Watershed Monitoring for NYC's Water Supply

by Kerri Alderisio, Lorraine Janus, Gerard Marzec, James Mayfield, Bryce McCann and Don Pierson

The New York City water supply system supplies drinking water to almost half the population of the State of New York, which includes over eight million people in New York City and one million people in upstate counties, plus millions of commuters and tourists. New York City's Catskill-Delaware System is one of the largest unfiltered surface water supplies in the world. (The Croton System, which supplies on average 10 percent of the City's demand, is expected to be filtered by 2012.) The water is supplied primarily from a network of 19 reservoirs and three controlled lakes that contain a total storage capacity of approximately two billion cubic meters (550 billion gallons). The total watershed area for the system drains approximately 5,100 square kilometers (1,972 square miles) and it extends over 200 kilometers (125 miles) north and west of New York City ***(Figure 1)***.

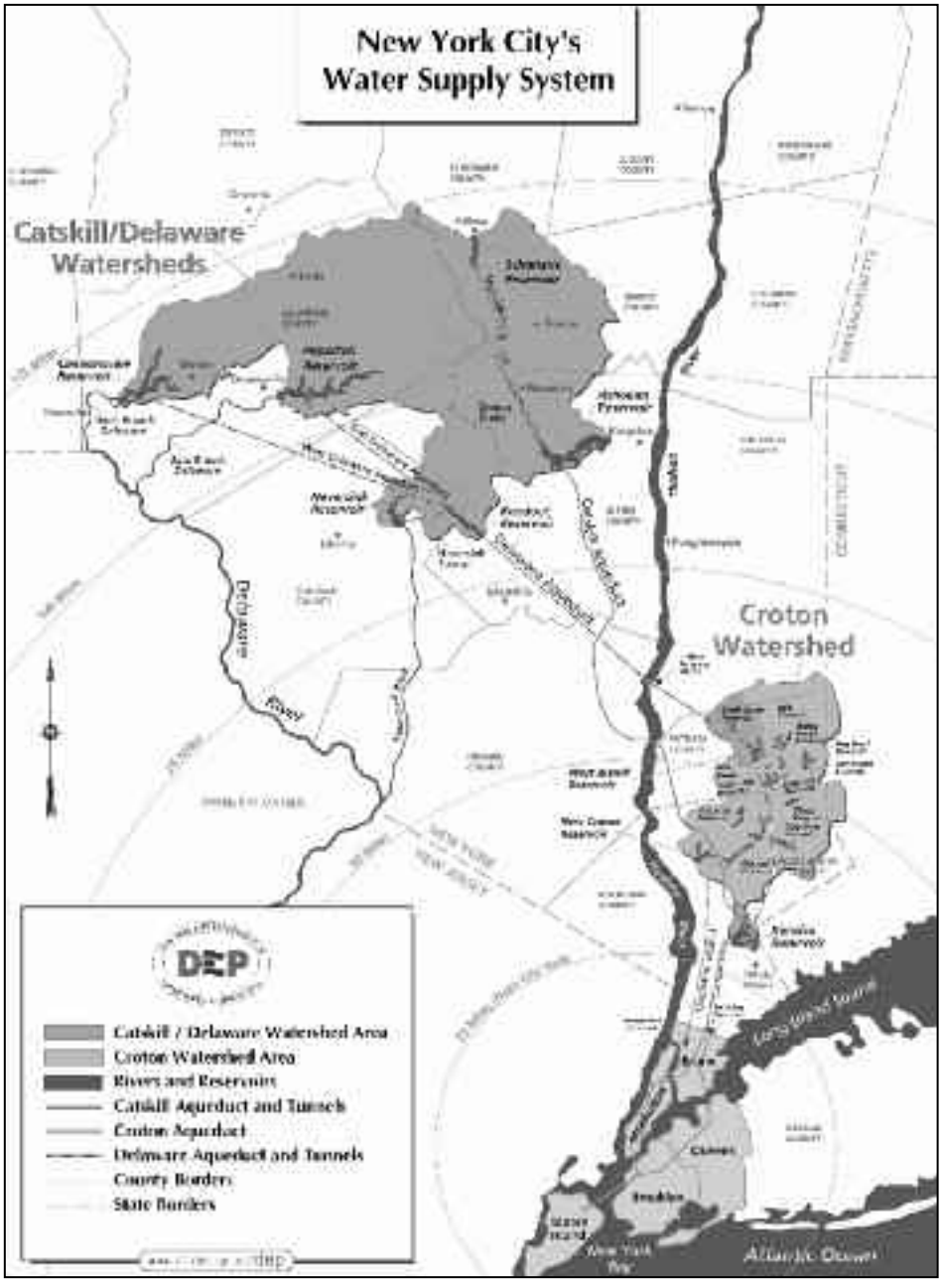
Primary Objectives and Design of the Monitoring Program

In order to ensure high quality drinking water, the New York City Department of Environmental Protection (DEP) conducts extensive water quality monitoring that encompasses all areas of the watershed, including sites at aqueducts (keypoints), streams, and reservoirs. The watershed monitoring program meets the sampling needs for regulatory compliance requirements and also forms the basis for the DEP's ongoing assessment of watershed conditions, changes in water quality, and ultimately develops any modifications to the policies, strategies, and management of the watershed protection program.

The overall goals of DEP are documented in the Watershed Water Quality Monitoring Plan (DEP 2008), which establishes an objective-based water quality monitoring network. This provides scientifically defensible information regarding the understanding, protection and management of the New York City water supply. The objectives of this monitoring plan have been defined by the requirements of those who ultimately require the information, including regulators, DEP programs administrators and other external agencies. As such, monitoring requirements were derived from legally binding mandates, stakeholder agreements, operations and watershed management information needs. The plan covers four major areas that require ongoing attention: Compliance, Filtration Avoidance Determination (FAD) Program Evaluation, Modeling Support and Surveillance Monitoring, with many specific objectives within these areas described in subsequent sections.

Monitoring design must consider several elements, including choice of sites, analytes, analytical methodology and detection limits, and sampling frequency. Where possible, statistical features of the historic database were used to guide the sampling design. For example, analyses of past data revealed that some sites were not significantly different from others, indicating that they could be adequately represented by similar sites. Sampling frequencies were based approximately on the rates of processes governing variability in water quality data in order to track such processes. This statistical screening of differences between sites and collection times was used to streamline the monitoring site plans and to determine appropriate collection frequencies.

Compliance Sampling: The objectives in this section are focused on the regulatory compliance monitoring requirements in the New



Courtesy of NYCDEP

Figure 1. A map showing New York City's Water Supply System of watersheds

York City watershed. This includes the requirements of the Surface Water Treatment Rule (SWTR), and its subsequent extensions, as well as the New York City Watershed Rules and Regulations (WR&R), the Croton Consent Decree (CCD), Administrative Orders and State Pollution Discharge Elimination System (SPDES) permits. The sampling sites, analytes, and frequencies are defined in each objective according to each specific rule or regulation and are driven by the need of the water supply as a public utility to comply with all regulations. Since this monitoring is mandatory, it must maintain compliance with all US Environmental Protection Agency (EPA), NYS Department of Health (NYSDOH) and DEP regulations.

Filtration Avoidance and Watershed Protection Program Evaluation: New York City's water supply is one of the few large water supplies in the country that qualifies for Filtration Avoidance, based on both objective water quality criteria and subjective watershed protection requirements. The EPA has specified many requirements in the 2007 Filtration Avoidance Determination that must be met to protect public health. These objectives form the basis for the City's ongoing assessment of watershed conditions, changes in water quality, and ultimately any modifications to the strategies, management, and policies of the Long-Term Watershed Protection Program (DEP 2006). As watershed protection programs develop and analytical techniques for key parameters change, it is necessary to reassess the monitoring program to ensure that it continues to support DEP's watershed management program. The periodic reassessment of the City's monitoring program is achieved by critical review and revision of the monitoring plan approximately every five years. The City also conducts a periodic assessment of the effectiveness of the watershed protection program. The DEP's water quality monitoring data are essential to evaluate watershed programs. Program effects on water quality are reported in the Watershed Protection Summary and Assessment reports, also produced approximately every five years.

The 2007 FAD also requires that the DEP's watershed-wide monitoring program meets the needs of DEP 2006. The goals of this program are to:

- Provide an up-to-date, objective-based monitoring plan for the routine watershed water quality monitoring programs, including aqueducts, streams, reservoirs, and pathogens.
- Provide routine water quality results for aqueduct, stream, reservoir, and pathogen programs to assess compliance, provide comparisons with established benchmarks and describe ongoing research activities.
- Provide mid-term results from routine watershed (e.g., stream and water treatment plant) pathogen monitoring.
- Use water quality data to evaluate the source and fate of pollutants and the effectiveness of watershed protection efforts at controlling pollutants.
- Provide a comprehensive evaluation of watershed water quality status and trends to support assessment of the effectiveness of watershed protection programs.

These goals are met by targeting specific watershed protection programs and examining overall status and trends of water quality. Water quality represents the cumulative effects of land use and the DEP's watershed protection and remediation programs. The ultimate goal of the watershed protection programs is to maintain the status of the City's water supply, as one of the few large unfiltered systems in the nation, far into the future.

Water Quality Modeling Data Requirements: This section addresses the monitoring needs to meet both the long-term goals for water supply policy and protection, and to guide operational strategies when unusual water quality events occur. These goals outline the continuation of modeling efforts from previous FAD projects including: implementation of watershed and reservoir model improvements based on ongoing data analyses and research results; ongoing testing of the DEP's watershed and reservoir models; updating of data necessary for models, including land use, watershed program implementation data, and time series of meteorological, stream flow and water chemistry; development of data analysis tools supporting modeling projects; and applications of the DEP's models to support watershed management, reservoir operations, climate change analysis and long-term planning, as identified in the DEP's Climate Change Task Force Action Plan (2008).

The monitoring data needs for models are divided into three major areas: stream, reservoir and aqueduct, and meteorological data. The stream monitoring includes flow monitoring and targeted water quality sampling to support watershed and reservoir model development, testing, and applications. Reservoir monitoring includes flow and reservoir operations data to support reservoir water balance calculations as necessary model input, and reservoir water quality monitoring to adequately continue to test, apply, and further develop the DEP's one and two dimensional modeling tools. The meteorological data collection effort provides critical input necessary to meet both watershed and reservoir modeling goals.

Water Supply Surveillance: The surveillance section of the DEP's monitoring plan contains several objectives that provide information to guide the operation of the water supply system; other objectives to help track the status and trends of constituents and biota in the system; and specific objectives that include aqueduct monitoring for

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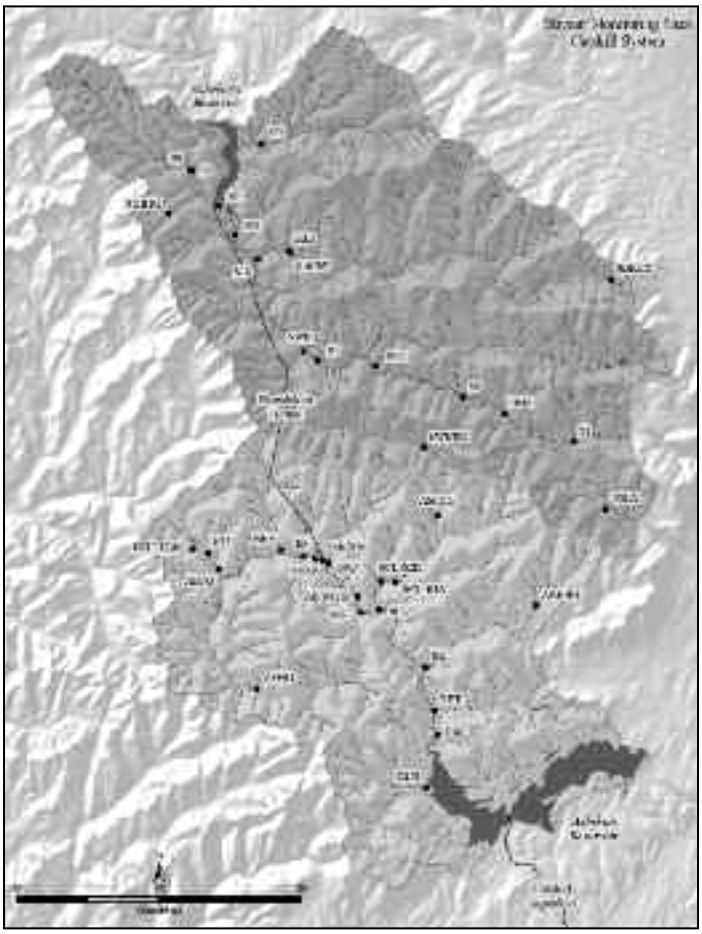

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Figure 2: Stream sampling sites within the Catskill System drainage basin

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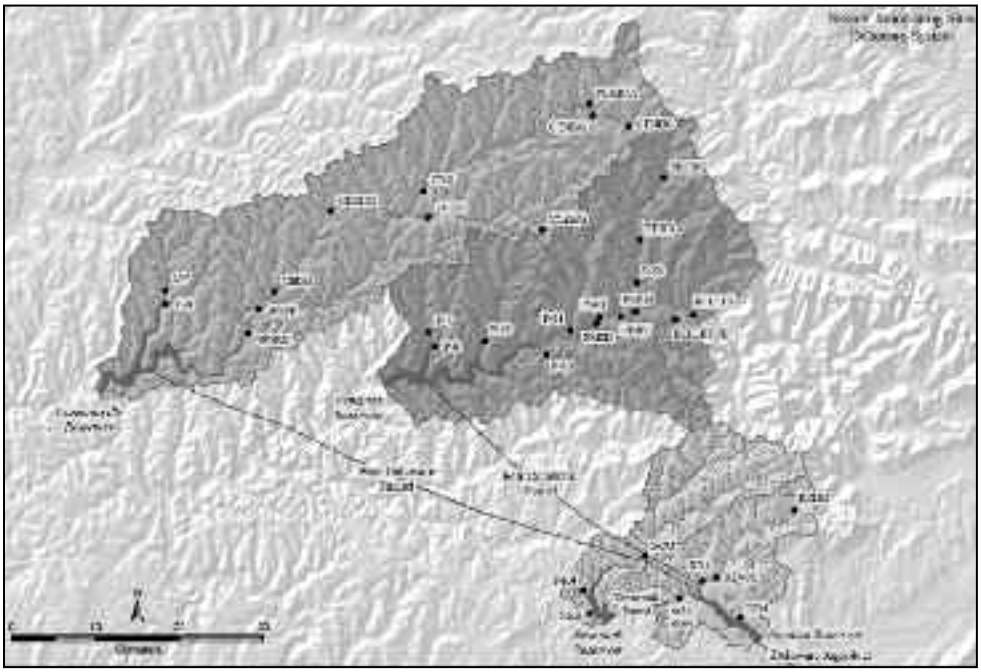
management and operational decisions. The aqueduct network of sampling points consists of key locations along the aqueducts, developed to track the overall quality of water as it flows through the system. Data of these key aqueduct locations are supplemented by reservoir water quality data. Another surveillance objective relates to developing a baseline understanding of potential contaminants that include trace metals, volatile organic compounds and pesticides, while another summarizes how the DEP monitors for the presence of zebra mussels in the system, a surveillance activity meant to trigger actions to protect the infrastructure from becoming clogged by these mussels. The remaining objectives pertain to recent water quality status and long-term trends for reservoirs, streams, and benthic macroinvertebrates in the Croton System. It is important to track the water quality of the reservoirs to be aware of developing problems and to pursue appropriate actions. Together, these objectives allow the DEP to maintain an awareness of water quality for the purpose of managing the supply to provide the highest quality drinking water possible.



Courtesy of NYCDEP

Figure 3: Stream sampling sites within the Delaware System drainage basin

Network Coverage

The DEP's watershed monitoring networks cover the entire watershed and include: meteorological stations, snow surveys, stream samples, limnological sites, aqueducts, and wastewater treatment plants. Each network provides data that are used to characterize "state variables" (quantities), as well as their transformation rates, which are important components of the water supply's hydrology and water quality. Hydrological flow is the essential underlying element of water quality phenomena and water quality models are based on the hydrodynamics of the system. The interplay of water flow rates and physical, chemical, and biological rates determine water quality outcomes. These outcomes can only be estimated through water quality modeling. Therefore, it is essential to know the basic hydrology of the watershed in order to anticipate water quality changes for proactive management of the water supply.

Meteorological Sites: Meteorological stations are located throughout the watershed. There are 20 sites west of the Hudson River and five sites east of the Hudson. This network was designed to provide the best data characterization of the conditions throughout the

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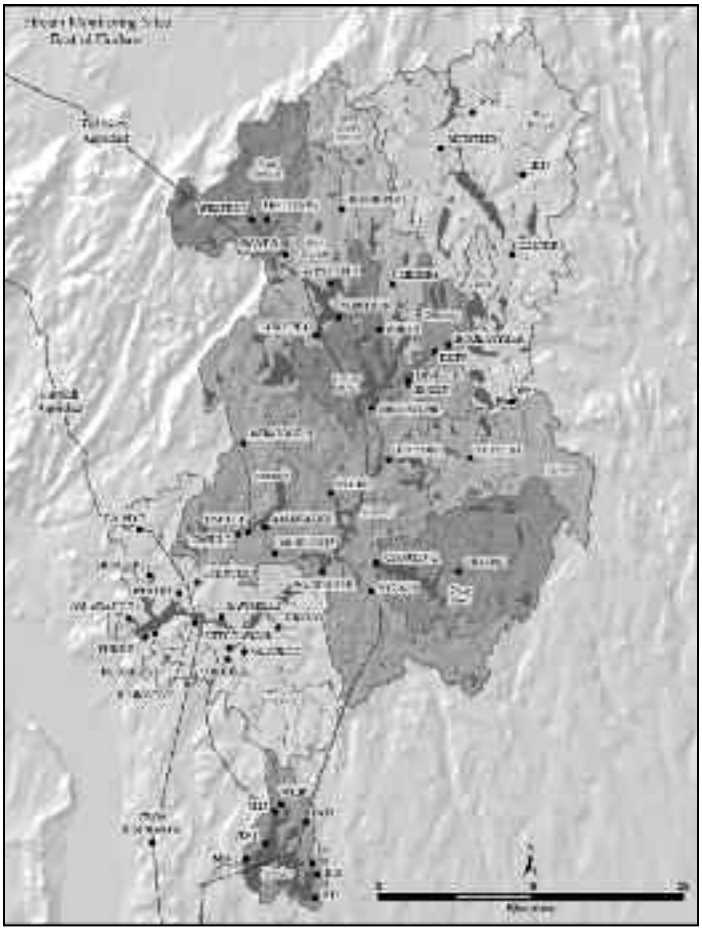

Courtesy of NYCDEP

Figure 4: Stream sampling sites east of the Hudson River

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Figure 5: Sampling for pathogens at a typical stream site

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watershed in order to allow extrapolation and estimation of total precipitation entering the system. Orographic effects (such as greater precipitation at higher elevation on the windward side of mountains) were considered during site selection, so different site elevations were selected to proportionately represent the full range of conditions (i.e., from the mountain peaks in the Catskills to the lower elevations of the Croton System). Sites were also located on the reservoirs in order to characterize the temperature and wind conditions needed for model input.

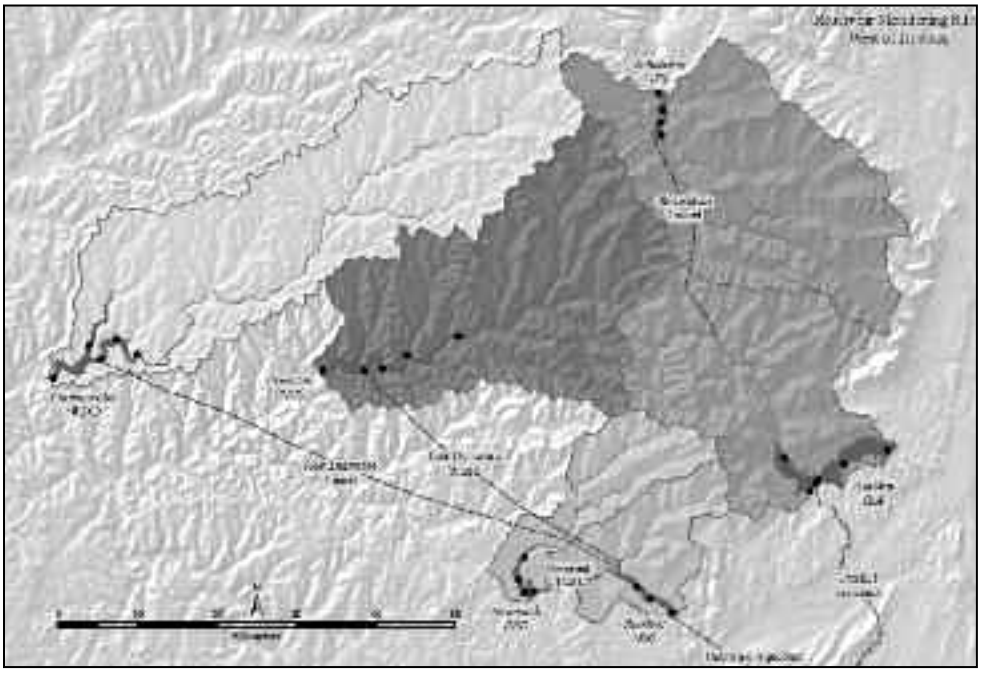
Snow Surveys: During the winter, snow surveys are periodically conducted to estimate how much water is stored on the watershed as snow and ice. These estimates are important in anticipating spring runoff and the impacts of rain-on-snow events, which may result in unusually large influxes of water to the reservoirs. Snow survey results also are used to determine reservoir release rates in accordance with the Flexible Flow Management Plan for NYCDEP's Delaware System reservoirs. Snow is an important part of the hydrological cycle and has an impact on stream and reservoir water temperatures throughout the spring.

Stream Sampling: Stream sampling sites are represented in ***Figures 2, 3, and 4***. They were established as water quality monitoring sites in order to monitor and pinpoint various potential sources of pollution. They also allow quantification of pollutants entering the system so that appropriate measures can be taken to minimize impairment of the drinking water. A typical stream site being sampled for pathogens is shown in ***Figure 5***. Water quality samplings of the streams and tributaries provide essential input for reservoir models that guide the management of the NYC reservoirs. A companion network to the DEP's water quality stream sites is the network of US Geological Survey (USGS) stream gauges. Most of the gauge sites are operated and maintained by the USGS on behalf of the DEP and provide important flow data. These data are available on the internet and are used widely by a variety of stakeholders. They are used by DEP to track the current condition of the system's stream flows, guide operational decisions, including meeting mandated flow targets, and also during droughts and floods. Stream flow data are particularly important to modeling, as they can provide key inputs to reservoir models that are used to evaluate the consequences of different operating strategies. They also provide data to calibrate and verify watershed models, which can estimate loads of water and nutrients to the reservoirs.

Limnological Surveys: Limnological sites (i.e., sites located on the reservoirs) for the Catskill and Delaware Systems are shown in ***Figure 6*** and limnological sampling is shown in ***Figure 7***. Sites were selected to provide coverage of water quality and physical conditions throughout each reservoir, and are typically sampled at multiple depths. Limnological surveys are important in serving many objectives. They provide information on the current status of basic physical, chemical and biological conditions that determine water quality in the system, allow tracking of trends, provide data for models, and guide current operational decisions.

Aqueduct Keypoints: Aqueduct "keypoint", ***Figure 8,*** monitoring is conducted as a means of keeping a "finger on the pulse" of the water supply with respect to the major water flowing through the system and into distribution. Monitoring at these sites is conducted through the use of continuous monitoring equipment, and taking daily or weekly grab samples. These sites have some of the highest frequencies of sampling, the purpose of which is to maintain a high degree of reliability in the quality of water entering the distribution system. In addition to sites used for operational decisions, aqueduct monitoring includes compliance sites for the Surface Water Treatment Rule (SWTR), and they are of utmost importance for operation of the system to maintain the status of "filtration avoidance".

Water Treatment Plants: Finally, the DEP monitors wastewater treatment plants (WTPs) located throughout the watershed. The locations of these treatment plants are potential sites of impairment. However, this risk has been enormously reduced in recent years because all treatment plants in the watershed have been upgraded to microfiltration (or the equivalent) with tertiary treatment (nutrient removal). Plant upgrades have nearly eliminated the impacts that these plants formerly had in terms of nutrient and microbiological inputs. In this plan, WTP monitoring relies primarily on compliance monitoring to meet SPDES permits. Although DEP only owns six of the treatment plants and conducts monitoring according to their SPDES permits, additional monitoring of all plants is conducted to ensure that no problems arise.



Courtesy of NYCDEP

Figure 6: Limnological sampling sites for reservoirs west of the Hudson River

Monitoring Means Safe Water

The Watershed Water Quality Monitoring Plan should be seen as superimposed networks that build on each other, provide multidimensional information, and multiple lines of evidence to support operational and policy decisions. Water quality management often requires a network design which can address water quality issues that demand distinct spatial and temporal monitoring efforts. These efforts may, for example, require a combination of long-term fixed-frequency surveys, supplemented by intensive short-term strategies. The design of water quality monitoring networks can be significantly enhanced by the coordination and integration of such monitoring strategies.

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Courtesy of NYCDEP

Figure 7: Limnology is the science of freshwater lakes and reservoirs and limnology sampling is typically done at several depths to characterize the different chemical, physical and biological characteristics of the layers that develop with seasonal warming, a condition referred to as stratification. DEP samplers are shown on Ashokan Reservoir.

The integration of water quality monitoring networks is essential for deriving the best value from the water quality data collected. The use of data gathered by the water quality monitoring network is routinely used to support water supply operations. In addition, the importance of the monitoring networks and full value of the data materializes when scientists provide analysis and interpretation for scientific reports and publications.

The monitoring plan has been designed to meet the broad range of the DEP's many regulatory and informational requirements. These requirements include: compliance with all federal, state and local regulations to ensure safety of the water supply for public health; watershed protection and improvement to meet the terms of the 2007 Filtration Avoidance Determination (FAD); the need for current and future predictions of watershed conditions and reservoir water quality to ensure that operational decisions and policies are fully supported over the long term; and that ongoing surveillance of the water supply will continue to ensure delivery of the best water quality to consumers.

Courtesy of NYCDEP

Figure 8: Surveillance at "keypoints," is performed by continuous monitoring equipment found at stations, such as this one, at multiple locations along Catskill and Delaware aqueducts.

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