4.7 Turbidity plots for routine Kensico Reservoir monitoring data, April-December, 2009.

One special survey was conducted during 2009. A storm caused increased turbidity levels in the Ashokan Reservoir and the Catskill Aqueduct. Consequently, water with high turbidity was observed at CATUEC and CATLEFF on April 20 and 21. The Catskill Aqueduct was shut down and Kensico effluent water quality was closely monitored during this turbidity alert.

This special investigation did not yield any extreme values for turbidity. However, turbidity values of 2.6 and 4.2 NTU were observed at CATUEC on April 21 (10:13 AM and 10:05 AM samples, respectively).

4.4.3 Keypoints

A turbidity grab sample is obtained five days per week at the Kensico influent keypoints (CATALUM and DEL17). These data allow DEP Operations to employ the optimal strategy for achieving the best water quality possible at the reservoir effluents, which are subject to the SWTR. Maintaining turbidity below regulatory limits is achieved by constant surveillance of the reservoir and its influent and effluent water quality, anticipation of problems (e.g., large storm events), and careful operation of reservoir gates at the effluents to avoid the re-suspension of sediments.

Median turbidity from December 1, 2008 to November 30, 2009 was 2.00 NTU at CATALUM and 0.80 NTU at DEL17. Mean turbidity for the same time period was 0.90 NTU at CATALUM and 2.1 NTU at DEL17. During this period, the maximum turbidity measurements were 3.90 NTU at CATALUM and 1.90 NTU at DEL17 (Figure 4.8a,b). These data indicate that the SWTR limit of 5 NTU at the effluents was consistently met by sources upstream of the reservoir.

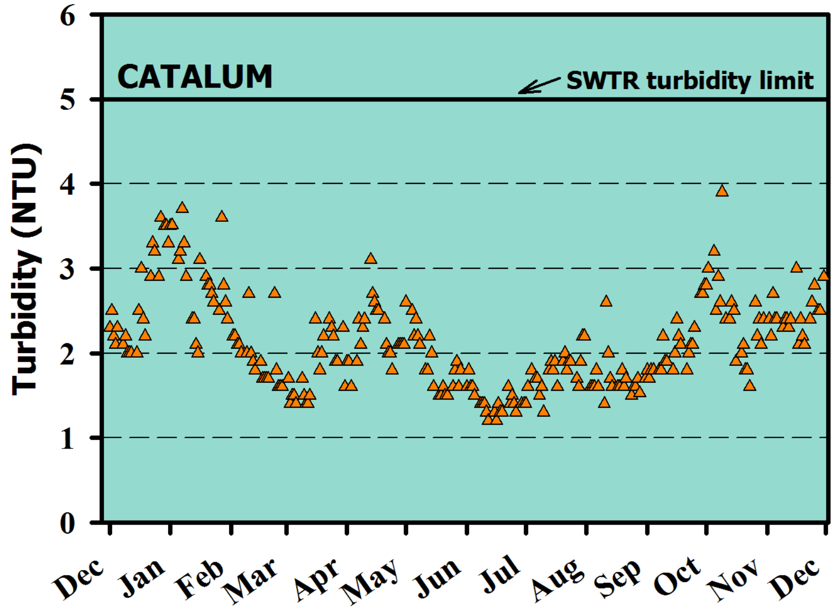

Figure 4.8a Five day per week turbidity grab sample results at the Catskill Aqueduct Kensico influent keypoint (CATALUM). Note: While the SWTR turbidity limit is indicated as a reference point, the influent keypoint is not subject to the SWTR. It is monitored in operational support of the effluent keypoint, which is subject to the SWTR.

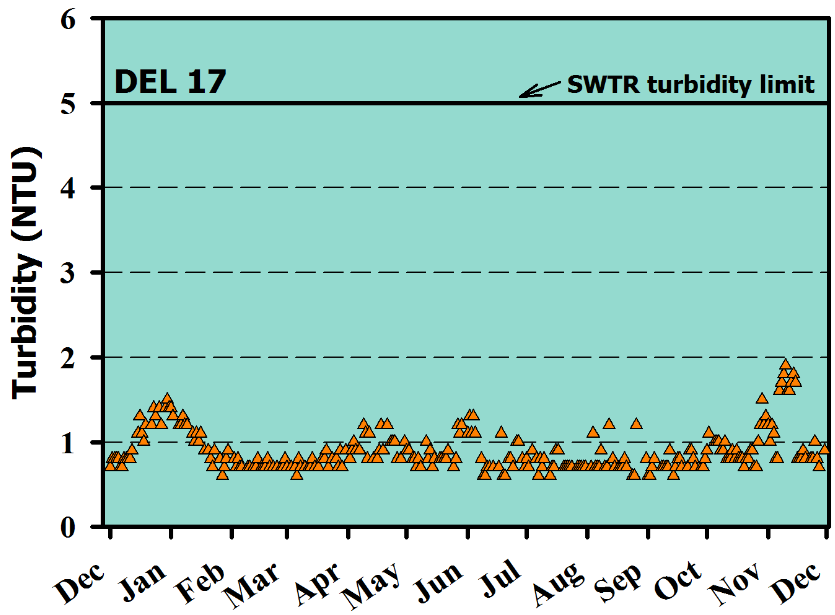

Figure 4.8b Five day per week turbidity grab sample results at the Delaware Aqueduct Kensico influent keypoint (DEL17). Note: While the SWTR turbidity limit is indicated as a reference point, the influent keypoint is not subject to the SWTR. It is monitored in operational support of the effluent keypoint, which is subject to the SWTR.

A turbidity grab sample is obtained every four hours at the Kensico effluent keypoints (CATLEFF and DEL18) as per the SWTR. Median turbidity from December 1, 2008 to November 30, 2009 was 0.80 NTU at CATLEFF and 0.90 NTU at DEL18. Mean turbidity for the same time period was 0.86 NTU at CATLEFF and 0.96 NTU at DEL18. During this period, the maximum 4-hour turbidity measurements were 3.60 NTU at CATLEFF and 3.10 NTU at DEL18 (Figure 4.9a,b). Thus, the SWTR limit of 5 NTU was consistently met at both keypoints, similar to last year's results.

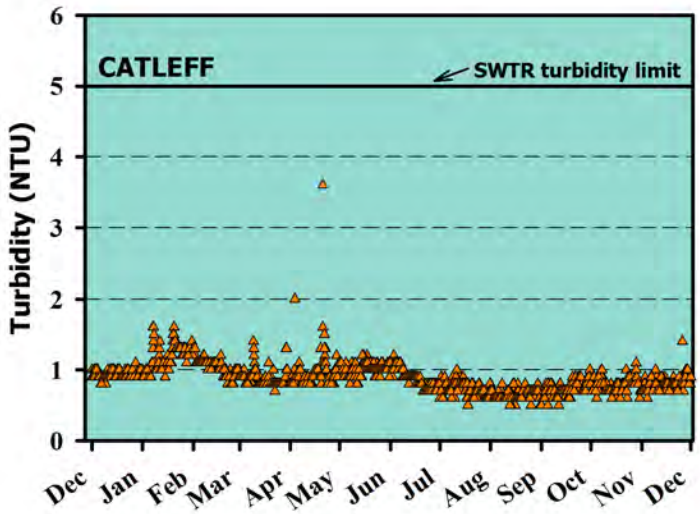

Figure 4.9a 4-hour turbidity grab sample monitoring results, as per SWTR, at the Catskill Aqueduct Kensico effluent keypoint (CATLEFF).

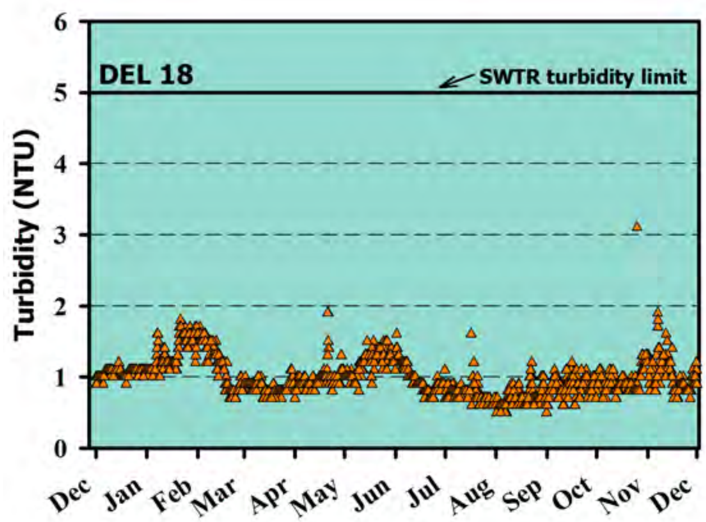

Figure 4.9b 4-hour turbidity grab sample monitoring results, as per SWTR, at the Delaware Aqueduct Kensico effluent keypoint (DEL18).

A comparison of the influent and effluent keypoints indicates two distinct peaks in turbidity for the influents (mid-December 2008, end of April 2009) and two distinct peaks for the effluents (mid-January 2009, end of June 2009). This indicates there is an approximately 30-day water residence time in Kensico Reservoir during isothermal conditions, as is already known. The travel time from the influents provides a window for planning operational strategies for water entering Kensico from the influent aqueducts.

4.5 Protozoa and Human Enteric Viruses

4.5.1 Streams

Routine Sampling

Eight perennial streams flow into Kensico Reservoir (Figure 4.10). In past years, the sampling interval at these sites varied; however, the 2009 Watershed Water Quality Monitoring Plan (WWQMP) set the protozoan monitoring interval for all Kensico stream sites to monthly in order to help capture some of the seasonal variation in protozoan occurrence. Results for these samples are presented in Tables 4.1 through 4.4. No HEV samples were collected in 2009 at the Kensico perennial streams.

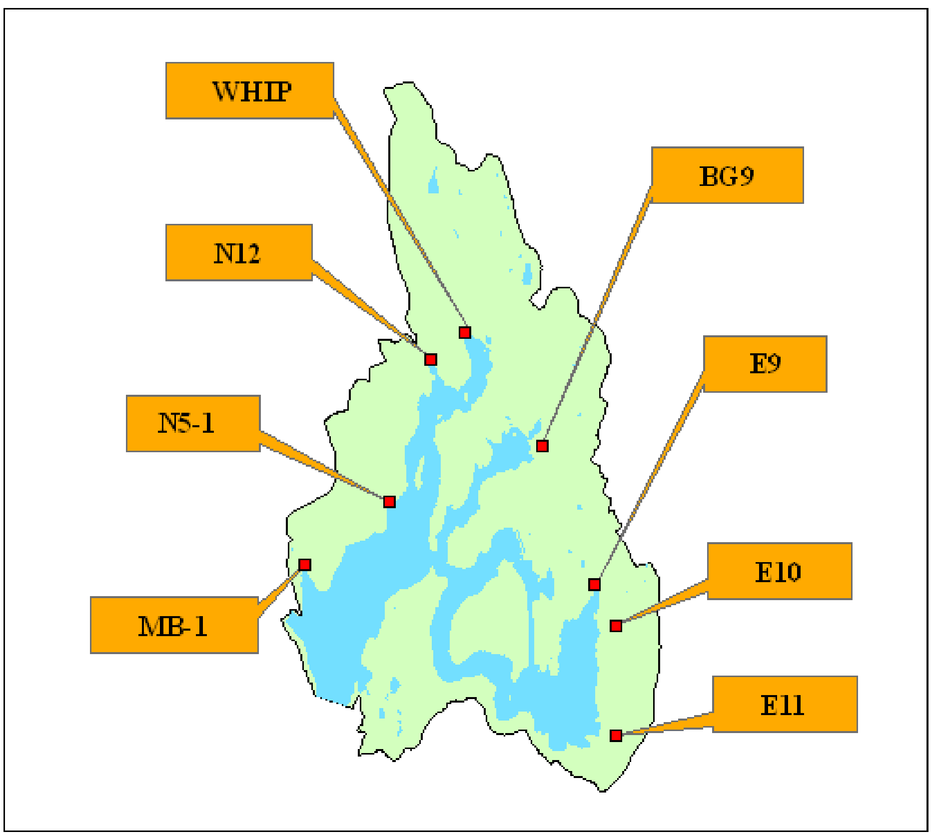

Figure 4.10 Kensico Reservoir routine pathogen stream sites sampled monthly in 2009.

As seen in past years, there were low concentrations of *Cryptosporidium* in the Kensico streams in 2009 (Table 4.1). One stream, E11, had no positive *Cryptosporidium*, and five of the remaining seven streams had concentrations ranging from only 0 to 2 oocysts per volume collected. The other two streams, BG9 and E10, had most results from 0 to 2 also; however, they each had one result of 3 oocysts as well.

Table 4.1. *Cryptosporidium* results and sample volumes from perennial Kensico streams, January 1– December 31, 2009.

	BG9		E10		E11		E9		MB-1		N12		N5-1		WHIP	
Date	C	Vol(L)	C	Vol(L)	C	Vol(L)	C	Vol(L)	C	Vol(L)	C	Vol(L)	C	Vol(L)	C	Vol(L)
Jan	2	50	1	50	0	49.75	1	23.25	0	50	1	50	0	50	1	50
Feb	0	50	0	50	0	50	1	28	2	50	0	50	0	50	1	50
Mar	1	50	1	52	0	24.25	1	49.25	0	50	0	50	0	50	1	50
Apr	1	38	0	50	0	30	0	42	0	39.5	0	50	1	33.5	1	50
May	0	32.75	3	50	0	47	0	18	0	50	0	50	0	40	0	50
Jun	0	38	0	50	0	50	0	20	0	40	0	50	2	40	0	50
Jul	0	41	0	50	0	30	0	16	1	40	0	50	0	40	0	50
Aug	0	50	0	50	0	17	0	20	0	42	0	50	0	50	1	50
Sep	0	50	0	50	0	47	0	24	0	50	0	50	0	49	1	50
Oct	0	50	0	50	0	43	1	32	0	41	0	50	0	45	0	50
Nov	3	48	0	50	0	44	0	50	0	50	2	50	0	50	0	50
Dec	0	50	0	50	0	50	1	27	0	50	0	50	1	50	0	50

Cryptosporidium occurrence was also low with a 74% non-detection rate when all stream data were pooled. Overall, 25 out of 96 samples were positive for all streams, with a range of 0 to 3 oocysts per volume sampled, and a combined mean of 0.008 per liter. WHIP had the highest detection rate at 50% and E9 had the highest per liter mean concentration at 0.014 oocysts L^{-1} (Table 4.2). BG9 had the highest per liter maximum concentration of oocysts in November; however, this result was still quite low (3 oocysts in a 48 L sample). These results are somewhat lower than those for 2008, though oocyst detection in both years was quite low.

Table 4.2. Monthly Kensico perennial stream *Cryptosporidium* results summary, January 1 – December 31, 2009.

	Cryptosporidium							
	BG9	E10	E11	E9	MB-1	N12	N5-1	WHIP
# of Samples	12	12	12	12	12	12	12	12
# of Positives	4	3	0	5	2	2	3	6
% Positives	33%	25%	0%	42%	17%	17%	25%	50%
Mean (L^{-1})	0.012	0.008	0.000	0.014	0.005	0.005	0.008	0.010
Median (L^{-1})	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
Maximum (L^{-1})	0.063	0.060	0.000	0.043	0.040	0.040	0.050	0.020

As in previous years, 2009 samples from the Kensico streams had higher concentrations of cysts (Table 4.3), and were more frequently positive for *Giardia* (Table 4.4), when compared to *Cryptosporidium* (Table 4.2). Consequently, the fact that not all samples had the same volume had a greater potential impact on the interpretation of these results. Three of the eight streams (E10, N12, and WHIP) had volumes of at least 50L throughout the year. Unfortunately, samples collected at the remaining five streams had volumes ranging from 16 to 50L, and cyst results from 0 to 94. These broad ranges made it challenging to compare the data. To aid the comparison, per liter values have been provided (Table 4.4). Using this approach, BG9 and E9 stand out as having the highest mean and maximum *Giardia* values compared to the other six streams for 2009. Conversely, N12 samples, which were all 50L, had the lowest mean and maximum values, with *Giardia* concentrations ranging from only 0 to 4 cysts.

Table 4.3. *Giardia* results and sample volumes from perennial Kensico streams, January 1 – December 31, 2009.

	BG9		E10		E11		E9		MB-1		N12		N5-1		WHIP	
Date	G	Vol(L)	G	Vol(L)	G	Vol(L)	G	Vol(L)	G	Vol(L)	G	Vol(L)	G	Vol(L)	G	Vol(L)
Jan	94	50	12	50	21	49.75	4	23.25	6	50	0	50	9	50	10	50
Feb	30	50	6	50	13	50	3	28	18	50	0	50	6	50	5	50
Mar	30	50	5	52	1	24.25	8	49.25	2	50	0	50	3	50	6	50
Apr	7	38	13	50	5	30	3	42	0	39.5	2	50	9	33.5	0	50
May	3	32.75	6	50	15	47	0	18	0	50	0	50	3	40	2	50
Jun	0	38	0	50	0	50	5	20	1	40	0	50	0	40	0	50
Jul	4	41	3	50	3	30	7	16	1	40	2	50	0	40	2	50
Aug	2	50	0	50	0	17	8	20	1	42	2	50	3	50	2	50
Sep	2	50	1	50	0	47	7	24	4	50	0	50	1	49	1	50
Oct	1	50	0	50	4	43	29	32	0	41	1	50	1	45	0	50
Nov	3	48	1	50	0	44	3	50	2	50	3	50	1	50	0	50
Dec	48	50	3	50	1	50	2	27	12	50	4	50	8	50	2	50

While *Cryptosporidium* had a 74% non-detection rate, *Giardia* had a 75% detection rate. The lowest occurrence was at N12 with 50% of samples positive for *Giardia*, while the greatest occurrence of cysts was 92% at BG9 and E9. With the exception of one elevated result at E11 in 2008, these rankings are consistent with last year's data.

Table 4.4. Monthly Kensico perennial stream *Giardia* results summary, January 1 – December 31, 2009.

	Giardia							
	BG9	E10	E11	E9	MB-1	N12	N5-1	WHIP
# of Samples	12	12	12	12	12	12	12	12
# of Positives	11	9	8	11	9	6	10	8
% Positives	92%	75%	67%	92%	75%	50%	83%	67%
Mean (L^{-1})	0.381	0.083	0.119	0.244	0.079	0.023	0.082	0.050
Median (L^{-1})	0.095	0.060	0.067	0.167	0.033	0.010	0.060	0.040
Maximum (L^{-1})	1.880	0.260	0.422	0.906	0.360	0.080	0.269	0.200

Enhanced Sampling

No enhanced sampling was performed on Kensico streams in 2009.

4.5.2 Keypoints

As per the WWQMP, Kensico Reservoir's aqueduct influents and effluents are monitored weekly for protozoa and HEVs as the source water keypoints for New York City's watershed. A total of 208 protozoan samples and 212 HEV samples were collected at the Kensico keypoint sites in 2009. Results for 204 protozoan samples (up to December 21, 2009) and 188 HEV samples (up to November 23, 2009) were available for inclusion in this report.

Influent Keypoints

Kensico Reservoir influent keypoints (CATALUM and DEL17) were sampled weekly for *Cryptosporidium* and *Giardia*. The summary results are presented in Table 4.5. In 2009, *Cryptosporidium* was detected in seven and four samples (out of 51) for CATALUM and DEL17, respectively, and at low concentrations (maxima = 2 and 1 oocysts 50 L^{-1}, respectively). This is consistent with results from previous years. For example, in 2008 *Cryptosporidium* was detected in seven samples for CATALUM and six samples for DEL17.

Table 4.5. Weekly Kensico Reservoir influent keypoint results, *Cryptosporidium* and *Giardia* summary, January 1 – December 21, 2009.

		CATALUM	DEL17
Cryptosporidium ($50L^{-1}$)	# of Samples	51	51
	# of Positives	7	4
	% Positives	13.7%	7.8 %

Table 4.5. (Continued)Weekly Kensico Reservoir influent keypoint results, *Cryptosporidium* and *Giardia* summary, January 1 – December 21, 2009.

		CATALUM	DEL17
	Mean	0.16	0.08
	Median	0.00	0.00
	Maximum	2.00	1.00
Giardia (50L^{-1})	# of Samples	51	51
	# of Positives	29	41
	% Positives	56.9%	80.4%
	Mean	1.49	1.84
	Median	1.00	1.00
	Maximum	7.00	7.00

Giardia was detected in 29 and 41 samples (out of 51) collected at CATALUM and DEL17, respectively, in 2009, with maxima of 7 cysts 50 L^{-1} at both sites. For comparison, in 2008, *Giardia* detection occurred in 20 and 26 samples (out of 52) collected for CATALUM and DEL17, respectively, with maxima of 5 cysts 50 L^{-1} at both sites. The mean concentration of *Giardia* at CATALUM in 2009 was more than double the concentration in 2008, rising from 0.71 to 1.49 cysts 50 L^{-1}. The mean *Giardia* concentration at DEL17 was approximately 80% higher, increasing from 1.02 to 1.84 cysts 50 L^{-1}. Changes in operational mode may account for these differences; however, all possibilities are being investigated.

Effluent Keypoints

The effluent keypoints of Kensico Reservoir (CATLEFF and DEL18) were also sampled weekly for *Cryptosporidium* and *Giardia* in 2009. *Cryptosporidium* was detected in 1 sample at CATLEFF and 4 samples at DEL18 (Table 4.6). For comparison, in 2008, *Cryptosporidium* was detected in 10 samples at CATLEFF and 1 sample at DEL18. As in past years, *Cryptosporidium* was found only at low levels at the Kensico effluents, with a maximum count of 1 oocyst 50 L^{-1} for both sites. The mean *Cryptosporidium* concentrations were low for these sites as well, at 0.02 and 0.08 oocyst 50 L^{-1} (CATLEFF and DEL18, respectively.) This is a substantial decrease at CATLEFF when compared to the 2008 value of 0.23 oocyst 50 L^{-1}.

Table 4.6. Weekly Kensico Reservoir effluent keypoint results, *Cryptosporidium* and *Giardia* summary, January 1 – December 21, 2009.

		CATLEFF	DEL18
Cryptosporidium(50L^{-1})	# of Samples	51	51
	# of Positives	1	4
	% Positives	2.0%	7.8%
	Mean	0.02	0.08
	Median	0.00	0.00
	Maximum	1.00	1.00
Giardia (50L^{-1})	# of Samples	51	51
	# of Positives	43	38
	% Positives	84.3%	74.5%
	Mean	2.00	1.57
	Median	2.00	1.00
	Maximum	8.00	5.00

There were 43 and 38 positive detections of *Giardia* at CATLEFF and DEL18, respectively, out of 51 samples collected in 2009. In 2008, *Giardia* detections were comparable—46 and 39 positive detections (out of 52 samples, CATLEFF and DEL18, respectively.) Maximum *Giardia* cyst concentrations were also comparable to prior years at 8 and 5 in 2009, versus 7 and 8 in 2008 (CATLEFF and DEL18, respectively). Mean *Giardia* concentration at CATLEFF for 2009 (2.00 cysts 50 L^{-1}) was quite similar to that of 2008 (2.02 cysts 50 L^{-1}). The DEL18 mean *Giardia* concentration for 2009 (1.57 cysts 50 L^{-1}) was similar to those in past years, with only a slight decline from 2008 (1.69 cysts 50 L^{-1}).

Human Enteric Virus Monitoring

All Kensico Reservoir keypoints (CATALUM, DEL17, CATLEFF, and DEL18) were monitored weekly for human enteric viruses. A summary of the results is presented in Table 4.7. Results up to November 23, 2009 were available for inclusion in this report. One set of four results from August 17, 2009, however, is not included in this report, because samples arrived at the contract laboratory over 20° C. These samples were analyzed, but due to the elevated temperature, resamples were collected on August 20, 2009; those are the data included in this report. As a note, both the original samples and the resamples were all non-detect.

Table 4.7. Summary of human enteric virus results at Kensico keypoints, January 1 – November 23, 2009.

	Human enteric viruses (MPN 100 L^{-1})*			
	CATALUM	CATLEFF	DEL17	DEL18
# of Samples	47	47	47	47
# of Positives	5	3	2	4
% Positives	10.6%	6.4%	4.3%	8.5%
Mean	0.26**	0.11**	0.04**	0.09**
Median	0**	0**	0**	0**
Maximum	5.75	3.25	1.03	1.03

*Results for samples after November 23, 2009, are pending.
**Zero value was substituted for non-detect values when calculating mean and median results.

Average HEV detection rates at Kensico were quite low for all sites (Figure 4.10). Percent detection at the influent sites was equal to that at the effluents of Kensico Reservoir in 2009 (7.4%). As observed in past years, nearly all the detections of viruses occurred in the winter/spring period (Figure 4.11). The only exception in 2009 was a detect in late July at Del17.

Mean virus concentrations were also low at each site with a combined influent mean of 0.15 MPN 100L^{-1}, and a pooled effluent mean of 0.10 MPN 100L^{-1}. Results did not indicate a significant difference in virus concentrations between the Catskill and Delaware Systems, although the Catskill System was slightly higher due to both maximum values occurring in that system (CATALUM, 5.75 MPN 100L^{-1} and CATLEFF, 3.25 MPN 100L^{-1})) (Table 4.7).

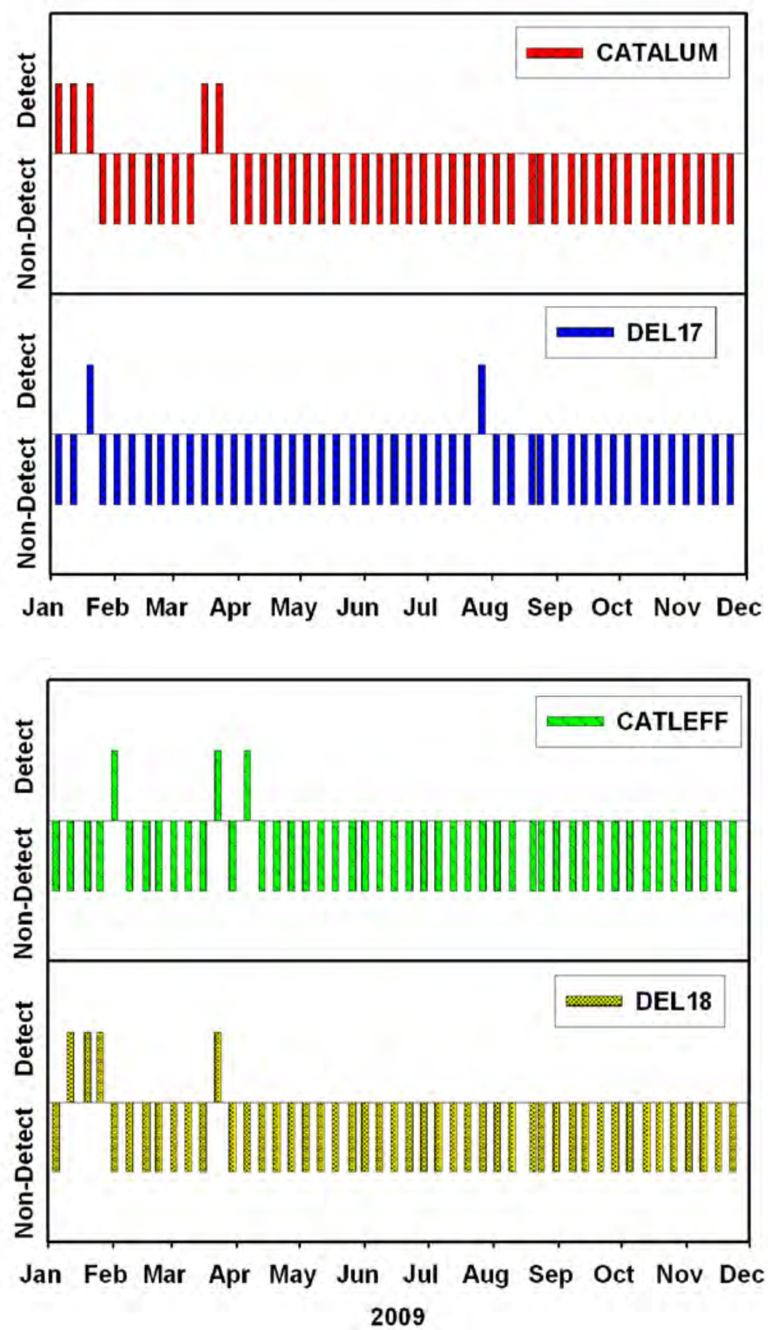

Figure 4.11 Positive detection frequency of human enteric viruses at the four Kensico keypoints, January 1 – November 23, 2009. HEV results for samples taken after November 24, 2009 are pending.

4.6 Other Results

4.6.1 Stream Chemistry

The surveillance of Kensico Reservoir is a primary requirement of the 2007 FAD under Section 4.10, "Kensico Water Quality Control Program." In addition to the coliform bacteria, turbidity, and pathogen results previously discussed, DEP also monitors the perennial streams for other analytes, including temperature, pH, specific conductivity, alkalinity, dissolved oxygen, chloride, total suspended solids, and nutrients. Monitoring for these analytes is an important component of the surveillance program. Descriptive statistics of the 2009 results for these analytes are displayed in Table 4.8 .

Table 4.8. Annual statistics for physical, nutrient, and other chemical analytes in Kensico's perennial streams, January–November, 2009.

Analyte	Site	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
Temperature (°C)	BG9	11	1.4	2	12.2	21.5	22.5
	E10	11	0	2.4	11.5	16.6	19
	E11	11	1.5	2.3	12.5	20.6	22.6
	E9	11	0.5	1.3	12.9	16.9	20.8
	MB-1	11	1.2	2.6	12.5	17.9	20.8
	N12	11	0.1	2.5	11.5	15.4	17.8
	N5-1	11	1.4	3.3	11.1	16.9	20
	WHIP	11	0.1	3.4	11.9	16.2	20
Dissolved Oxygen (mg L^{-1})	BG9	11	0.6	6.3	8.2	11.6	12.8
	E10	11	8.3	8.8	10.7	13.7	15.1
	E11	11	2.7	7.4	10	11.6	15.5
	E9	11	2	3.1	3.7	9.4	10.9
	MB-1	11	8.6	9.4	10.1	13.4	14
	N12	11	9.5	10.3	12.5	14.6	15.6
	N5-1	11	8.5	9.8	10.9	13.8	15.5
	WHIP	11	8.9	9.7	11.1	15	24.1
Specific Conductivity (µmhos cm^{-1})	BG9	12	102	567.5	627.5	759.8	870
	E10	10	647	780.8	923	1052.3	1283
	E11	11	400	434	474	518	543
	E9	11	433	490	530	626	659
	MB-1	12	118	460.5	583	642.3	939

Table 4.8. (Continued) Annual statistics for physical, nutrient, and other chemical analytes in Kensico's perennial streams, January–November, 2009.

Analyte	Site	N	Minimum	25^{th} Percentile	Median	75^{th} Percentile	Maximum
	N12	12	70	347.8	391.5	427.8	1300
	N5-1	12	109	446.8	490.5	521	835
	WHIP	12	43	369.5	388	415	424
Chloride (mg L^{-1})	BG9	9	110.5	119.8	127.6	179.1	252.6
	E11	10	44	47.3	59.75	70.98	80
	MB-1	10	60.4	92.3	115.1	150.7	298.5
	N12	10	46.7	55.3	59	87.8	336
	N5-1	10	64.6	78.3	81.9	119.9	269.6
	WHIP	10	64.1	64.88	69.75	76.55	82.1
pH	BG9	11	6.63	7.05	7.13	7.21	7.5
	E10	11	7.43	7.55	7.63	7.73	7.8
	E11	11	6.67	7.3	7.59	7.76	8.47
	E9	11	6.7	6.74	7.06	7.15	7.69
	MB-1	11	6.97	7.18	7.37	7.44	7.64
	N12	11	7.5	7.63	7.74	7.89	8.04
	N5-1	11	7.16	7.49	7.56	7.61	7.68
	WHIP	11	7.47	7.67	7.75	7.93	8.1
Alkalinity (mg L^{-1} $CaCO_3$)	BG9	11	53.9	62.9	70.5	89	101
	E11	11	114	122.3	128.5	135	145.2
	MB-1	11	63.8	71.5	81.7	87.6	91.2
	N12	11	55.9	57.7	67.2	87.8	95.1
	N5-1	11	68.6	73.4	77.2	88.3	95.5
	WHIP	11	44.5	46.8	58.5	64.2	83.3
Dissolved Organic Carbon (mg L^{-1})	BG9	10	1.7	1.8	2.85	3.925	4.4
	E11	10	3.2	3.95	4.45	5	17.6
	MB-1	11	1.7	2.1	3.3	3.6	4.9
	N12	11	1.5	1.7	2.2	2.6	3
	N5-1	11	1.6	1.9	2.5	3.1	4.6
	WHIP	11	1.8	1.8	2.4	2.8	3.2
Total Phosphorus (µg L^{-1})	BG9	10	11	15	17.5	24.75	29
	E11	11	10	17	24	28	107

Table 4.8. (Continued) Annual statistics for physical, nutrient, and other chemical analytes in Kensico's perennial streams, January–November, 2009.

Analyte	Site	N	Minimum	25^{th} Percentile	Median	75^{th} Percentile	Maximum
	MB-1	11	13	22	27	61	100
	N12	11	6	9	11	22	29
	N5-1	11	17	22	35	54	65
	WHIP	11	8	10	14	24	38
Total Nitrogen (mg L^{-1})	BG9	11	0.29	0.34	0.45	0.57	0.65
	E11	10	0.19	0.2775	0.28	0.3025	0.32
	MB-1	11	0.29	0.42	0.55	0.64	0.99
	N12	11	0.28	0.84	1	1.16	1.38
	N5-1	11	0.42	1.07	1.2	1.33	1.66
	WHIP	11	0.13	0.82	0.91	1.01	1.27
NH_3-N (mg L^{-1})	BG9	10	<.01	0.019	0.034	0.038	0.071
	E11	11	<.01	-	-	-	<.02
	MB-1	11	<.01	-	0.012	0.035	0.063
	N12	11	<.01				<.02
	N5-1	11	<.01	0.009	0.036	0.059	0.077
	WHIP	11	<.01	-	-	-	<.02
NO_3+NO_2-N (mg L^{-1})	BG9	10	0.061	0.1338	0.231	0.3913	0.536
	E11*	11	<.02	-	0.044	0.05	0.302
	MB-1	11	0.08	0.215	0.307	0.391	0.642
	N12	11	0.774	0.842	0.968	1.195	1.331
	N5-1	11	0.618	0.969	1.031	1.305	1.611
	WHIP	11	0.71	0.73	0.895	1.057	1.21
Total Suspended Solids (mg L^{-1})	BG9	12	1	1.4	2.45	3.2	9.6
	E11*	12	<1	1.7	2.3	7.1	11.8
	MB-1*	12	<1	1.6	2.3	4.6	4.8
	N12*	12	<1	1.1	2	3.1	7.5
	N5-1*	12	<1	-	3.6	5.3	8.7
	WHIP*	12	<1	-	1.2	2.2	5.3

* Due to the presence of censored data, Kaplan-Meier methods were used to estimate the percentiles.

\- Due to the presence of censored data, the percentile could not be estimated.

4.7 BMP Evaluation

As part of DEP's efforts to improve the water quality of Kensico Reservoir, NYC's terminal reservoir prior to treatment and eventual distribution to consumers, 45 Best Management Practice (BMP) structures have been built. This section fulfills the requirement in the 2007 FAD (Section 4.10) to report on the findings of the stormwater BMP monitoring program. The goal of the program was to take samples during storm events in order to test the BMPs' efficiencies. The five BMPs selected for the study were BMP 12, BMP 13, BMP 37, BMP 57, and BMP 74 (Figure 4.12, Table 4.9). The evaluation period during which each BMP was sampled and the number of storms analyzed for each BMP are displayed in Table 4.10.

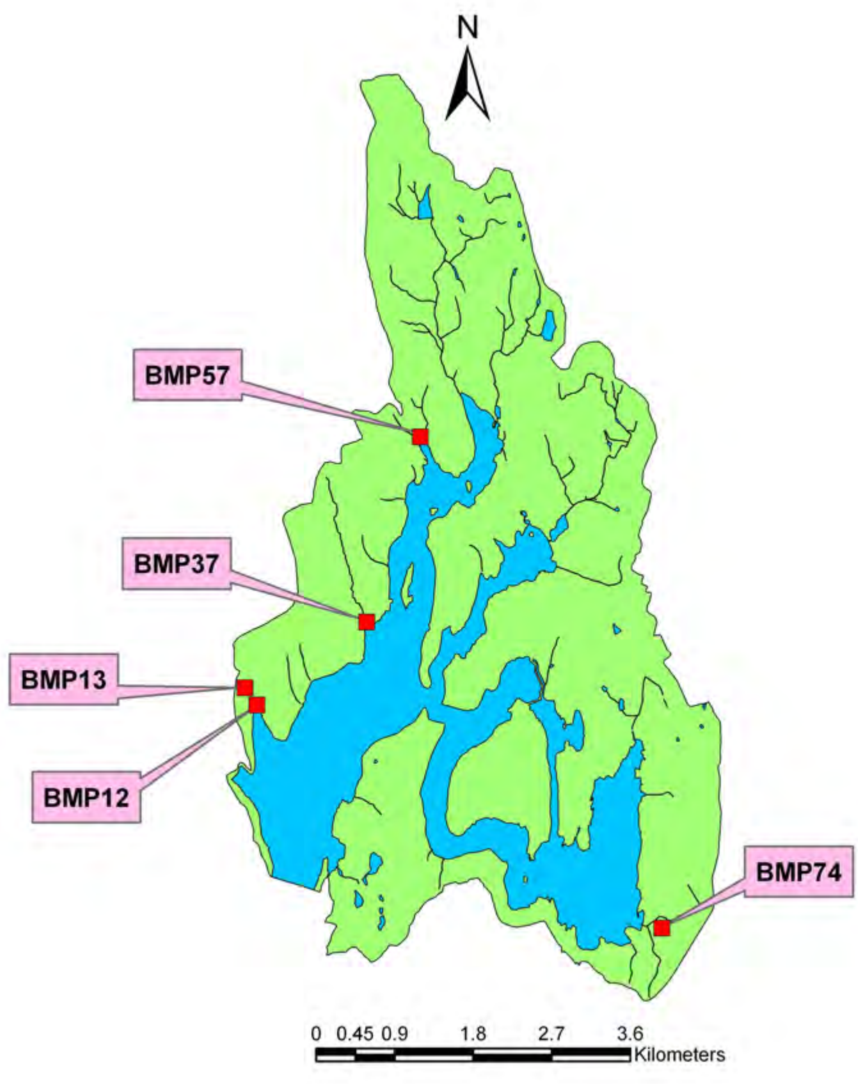

Figure 4.12 Map of the Kensico watershed with the five BMP sites selected for evaluation.

Table 4.9. Sample site description.

BMP #	BMP Type	Tributary Name	Design Storm (inches)	Sampling Locations
12	Retention Pond (Wet) - Surface Pond with Permanent Pool	Malcolm Brook	1.0	Inlets: MB-3, MB-4 Outlet: MB-1
13	Wetland - Basin without Open Water (Wetland Meadow Type)	N1	1.5	Inlet: BMP13IN Outlet: BMP13OUT
37	Retention Pond (Wet) - Surface Pond with Permanent Pool	N5	1.2	Inlet: N5-1 Main Outlet: N5-1
57	Sand Filter with Layered Media	None	1.0	Inlet: BMP57IN Outlet: BMP57OUT
74	Retention Pond (Wet) - Surface Pond with Permanent Pool	E11	1.0	Inlets: E11N1, E11S1 Outlet: E11

Table 4.10. Sample site evaluation period and number of storm events analyzed.

Site	Monitoring Period	# Events Monitored	# Events Analyzed
BMP12	Feb. 2000 - Sep. 2001	17	15
BMP13	Apr. 2005 - Oct. 2006	14	11
BMP37	Sep. 2002 - Sep 2004	19	?
BMP57	Apr. 2005 - Oct. 2006	11	7
BMP74	Oct. 2006 - Oct. 2007	8	8

Although these BMPs were designed to reduce suspended solids, the specific objectives of the study were:

1) To quantify the fecal coliform and total suspended solids load reductions that can be attributed to four extended detention basins and one sand filter constructed within Kensico catchments. To determine the effectiveness of BMPs, load reductions were calculated on an event basis and as average annual storm loads, and compared to their design removal rates.

2) To quantify the total phosphorus load reduction that can be attributed to four extended detention basins and one sand filter constructed within Kensico catchments. Load reduction was calculated on an event basis, and as average annual storm loads.

Methods

Monitoring stations were established at the influents and effluents of each BMP. Each monitoring station was equipped to measure stream discharge as well as take discrete samples at different times during a storm, using autosamplers. Water quality measurements were performed in the laboratory (Figure 4.13).

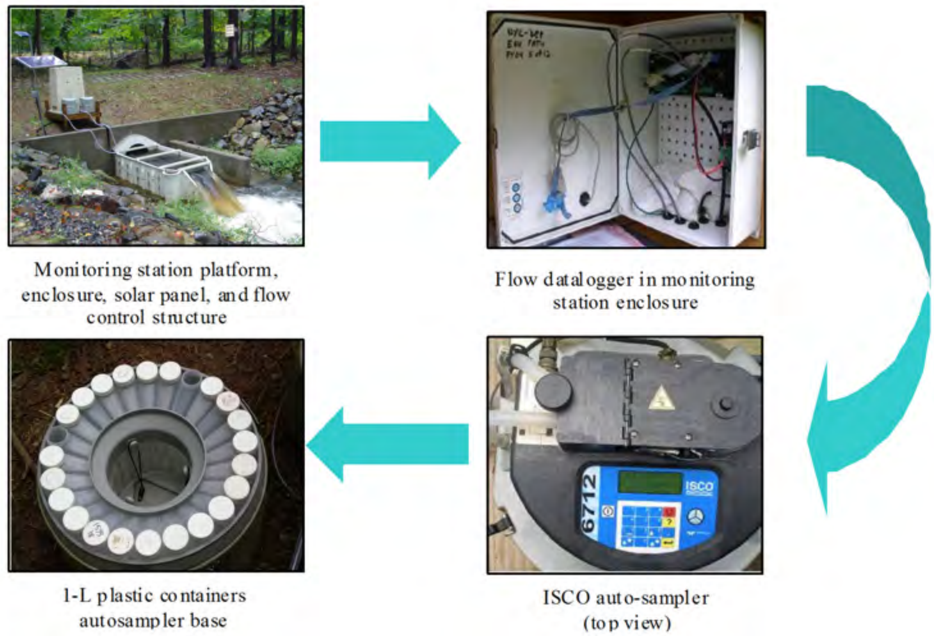

Figure 4.13 Stream monitoring station equipment for stream discharge measurements and data storage as well as for obtaining discrete samples at different times during a storm event.

Monitoring of storm events at each BMP was conducted in accordance with the Quality Assurance Protection Plan (QAPP), *Monitoring Plan for Kensico Streams Best Management Practices to Fulfill Integrated Monitoring Report Objective 2.7.3* (DEP 2004). The program objective was to monitor 10 high-flow storm events below the design storm event (1.0-1.5 inches) for each BMP. Samples were collected over the duration of each storm event using an ISCO autosampler and accessories that included a staff gage, datalogger and pressure transducer, a weir or flume, ice, and approximately 200 autosampler bottles. Continuous stage and discharge data were recorded throughout each event. Grab samples were collected at periodic intervals during the storm at the BMP's inlet and outlet. Samples were transferred under chain-of-custody protocol to DEP's ELAP-certified Kensico Laboratory for analysis. In the laboratory, 10 samples were selected from each sampling station (if possible) to characterize the storm hydrograph; ideally, these samples represented the hydrograph's rising limb, peak, and descending limb. Each sample was analyzed for fecal coliform, turbidity, total suspended solids, and total phosphorus. All samples were subject to the QA/QC procedures outlined in the QAPP.

Data obtained from these analyses were used to quantify load reduction (and thus BMP efficiency). Load was calculated by calculating the sum of all the samples for a particular parameter of a given storm. To compare the influent and effluent load among the sample sites, the flow volume associated with a given sample had to be taken into account. Ideally, the flow volume into a BMP during the sampling period should be equivalent to the flow volume at the effluent. However, this was difficult to achieve, given that there is a lag time between water entering and exiting a BMP. Moreover a similar volume of water takes longer to exit a BMP since it attenuates the flow. Hence, to optimize the load comparison between the influent and effluent of a given BMP, the load must be indexed to flow volume. For this study, loading was indexed to the volume at the effluent according to the following equation:

$$\text{Loading} = (\Sigma V_{inf.} / \Sigma V_{eff.}) * \Sigma P$$

where

$\Sigma V_{inf.}$ = the sum of the sample volumes at the BMP influent

$\Sigma V_{eff.}$ = the sum of the sample volumes at the BMP effluent

ΣP = the sum of the sample parameters (Fecal Coliform (FC), Total Phosphorus (TP), Total Suspended Solids (TSS), or Turbidity) for a given storm event at a given sample site

Results

According to the QAPP, the analysis of a BMP should be represented by an analysis of at least 6-10 storms at each site, which was achieved (Table 4.11). The goal of the sampling was to appropriately characterize the storm hydrograph by obtaining samples at the different storm phases. However, not every storm sampled at a given BMP could be used in the analysis of its effectiveness, because not every storm hydrograph was adequately characterized by the sampling. This was due to equipment malfunction and other errors.

Table 4.11. Summary of the number of storm events sampled and analyzed at each BMP.

Site Name	# of storms sampled	# of storms analyzed
BMP12	20	15
BMP13	14	12
BMP37	19	13
BMP57	10	8
BMP74	8	8

The loading results indicate that all the BMPs produced some degree of load reduction for FC, TSS, turbidity, and TP, for storms within their design (Figures 4.14 through 4.18). However, load reduction was not a linear relationship, and in a few cases the BMPs even caused an increase. Load reduction was minimal at lower loads, but showed a tendency to improve as load increased. The lower load reductions at lower concentrations, usually associated with lower precipitation and hence a lower potential for transport across the reservoir, are likely related to the fact that the loads were close to the “irreducible pollutant concentration” (Schueler 1996), which is a threshold concentration which cannot be further reduced for a specific pollutant by a given BMP. On the other hand, the progressively increasing load reduction at the higher loads is more likely associated with larger storms, with their higher potential for transport. This demonstrates that the BMPs constructed on Kensico Reservoir are providing a benefit to water quality.

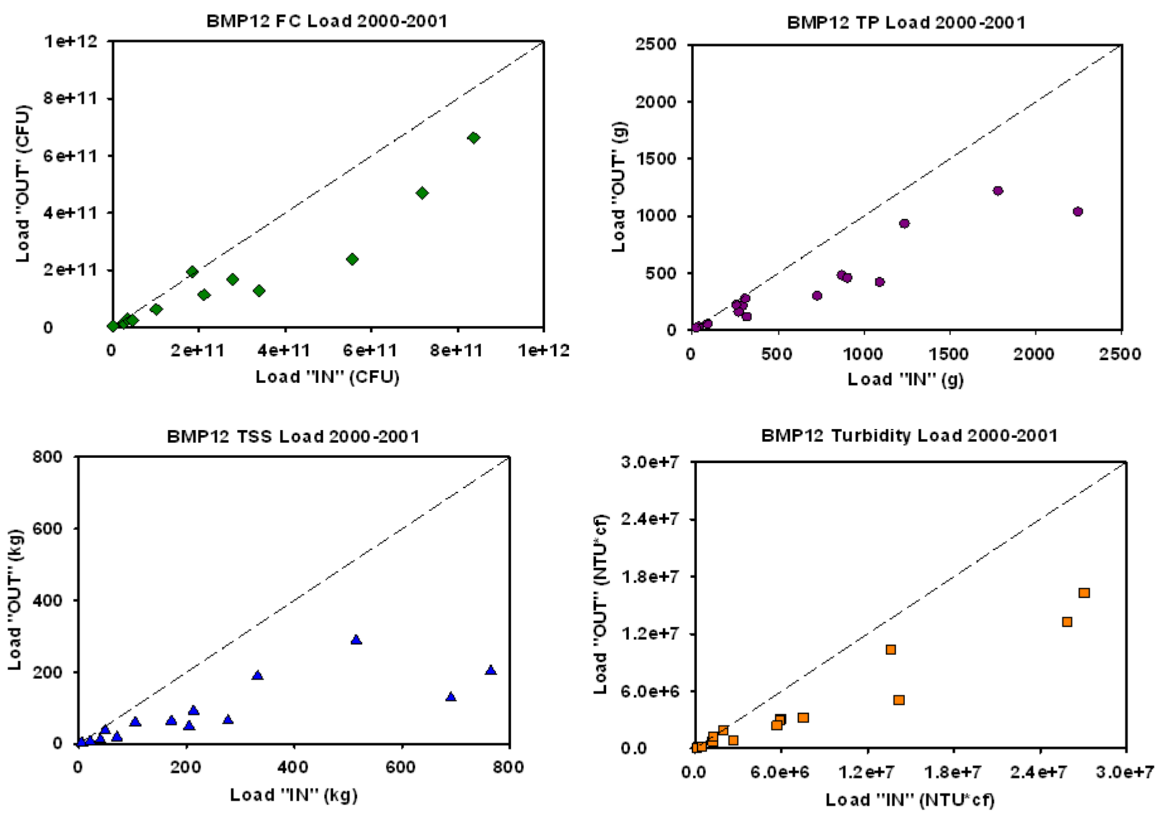

Figure 4.14 BMP12 efficiency assessment (comparison of influent versus effluent) for fecal coliform (FC) load, total phosphorus (TP) load, total suspended solids (TSS) load, and turbidity load.

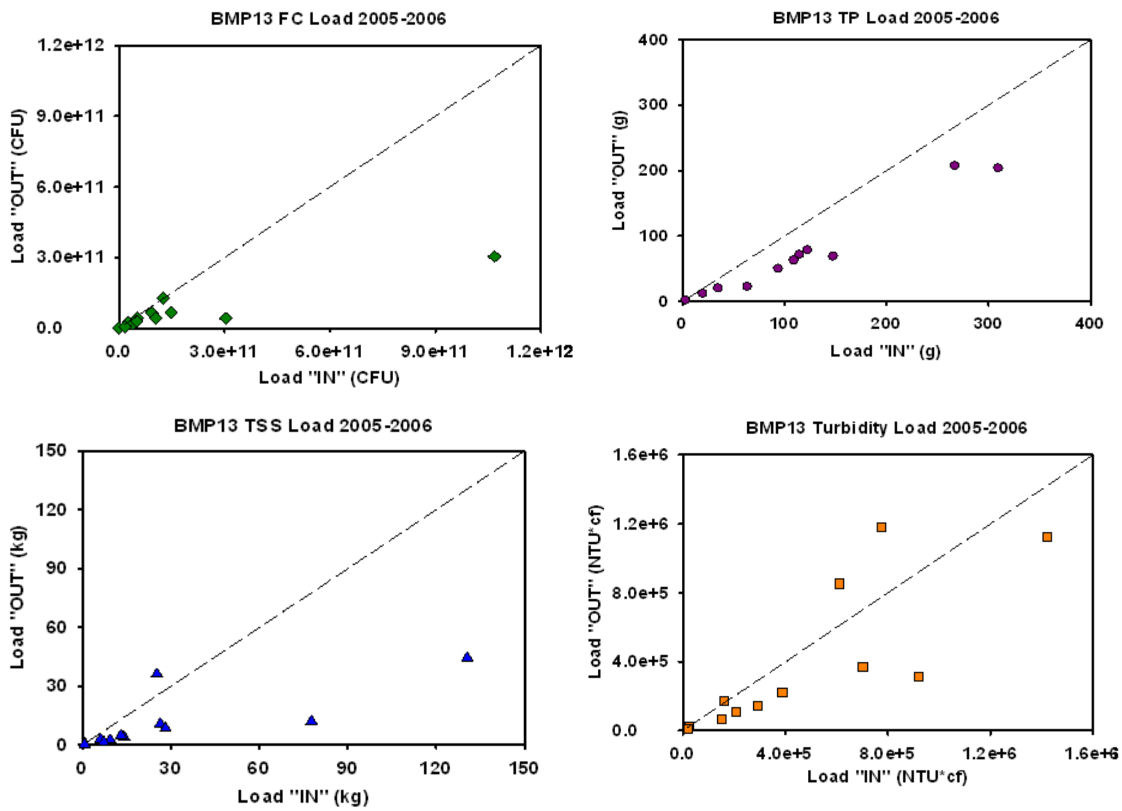

Figure 4.15 BMP13 efficiency assessment (comparison of influent versus effluent) for fecal coliform (FC) load, total phosphorus (TP) load, total suspended solids (TSS) load, and turbidity load.

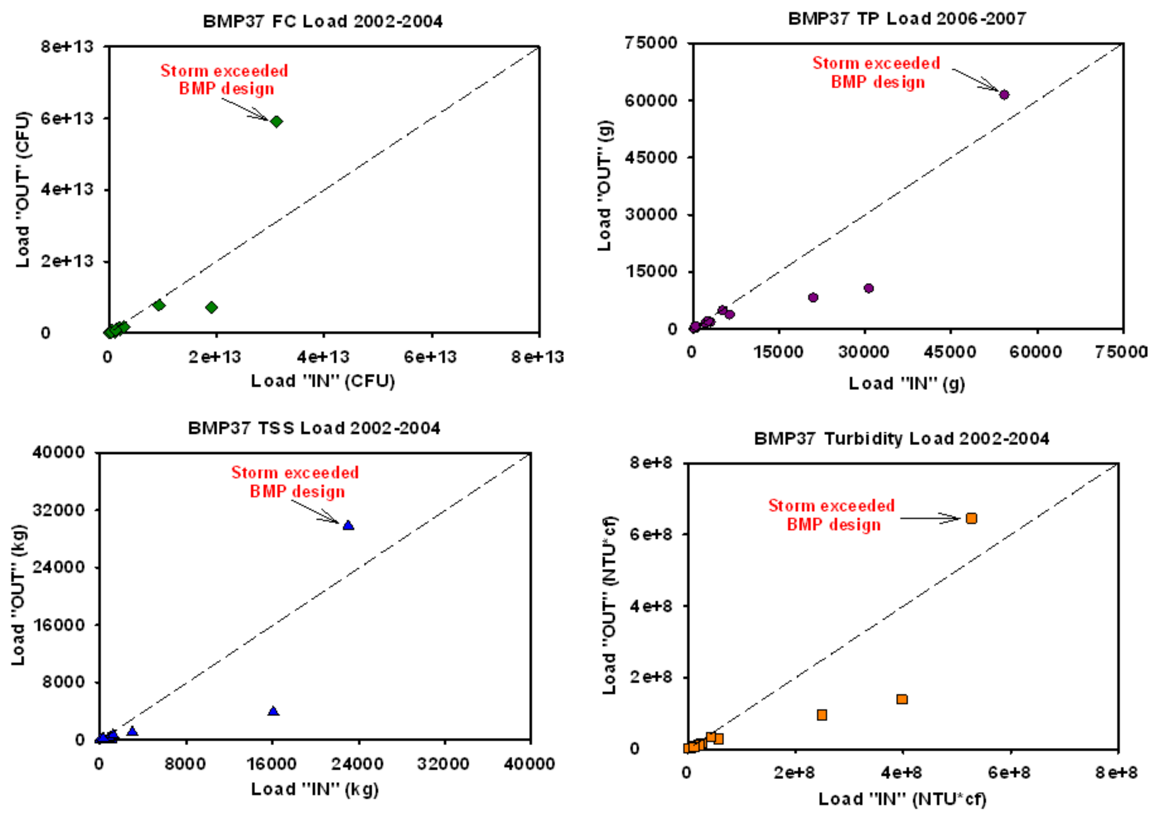

Figure 4.16 BMP 37 efficiency assessment (comparison of influent versus effluent) for fecal coliform (FC) load, total phosphorus (TP) load, total suspended solids (TSS) load, and turbidity load. Note that one monitored storm exceeded the BMP design and resulted in greater FC, TP, TSS, and turbidity at the BMP effluent.

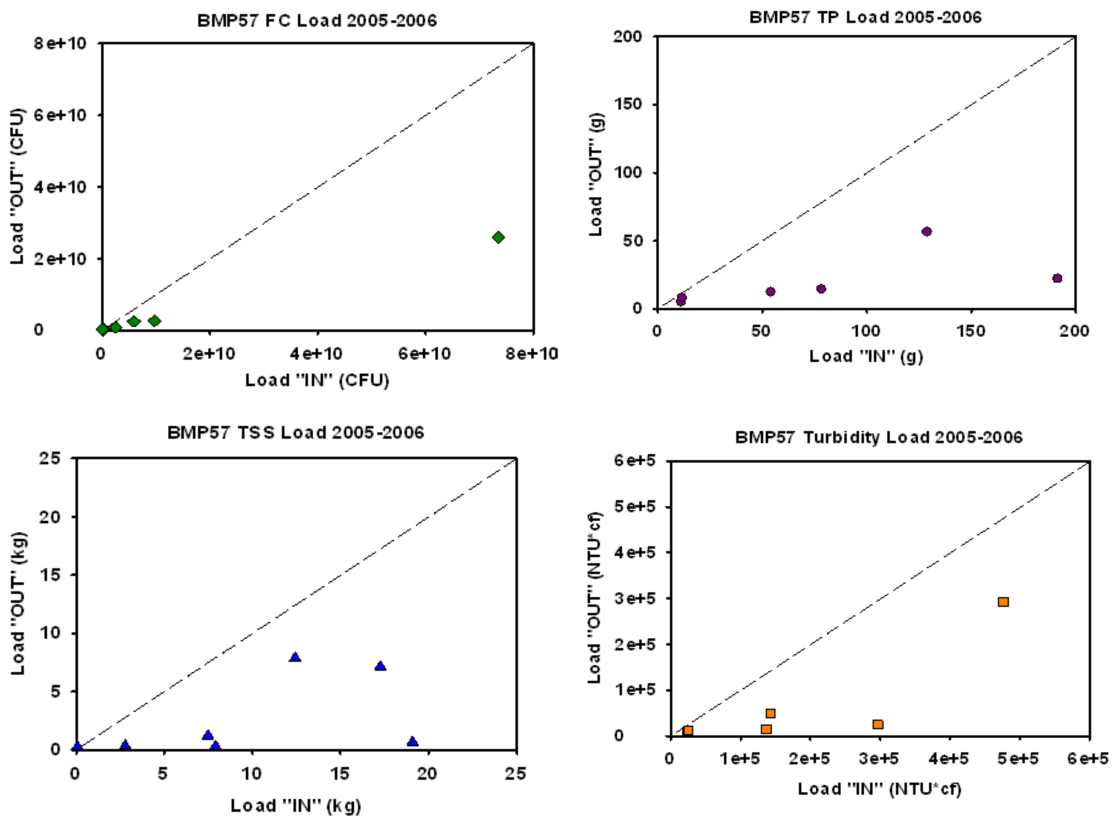

Figure 4.17 BMP57 efficiency assessment (comparison of influent versus effluent) for fecal coliform (FC) load, total phosphorus (TP) load, total suspended solids (TSS) load, and turbidity load.

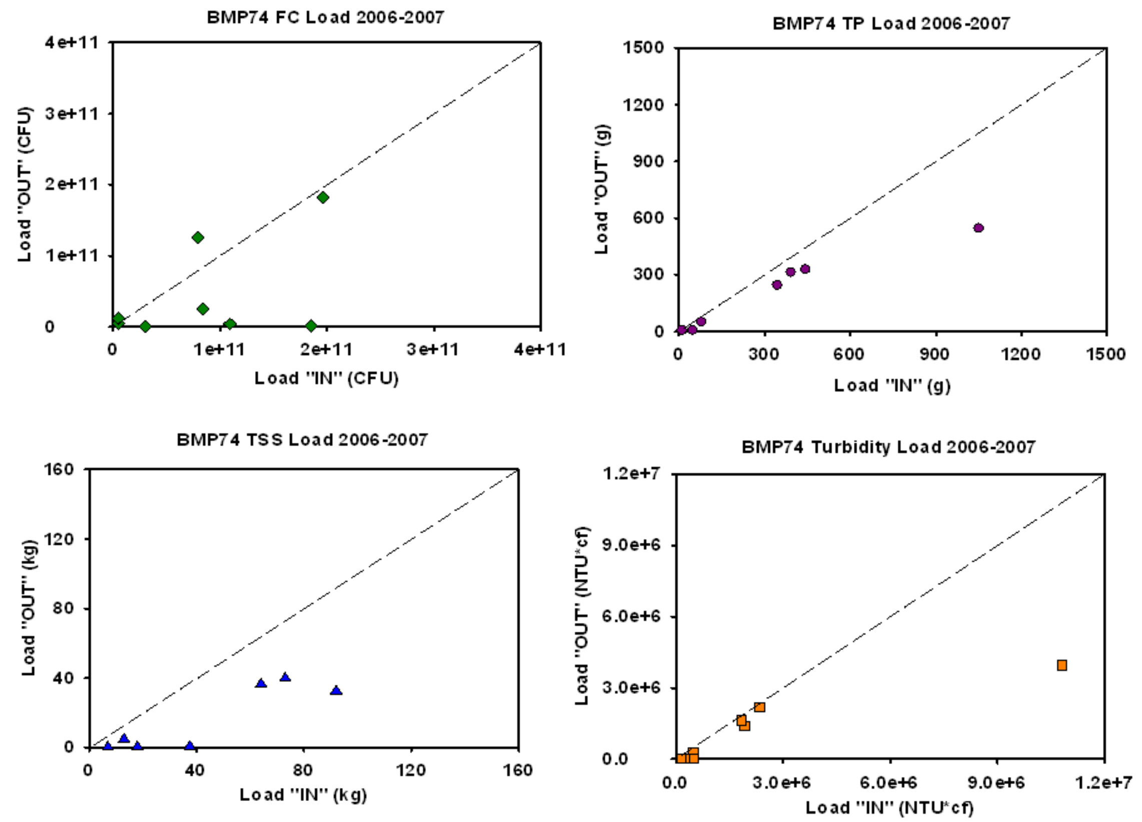

Figure 4.18 BMP 74 efficiency assessment (comparison of influent versus effluent) for fecal coliform (FC) load, total phosphorus (TP) load, total suspended solids (TSS) load, and turbidity load.

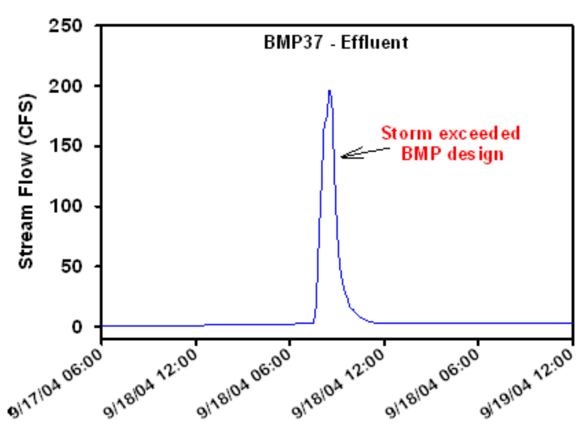

Figure 4.19 Hydrograph of a 2.4-inch storm at the effluent of BMP37, indicating the BMP design (1.2 inches) was exceeded.

For storms exceeding the BMP design—for example, a >1-inch storm at a BMP structure designed to capture a 1-inch storm—the load associated with the portion of the storm exceeding the design would theoretically not be attenuated. A clear example of this was seen at BMP 37, which is designed to capture a 1.2-inch storm. A 2.4-inch storm occurred on September 17, 2004, over the course of 12 hours. For this particular storm, the hydrograph showed a sharp spike in flow, indicating that the amount of water generated by the storm greatly exceeded the BMP design (Figure 4.19).

The FC, TP, TSS, and turbidity data at BMP 37 all indicated a higher load at the effluent site (Figure 4.16). This finding was important because, for storms exceeding the design, it suggests that the BMP may actually increase loads rather than reduce them. This is supported by similar findings at the other BMPs, where a greater load at the effluent occurred during storms exceeding the BMP design. Despite this finding, there were also examples of storm events exceeding the design where a load increase at the BMP effluent was not observed. A closer look at individual storms indicates that in most cases, larger storms that were drawn out over a longer period did not cause a sharp increase in stream flow, and in turn did not cause an increase in load at the BMP effluent. This suggests that higher intensity storms that exceed the BMP design due to a rapid increase in stream flow and the likely resuspension of the BMP sediment (such as the one that occurred on September 17, 2004) may be the reason for the increase in load.

In summary, the results of this study suggest that BMPs do indeed provide a reduction in TSS, turbidity, FC, and TP load, and hence provide an improvement to water quality compared to what would be observed were BMPs not present. The BMPs were not specifically designed to remove fecal coliforms because it had been assumed that removal of suspended solids would result in a reduction in fecal coliform concentrations. Nevertheless, the loading results do indicate some degree of reduction, depending on initial load, size and intensity of the storm, provided it is a storm within the design of the BMP.

A complementary analysis performed by consultants EA Engineering P.C. and its affiliate EA Science and Technology Inc. (2007), examining BMP performance by looking at different measures of BMP efficiency (Event Mean Concentration and the Effluent Probability Method) also indicated that the BMPs functioned according to design. However, the EA analysis indicated that for its measures of BMP efficiency, the reduction in fecal coliforms was not statistically significant. This difference may be due to the fact that some storms included in the consultant’s analysis were excluded from the storms analyzed by DEP.

5. Robotic Water Quality Monitoring Network on Kensico Reservoir

The project described below represents the first year of a three-year effort, performed under contract by the Upstate Freshwater Institute (UFI), to deploy, operate, and maintain a robotic monitoring network on portions of the NYC system of reservoirs. This report will focus on the progress on Kensico Reservoir.

5.1 Background

Water quality monitoring information is critical to guide effective management and protection of water supplies. In many situations monitoring needs can be met by manual fixed-frequency programs. However, event-based water quality problems, such as the elevated turbidity levels that are experienced in certain NYC reservoirs in response to runoff events, represent special challenges for effective monitoring. Effective monitoring is necessary to establish reasonable expectations with respect to the magnitude and duration of impacts from runoff events, and to form a basis for management action such as modifications in operations of the various reservoirs in the system.

Effective monitoring of runoff events to support related management needs has two basic requirements: (1) representative measurements in time and space of forcing, or driving, conditions (e.g., stream turbidity levels) and in-reservoir patterns, and (2) timely communication of measurements to managers and management tools (e.g., mathematical models). New remote robotic monitoring technologies have been developed, and recently successfully demonstrated within the NYC water supply watershed (O'Donnell and Effler 2006), that can meet these requirements. These devices provide more complete monitoring coverage and transfer data to managers more rapidly than could realistically be achieved through manual efforts. Moreover, this information can be obtained and delivered in a more cost-effective manner through these technologies, over the long-term, than could be achieved through manual monitoring approaches.

The Kensico Reservoir robots will be deployed as long as the reservoir remains ice free. The buoys continue to operate reliably under snow/ice cover, but routine access to buoys would not be safe for field technicians. All the robots are configured with sensors that measure an array of parameters of particular interest to water quality and related features of transport. An effective data transmission system is being implemented to deliver measurements to DEP staff in near-real-time (NRT). Data will be presented in engaging formats to allow DEP staff to identify salient information and noteworthy changes. Additionally, these data will be processed in an appropriate manner to facilitate use as inputs for water quality models now used by DEP.

Figure 5.1 depicts the location of the monitoring sites on Kensico Reservoir. Table 5.1 lists the sites with brief descriptions of locations, monitoring equipment type, and deployment dates.

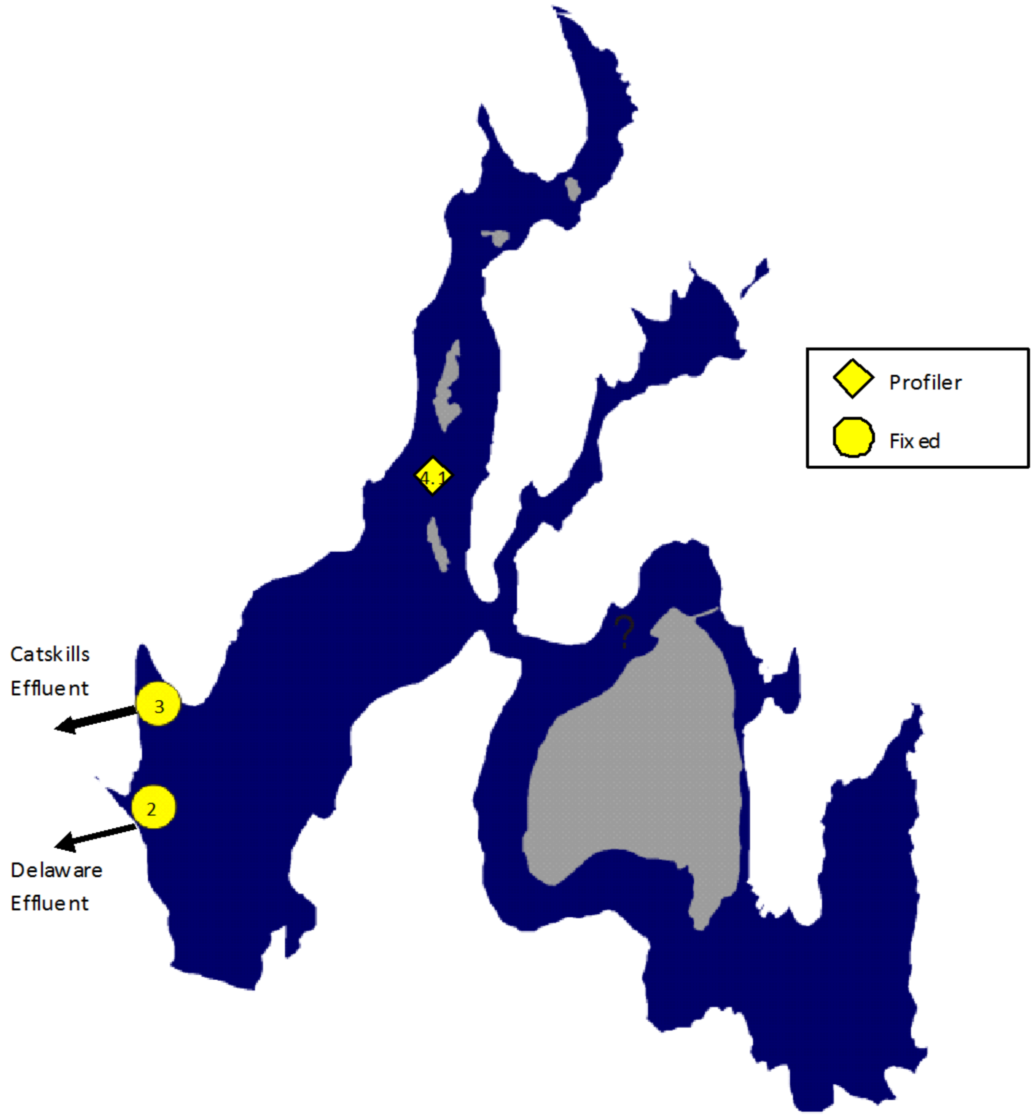

Figure 5.1 Kensico Reservoir robotic buoy locations.

Table 5.1. Robotic monitoring location, equipment type, and deployment date.

Location	Station Description	Type	Deployment Date
Station 4.1	Reservoir arm containing Catskill influent	Profiling/Sonde	5/5/2009
Station 3	Catskill effluent	Fixed/Transmissometer	8/20/2009
Station 2	Delaware effluent	Fixed/Transmissometer	12/2/2009

5.2 Monitoring Equipment

The robotic network consists of a profiling buoy manufactured by YSI, Inc. and two fixed depth buoys developed by the Upstate Freshwater Institute (UFI). The type of buoy used is determined by the measurement needs (e.g., depth resolution and measurement frequency) at each site at which a buoy is to be located, while recognizing the limitations of different monitoring equipment. The profiling buoy is located in the Catskill influent arm of the reservoir (Figure 5.1). At this location, the profiling capability provides water quality data at 1 m depth intervals from 1 m below the surface to about 1 m above the reservoir bottom. Profiling frequency is up to 4 times per day (every 6 hours). These data are used to assess thermal stratification and turbidity. During elevated turbidity events in Ashokan Reservoir, this buoy can provide an early warning of turbidity transport from the Catskill influent. Detailed vertical profiles from this buoy will be used as model input (initial conditions) and to evaluate model performance.

The fixed depth buoys (Figure 5.1) are located near the Delaware (Station 2) and Catskill (Station 3) effluent chambers. The fixed depth buoys are capable of measuring turbidity at 4 discrete depths. They are intended to provide an early warning of in-reservoir turbidity levels near the effluent chambers. The fixed depth system is capable of making measurements at a greater frequency (at least every 15 minutes) than the profiling system.

5.2.1 Profiling Buoy

The profiling buoy consists of a pontoon type buoy (4' x10') that supports an onboard computer/datalogger, telemetry (cellular broadband), battery and solar panels, and the profiling mechanism. The profiling mechanism consists of a winch with cable guide (level wind) that spools an underwater data cable. The underwater cable provides both the means to communicate with a multiprobe data sonde (YSI 6600) and to move the sonde vertically through the water column. The onboard datalogger is used to both store the sonde and control the winch. Commands can be remotely downloaded to the datalogger to control profiling frequency. The probes deployed on the sonde include temperature, conductivity, depth, turbidity, dissolved oxygen (optical), and fluorometric chlorophyll *a*. The buoy carries a meteorological station that measures air temperature, wind speed and direction, incident solar radiation, relative humidity, and barometric pressure.

The buoy was delivered to UFI in Syracuse, NY, in April 2009. UFI staff tested the equipment in-house and worked with the manufacturer on various issues identified during the testing. The buoy was deployed in May 2009. Since then, UFI staff has continued to work with the manufacturer to address remaining issues with the system.

5.2.2 Fixed Depth Buoys

The fixed depth buoys were built by UFI using off-the-shelf parts. Each system consists of a pontoon type buoy (6' x 8'), transmissometers (WETLabs® CStar) suspended from Kevlar reinforced underwater cables at user selectable depths (maximum of four transmissometers), a datalogger (Campbell Scientific® CR1000), cellular broadband for telemetry, and a solar panel for battery recharge. To reduce fouling, each transmissometer is outfitted with a 12V submersible pump that directs a jet of water across both optical windows prior to making measurements. The first buoy was deployed in August 2009. The transmissometers measure the beam attenuation coefficient at 660 nm ($\underline{c}_{660}$ m^{-1}). $\underline{c}_{660}$ is a surrogate measure of turbidity, and given a 25 cm measurement path length these instruments are much more sensitive than the turbidity probes used on the profiling buoy system described above. The transmissometers provide sensitive monitoring of the low turbidity levels that are in the vicinity of the Kensico aqueduct effluents.

5.3 Network Operations

Data are automatically downloaded at least every three hours. These data then undergo an automated QA process. Data that are found to be outside an expected range are flagged. An email message containing the details of the failure is sent to the UFI person responsible for robotic network maintenance. Data are then uploaded to an FTP server for access by DEP staff.

Future updates to the network include automatically generating email alerts to key DEP staff when elevated turbidity levels are detected at the monitoring sites.

5.4 Maintenance and Verification

UFI is presently conducting routine biweekly maintenance on the buoys. UFI has been working with the profiling buoy's manufacturer to correct ongoing issues with the profiling system. These include repeated power system issues caused by the manufacturer's mis-wiring of the solar panels (corrected after several months), the depth finders (used to determine profiling end depths) not working correctly (this is ongoing), communication issues (corrected) and various software issues (ongoing).

UFI continues to improve the reliability of the fixed depth systems. Shorty after deployment, UFI observed significant fouling on the optical windows of the transmissometers located within the photic zone. The fouling was largely the result of zooplankton (*Sida crystalline*) attaching to the windows. UFI is continuing to evaluate methods to eliminate or reduce fouling. These include increasing the duration or frequency of running the submersible pump and/or utilization of flow tubes with coarse (250 μm) filters to limit zooplankton access to the windows. Other methods will be evaluated if necessary.

5.5 Conclusion

Once the robotic monitoring equipment has been thoroughly tested, it is expected to provide new insights and water quality management opportunities based on high frequency measurements that are not otherwise available.

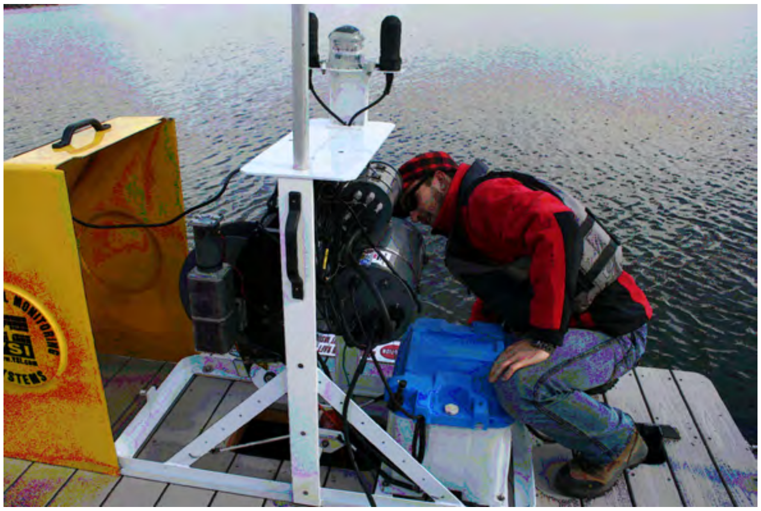

Figure 5.2 Maintenance on profiling buoy. Winch components are on left side of picture, electronics (datalogger, modem) are on right side.

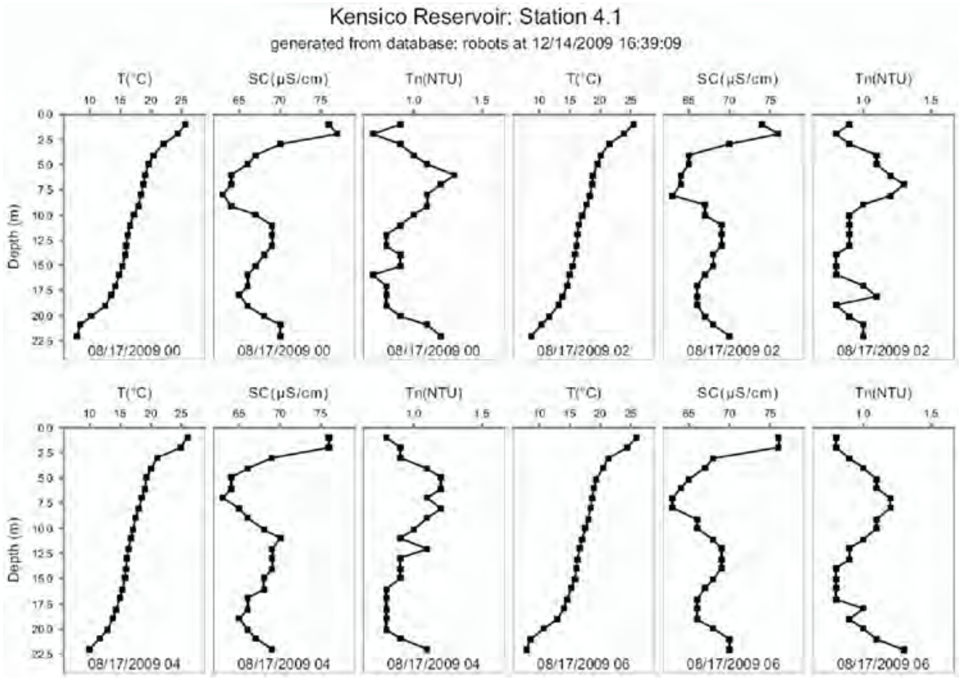

Figure 5.3 Examples of profiles from Station 4.1.

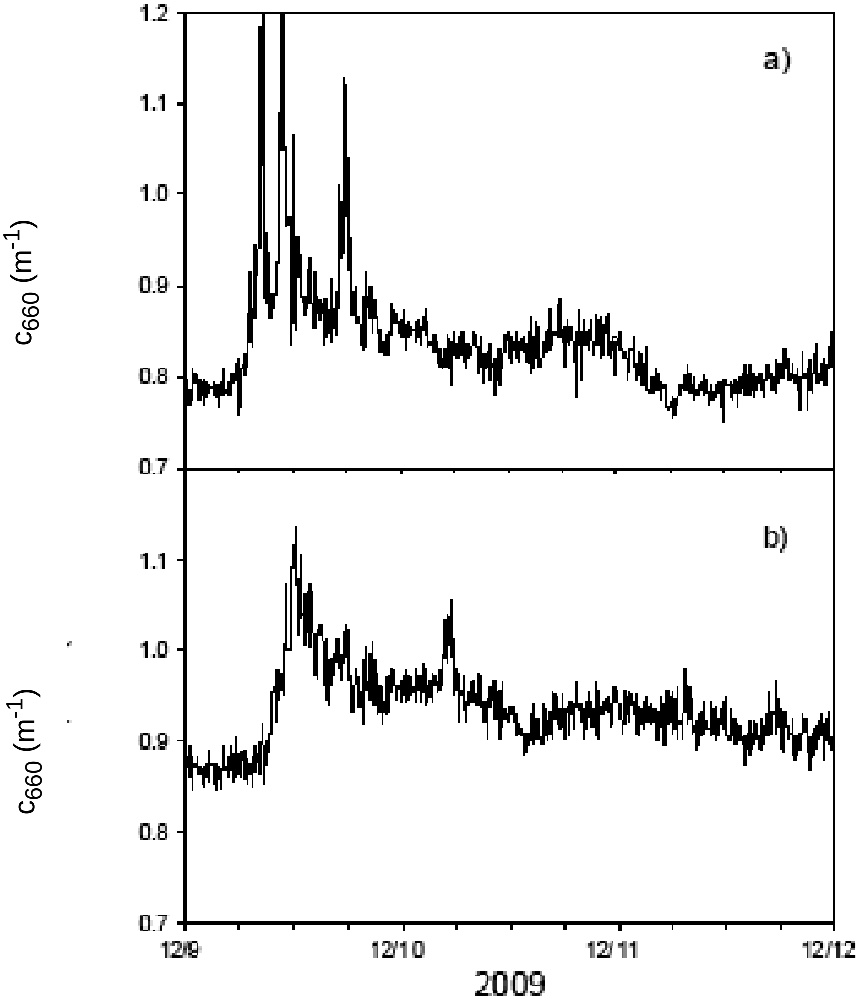

Figure 5.4 Selected time-series from the 10 m transmissometers located on fixed depth buoys at a) Station 2 and b) Station 3. Example shows elevated turbidity during wind (65 km/hr gusts) and rain event (3.5 cm rainfall) on December 9, 2009.

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