NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER SUPPLY

2008 Kensico Water Quality Annual Report

March 2009

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

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List of Acronyms

Acronym	**Definition of Acronym**
CATALUM	Catskill Alum Chamber
CATIC	Catskill Influent Chamber
CATLEFF	Catskill Lower Effluent Chamber
CATUEC	Catskill Upper Effluent Chamber
CFPS	Catskill Falls Pump Station
CFU	Colony Forming Units
DEL 17	Delaware Aqueduct Shaft Building 17
DEL 18	Delaware Aqueduct Shaft Building 18
DEC	New York State Department of Department of Environmental Conservation
DEP	New York City Department of Environmental Protection
DOH	Department of Health
DOT	Department of Transportation
EOH	East of Hudson
USEPA	United States Environmental Protection Agency
FAD	Filtration Avoidance Deliverable
HEV	Human Enteric Virus
ICR	Information Collection Rule
MGD	Million Gallons per Day
MPN	Most Probable Number
NYWEA	New York Water Environment Association?
NOC	Non-Halogenated Organic Carbon
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
VOC	Volatile Organic Compound
WMP	Waterfowl Management Program
WRDA	Water Resource Development Act

Acknowledgements

The Deputy Commissioner of the Bureau of Water Supply, Mr. Paul Rush, and Mr. Steven Schindler, Director of the Water Quality Directorate (WQD), continued to provide general direction for operation of Kensico Reservoir and watershed activities throughout 2008. Continuously changing conditions 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 for NYC consumers.

The members of theWatershed Water Quality Science and Research Division were responsible for coordination, data analysis, and primary authorship roles for this report. They include: Dr. Lorraine Janus, Mr. James Mayfield, Mr. Bryce McCann, Mr. Gerard Marzec, Mr. David Quentin, Mr. Ray Homolac, Dr. Yucel Tokuz, Ms. Kerri Alderisio, Mr. Steve DiLonardo, Mr. Christian Pace, Dr. Don Pierson, Dr. Elliot Schneiderman, Mr. Mark Zion, and Mr. David Lounsbury. 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 that provided the database for this report. The Waterfowl Management Program (WMP) managed by Mr. Chris Nadareski, the East of Hudson Operations managed 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 introductory description of Kensico Reservoir operations. 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.

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.

Executive Summary

Kensico Reservoir, one of the most important locations in the NYC water supply system, was sampled intensively throughout 2008. Over 1600 water quality samples were taken and over 2000 compliance samples for turbidity were taken.

From January to December 2008, daily regulatory samples for fecal coliform were well below the SWTR limit at both Kensico effluents. The concentrations were above 20 CFU $100mL^{-1}$ only twice at the Catskill Lower Effluent Chamber (CATLEFF) and four times at the Delaware Effluent Chamber (DEL18), which is well below the 18 occurrences allowed. The mean concentrations for this period were 1.8 and 2.2 CFU $100mL^{-1}$ for CATLEFF and DEL18, respectively. These concentrations are similar to the last reporting period.

Operation of the Croton Falls Pump Station (CFPS) was conducted as part of a planned outage of the Rondout-West Branch Tunnel and subsequent system refill, with approval from DOH and EPA. Pumping operation began on October 27, 2008 and ended on December 11, 2008. No water quality or operational issues were encountered throughout the period of the CFPS operation. The "Croton Falls Pumping Station Operation After Action Report" (DEP, 2009) contains details of the monitoring required for this operation.

Overall, the management of waterbirds at Kensico Reservoir was deemed highly successful during 2008, as demonstrated by the reduction in migratory and resident bird populations to levels low enough to remain in full compliance with the SWTR for fecal coliform bacteria counts. These reductions mirror the results achieved in every year since the start of the program in 1993. The implementation of the Waterfowl Management Program continues to be the most cost-effective way to reduce fecal coliform bacteria levels and achieve full compliance with the SWTR.

In 2008, turbidity, measured every four hours, did not exceed the SWTR limit of 5 NTU at CATLEFF or at DEL18. Mean turbidity measured at the reservoir effluent keypoints was only 1.0 NTU at CATLEFF and 1.0 NTU at DEL18. Therefore, both the fecal coliforms and turbidity were well below SWTR limits throughout 2008.

Annual surveillance monitoring of DEL18 and CATLEFF for 67 volatile organic compounds (VOCs) and 68 semi-volatile organic compounds (SVOCs) resulted in no compounds being detected.

Routine stream monitoring continued in 2008. Data collected this year were not significantly different from data collected during previous years. All Kensico streams had median values for fecal coliforms much less than 200 colony forming units per 100mL (CFU $100mL^{-1}$). Stream N5-1 had the highest median fecal coliform value at 155 CFU $100mL^{-1}$ while BG9 had the lowest at 24.5 CFU $100mL^{-1}$. With regard to total coliforms, some of the Kensico streams had an occasional occurrence above 5,000 CFU $100mL^{-1}$ (6 occurrences, 3 of which occurred at N5-1) in 2008. Median turbidity data were less than 5 NTU for all streams. Notably, streams represent less than 5% of the inflow to Kensico, which is dominated by the aqueduct inflows.

Sampling of the BMPs installed on streams tributary to Kensico Reservoir was concluded in 2007. As per the 2007 FAD, a more detailed report of DEP's findings will be presented in the 2009 Kensico Programs Annual Report, and data preparation and analysis for this report was begun in 2008.

In 2008, 380 routine 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 only two instances where fecal coliform samples exceeded the DEP guideline. Turbidity only exceeded 5 NTU in one of the 433 samples collected. As in the past, Site 5 near the Catskill Influent had the highest median turbidity (1.8 NTU) of the eight sites. At the sites closest to the effluent chambers (sites 2 and 3), the turbidity was less than 3.0 NTU for all routine samples.

DEP reviews reports of semi-annual sampling of Westchester County Airport groundwater monitoring wells by Westchester County DOT. Results continue to indicate that groundwater beneath the airport is not a water quality concern regarding VOCs, SVOCs, NOCs, and metals for Kensico Reservoir.

Overall, results from the 2008 fixed frequency stream monitoring for protozoa were consistent with historical data. *Cryptosporidium* oocysts were not usually detected, and when they were, results generally ranged from 1 to 4 oocysts per volume sampled. The higher concentrations were discovered in the colder months as has been seen before in the watershed. With the exception of the detection of 590 cysts on June 3 at E11, *Giardia* results ranged from 0 to 65 cysts per volume sampled and again these data were similar to historical results. Follow-up sampling at E11 did not suggest any chronic environmental issue, as results shortly returned to the low concentrations previously observed at that site.

Cryptosporidium at the influents of Kensico (CATALUM and DEL17) was detected in seven and six samples, respectively, with both sites at low concentrations (1 to 2 oocysts·50 L^{-1}). As in previous years, a high proportion of the samples resulted in no detection of oocysts. *Giardia* was detected in 20 and 26 samples collected at CATALUM and DEL17, respectively in 2008, with a maximum of 5 cysts·50 L^{-1} for both sites. For the effluents of Kensico (CATLEFF and DEL18), *Cryptosporidium* was detected in 10 samples and 1 sample, respectively. Concentrations were very low in 2008 (1 to 2 oocysts·50 L^{-1}). *Giardia* was detected in 46 samples collected at CATLEFF (with a maximum of 7 cysts·50 L^{-1}) and 39 samples collected at DEL18 (with a maximum of 8 cysts·50 L^{-1}).

In general, the mean virus concentrations were very low at all sites. Only 13% (26/196) of the samples collected at the four sites indicated a presence of HEVs in 2008, which was down from 21% in 2007. In addition, the majority of the detections (92%) had concentrations < 3 MPN·100 L^{-1} Consistent with past results, the number of detects was lower at the effluents, indicating a reduction of viruses as water travels through Kensico Reservoir.

The stormwater protozoan monitoring project extended into May of 2008. Five storms were sampled to examine the effectiveness of BMPs, resulting in the collection of 61 composite samples. Samples separated into the three segments of the hydrograph show evidence to support the finding that protozoan concentrations from BMPs were highest during peak flows, in contrast to the descending limb when only two segments of the storm were used for resolution of transport dynamics.

In 2008 water quality models were used to assist in managing turbidity levels in Kensico Reservoir, which were a concern due to elevated Catskill turbidity following a large storm event in March and April. Model simulations were used to predict the results of various reductions in Catskill Aqueduct flow on the turbidity levels measured at the Kensico Reservoir effluent locations. Operational decisions were based partially on the guidance provided by the model simulations. The models provided information that helped optimize turbidity and reservoir flow operations during this event.

1. Introduction

Kensico Reservoir signage with contact number to report pollution.

The 2007 Filtration Avoidance Determination (Section 4.10, Kensico Water Quality Control Program) calls for semi-annual 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. This report fulfills the FAD requirement to provide water quality data to complement the information on program implementation. For the purposes of continuity, the format of this report is very similar to previous Kensico reports delivered for this requirement.

The role of this report is to analyze and discuss the ongoing water quality data collections in order to confirm protection 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 this report. DEP's ongoing Waterfowl Management Program, which has been instrumental in keeping coliform bacteria concentrations low, is also described. Other sections of this report 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. Note that water quality results are reported here, while implementation of watershed protection programs is reported elsewhere.

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 2008, normal operations were interrupted only once, when the Catskill Aqueduct was shut down for about nine hours on March 5 due to high turbidity. The other event in 2008 with potential to affect the operation of Kensico was the shutdown of the Rondout to West Branch Tunnel (RWBT), as described below.

On October 25, 2008, DEP began a planned 28-day shutdown of the Rondout to West Branch Tunnel (RWBT) to perform a necessary valve replacement. This shutdown interrupted the transfer of Delaware System water to West Branch Reservoir and therefore also to Kensico Reservoir. Having this major sub-system of the water supply out of service required significant adjustment to our operational configuration to meet the daily water demand 1.2 MGD. To compensate for this loss in water quantity, DEP maximized the use of both the Catskill and Croton Systems. The flow from Ashokan Reservoir to the Catskill Aqueduct was increased to approximately 600 MGD and BWS began operation of the Croton System up to about 170 MGD. During the shutdown, water stored in West Branch continued to be delivered to Kensico through the Delaware Aqueduct. To bolster the storage of West Branch Reservoir, the release of water from Boyd Corners Reservoir was maximized. As an additional measure to protect Kensico Reservoir from drawdown and thus protecting Kensico water quality, DEP requested regulatory approval for operation of the Croton Falls Pump Station (CFPS) and on October 27, 2008, began operation of the station. The CFPS can transfer up to 35 MGD of water from Croton Falls Reservoir into the Delaware Aqueduct for delivery to Kensico Reservoir.

During the RWBT shutdown DEP increased water quality monitoring of Kensico Reservoir and Aqueduct keypoints. The elevation of Kensico was maintained at normal operating levels and the quality of water at the Kensico effluents remained consistently high throughout the shutdown process. Despite the significant draw down of West Branch Reservoir, Delaware influents to Kensico only experienced slightly elevated turbidity readings. No operational changes or shutdowns at Kensico Reservoir were made in response to water quality issues. DEP began refill of the RWBT on November 24, 2008 and a period of system refill followed. During this refill process, the DEP operated the CFPS continuously ending on December 11, 2008, at which point normal operation of the water supply system resumed.

2. Sampling Strategy

Kensico Reservoir water quality monitoring that was conducted in 2008 included 1651 samples at 86 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 733 times and in the reservoir 380 times. Of the 332 pathogen samples, 70 were “enhanced”, or non-routine, samples. 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 2.1) and sampled manually at 4-hour intervals. Other parameters that are monitored continuously are pH, temperature, and conductivity. The overall water quality sampling effort within the Kensico basin is summarized in Table 2.1 and the results from these samples are discussed throughout the remainder of this report. A map of routine sampling sites is shown in Figure 2.2.

Figure 2.1 Continuous monitoring instrumentation at Kensico Reservoir (Catskill Lower Effluent Chamber).

2.1 Streams

DEP continues to monitor the hydrology of the Kensico watershed. Samples are collected at eight fixed sampling sites to quantify flow and water quality at each of the perennial streams (BG9, E10, E11, E9, MB-1, N12, N5-1, WHIP) as shown in Figure 2.2. Routine sampling of Kensico streams was conducted monthly in 2008.

Stream water quality sampling

2.2 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 2.2. Routine limnological and supplementary survey monitoring of Kensico Reservoir was conducted twice each month from April 8 through December 23, 2008.

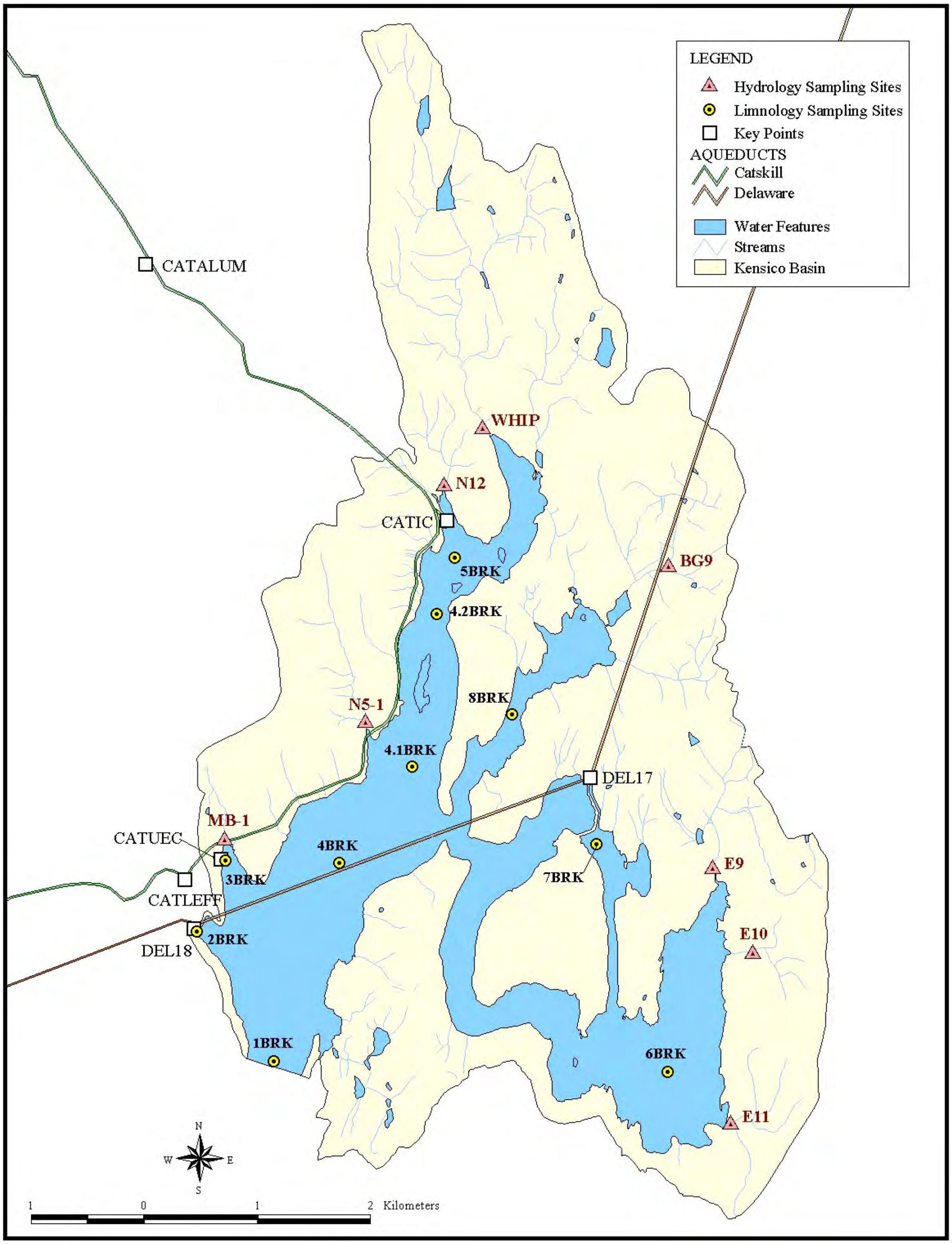

Figure 2.2 Kensico Reservoir, showing limnological and hydrological sampling sites, keypoints, and aqueducts. There is a meteorological station at DEL18.

Table 2.1. Summary of Kensico Reservoir water quality monitoring conducted in 2008.

Kensico Sampling Programs	# of sites	Parameters	Routine Frequency	Sampling Agency	Number of samples collected in 2008
Streams	8	bacteria, turbidity, nutrients, chemistry	monthly	DEP	96
Reservoir	8	bacteria, turbidity, nutrients, chemistry	2x /month Apr-Dec	DEP	380
Keypoints at effluents	2	bacteria, turbidity, nutrients, chemistry	daily	DEP	733
Toxic Chemicals at effluents	2	VOCs, SVOCs	annually	DEP	2
Groundwater at county airport	54	VOCs, SVOCs, NOCs, metals	semi-annually	West.Cty. DOT	108
Pathogens	12	*Cryptosporidium*, *Giardia*, HEV	4 keypoints weekly 7 streams bi-monthly and monthly at Malcolm Brook	DEP	332
SWTR compliance	2	turbidity	every 4 hours	DEP (Operators)	2190
Total	88	-	-	-	3841

In addition to the routine surveys, special sampling may be required when a water quality issue or concern develops. These additional surveys involved more frequent sampling, sampling at different locations within the reservoir, and/or sampling for additional analytes, as needed. Additional surveys conducted in 2008 were related to a brief shutdown of the Catskill Aqueduct in March, a brief shutdown of Rondout and West Branch in September, and for assessment of Kensico Reservoir during the Rondout/West Branch shutdown and Croton Falls pump station operation. 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, 2009) contains details of the monitoring required for this operation. DEP submitted a request to DOH to operate the Croton Falls pump station and this request was approved on October 24, 2008. 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 October 27, 2008 and pumping was continuous for 45 days ending on December 11, 2008. No water quality or operational issues were encountered throughout the entire period of operation of the CFPS.

2.3 Keypoints

DEP routinely conducts water quality compliance monitoring at aqueduct keypoints, including CATLEFF and DEL18, where Kensico Reservoir water enters the Catskill and Delaware Aqueducts, respectively. These two sample points are located just prior to disinfection. Fecal coliforms are monitored daily via grab samples, and turbidity is measured every four hours, in accordance with SWTR regulations. These sites are also equipped with continuous monitoring of temperature, pH, conductivity, and turbidity. The exceptional importance of these keypoints (as source water compliance monitoring sites) warrants this high intensity monitoring.

2.4 Pathogens

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 2008, 332 samples were collected and analyzed for *Cryptosporidium* and *Giardia* within the Kensico Reservoir watershed, which is approximately 91 samples less than 2007. This sample set included 208 routine fixed-frequency samples from four keypoints (Kensico Reservoir influent and effluent aqueducts); and 54 fixed-frequency, with nine enhanced monitoring samples, at the eight perennial Kensico tributaries (Figure 2.8). In addition, 61 samples were collected for the extension of the Event Based Pathogen Monitoring project under a grant from the Water Resource Development Act (WRDA) at selected Kensico stream sites. Lastly, 208 samples were collected for human enteric virus analysis at the Kensico Reservoir influent and effluent aqueducts.

Keypoint sampling for Kensico Reservoir is performed at the aqueduct influent locations (CATALUM and DEL17) and the effluent locations (CATLEFF and DEL18) on a routine basis. As in the past, monitoring during 2008 included weekly fixed frequency sampling at these locations. No enhanced samples were necessary in 2008 for any of the four keypoint sample locations.

Monitoring for *Cryptosporidium* and *Giardia* involved the filtration of 50 L samples, and laboratory analysis according to Method 1623 (USEPA 2001). Human enteric virus sampling involved the filtration of 200-300 L samples, and the laboratory analysis was as per the ICR method (USEPA 1996).

Occasionally, water samples had elevated turbidity (e.g., after storm events or at some stream sites), which resulted in clogging of the sample filter and attaining less than the targeted sample volume. Rather than extrapolate the result to the targeted sample volume, the results are reported with the corresponding volume collected. In addition, enhanced monitoring was performed when necessary, in response to elevated *Cryptosporidium*, *Giardia*, or other relevant water quality results (e.g., turbidity), and are distinguished as enhanced samples in the appropriate sections.

2.5 Waterfowl Management Program

DEP's Wildlife Studies Section is responsible for oversight of the Waterfowl Management Program, 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 DEP's Waterfowl Management Program please refer to the annual FAD submission under section 4.1 dated July 31, 2008.

The basic objectives of the Waterfowl Management Program are:

- Record daily waterbird survey 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 boat and/or shoreline. The morning survey data are used to evaluate the success of the previous day's bird harassment efforts.
- 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 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. A fish deterrent system to prevent the transport ofalewives from Ashokan Reservoir to Kensico was delayed and is expected to be installed in 2010.

Additional waterbird management measures employed annually in the spring include the following:

- Eggs and nests of Canada Geese (*Branta canadensis*) and Mute Swans (*Cygnus olor*), shown in photos below (Figure 2.3a and b), are depredated under Federal and State permits from April through June annually.
- Meadow management includes maintenance of shoreline fencing to discourage nesting geese from occupying the area around the DEL18 water intake facility, as well as maintenance of a meadow-like field to eliminate mowed lawns, which attract goose foraging.

Similar management measures were continued at six additional reservoirs, all source waters to Kensico (Rondout, West Branch, Ashokan, Croton Falls, Cross River, and Hillview) on an "as needed" basis as outlined in the 2002 Filtration Avoidance Determination.

Figure 2.3 a) Pair of Mute Swans (*Cygnus olor*). b) Female Canada Goose (*Branta canadensis*) on nest.

2.6 Groundwater

The Kensico Groundwater Monitoring Program was implemented 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 USEPA, 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.

2.7 Toxic Chemicals Surveillance

DEP annually samples 10 upstate reservoir aqueduct keypoints to complement required surveillance of VOCs and sSVOCs conducted within the NYC Water Supply distribution system. This keypoint survey includes the sampling of the Delaware (at DEL18) and Catskill (at CATLEFF) aqueducts leaving Kensico Reservoir (Figure 2.4).

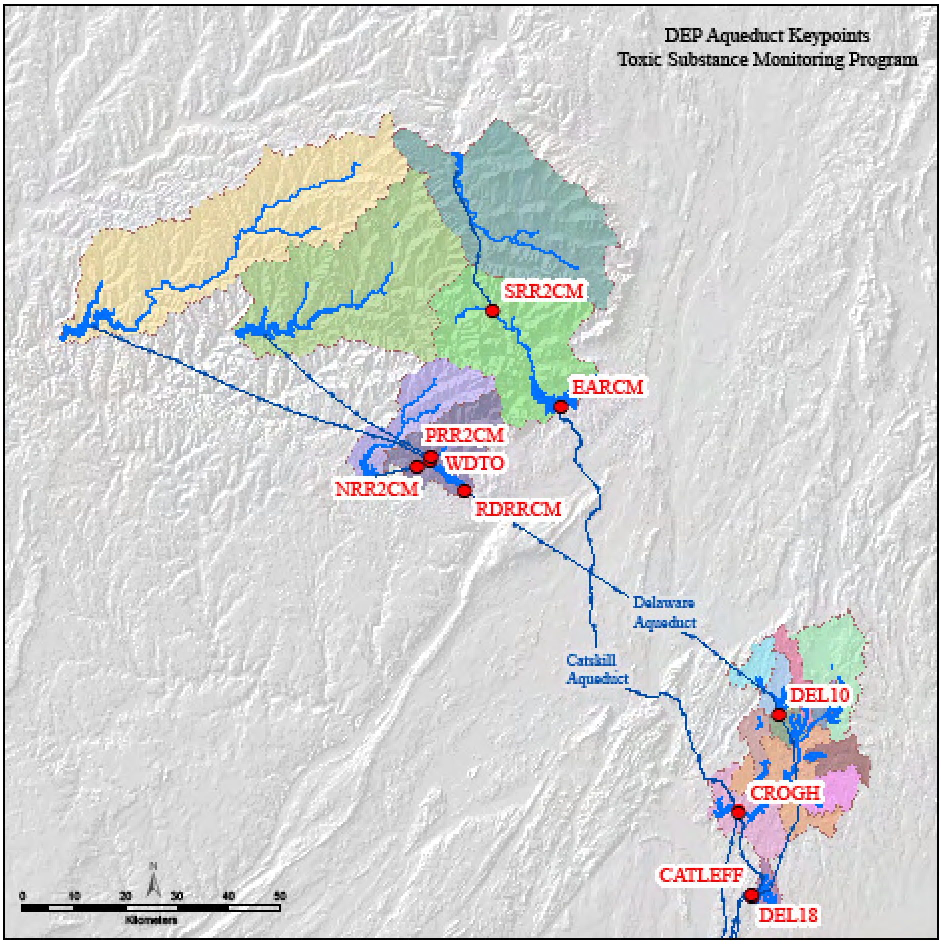

Figure 2.4 Aqueduct keypoint sites sampled annually for VOCs and SVOCs.

3. Results and Discussion

3.1 Coliform Bacteria

3.1.1 Bird Management for Fecal Coliform Control

DEP's Waterfowl Management Program (WMP) continued to show notable results in the reduction of roosting and nesting waterbirds at Kensico Reservoir in 2008. The WMP was first implemented in 1993 and remains a key program for the seasonal reduction of reservoir fecal coliform bacteria levels, insuring continued compliance with the Federal Surface Water Treatment Rule (SWTR).

Long-term waterbird data collected from August 1, 1992 through December 31, 2008 are presented in Figure 3.1. Data collected from 1992 to 1993 preceded the inception of bird harassment efforts. Bird counts for 2008 remained relatively low compared to the early 1990s, the period prior to implementation of the bird dispersal program.

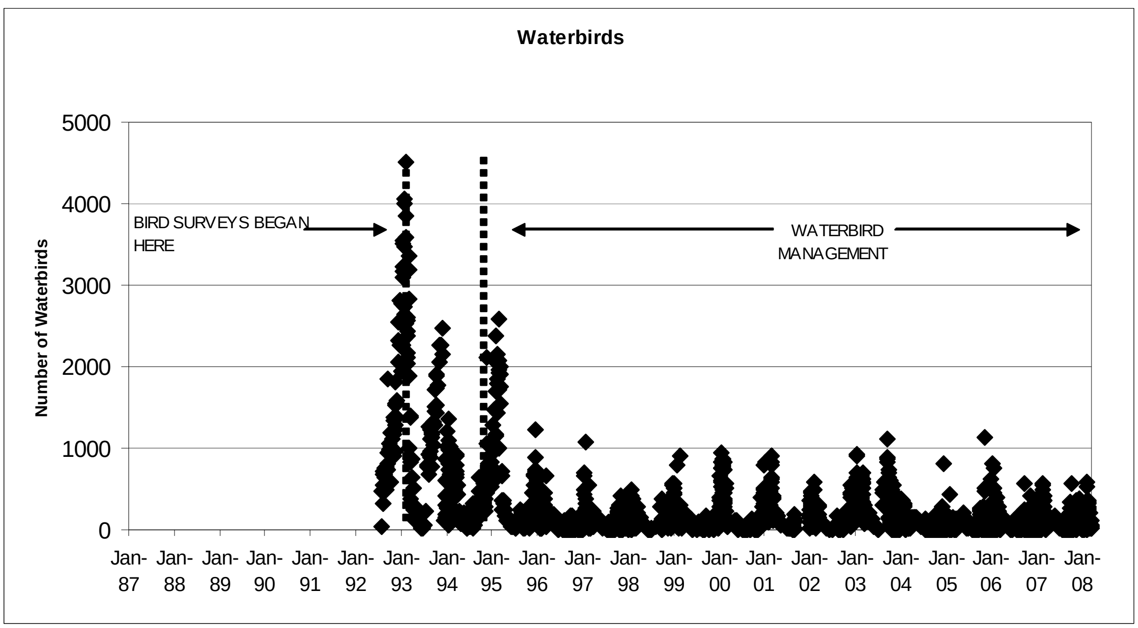

Figure 3.1 Waterbird counts at Kensico Reservoir (all sites), 1992-2008.

Figures 3.2 and 3.3 compare the regulatory source water samples collected from DEL18 and CATLEFF (the Kensico effluents) with respect to fecal coliform bacteria and reservoir bird counts. Of the 366 daily regulatory samples analyzed in 2008, only 6 were above the 20 CFU $100mL^{-1}$ SWTR standard (4 at DEL18 and 2 at CATLEFF). (The rule allows for 18 values above 20 CFU $100mL^{-1}$in any six-month period.) Therefore, Kensico Reservoir remained well within compliance limits for fecal coliforms throughout 2008.

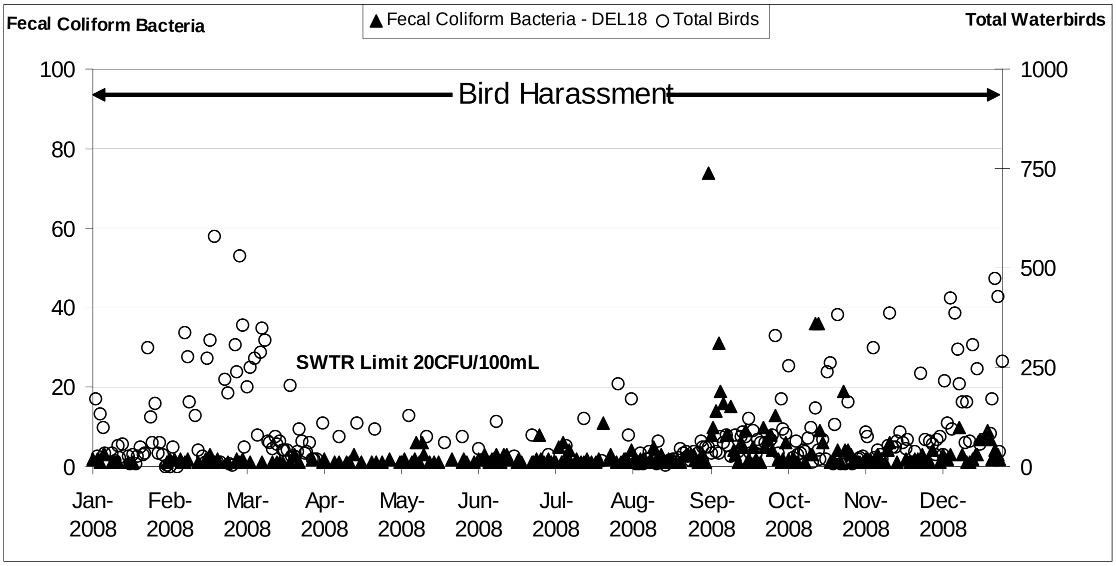

Figure 3.2 DEL18 fecal coliform bacteria and total waterbirds for 2008.

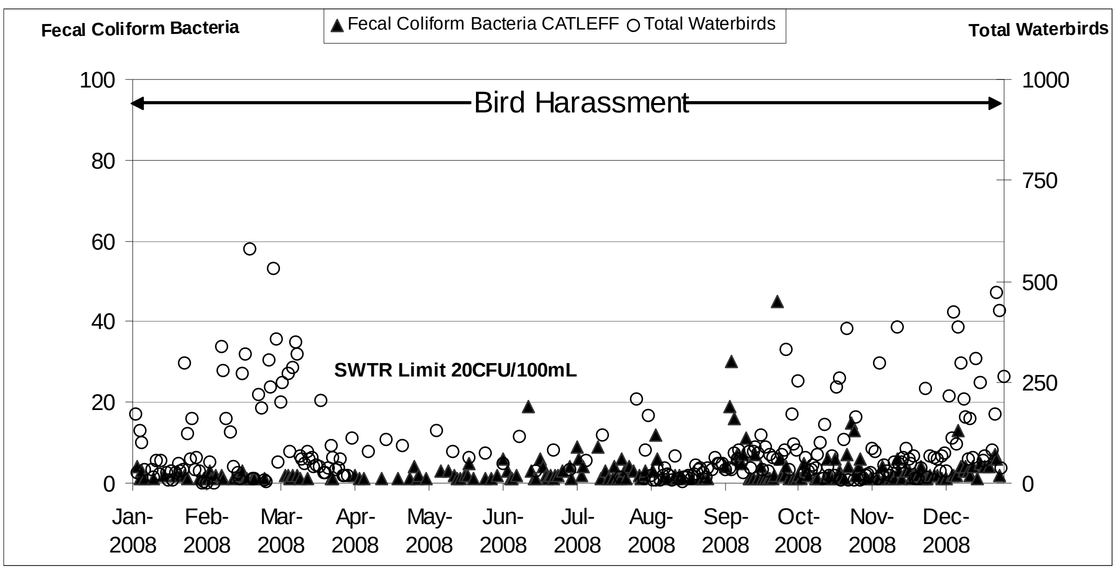

Figure 3.3 CATLEFF fecal coliform bacteria and total waterbirds for 2008.

Of the six samples with bacteria counts above the 20 CFU $100mL^{-1}$ limit, four were recorded in September, the month with the highest recorded precipitation (7.52 inches), suggesting a possible relationship between elevated fecal coliform water samples and precipitation events. (Table 3.1). Thus, the 30 CFU at CATLEFF and the 31 CFU at DEL18 recorded on September 8 followed two days of precipitation totaling 4.54 inches of rain, while the 45 CFU recorded at CATLEFF on September 27 followed 1.53 inches of rain. On the other hand, three of the six samples above the SWTR standard (including one of the September samples) cannot be explained by precipitation: 74 CFU at DEL18 on September 4 and 36 CFU at DEL18 on October 17 and 18. The elevated bacteria counts on September 4 occurred at a time when bird counts were low (49 that day, 33-64 on the three previous days, with no birds recorded at the two intake coves). Bird counts on October 18 were similarly low (42). October 17 bird counts were higher, but 125 of the 146 birds observed were found at the opposite end of the reservoir, far from the intake facilities. Moreover, the two intake coves adjacent to DEL18 and CATLEFF remained free of birds on both these dates.

Table 3.1. Water samples recorded above 20 CFU 100mL^{-1}.

Water Samples Recorded above 20CFU/100mL	Facility Location of Water Sample	Reservoir Bird Counts	Precipitation Levels
September 4, 2008	DEL18	49	None
September 8, 2008	DEL18	31	4.54 inches
	CATLEFF	30	
September 27, 2008	CATLEFF	45	1.53 inches
October 17, 2008	DEL18	36	None
October 18, 2008	DEL18	36	None

Figure 3.4 presents, for the years 1987-2008, the percentage of samples with results greater than 20 CFU100ml^{-1} as a running average over the previous six-month period. In 2008, DEP maintained full compliance with the SWTR at both the CATLEFF and DEL18 water intake facilities, with only 1.3% and 3.3%, respectively, of source water samples for the previous six months above 20 CFU 100mL^{-1}.

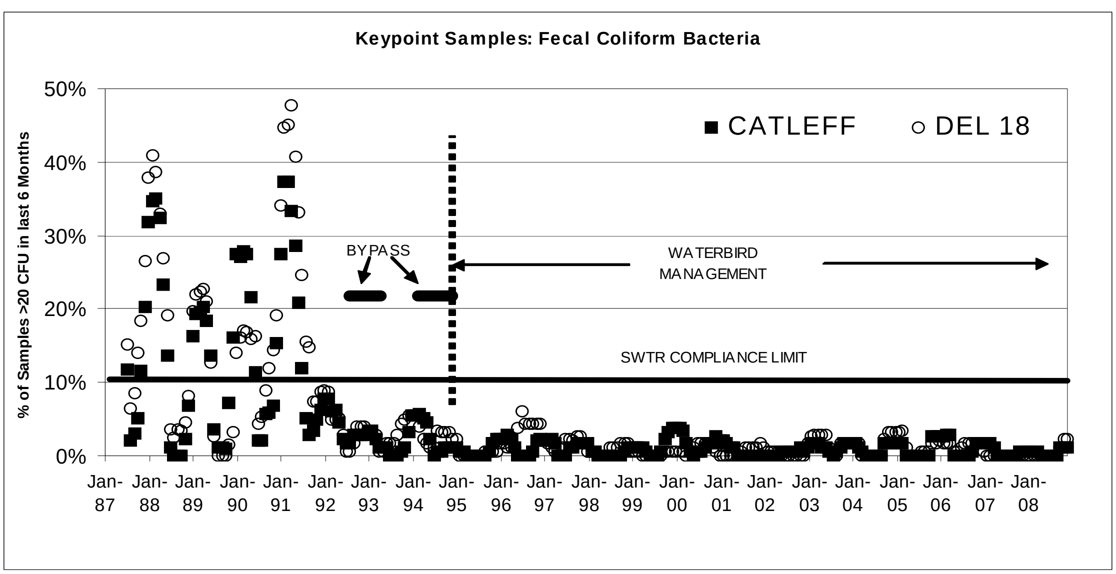

Figure 3.4 Kensico Reservoir keypoint water samples, 1987-2008.

In 2008, DEP continued a reproductive management program at Kensico and 15 additional reservoirs for two locally breeding species of waterbirds, Canada Goose and Mute Swan. A total of 159 eggs from 40 goose nests were treated at Kensico. Depredation success rate was 94%; the remaining 6% (10 goslings) hatched but disappeared before reaching maturity. A total of 12 eggs from 1 Mute Swan nest were also depredated at Kensico. The depredation success rate for the swans was 80%; the remaining 20% (four cygnets) hatched and were successfully reared.

Overall, the management of waterbirds at Kensico Reservoir was deemed highly successful during 2008, as demonstrated by the reduction in migratory and resident bird populations to levels low enough to remain in full compliance with the SWTR for fecal coliform bacteria counts. These reductions mirror the results achieved in every year since the start of the program in 1993. The implementation of the WMP continues to be the most cost-effective way to reduce fecal coliform bacteria levels and achieve full compliance with the SWTR.

3.1.2 Streams

The routine fecal coliform data for the period January 2008 through December 2008 are plotted in Figure 3.5. Censored box plots are being 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 (less than 1 CFU $100mL^{-1}$) 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, 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 detection limit are not displayed.

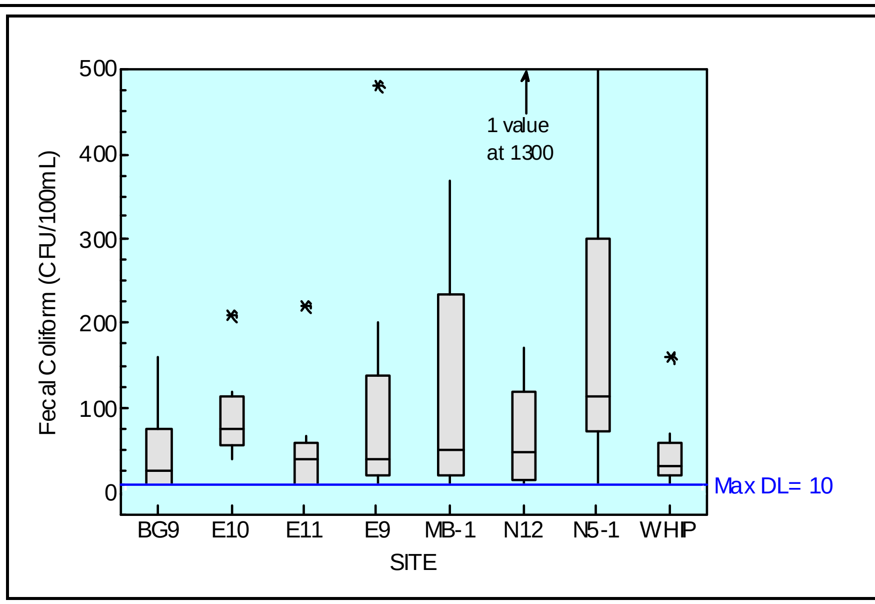

Figure 3.5 Fecal coliform plots for routine Kensico streams monitoring data, January–December, 2008.

All Kensico streams had median values less than 200 CFU 100mL^{-1}. Stream N5-1 had the highest median value at 155 CFU 100mL^{-1}, while BG9 had the lowest at 24.5 CFU 100mL^{-1}. Fecal coliform values this year were consistent with previous years. The highest values were generally seen on the August 5, 2008, sampling date. Kensico received over an inch of rain on that date. Other occasions having somewhat elevated coliform levels were also associated with rainfall events, which is typical for stream data at any site.

NYSDEC Part 703 water quality standards for coliform have been used as a guideline for the comparison of stream water quality, based on DEP's monthly fixed frequency monitoring program. For each stream sampling site, Table 3.2 indicates the number of occurrences during the sampling period that total coliform values were elevated above the 5000 CFU 100mL^{-1} value. These data confirm that some of the streams have an occasional occurrence above 5000 CFU 100mL^{-1}, which may be associated with a fixed frequency sample being collected during or immediately following wet weather. This can be seen in the data collected on August 5, 2008, when, as indicated above, over an inch of rain fell. However, not all occurrences were attributed to rain. These additional occurrences may be attributed to the residential character of the catchments or may be a function of the fact that the BMPs, whose permanent pools attract wildlife throughout the year, are located immediately upstream of the sampling sites.

Table 3.2. Occurrences of total coliform values >5000 CFU 100mL^{-1} in Kensico perennial streams during 2008, based on fixed frequency monthly sampling.

Site	n	Total Coliform Value > 5000 CFU 100mL^{-1}
BG9	12	0
E10	12	0
E11	12	0
E9	11	1
MB-1	12	0
N12	12	1
N5-1	12	3
WHIP	12	1

Limnology survey on Kensico Reservoir.

3.1.3 Reservoir

A total of 380 routine bacteria samples were collected from Kensico Reservoir for total and fecal coliforms analyses during the period April through December, 2008. Box plots for these data are shown in Figure 3.6. The results are compared with 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 a six-month running average of 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.

During this reporting period all sites had a median total coliform value less than 100 CFU $100mL^{-1}$. Site 5 had the highest median at 90, followed by Site 8 (75 CFU $100mL^{-1}$). Sites 1.1 and 4 shared the lowest median value of 20 CFU $100mL^{-1}$. Depending upon the site, 20 to 40% of the total coliform bacteria levels were above DEP guidelines. 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 under 20 CFU $100mL^{-1}$. Median values were 2 CFU $100mL^{-1}$ for sites 5 and 6, and 1 CFU $100mL^{-1}$ for the rest of the sampling sites. There were two instances where the fecal coliform levels from discrete samples were above the DEP guidelines of 20 CFU $100mL^{-1}$. Fecal

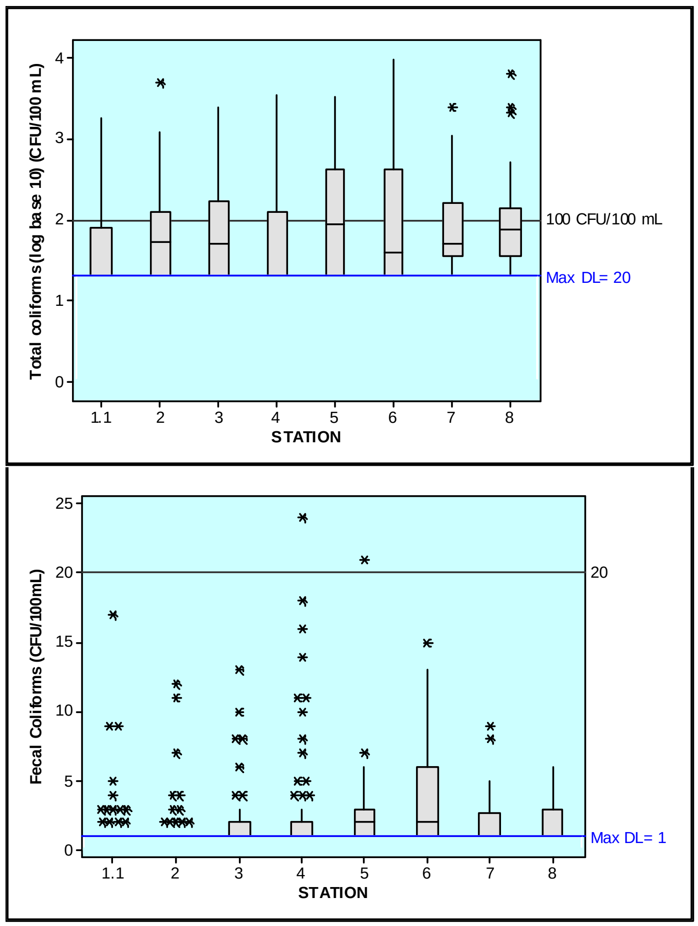

Figure 3.6 Total and fecal coliform plots for routine Kensico monitoring data, April–December, 2008. Box plots are censored at the maximum detection limit. See Section 3.1.3 for details.

coliform values of 21 and 24 CFU 100mL^{-1} were observed at sites 2 and 3, respectively, in the month of September 2008. These were apparently related to localized storms early in the month.

3.1.4 Keypoints

Median fecal coliform concentrations measured from January to December 2008 were 1 cfu 100mL^{-1} at CATLEFF and 1 cfu 100mL^{-1} at DEL18. Mean values were 1.8 and 2.2 cfu 100mL^{-1}, respectively. During the same period, values above the regulatory benchmark of 20 CFU 100mL^{-1} were only observed twice at CATLEFF, and four times at DEL18 (Figure 3.7). (Eighteen values above 20 CFU 100mL^{-1} are permitted by the regulations within any 6-month period at each keypoint.) Of the six values, five were associated with precipitation. This continues to support the conclusions of previous DEP studies, which have indicated that almost all fecal coliform problems since the inception of DEP's Waterfowl Management Program (See Section 5.1) occurred following precipitation events.

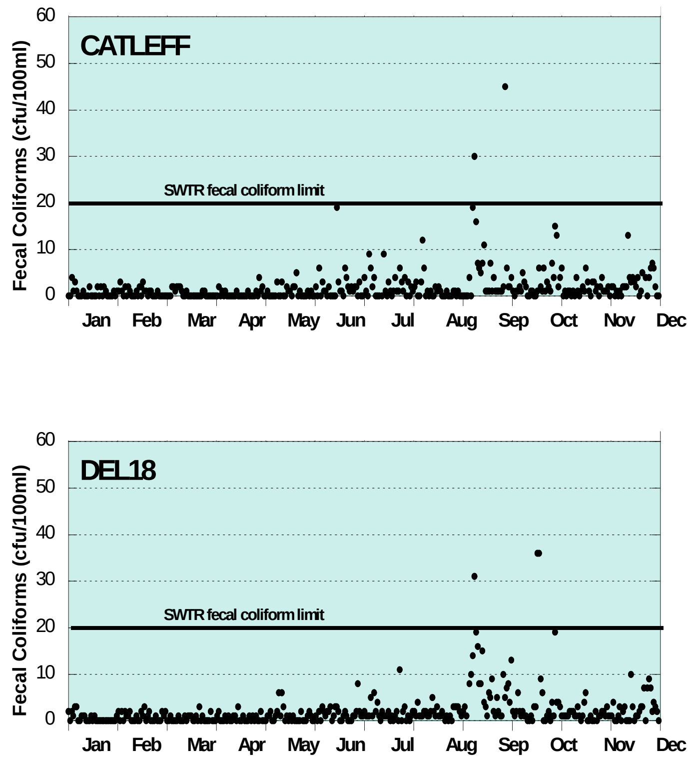

Figure 3.7 Daily fecal coliform concentrations for the CATLEFF and DEL18 keypoints, 2008. The SWTR fecal coliform limit requires that at least 90% of samples in a six-month period be below 20 CFU 100mL^{-1}.

3.1.5 Special Surveys

Special surveys during 2008 included monitoring of Kensico effluent water quality during a turbidity alert (January 9), and work associated with shutting down the Catskill Aqueduct at the effluent and bringing it back on (March 5 and March 9). On March 24 a special investigation was undertaken to assess turbidity conditions. A special survey to collect data to support modeling of the Rondout/West Branch shutdown was carried out on September 26. The special surveys on October 10, 16, and 22 provided data to assess the conditions for the Rondout/West Branch shutdown and meet the requirements for operation of the Croton Falls pump station.

'These investigations did not yield any extreme values of turbidity, fecal coliforms, or total coliforms. However, the following values above baseline conditions were observed. A turbidity value of 5.3 NTU was observed on October 16 at Site 5. Total coliform samples collected on October 22 at Sites 2 and 3 were at or above the value of 100 CFU $100mL^{-1}$ and varied between 100 and 160. However, these were isolated instances that did not persist.

3.2 Pathogens: Protozoa and Human Enteric Viruses

3.2.1 Routine Stream Sampling for Pathogens

Eight perennial streams flow into Kensico Reservoir (Figure 3.8). Of these, 7 are sampled bimonthly and one, Malcolm Brook (MB-1), is sampled monthly, due to its proximity to the Catskill Aqueduct effluent.

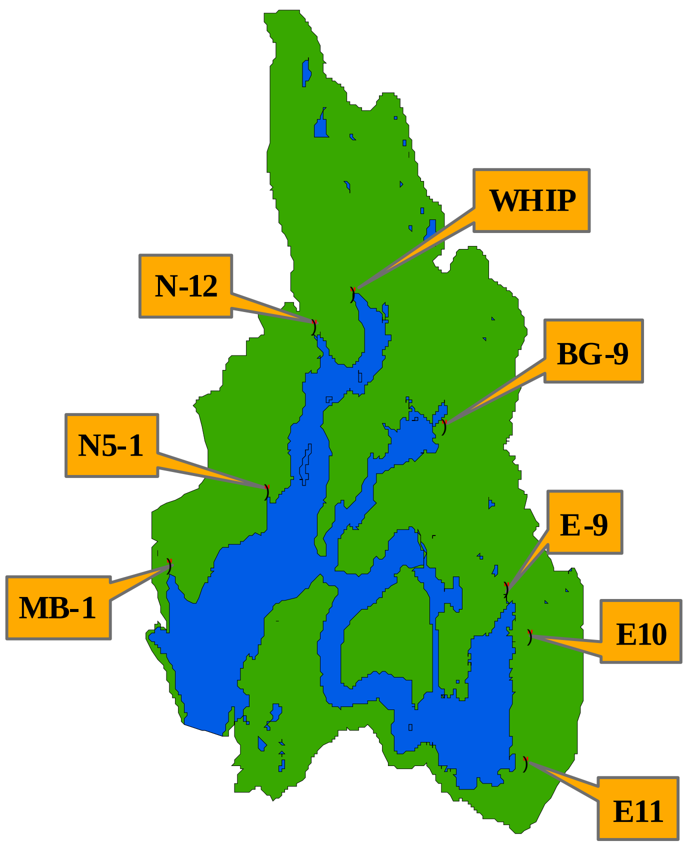

Figure 3.8 Routine pathogen sampling sites at Kensico Reservoir streams, 2008.

Overall, results from the 2008 fixed frequency monitoring for protozoa were consistent with historical data. *Cryptosporidium* oocysts were not usually detected, and when they were, results generally ranged from 1 to 4 oocysts per volume sampled (Table 3.3). On two occasions, 6 oocysts were detected in the coldest months, once at N5-1 in January and the other at E9 in February. *Giardia* results ranged from 0 to 65 cysts per volume sampled and again these data were similar to historical results. One exception, on June 3, E11 yielded 590 cysts per 43 L of stream water. This result was out of the normal cyst range for all Kensico streams, and as a result enhanced sampling was performed and those results are discussed in Section 3.2.2.

Table 3.3. Cryptosporidium results and sample volumes from Kensico streams, January 1-December 31, 2008.

Sample Date	BG9	E10	E11	E9	MB-1	N12	N5-1	WHIP
Cryptosporidium oocysts (sample volume in liters)								
02-Jan-08	■	■	■	■	3 (50)	1 (50)	6 (50)	0 (50)
05-Feb-08	2 (50)	0 (50)	1 (35)	6 (50)	1 (50)	■	■	■
04-Mar-08	■	■	■	■	0 (50)	0 (50)	0 (50)	1 (50)
01-Apr-08	1 (50)	0 (50)	0 (50)	4 (50)	0 (50)	■	■	■
06-May-08	■	■	■	■	0 (33)	0 (50)	0 (40)	0 (51)
03-Jun-08	0 (46)	0 (50)	2 (43)	0 (21)	0 (32)	■	■	■
01-Jul-08	■	■	■	■	0 (38)	0 (50)	0 (38)	0 (50)
05-Aug-08	0 (50)	0 (50)	0 (37)	0 (19)	0 (44)	■	■	■
02-Sep-08	■	■	■	■	0 (50)	0 (50)	0 (24)	1 (50)
09-Oct-08	0 (50)	0 (50)	0 (50)	1 (50)	0 (50)	■	■	■
03-Nov-08	■	■	■	■	0 (50)	0 (50)	0 (50)	0 (50)
02-Dec-08	1 (50)	0 (50)	3 (50)	1 (28)	1 (50)	■	■	■
Maximum	2 (50)	0 (50)	3 (50)	6 (50)	3 (50)	1 (50)	6 (50)	1 (50)
Giardia cysts (sample volume in liters)								
02-Jan-08	■	■	■	■	23 (50)	2 (50)	23 (50)	9 (50)
05-Feb-08	14 (50)	8 (50)	10 (35)	3 (50)	10 (50)	■	■	■
04-Mar-08	■	■	■	■	3 (50)	0 (50)	4 (50)	2 (50)
01-Apr-08	13 (50)	3 (50)	32 (50)	6 (50)	4 (50)	■	■	■
06-May-08	■	■	■	■	5 (33)	2 (50)	2 (40)	1 (51)
03-Jun-08	2 (46)	3 (50)	590 (43)	1 (21)	0 (32)	■	■	■
01-Jul-08	■	■	■	■	0 (38)	2 (50)	1 (38)	3 (50)
05-Aug-08	0 (50)	1 (50)	14 (37)	0 (19)	1 (44)	■	■	■
02-Sep-08	■	■	■	■	0 (50)	17 (50)	0 (24)	10 (50)
09-Oct-08	34 (50)	3 (50)	51 (50)	24 (50)	6 (50)	■	■	■
03-Nov-08	■	■	■	■	2 (50)	4 (50)	5 (50)	4 (50)
02-Dec-08	39 (50)	8 (50)	65 (50)	34 (28)	7 (50)	■	■	■
Maximum	39 (50)	8 (50)	590 (43)	34 (28)	23 (50)	17 (50)	23 (50)	10 (50)

3.2.2 Enhanced Stream Sampling

In 2008, enhanced sampling was performed at E11 during the month of June, in response to an elevated *Giardia* result (590 cysts·43L^{-1}). The E11 sample site is a BMP effluent located in the southeast portion of Kensico Reservoir between Highway 684 and Westchester County Airport. Enhanced samples were obtained at the BMP, the influent sites (E11 N1 and E11 S1) as well as the sediment of the BMP inlet and main basin (Table 3.4). Results did not suggest any chronic environmental issue, as they shortly returned to the low concentrations previously observed at that site. No cysts were found in the three sediment samples from the BMP at E11.

Table 3.4. 2008 enhanced monitoring results at E11 in response to an elevated *Giardia* result.

Sample Date	Site	Sample Volume (L)	*Cryptosporidium* (#oocysts)	*Giardia* (#cysts)
11-Jun-08	E11	50	0	26
	E11N1	50	1	4
	E11S1	50	0	3
26-Jun-08	E11*	n/a	0	0
	E11 MAIN*	n/a	0	0
	E11N INLET*	n/a	0	0
	E11	30	1	0
	E11N1	50	0	7
	E11S1	50	0	6

*Sediment samples.

3.2.3 Influent Keypoints

Kensico Reservoir influent keypoints (CATALUM and DEL17) are sampled weekly for *Cryptosporidium* and *Giardia*. In 2008, *Cryptosporidium* was detected in seven and six samples at CATALUM and DEL17, respectively, and at low concentrations (1-2 oocysts·50 L^{-1}) (Table 3.5). In 2007, *Cryptosporidium* was detected in one CATALUM sample and in six samples at DEL17. Therefore, as in previous years, a high proportion of the samples resulted in no detection of oocysts and therefore a low incidence of *Cryptosporidium*.

Table 3.5. Summary of results for *Cryptosporidium* and *Giardia* at Kensico Reservoir influent keypoints, January 1–December 31, 2008.

		CATALUM	DEL17
Giardia (50L^{-1})	Number of Samples	52	52
	Number of Positives	20	26
	Mean	0.71	1.02
	Median	0	1
	Maximum	5	5

Table 3.5. (Continued) Summary of results for *Cryptosporidium* and *Giardia* at Kensico Reservoir influent keypoints, January 1–December 31, 2008.

		CATALUM	DEL17
Cryptosporidium ($50L^{-1}$)	Number of Samples	52	52
	Number of Positives	7	6
	Mean	0.13	0.15
	Median	0	0
	Maximum	1	2

Giardia was detected in 20 and 26 samples collected at CATALUM and DEL17, respectively in 2008, with a maximum of 5 cysts·50 L^{-1} for both sites. This is similar to, yet slightly lower than, the 2007 results, in which *Giardia* detection occurred in 23 and 32 samples at CATALUM and DEL17, with maximum values of 5 and 7 respectively.

3.2.4 Effluent Keypoints

Kensico Reservoir effluent keypoints (CATLEFF and DEL18) are also sampled weekly for *Cryptosporidium* and *Giardia* (Table 3.6). *Cryptosporidium* was detected in 10 samples at CATLEFF and 1 sample at DEL18 in 2008. Concentrations of positive samples were again very low this year (1-2 oocyst·50 L^{-1}). Comparatively, *Cryptosporidium* was detected in four samples at CATLEFF and in one sample at DEL18 in 2007. As in previous years, a high proportion of the samples resulted in no detection of oocysts.

Table 3.6. Summary of results for *Cryptosporidium* and *Giardia* at Kensico Reservoir effluent keypoints, January 1–December 31, 2008.

		CATLEFF	DEL18
Giardia ($50L^{-1}$)	Number of Samples	52	52
	Number of Positives	46	39
	Mean	2.02	1.69
	Median	2	1
	Maximum	7	8
Cryptosporidium ($50L^{-1}$)	Number of Samples	52	52
	Number of Positives	10	1
	Mean	0.23	0.02
	Median	0	0
	Maximum	2	1

Giardia was detected in 46 samples collected at CATLEFF and 39 samples collected at DEL18 in 2008, with respective maximum values of 7 and 8 cysts 50 L^{-1}. This is comparable to the 2007 results, in which *Giardia* detection occurred in 43 samples at CATLEFF and 41 samples at DEL18, with maximum values of ten and eight, respectively.

3.2.5 Human Enteric Virus Monitoring

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. The four Kensico Reservoir keypoints (CATALUM, DEL17, CATLEFF, DEL18) were sampled weekly for human enteric viruses (HEV). At the time of this writing, HEV results were only available until December 8, 2008. In general, the mean virus concentrations were very low at all sites (Table 3.7). Only 13% (26/196) of the samples collected at the four sites indicated a presence of HEVs in 2008, which was down from 21% in 2007. In addition, the majority of the detections (92%) had concentrations < 3 MPN·100 L^{-1}. The two remaining samples, which had concentrations > 3 MPN·100 L^{-1}, occurred at CATLEFF (5.75 MPN·100 L^{-1}) and DEL17 (4.46 MPN·100 L^{-1}). The virus data did not indicate a notable difference in the number of detects between the Delaware and Catskill Aqueducts (Table 3.7 and Figure 3.9). Consistent with past results, the number of detects was lower at the effluents, indicating a reduction of viruses as water travels through Kensico Reservoir.

Table 3.7. Summary of human enteric virus results at Kensico keypoints, January 1–December 31, 2008.

	Human enteric viruses (mpn 100L^{-1})			
Site	CATALUM	CATLEFF	DEL17	DEL18
Number of samples	49*	49*	49*	49*
Number of positive samples	9	2	11	4
Mean	0.25	0.16	0.32	0.08
Median	0**	0**	0**	0**
Maximum	2.11	5.75	4.46	1.03

*HEV results for December 15, 22, and 29, 2008, are pending.
**Zero values substituted for non-detect values when calculating mean results.

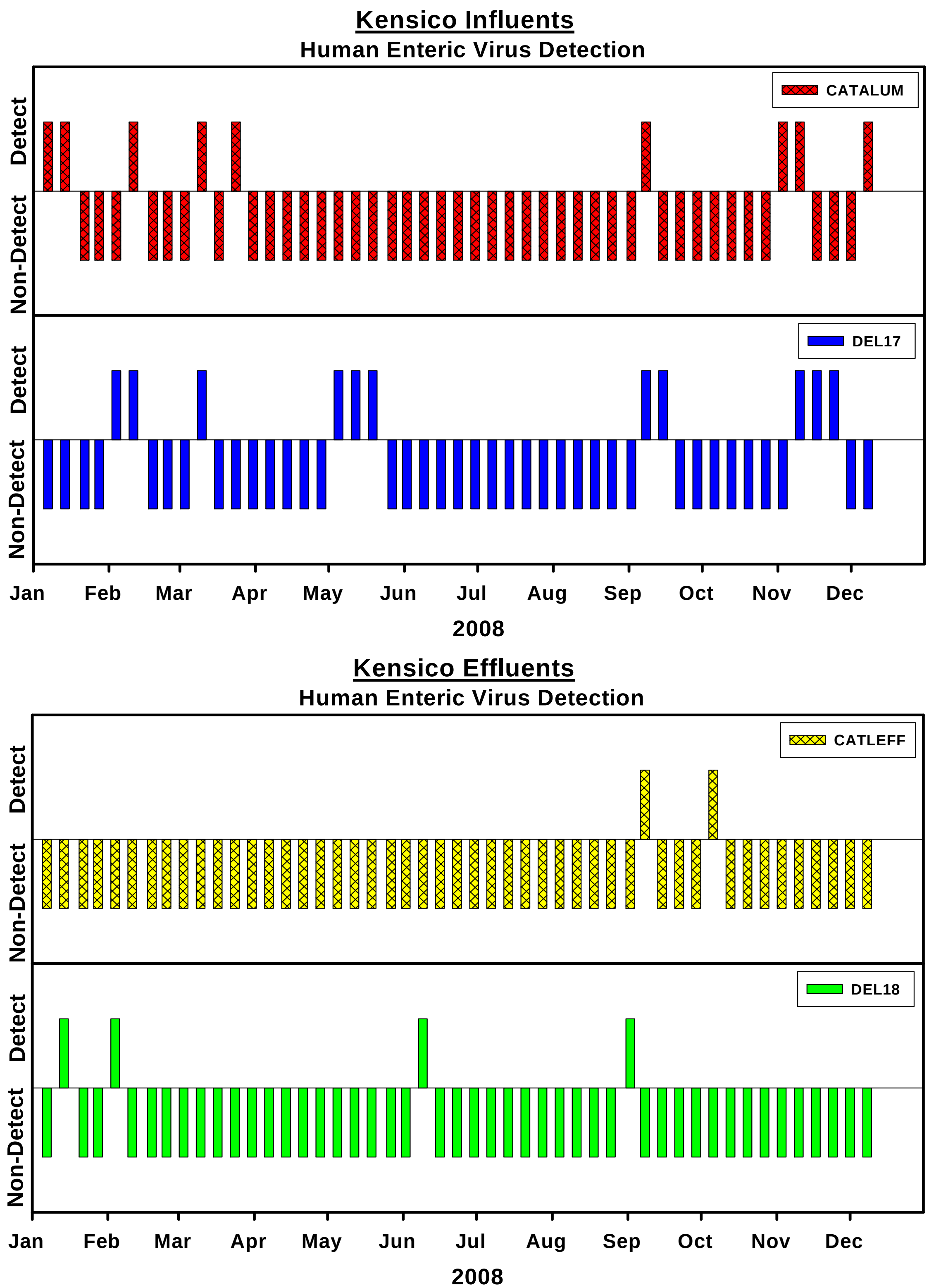

Figure 3.9 Detection of human enteric viruses at the four Kensico keypoints, January 1–December 31, 2008. HEV results for December 15, 22, and 29, 2008, are pending.

3.2.6 Development of Storm Event Pathogen Monitoring Strategies for Streams (WRDA Grant)

The primary objectives of this study were to establish and build out sampling sites, develop automated sampling methods, and evaluate intra-storm patterns to determine the relative importance of the phases of a storm (rising limb, peak, and descending limb).

East of Hudson stream sampling in 2005

The East of Hudson portion of this project incorporated the eight perennial tributaries of Kensico Reservoir. Sampling commenced in the fall of 2005, at three sites in the EOH district to facilitate the development of Phase I of the event-based pathogen monitoring program. For each storm event, 48 discrete, 1-L aliquots were collected at 30 min intervals and composited into two 24-L cubitainers using an ISCO auto-sampler. These composite samples were subsequently sent to DEP's laboratory for protozoan analysis and the data were used to determine the optimum storm sampling time duration for Phase II of the project. These Phase I data were presented at the 2006 New York Water Environment Association Watershed Science and Technical Conference (Alderisio *et al.* 2006).

Kensico Watershed (Oo)cyst Loading

During the first year of Phase II, a total of 197 composite 24-L storm samples were collected in 2006 for the Kensico WRDA sample sites which included E9, E10, E11, BG-9, WHIP, N12, MB-1, MB-3, MB-4, N5-1, N5-1 MAIN, N5-1 TRIB, N1 (Figure 3.10). DEP's primary focus during this portion of the study was to capture all the perennial streams at the same time in order to create storm loading estimates for Kensico Reservoir. One to three samples were pulled at each site during the storm to represent either the entire storm or different segments of the storm. Most often, the goal was to collect two composite samples; one to represent the rising limb of the hydrograph and a second to represent the descending limb. The analysis of this data included the creation of loading estimates, differences in concentration and loading between the two storm segments, efficacy of protozoan removal by in-line attenuation basins (BMP's), and the effects of storm size on loading. The analysis of this data was presented at the NYWEA Watershed Science and Technical Conference (Pace *et al*. 2007).

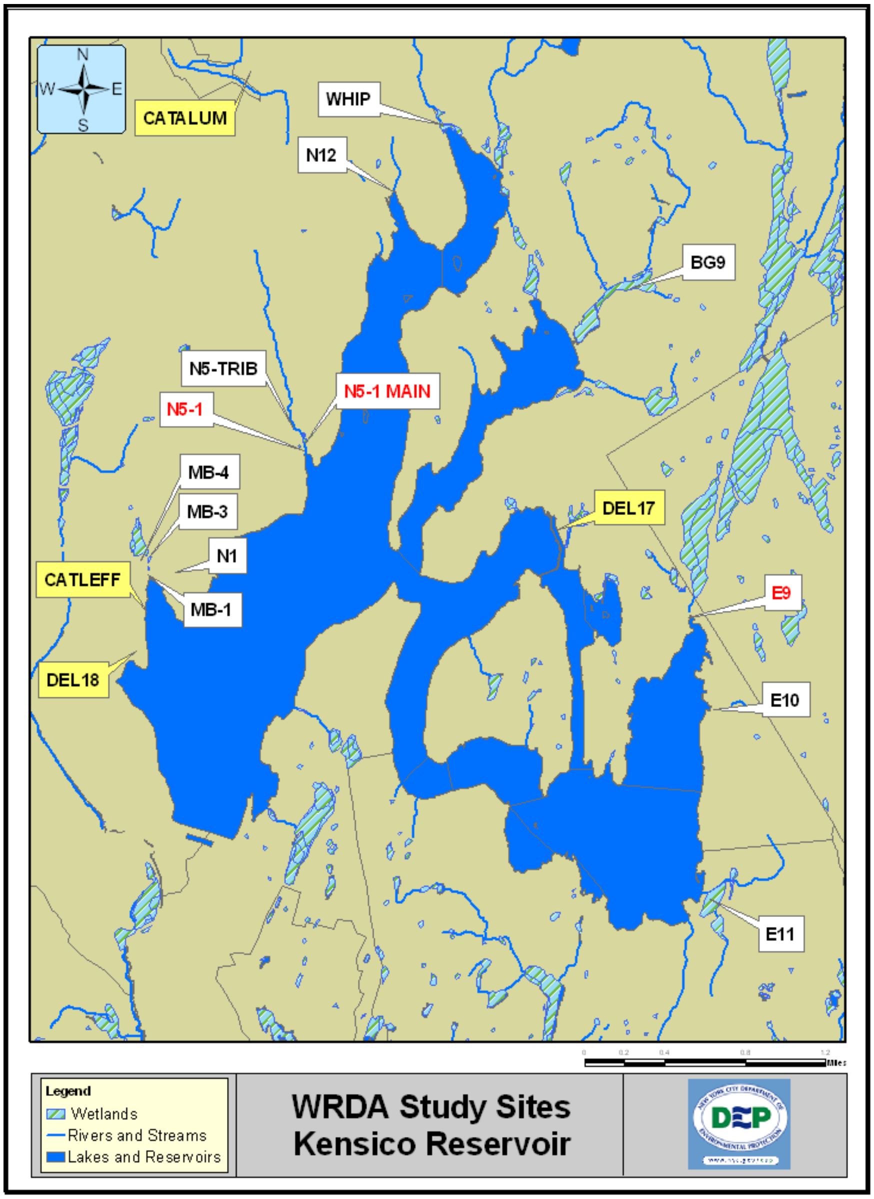

Figure 3.10 WRDA sample sites in the Kensico watershed.

Intra-storm Analysis – 2007 sampling

In 2007 (Phase II, Year 2), the WRDA study shifted its focus again to a higher resolution sampling effort at fewer sites, with the goals of a more refined analysis of the transport of (oo)cysts and a better understanding of the effect of BMP's on protozoan concentration and loading. The sites were selected as representative of either unmodified stream channels (E10, N5-1TRIB, and N5-1 MAIN) or streams modified with BMP's (MB-1, N5-1). Sites upstream and downstream of a BMP were chosen specifically to further investigate the BMP's effect on pathogens (N5 sample sites). Samples were collected by auto-sampler into 1-L bottles rather than compositing the samples into 24-L cubitainers. When the samples were brought back to the lab, the flow measurements for each stream were used to create hydrographs for the storm, which were then used to divide the 1-L samples into their respective storm phases and composite them into rising limb, peak, and descending limb samples.

This second year of WRDA Phase II in the Kensico basin was scheduled to end in December of 2007; however, due to the low number of complete storms and sample sets, DEP requested, and was granted, a five month extension of the project.

Intra-storm Analysis – 2008 sampling

The project was extended into May of 2008 in an effort to collect the minimum amount of data needed for an adequate statistical analysis. DEP returned to sample the same five sites as in 2007 (MB-1, N5-1, E10, N5-1TRIB, and N5-1 MAIN). During this five month period, nineteen storms occurred that had 0.20 inches or greater of rainfall. Five of these storms were sampled, resulting in the collection of 61 composite samples (Table 3.8). The same sampling methodologies were used as was described for 2007 storm sampling.

Table 3.8. WRDA storm events sampled during 2008.

Storm Date	Rainfall (inches)	Sampled Sites	Total # of Samples
March 19 - 20, 2008	1.15*	E10, MB-1, N5-1, N5-1MAIN, N5-1TRIB	14
April 4, 2008	0.39*	E10, MB-1, N5-1MAIN, N5-1TRIB	14
April 28, 2008	1.00* 0.51**	E10, MB-1, N5-1, N5-1MAIN, N5-1TRIB SSHG, S4, S5I	18
May 27 - 28, 2008	0.48*	E10, MB-1, N5-1, N5-1MAIN, N5-1TRIB	13
May 31 - June 1, 2008	0.20*	N5-1, N5-1MAIN, N5-1TRIB	8

* Rainfall as measured at Kensico meteorological station, Valhalla, NY (EKM220).

** Rainfall as measured at Schoharie met station, Gilboa, NY (CSM038).

Preliminary Analysis of WRDA Data

In this phase of the project, a successful storm sample set consisted of three samples of approximately equal volume representing the rising limb, peak, and descending limb over the course of a storm. This was quite challenging, in that it required intimate knowledge of each sample site to time the duration of sampling following the sampling trigger, while accounting for projected storm size and intensity. In total, 15 sets of samples were obtained during the five storm events sampled. Of these 15 sample sets, 10 sets met the criteria for distinctly representing each of the three storm phases. By chance, five samples from the 2007 and 2008 data resulted in an equal division of the rising limb and descending limb, which fit the analysis of the 2006 sampling year. Therefore, the data were used in combination with the 2006 results. Similarly, the samples obtained during 2008 were combined with previous years' WRDA sampling to fit the specific analyses performed as part of the WRDA objectives.

Streams were divided into two basic types for the purpose of describing the protozoan transport characteristics, unmodified stream channels and BMP-modified stream channels. Sample sets which fit the criteria for division into complete storm phase sets were then used to characterize mean conditions for stream type and storm phase. DEP's analysis of 2006 sampling, involved breakup of storms into two main phases (Pace *et al*. 2007). A plot of the concentrations during the two storm phases highlights a clear difference in the transport characteristics of (oo)cysts in unmodified (green and yellow) versus BMP-modified streams (green, blue and yellow) (Figure 3.11). The unmodified streams seem to support the "first flush phenomenon" described in prior storm water investigations for pollutants and pathogens (Krein *et al*. 2006; Davis *et al*. 1977; Ahfield and Minihane 2004). As presented in 2007, the two phase resolution (rising limb vs. descending limb) for samples obtained downstream of a BMP continue to suggest an attenuation or delay of (oo)cyst concentrations toward the descending limb of the event.

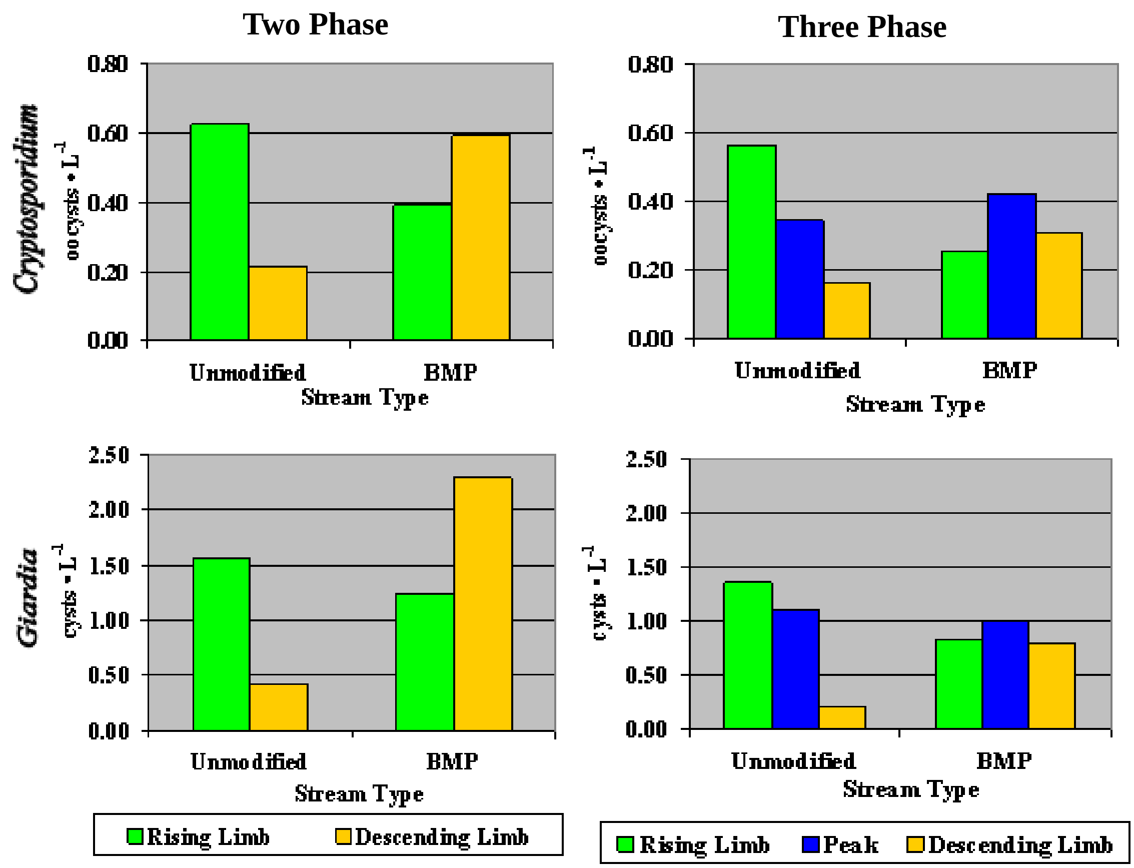

Figure 3.11 Mean concentration of *Cryptosporidium* and *Giardia* found in WRDA storm samples (October 2005–June 2008) where sample sets fit either a two- phase breakup or a three-phase breakup at unmodified sites (n = 13 and 12, respectively) and BMP sites (n = 13 and 14, respectively).

For 2007 and 2008, the goal was to increase the resolution to three storm phases (rising limb, peak, and descending limb). As in the analysis of rising limb vs. descending limb, the three segment sampling for unmodified stream storm data suggests that the rising limb yields the highest mean concentration of (oo)cysts (Figure 3.11). Unlike the rising limb vs. descending limb analysis for samples collected following BMPs, samples separated into the three segments show evidence to support that protozoan concentrations were highest during the peak flow rather than the descending limb. Further analysis will be provided in the final WRDA report.

These findings will be significant for assessing the effectiveness of BMPs, as well as the design of future BMP construction with respect to protozoan pathogen concentrations. In general, this information will be valuable in estimating the dynamics and timing of pathogen transport during storm events, which will in turn enable DEP to incorporate this information in watershed protection planning.

3.3 Toxic Chemical Surveillance

Annual samples for surveillance monitoring of Kensico Reservoir effluent keypoints DEL18 and CATLEFF on October 22, 2008 for 67 VOCs and 68 SVOCs resulted in no compounds being detected.

3.4 Turbidity

3.4.1 Stream Turbidity

The routine turbidity data for the period January 2008 through December 2008 are plotted in Figure 3.12. Median turbidity data are less than 5 NTU for all streams. Turbidity values in 2008 were consistent with data from previous years.

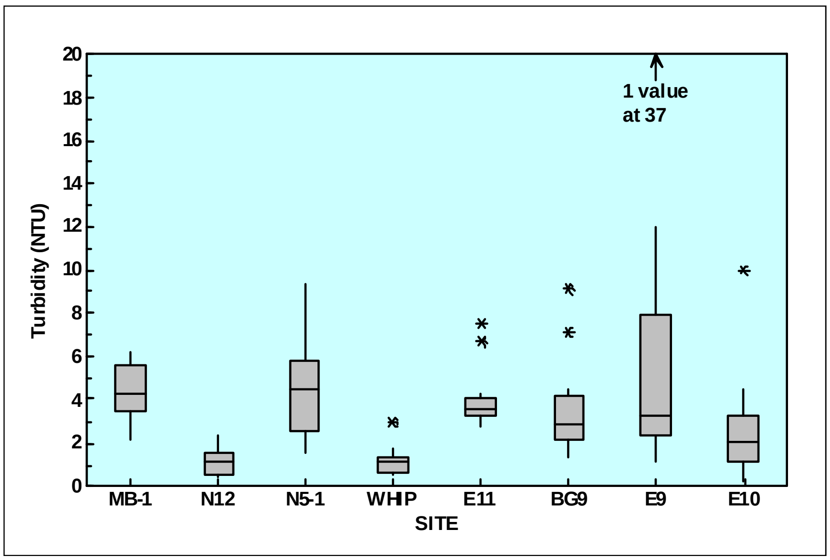

Figure 3.12 Turbidity data for routine Kensico streams monitoring data, January-December, 2008.

3.4.2 Reservoir Turbidity

A total of 433 turbidity samples were collected during routine monitoring of Kensico Reservoir in 2008. A box plot of the results from the routine limnological monitoring from April 2008 through December 2008 is presented in Figure 3.13. As in the past, Site 5 showed the highest median turbidity (1.8 NTU). At the sites closest to the effluent chambers (Sites 2 and 3) and throughout most of the reservoir (Sites 1.1, 4, 7, and 8), turbidity was under 3.0 NTU for all routine samples. Only Sites 5 and 6 tended to show slight, temporary increases, with 12 samples displaying turbidities ranging between 3.1 and 5.3.

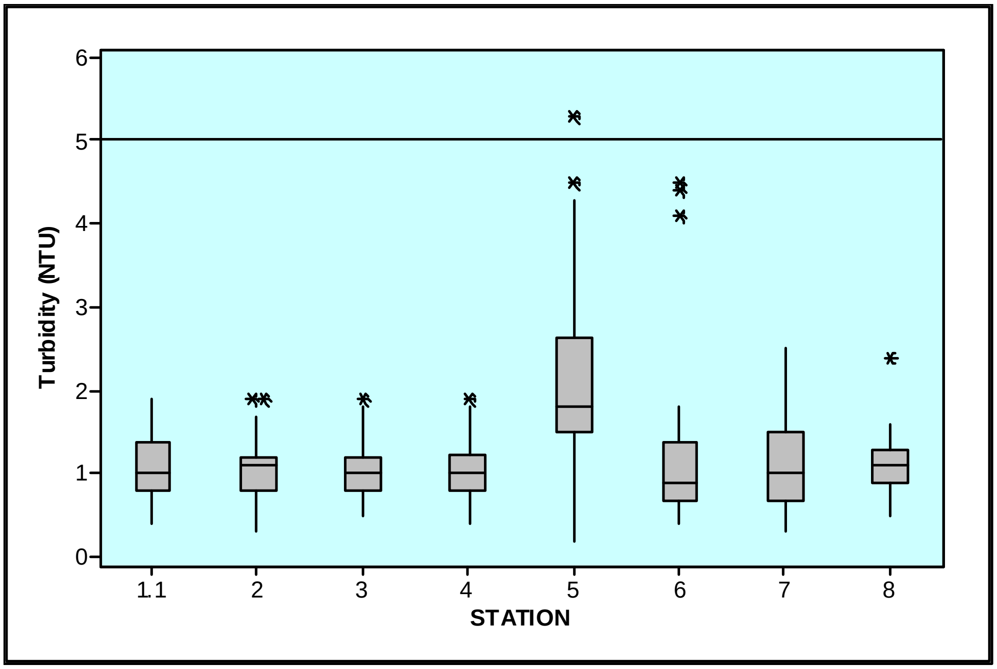

Figure 3.13 Turbidity plots for routine Kensico Reservoir monitoring data, April-December, 2008.

3.4.3 Keypoint Turbidity

Mean turbidity, measured on a four hour schedule, from January to November 2008 was 1.0 NTU at CATLEFF and 1.0 NTU at DEL18. The SWTR limit of 5 NTU was not exceeded at either keypoint. During this period the maximum 4-hour turbidity measurements were 4.0 NTU at CATLEFF, and 2.2 NTU at DEL18 (Figure 3.14). This is achieved by constant surveillance of the reservoir and its influent and effluent water quality, anticipation of problems, and careful operation of reservoir gates at the effluents to avoid resuspension of sediments.

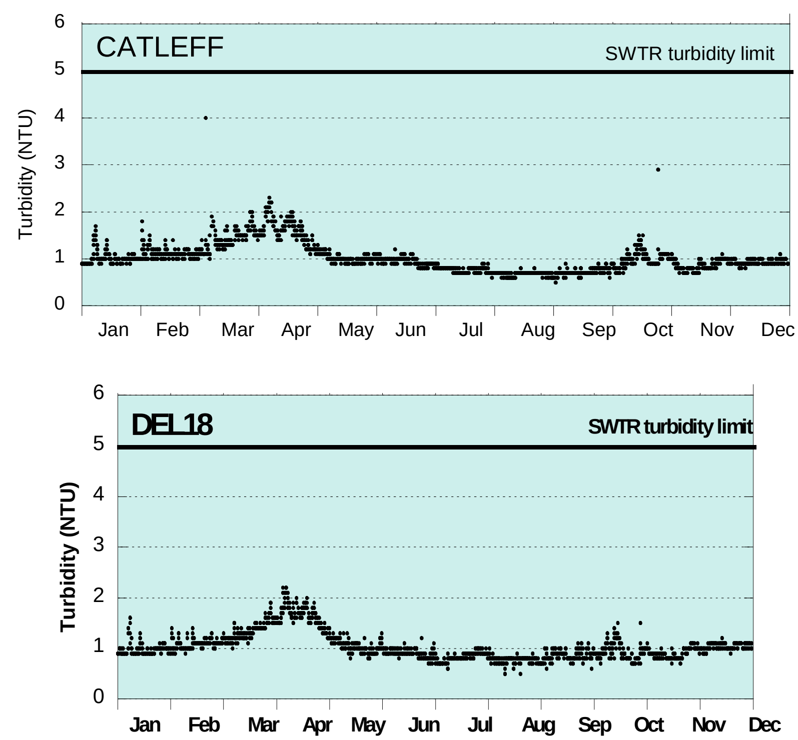

Figure 3.14 Four-hour turbidity data for the CATLEFF and DEL18 keypoints, 2008.

4. Turbidity Modeling

4.1 Kensico Reservoir Turbidity Simulations in Response to March 2008 Storm Event

Increases in Catskill System turbidity which could threaten Kensico Reservoir water quality were less frequent and less severe in 2008 than the increases produced by storms in 2005 and 2006 which required alum treatment. There were, however, a series of storms beginning in February 2008 and culminating in two closely spaced storm events between March 5 and March 12, 2008, that increased Ashokan Reservoir turbidity levels and the turbidity of water entering the Catskill Aqueduct (Figure 4.1). Peak turbidity levels resulting from these events, as measured in Esopus Creek just upstream of the confluence with Ashokan Reservoir, exceeded 250 NTU, which when combined with high discharge, led to an increase in Ashokan Reservoir turbidity ranging from 6 to 8 NTU at the Catskill Aqueduct effluent (Figure 4.1). Turbidity levels of this magnitude approach the threshold that would historically have triggered alum treatment. For this storm, however, as was the case for the storms which occurred during 2007 (DEP 2007), DEP pursued an alternative strategy that relied on reducing the Catskill Aqueduct flow while maximizing Delaware System withdrawal. This was a viable operating strategy under these conditions, given that Ashokan turbidity levels were high, but not extreme, and that Kensico Reservoir was well mixed. Model simulations were used to help define safe levels of Catskill Aqueduct flow as turbidity changed over the course of the event. Table 4.1 below summarizes the simulations that were run. A more detailed description of these simulations and the modeling methods has been presented in the Water Quality Modeling group's Annual Status Report (DEP 2008), which is another FAD deliverable.

The first set of simulations (March 7; Table 4.1) were made as the turbidity event unfolded. These are described in the most detail here since they demonstrate how the strategy of reducing Catskill Aqueduct flow was employed and how simulations were used to determine acceptable levels of aqueduct flow. For this set of simulations, the model was driven using measured Catskill and Delaware Aqueduct flow and turbidity data up until March 7, when the simulations were run. Following this initial period, the specific goal of each set of simulations was to forecast future turbidity levels at the Kensico Aqueduct effluents assuming constant conditions for approximately one month into the future. All simulations were run using DEP's CE Qual W2 model of Kensico Reservoir.

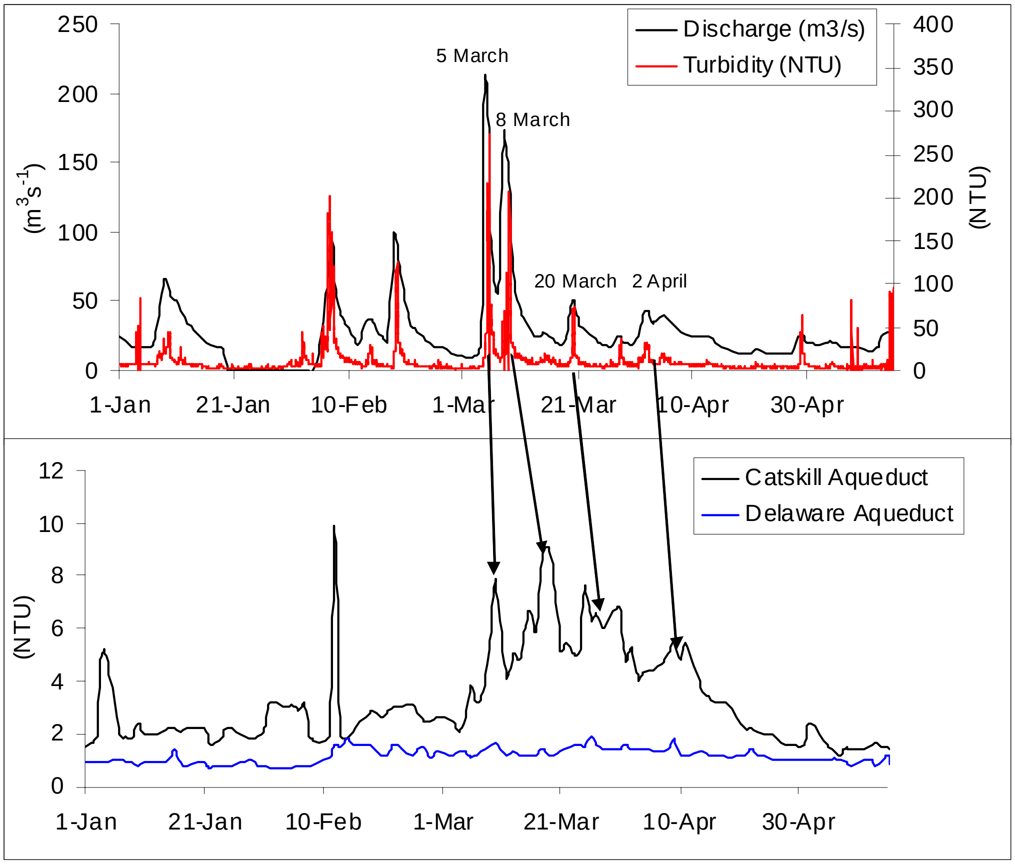

Figure 4.1 Conditions leading up to and following the March-April 2008 turbidity event. The top panel shows the discharge and turbidity measured in Esopus Creek near its confluence with Ashokan Reservoir. The bottom panel shows the turbidity levels measured in the Catskill and Delaware Aqueduct withdrawals from Ashokan and Rondout Reservoirs. The arrows show the correspondence between the storm event turbidity inputs to Ashokan Reservoir and the change of turbidity in the Catskill Aqueduct effluent withdrawn from the East Basin of Ashokan Reservoir.

Table 4.1. Kensico reservoir model simulations used to judge the need for alum addition during the March-April 2008 turbidity event.

Date	Description	Simulation Support
7 March	Following the first storm event on March 5, as reservoir turbidity levels continued to rise and approach 8 NTU. At this time Catskill Aqueduct flows were at approximately 600 MGD and it was not clear what maximum turbidity levels would be reached in the Catskill Aqueduct.	Simulations were run to examine the influence of increasing Catskill System turbidity inputs on Kensico Reservoir effluent turbidity levels, and the effects of reducing aqueduct flow by 50% using the same assumed turbidity increase. The effect of Catskill Aqueduct turbidity levels up to 20 NTU, while maintaining 600 MGD flow or reducing Catskill Aqueduct flow to 300 MGD, was examined.
10 March	By the time of these simulations, a second storm event had occurred on 8 March and Catskill aqueduct turbidity levels were again on the rise and exceeding 8 NTU. It was becoming increasingly clear that Catskill aqueduct flow would need to be decreased. It was not clear how high Catskill turbidity levels would go.	Simulations were run at two reduced flow rates. At 300 MGD the effects of turbidity ranging between 15-25 NTU were simulated. At 200 MGD the effects of turbidity ranging between 20-40 NTU were simulated. These simulations were used to provide guidance on acceptable Catskill Aqueduct flow in the event of worst case turbidity increases. Following these simulations the Catskill Aqueduct flow was decreased.
20 March	At the time of another storm event, that again raised aqueduct turbidity levels, and when Catskill Aqueduct flows had been reduced to approximately 300 MGD.	Simulations were run at the present Catskill Aqueduct flow rate of 300 MGD and at a further reduced flow of 150 MGD over a turbidity range of 15-30 NTU. The purpose was to examine the effects of the worst case increases in turbidity on Kensico effluent turbidity levels, and if needed, the effects of further reducing Catskill Aqueduct flow. The storm was not as large as predicted and the effect simulated here never occurred.
15 April	By this time Catskill Aqueduct turbidity levels were following a declining trend and were in the range of 3-4 NTU. Catskill Aqueduct flows were still at approximately 300 MGD.	Simulations were run to examine the impact of increasing the Catskill Aqueduct flow rate to 400 MGD, 500 MGD, or 600 MGD, while assuming that Catskill Aqueduct turbidity levels would range between 4-8 NTU. The results suggested that aqueduct flow rates could be increased to 600 MGD at present turbidity levels.

Based on the measured turbidity immediately following the storm and on a continuing upward trend in turbidity (Figure 4.1), a series of simulations were run on March 7 (Table 4.1), with Catskill input turbidity levels ranging between 6 and 20 NTU, and Delaware Aqueduct turbidity levels set at a constant 1.5 NTU. Simulations were first run for the actual Catskill Aqueduct flow of 600 MGD, and then repeated using a reduced Catskill Aqueduct flow of 300 MGD, while increasing the Delaware Aqueduct flow by an equivalent amount. The results of two of these simulations, based on an assumed Catskill aqueduct turbidity of 10 NTU and 15 NTU, are shown in Figure 4.2.

Comparison of the simulated and measured Kensico effluent turbidity levels leading up to the turbidity event show that the model was capable of predicting the pre-event turbidity levels within the margin of error related to uncertainty in particle sinking. During the forecast period the results suggested that as long as turbidity levels remained at or below 10 NTU the current Catskill Aqueduct flow of 600 MGD could be maintained without serious consequences to Kensico effluent turbidity levels. However, if turbidity levels reached 15 NTU, there could be serious consequences, with the Kensico effluent levels approaching or exceeding the 5 NTU regulatory limit. When Catskill Aqueduct flow was reduced to 300 MGD using the same assumed turbidity inputs, a sustained input of 10-15 NTU could be tolerated for three to four weeks.

It was recommended that under current operating conditions Catskill input turbidity levels up to, but not exceeding, 10 NTU could be tolerated. Further reductions in Catskill Aqueduct flow to at least 300 MGD would be required if turbidity exceeded 10 NTU, in order to maintain a reasonable margin of safety in approaching the 5 NTU regulatory limit. Actual Catskill Aqueduct turbidity levels remained below 10 NTU, but on a number of occasions peaked close to this value (Figure 4.3). Given that DEP had the capability to reduce the Catskill flows and that Catskill turbidity levels were approaching a level that could lead to increases in Kensico effluent turbidity, a decision was made to reduce Catskill Aqueduct flows by approximately 50 percent on March 11 (Figure 4.3).

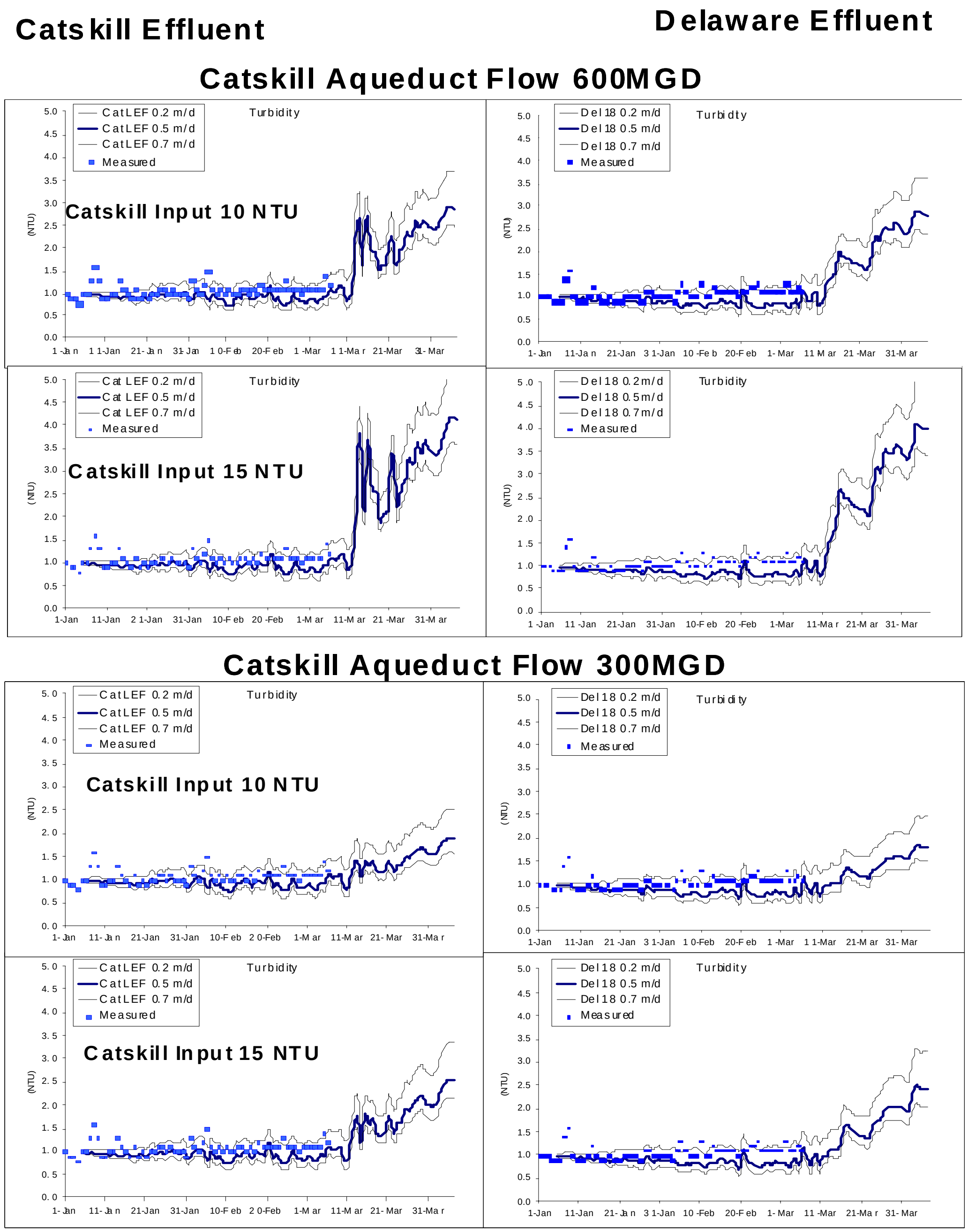

Figure 4.2 Simulated Catskill and Delaware Aqueduct effluent turbidity levels for simulations run on March 7, 2008. The Catskill effluent results are shown in the left column of graphs, while the Delaware effluent results are seen in the right column of graphs. Simulations used the actual Catskill Aqueduct flow of 600 MGD at two input turbidity levels (top four graphs) and also at a Catskill Aqueduct flow of 300 MGD (bottom four graphs). The three lines on each graph show variations in model output over a reasonable range of particle settling rates. Points plotted during the initial simulation period are measured data.

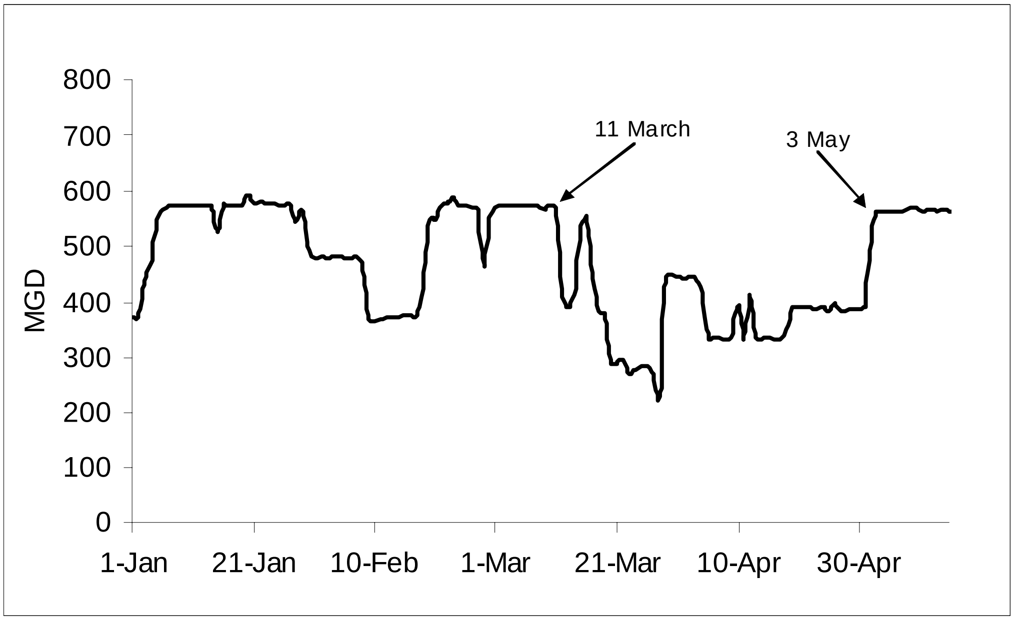

Figure 4.3 Catskill Aqueduct flow rates during the period leading up to, and following, the March-April 2008 turbidity event. In response to the elevated turbidity levels in Ashokan Reservoir, Catskill Aqueduct flow was reduced by roughly 50% between March 11 and May 3.

The March-April 2008 event described above was a moderate event that led to elevated turbidity levels in Catskill System water. Turbidity increases were not extreme enough to require alum treatment. Rather, it was possible to mitigate the effects of elevated Catskill turbidity by cutting back on the Catskill System flow entering Kensico Reservoir. The use of models to help optimize reservoir operations during this event helped DEP define aqueduct flow rates to achieve acceptable reservoir system turbidity levels.

5. Other Areas of Interest

5.1 Routine Inspections of the Turbidity Curtain at the Catskill Effluent

DEP's Water Quality Directorate conducts visual inspections of the turbidity curtain at the Catskill Upper Effluent Chamber cove (Figure 5.1). Table 5.1 lists the dates and results of the turbidity curtain inspections carried out in 2008. If observations 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 5.1 Catskill Upper Effluent Chamber turbidity curtain.

Table 5.1. Visual inspections of the Catskill Upper Effluent Chamber turbidity curtain.

Inspection Dates	Comments
01/09/08	No unusual observations
01/23/08	No unusual observations
02/06/08	No unusual observations
02/20/08	No unusual observations
03/05/08	No unusual observations
04/03/08	No unusual observations
04/16/08	No unusual observations
05/01/08	No unusual observations
05/16/08	No unusual observations
05/28/08	No unusual observations
06/11/08	No unusual observations
06/25/08	No unusual observations
07/09/08	No unusual observations
07/23/08	No unusual observations
08/08/08	No unusual observations
08/20/08	No unusual observations

Table 5.1. (Continued)Visual inspections of the Catskill Upper Effluent Chamber turbidity

Inspection Dates	Comments
09/06/08	No unusual observations
09/17/08	No unusual observations
10/01/08	No unusual observations
10/15/08	No unusual observations
10/30/08	Maintenance required
11/12/08	Maintenance required
11/26/08	Maintenance in progress
12/17/08	No unusual observations

5.2 Special Investigations

No unusual events or spills were discovered in 2008 and, as a consequence, there were no special investigations conducted within the Kensico Reservoir watershed during 2008.

5.3 Dredging at the Catskill Influent Cove (CATIC)for Alum Removal

Beginning in April 2005, several heavy rain events occurred 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. In response, DEP applied for a SPDES permit to allow aluminum sulfate (alum) treatment to coagulate the suspended solids in Catskill water entering Kensico Reservoir during such high turbidity events. The permit, issued by DEC on December 20, 2006, includes a condition that DEP remove the floc resulting from the alum addition, including the entrained solids, from the reservoir. To meet this requirement, DEP will procure the services of a dredging contractor, through competitive bidding. Floc will be removed in the vicinity of the Catskill Influent Chamber (CATIC), where water from the Catskill Aqueduct enters Kensico Reservoir. Hydraulic dredging and mechanical dewatering, with the resultant concentrated cake disposed of at an offsite location, has been determined to be the best method of removal at this time.

As per the stipulations in the SPDES permit, scientific investigations of the area of floc deposition were completed in 2007. DEP and the design consultants at Malcolm Pirnie, Inc., submitted reports detailing the bathymetric, benthic, core sampling, computer modeling, and flow study findings to DEC in October 2007. After reviewing all 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 the scientific data collected during the investigation of alum floc deposition in the 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 addition to the engineering and scientific reports specified in the SPDES permit, DEP has provided DEC and NYSDOH with a monthly progress report since October 2005, describing the investigations conducted to finalize the construction contract for this project. Also, the environmental review for SEQR and the required permitting process have been initiated. Contract documents were completed in 2007 and have undergone NYC legal review. DEC is currently reviewing all the submitted reports.

5.4 Groundwater

DEP reviews results of ongoing sampling of Westchester County Airport groundwater monitoring wells by Westchester County DOT as a matter of routine surveillance. The parameters analyzed are volatile, semivolatile, and nonhalogenated organic compounds, and metals.While data indicate that some groundwater contamination remains beneath the Airport, it is not believed that the contamination reflected in the sampling data is a water quality concern for Kensico Reservoir.

5.5 BMP Monitoring

As a key component of DEP's Kensico Water Quality Control program, 45 stormwater management and erosion abatement facilities were constructed throughout the Kensico watershed in order to reduce pollutant loads conveyed to the reservoir by stormwater (Figure 5.2). The initial installation was in March 1999 and the last was completed in November 2004. Water quality sampling at selected Kensico best management practices (BMPs) was begun in 2000 and completed in 2007 in accordance with the monitoring plan for the Kensico basins. 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 the watershed that were constructed as part of this program. While the sampling effort concluded in 2007, a more detailed report of the findings will be presented in the 2009 Kensico Programs Annual Report (as required by the 2007 FAD). In 2008 efforts were begun to prepare and analyze the Kensico BMP data for this forthcoming report.

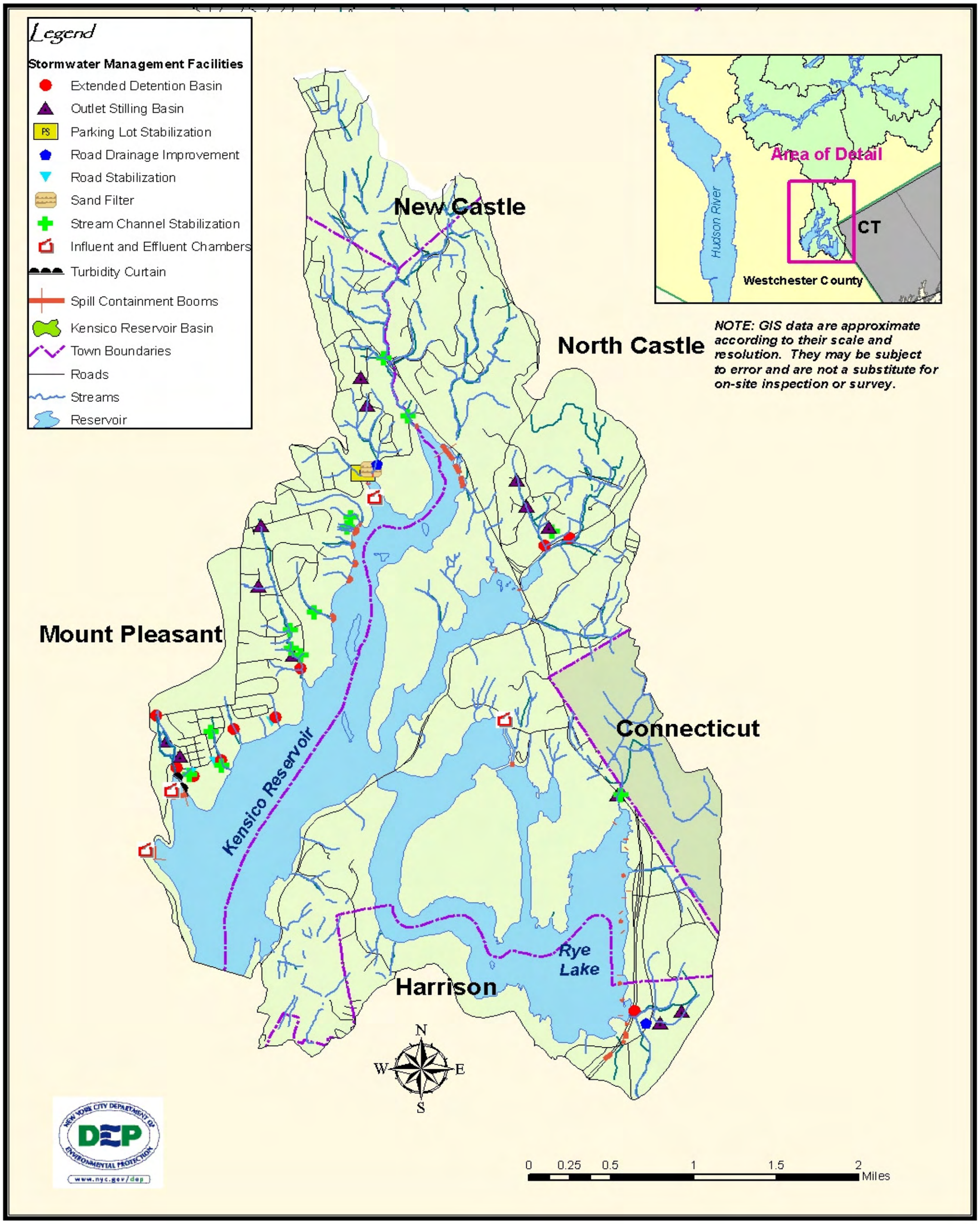

Figure 5.2 Location of stormwater management facilities in the Kensico Reservoir watershed.

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