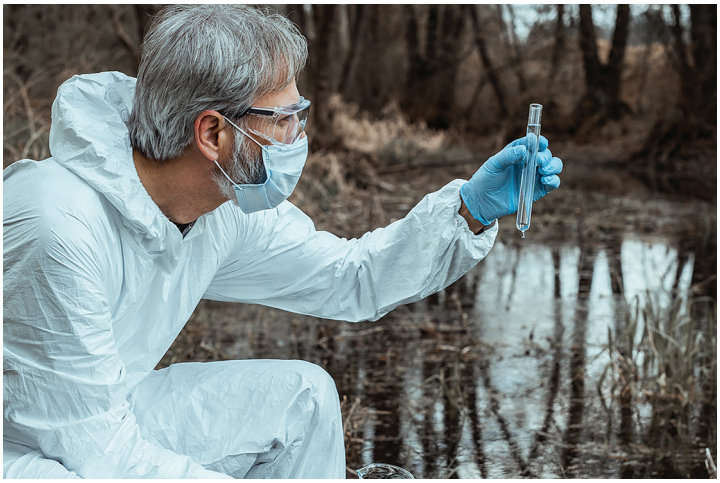

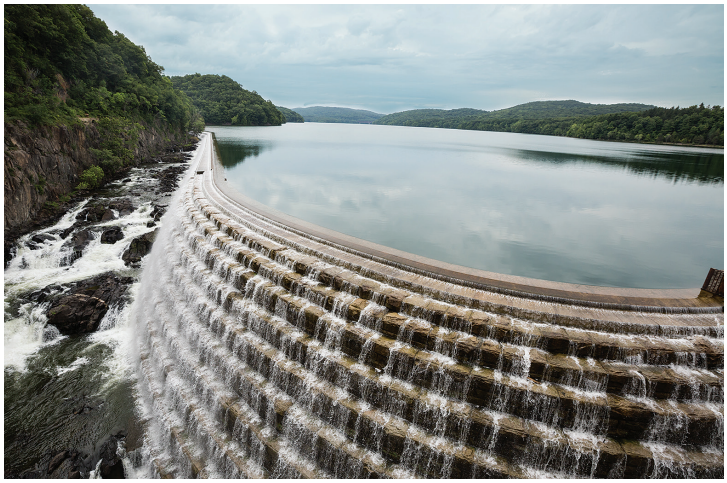

Water Quality Issues in the NYC Watershed and Beyond

NYC Watershed Science and Technical Conference

September 12, 2018

Diamond Mills Hotel, Saugerties, NY

NYWEA
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INTRODUCTION AND ACKNOWLEDGMENTS

Dear Conference Participants,

In 1997, the signatories to the historic New York City Watershed Agreement formed an enduring partnership to protect and enhance the City's Watershed and the scores of communities living within it.
Underlying this complex social and political undertaking has been an unprecedented technical initiative among scores of local, State and Federal agencies with one common goal: to advance the science of watershed protection.

The Watershed Science and Technical Conference was created as an annual opportunity to bring scientists, professionals, and other experts together with watershed stakeholders and the public, to technically inform, exchange ideas, and unveil new information regarding the protection of the nation's largest unfiltered surface water supply.

Each year, this conference showcases the most current trends, technologies and scientific developments in the arena of watershed protection and management. The conference continues to punctuate the multiple longstanding themes that remain central to the business of caring for a watershed:

- Stormwater control,
- Wastewater treatment,
- Stream health,
- Emerging contaminants and microconstituents,
- Monitoring and modeling,
- Pathogens, nutrients, and turbidity,
- Recreational use, forestry, agriculture, and more.

The Conference Call for Abstracts was made to agencies and stakeholders in and beyond the New York City Watershed. The resulting responses were reviewed by the Watershed Technical Program Committee for technical merit and interdisciplinary utility, as well as temporal and substantive relevance. Those chosen by the Committee for presentation at this year's Conference are included in this Compendium.

In addition to our esteemed presenters and all those who submitted their scientific endeavors, we wish to thank the many agencies, professional organizations, and individuals who contributed to the success of this conference. It is our hope that all who attend will be edified by the scientific data presented, and inspired by the dedication and hard work of those who, each day, advance our insight into the science of protecting the drinking water for nine million New Yorkers.

Respectfully,

Lisa Melville

Lisa Melville
NYC Watershed Programs Coordinator
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Watershed Protection and Partnership Council

For the Conference Organizers and Sponsors:

The Watershed Protection and Partnership Council
The New York Water Environment Association, Inc.
The New York State Department of State
The New York State Department of Environmental Conservation
The New York State Department of Health
The New York City Department of Environmental Protection
The Catskill Watershed Corporation
The Watershed Agricultural Council
The United States Geological Survey
The New York State Environmental Facilities Corporation

Data Review from Routine and Advanced Methods to Inform Cryptosporidium Risk at a Terminal Reservoir

Kerri Alderisio, NYC Department of Environmental Protection

The United States Environmental Protection Agency's Long Term 2 Enhanced Surface Water Treatment Rule (LT2) requires the covering or downstream treatment of open, finished water reservoirs. For New York City's (NYC) water supply, this means covering the nearly one-billion gallons of water stored in Hillview Reservoir located in Yonkers, New York. However, the requirements of the LT2 were primarily guided by data gathered at open, finished water reservoirs that are very different from Hillview Reservoir, and with older methods than are available today. The NYC Department of Environmental Protection (DEP) has taken great interest in analyzing available data and employing advanced methods in order to establish whether a cover would benefit water quality at Hillview Reservoir with regard to Cryptosporidium. Available historical information, along with additional data from studies performed more recently will be discussed. Data from various microbial source tracking projects, the location and geography of the reservoir itself, as well as recent Cryptosporidium genotyping and infectivity method advancements will provide valuable information regarding oocyst occurrence and risk. Ideally, risk at the reservoir outflow should be based on all existing data and facts, rather than solely on the enumeration of oocysts. The sum of all available information regarding the sources and condition of the infrequent oocysts that are recovered should be considered. The current approved method for the recovery of Cryptosporidium from water cannot identify whether an oocyst is dead, alive, infectious, or if it is a species or subtype that can even infect humans. When trying to evaluate potential risk, this is a lot of missing information. This presentation will review steps taken and methods explored to answer some of these additional questions.

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Lessons from the Chesapeake Bay – Leveraging Ecosystem Restoration TMDL Reduction Practices for Comprehensive Resilient Solutions

Doug Beisch, Glenn Muckley, P.E., Stantec Consulting Services Inc.

Watershed retrofitting to improve water quality can be met with many challenges, physical, monetary, and resistance to cultural change, among others. But where these initiatives align with ongoing flooding issues or other critical infrastructure needs, targeted investments may be made that can improve resiliency, public safety, and provide habitat enhancement. This can happen when mandated TMDL reductions or flood risk issues are viewed as opportunities for community solutions.

Lithia Road Stream Restoration project is one example. Under multiple contract vehicles with the Virginia Department of Transportation (VDOT), Stantec provided design and support required to repair and address flooding issues along a section of Back Creek located immediately adjacent to Route 640. Additionally, substantive pollutant reductions were quantified based on project as-built conditions, creditable to VDOT's Chesapeake Bay TMDL obligations under its MS4 permit.

Originally, the project was initiated by VDOT to address historic flood damage, where bank armoring and the installation of a deflector log were used as an emergency repair. Overall stream conditions, even with the armoring and repair, still resulted in frequent flooding of Route 640, including during smaller storm events. Residents reported the road was impassable up to 30 times a year during rain events.

In 2016, VDOT requested Stantec assess potential creek relocation alternatives to both reduce flooding and improve water quality, quickly resulting in corrective action plan recommendations, which were expedited through an alternative project delivery mechanism. Using bio-engineering and Natural Channel Design (NCD) techniques, Back Creek and three influent tributaries were restored to improve overall corridor function, address erosive velocities, provide habitat for aquatic species, and improve conveyance in large storm events to reduce flooding.

In this session, experiences and observations from the project will be reviewed. Topics will include:

- Design considerations
- TMDL reduction and crediting alternatives
- Long-term Stakeholder considerations
- Procurement, construction, and maintenance issues
- Permit-related monitoring

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Implementing Precision Feed Management in the NYC Watershed Agricultural Program

Paul Cerosaletti, Dale Dewing, Cornell Cooperative Extension of Delaware County; Larry Hulle, Watershed Agriculture Council

Feed nutrients represent the largest pool of nutrients on livestock farms in the NYC Watershed. In the last two

years, the NYC Watershed Agricultural Program (NYCWAP) West of Hudson added precision feed management (PFM) as a nutrient management planning best management practice for dairy and beef farms in that watershed. This BMP, developed and piloted by Cornell Cooperative Extension over the last fifteen years, reduces feed nutrient imports, improves milk/beef nutrient exports, and minimizes excessive manure nutrient excretions through an approach integrating homegrown feed production, ration management, and cattle production best practices. PFM addresses both on-farm nutrient cycling and whole farm mass nutrient balance. In a process unique to the NYCWAP, PFM combines a feed management plan written and renewed every three years and according to the USDA NRCS feed management standard, an annual feed management implementation plan, and quarterly ration monitoring to ensure rations consistently meet precision feed management benchmarks. Regular assistance by PFM planners help farmers implement strategies identified in their feed management plans. In 2017, PFM was implemented on 32 dairy farms and over 2,000 cows, with 54,985 kg of feed phosphorus (P) and 360,386 kg of feed nitrogen (N) under management. On farms where dietary interventions were made, a 23 percent reduction in manure P excretion (5.5 kg per cow per year) and a 7 percent reduction in manure N excretion (10.2 kg/cow/year) was modelled. Precision feed management can be a win-win for both the environment and farms. Farmer participants frequently cite the regular contact and management assistance from PFM planners as helpful to their businesses. With assistance from their PFM planner, one farm in the past year increased homegrown feed levels 27 percent, reduced purchased grain nutrient imports 47 percent and increased milk income over purchased fee costs $1 per cow per day.

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Utilizing 3D Laser Scanning to Estimate Bank Erosion

Jillian Cole, Matt Lajoie, Stantec

In the fall of 2017, Stantec Consulting began working with the Ashokan Watershed Stream Management Program (AWSMP) to develop a bank erosion rating curve specific to the Ashokan Reservoir watershed. The rating curve is used to estimate the amount of sediment being contributed to the stream system from eroding banks. To develop the rating curve, a Bank Assessment for Non-point source Consequences of Sediment (BANCS) was completed for 36 study banks at various locations throughout the watershed and cross sections of the bank were surveyed in detail using the traditional method of a site level and stadia rod. Subsequent surveys were completed after any discharge event that was equal to or greater than bankfull as well as annually and the data was compared to the previous survey data to determine the amount of sediment lost from the bank. The sediment loss at the cross section location is extrapolated for the length of the eroding bank to determine the total annual sediment load being contributed from the bank.

While traditional survey methods provide an estimate of total bank erosion, Stantec and AWSMP wanted to evaluate the use of 3D laser scanners to actually measure bank erosion. 3D laser scanners rapidly collect data which can be developed into a 3D surface. If 3D laser scanners could be used to create a surface of an eroding stream bank, a more precise measurement of total bank erosion could be obtained. A pilot study was added to the current BANCS project to test the data quality, limitations, and cost-effectiveness of using 3D laser scanners. Three study sites were selected from the original 36 sites to have data collected with the 3D scanner. This presentation will discuss the results of data collection, a comparison of both methods, the accuracy and applicability of each and the limitations.

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Chadwick Lake WTP Improvements to Support the NYC Delaware Aqueduct Shutdown

Scott Davis, James Jensen, HDR

The Town of Newburgh, NY receives its water supply from two sources: Chadwick Lake, which is owned by the Town, and the New York City Department of Environmental Protection's (NYCDEP) Delaware Aqueduct. The Town identified a need to evaluate the reliability of the Chadwick Lake water supply and water treatment plant to meet the Town's water supply needs both over the short-term and long term time horizons. The short term challenge is to ensure adequate water supply during NYCDEP's planned 2022 shutdown of the Delaware Aqueduct, for which a minimum production capacity of 2 MGD from the Chadwick Lake WTP is targeted, with up to an additional 2 MGD from the Town of New Windsor. The longer term challenge is to ensure reliable high quality supply from the Chadwick Lake WTP for up to 4.5 MGD.

With these concerns, the Town commissioned an engineering evaluation focused on three key areas:

1) determine the actual supply capacity (safe yield) of Chadwick Lake and the ultimate treatment capacity of the water treatment plant;
2) identify source water quality and watershed challenges which impact key water quality

parameters and the performance of the water treatment plant and evaluate and develop practical cost-effective water quality management methods to improve raw water quality, and

3) evaluate & recommend both short-term and long-term improvements to the treatment plant to ensure compliance with both current and future water quality regulatory requirements. The focus of this presentation will primarily be on managing source water quality in Chadwick Lake.

This study identified and evaluated source water quality areas that impact the overall operation of the Town Chadwick Lake WTP and recommended management actions that could be initiated to:

1) reduce the occurrence of cyanophyte blooms (harmful algal blooms) that result in taste and odor events and potential cyanotoxin production;
2) reduce the total organic carbon (TOC) and manganese levels in the raw water delivered to the WTP, and
3) improve water quality protective and remedial measures within the Chadwick Lake watershed. In-lake management measures and evaluated included chemical treatment, aeration, intake modification/ management, biofiltration/inflow containment, dredging, and watershed treatment. The watershed treatment analysis considered total phosphorus loading and yield in major watershed catchments and strategies for reducing phosphorus loading in the watershed. In addition to watershed and in-lake management strategies, this study considered both short and long term improvements to the Chadwick Lake WTP to address water quality challenges and improve treated water quality.

This presentation will focus on the results of the engineering analysis including the evaluation of in-lake and watershed management strategies to enhance raw water quality and treatability at the Chadwick Lake WTP.

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Improving Regionalization of Bankfull Discharge and Hydraulic Geometry Regression Models Developed for the Catskill Mountains, NY

Dany Davis, Mark Vian, NYC Department of Environmental Protection; Sarah Hinshaw, Colorado State University (Graduate Student); Emily Polinsky, SUNY Ulster

Bankfull discharge is a common reference discharge representing a discrete recurring streamflow associated with maintaining channel morphology in alluvial streams and accounting for time-integrated sediment transport in most streams. The assumed average magnitude-frequency recurrence interval for bankfull discharge is 1.5 years. Estimating bankfull discharge (Qbf) and associated channel hydraulic geometry (HGbf) for a stream reach is a key component in many fluvial geomorphology investigations and applications. Regionalized regression equations expressing scalar relationships of drainage area (DA) to Qbf and HGbf are standard estimation tools in stream diagnostic assessments, channel design process, stream classification, and flow modeling. The existing Catskill Mountain bankfull regression relationships first developed between 1999 and 2003 are based on bankfull stage-discharge calibration surveys at 18 USGS stream gage study reaches. The published relationships are regionalized by stratifying study reach data by three hydrologic regions (4, 4a, and 5) delineated by USGS in 1991 for NYS flood frequency-magnitude regression relationships. They are further optimized by stratifying the data by mean annual runoff (MAR) for the gaged basin. In 2016-2017 NYCDEP's Stream Management Program (SMP) updated the regression relationships database for the Catskill Mountain region by incorporating additional field calibrated Qbf and HGbf values at 7 USGS stream gage study reaches. The increased sample size was used to test new optimization regression relationships and use of the database to inform watershed-specific regression relationships. Based on preliminary results we conclude that there is limited value in adding additional USGS gage study reaches beyond the current updated set and that the best use of the existing data is to develop watershed-specific relationships using supplemental data obtained at stable geomorphic reference reaches and opportunistic surveys following USGS gage confirmed bankfull discharge events. A case study for the West Branch Neversink River will be presented.

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Developing the Harlem River Watershed and Natural Resources Management Plan for the Bronx, NY

Katie Friedman, Sara Powell, Jamie Ong, NYC Department of Parks and Recreation

Urban areas offer unique challenges and opportunities for river restoration. By taking a watershed-scale approach to natural resource management and planning, the New York City Department of Parks & Recreation (NYC Parks) is developing a collaborative framework, initiated through community advocacy, to restore the Harlem River watershed in the Bronx, NY.

The Harlem River, a 9.3-mile tidal strait connecting the Hudson and East Rivers, was drastically altered during the

late 19th and early 20th centuries by dredging and channelization. These processes supported shipping and industrial development but degraded water quality and habitat. Over the last decade, NYC has started to transform the Bronx shoreline through rezoning, land acquisition, and construction of new waterfront parks and greenways. However, much remains to be done to restore the river and its watershed. The Harlem River Watershed and Natural Resources Management Plan for the Bronx identifies challenges and opportunities to address the following watershed restoration goals, established with community input:

1) Protect, restore, and enhance natural resources;
2) Manage stormwater through green infrastructure;
3) Promote waterfront access and connectivity; and
4) Engage and educate the public.

Restoration challenges range from hardened shorelines, buried streams, and degraded water quality to complex transportation infrastructure, lack of waterfront access, and threats to existing natural resources. Examples of restoration recommendations, resulting from a robust watershed characterization and community engagement process include:

- Interagency collaboration to expand green infrastructure,
- Incorporating living shorelines into waterfront planning, and
- Connecting the community to their shoreline via greenways and street tree corridors.

The plan also identifies priorities as a focus for future funding, provides design concepts for key projects, and builds on recommendations from previous community-based site-specific planning efforts. Funded by the New York State Department of State, the Harlem River Watershed and Natural Resources Plan will serve as a roadmap for watershed-scale restoration.

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Ultrasonic Technology for Cyanobacteria Control: A Pilot Study on Two New York City Reservoirs

Kurt Gabel, Lori Emery, NYC Department of Environmental Protection

Information presented at the 2017 AWWA Water Quality Technical Conference and discussion with other utilities led BWS to purchase algae control systems developed by Algae Control US, LLC in Charleston, South Carolina. Specifically, the Quattro-DB Algae and Biofilm Control Systems provide a multi-directional, dual bandwidth sonic head that provides radial sound output achieved with two piezo sound emitters. The device operates in two different bandwidths; a lower frequency range from 24-58 kHz for green algae and diatom control, and a higher frequency range from 195-205 kHz for control of cyanobacteria. For cyanobacteria, the device emits a frequency at the critical structure resonance, causing the gas vacuoles to collapse. Without intact gas vacuoles, the cyanobacteria lose their buoyancy and sink to the bottom where they die due to lack of photosynthesis. Since ultrasound at these frequencies does not lyse cells, the ultrasonic treatment is reported to result in lower concentrations of toxins as compared to chemical treatment.

To evaluate the effectiveness of this technology, BWS chose two locations in the East of Hudson watershed that typically exhibit blooms - the smallest of three basins in the Croton Falls Reservoir and the shallow, northeastern tip of the New Croton Reservoir. On Croton Falls, BWS established treated and control sites to study the system's effectiveness in preventing blooms from developing. For the New Croton Reservoir, BWS deployed the unit at an existing bloom site to study the system's effectiveness for eradicating a bloom. In addition to visual observations, samples were collected for the analysis of chlorophyll a, total phytoplankton, total BG algae, total phosphorus, dissolved oxygen and cyanotoxins (anatoxin-a, cylindrospermopsin, microcystin-LA, microcystin-LF, microcystin-LR microcystin-LY, microcystin-LF microcystin-RR, microcystin-YR and nodularin). This presentation will discuss the study design, the water quality results and the potential uses of this technology in the future.

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Automation of Input Data Collection and Watershed Model Execution for West of Hudson Watersheds

Jordan Gass, Rajith Mukundan, Rakesh Gelda, NYC Department of Environmental Protection; Elizabeth Nystrom, United States Geologic Survey

The New York City Department of Environmental Protection (DEP) utilizes simulation models to describe and understand hydrologic and water quality conditions in the water supply system, and to make predictions for future conditions. The Generalized Watershed Loading Function (GWLF) is a lumped parameter model that has been calibrated for all six West of Hudson watersheds to predict daily streamflow entering each reservoir from its watershed. The GWLF model is driven by meteorological time series data (*e.g.*, daily temperature and precipitation). DEP has developed a system that utilizes the PRISM climate model,

a 4- kilometer gridded dataset to provide continuous coverage of meteorological conditions throughout the watershed, along with 10-day weather forecast data available from Weather Underground, to generate the input time series for each basin. Both of these source datasets are provided as web services, making them ideal for automation of GWLF to predict streamflows as an operational input for other DEP models.

Using a series of Python scripts that are run daily, the GWLF model simulations have been automated to

a) harvest the latest input meteorology data;
b) prepare and format input datasets;
c) initiate GWLF model simulations;
d) post-process and store results; and
e) plot charts of model predictions compared with observed streamflows.

This presentation will focus on the process used to automate the model simulations and reporting, the benefits to DEP's Water Quality Modeling program, and plans for future improvements.

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Develop Climate Scenarios for Watershed and Reservoir Water Quality Models Using the Latest CMIP5 Climate Projections

Rakesh Gelda, Ph.D., Rajith Mukundan, Ph.D., Emmet M. Owens, P.E., NYC Department of Environmental Protection

Future climate projections at high spatial resolution (~4 – 6 km grid cells), generated from 20 global climate models (GCMs) and statistically downscaled, have been made available recently by the United States Geological Survey (USGS). These MACA (Multivariate Adaptive Constructed Analogs) datasets provide a number of key meteorological variables at a 1-day timestep. These and other similar climate projections have been used in numerous hydrological impact assessment studies at watershed scales. However, relatively few studies have been conducted to assess the impact of climate change on the hydrodynamics and water quality in lakes and reservoirs, primarily because models of these systems require meteorological variables, spatially downscaled to a point-scale to which such models have been calibrated and validated, at a high temporal resolution (*e.g.,* hourly). In this study, we fill this gap by utilizing high resolution MACA data, evaluating and correcting it for bias using equidistance quantile mapping, and implementing simple disaggregation models to generate point-scale hourly air and dew point temperature, wind speed and direction, and solar radiation, for use in water quality models. The approach is general and can be used to generate sub-daily time series of meteorological variables at any point location.

The proposed approach is demonstrated for six point locations within New York State, USA, four of which are within watersheds of the New York City (NYC) water supply system; the other two are nearby National Weather Service stations. Disaggregation models developed using historical observations reproduced hourly data well at all six locations. Additionally, for six sub-watersheds within the NYC watershed, MACA data are evaluated for biases in temperature and precipitation. Quantile mapping is shown to reduce biases in several evaluation measures including extreme precipitation indices.

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Cost-Effective Stormwater Best Management Practices for Regional Phosphorus Control

Zach Henderson, Joe Barbagallo, Steve Lauria, Woodard & Curran

In 2010, the East of Hudson Watershed municipalities were faced with new MS4 requirements by the New York State Department of Environmental Conservation. These new requirements included total phosphorus (TP) reduction targets for stormwater. After extensive negotiation, NYSDEC authorized the creation of a regional stormwater entity to achieve "bubble compliance" across the entire watershed.

After five-years of implementing stormwater projects, the coalition of municipalities—the East of Hudson Watershed Corporation (EOHWC)—hired Woodard & Curran to develop a retrofit plan for the next five years. As a part of this work, the project team performed a cost-benefit analysis of hundreds of projects implemented over the past several years to see which strategies were most efficient and cost-effective. The evaluation showed that the projected cost-per-pound of phosphorus removal varied significantly for several strategies. The EOHWC is using the findings from the study to modify its retrofit approach over the next five years to deliver the most cost-effective projects.
TP load reduction calculations are based on best available science and can change based on new stormwater management practice research. Often the load reduction calculations vary by state or region. In New England, EPA Region 1 has provided MS4 permittees with TP load reduction calculations based on performance curves with percent reduction of TP as a function of rainfall volume treated.

This presentation will present the results of the cost-benefit analysis to show the effectiveness of different

stormwater treatment projects for phosphorus load reduction and will compare how different calculations change estimates for load reduction costs and benefits. By sharing the lessons the coalition learned along the way, this presentation will make a case for considering regional strategies for phosphorus reduction to avoid costly investment as communities begin to plan for stormwater controls in their watersheds.

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A Water Quality Modeling Analysis to Evaluate the Response of Reservoirs to Watershed Management and Climate Variability

Theodore A. Kpodonu, Ph.D., Research Foundation, City University of New York; Emmet M. Owens, P.E., NYC Department of Environmental Protection

Reservoir dynamics and responses to anthropogenic pressures depend on the balance of external forcing factors such as climate and the quantity and quality of inflows, and internal factors such as internal nutrient loading and trophic structure. Wind, precipitation, air temperature, and solar radiation are components of the climate forcing that affect reservoir dynamics. Within a defined area, climate exerts a largely uniform, dominant control on limnological variables, except where internal factors such as internal nutrient cycling or biotic interactions are dominant and dampen the effects of inter-annual variations in climate. In this study, a 1-dimensional hydrodynamic model coupled to a biogeochemistry model (GLM-AED) was used to evaluate changes in biogeochemical fluxes as a consequence of historic climate variability in Cannonsville Reservoir. The impact of extreme events that have been captured in historical meteorological records is evaluated. Additionally, a coherence analysis was used to understand the synchronous behaviour of the Cannonsville and the Neversink reservoirs in response to regional climate. The degree to which reservoirs in a defined region have similar temporal responses to external forcing factors has been described as temporal coherence. This study answers these questions: (1) how much of the variability in reservoir water quality is attributable to climate, and (2) do Cannonsville and Neversink Reservoirs respond to varying climate in like manner?

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Turbidity and Suspended Sediment Monitoring in the Lower Esopus Creek

James Mayfield., NYC Department of Environmental Protection

In 2002 DEP undertook the Catskill Turbidity Control Study to provide a comprehensive analysis of potential engineering and structural alternatives to reduce turbidity levels in the Catskill System. Based on the results of this study and associated additional analyses, DEP made significant changes to its operations to better control turbidity in the Catskill System. One of the methods included in these changes was using the Ashokan Release Channel to release water to the lower Esopus Creek for turbidity control purposes. In October 2011 DEP began conducting releases based on an Interim Ashokan Release Protocol, which was updated in 2013. The protocol included a Water Quality Monitoring Plan with an objective to "monitor water quality in the Lower Esopus Creek (LEC) and other locations in support of analysis of the effects of the operation of the Ashokan Release Channel." When the channel is operating, the release, two sites on the lower Esopus, and two of its tributaries (Plattekill Creek and Sawkill Creek) are sampled on a weekly basis for turbidity, temperature, and total suspended solids. In addition to this monitoring program DEP funds two United States Geological Survey (USGS) streamgages on the lower Esopus, which measure streamflow and also includes monitoring turbidity and suspended sediment concentrations at these gages. Results from these monitoring efforts will be presented. Summary statistics for each site will be compiled for comparative purposes. Analyses will include an examination of turbidity and flow relationships, as well as relationships between turbidity and suspended sediment concentrations. Time series data from the various sites in the lower Esopus Creek will be compared to one another. These various analyses will be used to examine the current status of water quality in the lower Esopus Creek.

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A Tale of Two Watersheds: Assessing Sources of Organic Matter and Disinfection By-Product Precursors

Karen Moore, Ph.D., NYC Department of Environmental Protection; Wanjia Song, Fordham University

Disinfection by-products (DBPs) form when natural organic matter originating from in-reservoir and watershed sources is chlorinated. Although only a fraction of the organic matter pool forms DBPs, DEP has initiated efforts to model DBP precursors to inform water management. Beyond data on DBP formation potential (DBPfp), other proxy

measurements are needed both in the field and laboratory to characterize sources of natural organic matter. Study sites include Cannonsville and Neversink Reservoirs and their associated watersheds to represent different system characteristics. Cannonsville is the most eutrophic reservoir and Neversink is the most oligotrophic reservoir in the West of Hudson (WOH) system. The Cannonsville watershed has the most agricultural land in the WOH system, while Neversink is forest-dominated. This suggests that Cannonsville will have a greater amount of dissolved organic carbon (DOC) from in-reservoir sources, while Neversink will receive a greater proportion of its DOC from watershed sources. We employ multiple strategies to collect relevant data, including fixed-frequency sampling at reservoir and stream sites, storm event sampling at stream sites, and high frequency monitoring at reservoir buoys and stream stations using optical sensors. Analytes include temperature, conductivity, turbidity, chlorophyll and phycocyanin fluorescence, fluorescent dissolved organic matter (fDOM), absorbance at 254 nm (UV254), DOC, and DBPfp. We explore relationships that may provide surrogates for DBPfp with the ultimate goal of developing a predictive model to assist in making operational decisions to minimize the presence of DBPs in the NYC water supply.

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Probabilistic Estimation of Stream Turbidity and Application under Climate Change Scenarios

Rajith Mukundan, Ph.D., Rakesh Gelda, Ph.D., Emmet Owens; P.E., NYC Department of Environmental Protection

Streamflow-based rating curves are widely used to estimate turbidity or suspended sediment concentrations in streams. However, such estimates are often inaccurate at the event scale due to inter- and intra-event variability in sediment-flow relationships. In this study we use a quantile regression approach to derive a probabilistic distribution of turbidity predictions for Esopus Creek, a major stream in one of the watersheds that supply drinking water to New York City, using measured mean daily streamflow-turbidity data pairs for 2003 to 2016. While a single regression curve can under-predict or over-predict the actual observation, quantile regression can estimate a range of possible turbidity values for a given value of streamflow. Regression relationships for various quantiles were applied to streamflows simulated by a watershed model to predict stream turbidity under: (a) observed historical climate, and (b) future climate derived from 20 Global Climate Model (GCM) scenarios. Future scenarios using quantile regression in combination with these GCMs and a stochastic weather generator indicated an increase in the frequency and magnitude of hydrological events that may generate high stream turbidity and cause potential water quality challenges to the water supply. The methods outlined in this study can be used for a probabilistic estimation of stream turbidity for operational decisions and can be part of a vulnerability-based method to explore climate impacts on water resources.

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Watershed Protection Impacts on Cannonsville Stream and Reservoir Water Quality

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The New York City Department of Environmental Protection (NYCDEP) operates a water supply system that supplies 1.1 billion gallons of drinking water to 9 million residents of the City and surrounding areas. Approximately 90% of this supply comes from six reservoirs located west of the Hudson River; this portion of the supply receives no filtration. Over the last 25 years, NYCDEP has undertaken a watershed protection program to maintain and improve the quality of this unfiltered supply. Here we consider the application of models to evaluate the impact of major components of this watershed protection program on eutrophication-related measures of water quality in the major tributary to Cannonsville Reservoir, the reservoir water column, and diversion from the reservoir for water supply. We describe the application of the Hillslope modification to the Soil and Water Assessment Tool (SWAT-HS), a watershed hydrologic and water quality model. Predictions of streamflow quantity and quality from this model have been validated using recent observations. This model is applied to evaluate the impact of point source (wastewater treatment plant) reductions in nutrient (phosphorus and nitrogen) loads, and of nonpoint source reductions associated with improved agricultural practices in the Cannonsville watershed. The watershed model predictions are used as input to UFILS4, a one-dimensional reservoir hydrothermal and water quality model that has been validated for historical conditions in Cannonsville Reservoir. This model is used to predict the impacts on changes in the quality of inflows on the reservoir water column and on diversions from the reservoir for water supply.

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Occurrence and Growth of the Colonial Bryozoan Pectinatella Magnifica in the Kensico Reservoir Outflow Sluiceways

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In the fall of 2012, after the Catskill Delaware Ultraviolet Disinfection Facility (CDUV) went into operation, an issue arose where gelatinous masses mixed with decaying leaves became lodged in the perforated baffle plates at CDUV and began to impede flow into the plant. The gelatinous substance was identified as the ectocyst of bryozoans, predominantly from a native species called Pectinatella magnifica. This is a common species referred to as the magnificent bryozoan as it forms the largest colonies of any freshwater bryozoan. Bryozoans are a phylogenetic group of tiny, colonial, filter-feeding organisms which adhere to aquatic substrates. Some bryozoan species may proliferate to the extent they obstruct pipes, valves and interfere with the operation of critical elements of a water supply. In order to identify the extent of the colonization, overall abundance at the aqueduct intake, and to help determine optimal timing for removal, a monitoring program was developed for the sluiceways. On several occasions each growing season (May – September) from 2014 - 2017, an underwater video camera was lowered through each of the five sluiceways to record the location and growth of bryozoan colonies, especially P. magnifica. Water quality, operational flow data, and the presence of other bryozoan colonies, such as Cristatella mucedo were recorded by video and later processed into groups of still frames, to provide photographic documentation of the development and abundance of colonies.

This presentation will give an overview of each year of video monitoring, highlighting any remarkable observations such as extremely large colonies or heavily colonized areas of the sluiceways. Differences in colony size and abundance between sluiceways, and between years, will be compared and assessed with some discussion for potential causes. Environmental and operational impacts during those years which may have likely influenced colonization and growth will be summarized.

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Foamstream: A Discussion of an Alternative to Herbicides

David Quentin, Patrick Lambert, NYC Department of Environmental Protection

NYCDEP has been investigating alternatives to commonly used chemical herbicides for managing herbaceous weeds on City-owned property. Foamstream® created by WeedingTech, Ltd. is one of these alternatives. Foamstream is composed of superheated water surrounded by a proprietary foam product that insulates the water's scalding properties. Foamstream is applied under pressure via a wand directly onto the herbaceous plant, scalding the leafy structure above ground. DEP designed a study to test the efficacy of Foamstream, and its usefulness as a weed management tool. The study will be conducted from June 2018 to September 2018. The initial phase of the study will be the application of Foamstream at five upstate DEP sites during June and July, with subsequent observation of Foamstream efficacy conducted during the rest of the growing season. An inspection of the selected sites will be conducted during the spring of 2019 to look for regrowth, with the goal of making a final determination of the effectiveness of Foamstream and its potential future use by the NYCDEP. The objective is to use environmentally-friendly control measures to minimize any impacts on water resources.

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Safe Yield for Kingston's Cooper Lake

Kevin Ruswick, P.E., David M. Railsback, P.E., Gregory J. Daviero, Ph.D., P.E., Schnabel Engineering; Judith A. Hansen, City of Kingston Water Department

The City of Kingston Water Department was founded in 1895 to provide potable water to the residents of the City. The water source is the Mink Hollow stream that originates in the Catskill Mountains. The watershed is now entirely within the New York City watershed and Kingston is authorized to divert all flow from Mink Hollow except for a 0.5 MGD environmental release. Water from Mink Hollow is diverted at an intake structure and piped to Cooper Lake, which is impounded by Cooper Lake Dam located near the Ashokan Reservoir. The dam was initially constructed in the late 1800's and was raised in 1911, 1924, and 1927 to meet the growing water demands of the City.

An Engineering Assessment was performed for Cooper Lake Dam in 2012, which identified multiple deficiencies. Schnabel Engineering was retained in 2014 to develop rehabilitation plans for the dam, and a key portion of the work included an updated Safe Yield analysis. Mink Hollow is an ungaged stream, therefore the analysis evaluated 11 nearby gaged basins within the NYC Watershed. Recorded flows at each gage were scaled to the Mink Hollow watershed based on a drainage area ratio, and a hydraulic analysis of the Mink Hollow was performed to characterize the river flow versus diversion relationship. A long term water volumetric mass model was developed based on estimated inflows from each basin and compared with historically recorded lake levels in Cooper Lake. The Mill Brook gaged basin provided inflows that best correlated to

the most severe droughts of 1957 and 1961. The long period of record for this gage allowed for a comprehensive assessment of safe yield including evaluation of improvements at the Mink Hollow intake structure, raising of Cooper Lake Dam, and a risk-based assessment of lowered pool elevations during construction.

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Community Wastewater Management Program (CWMP) Past and Future Projects

Nicholas Sadler, P.E., NYC Department of Environmental Protection

This presentation will give an overview of the Community Wastewater Management Program (CWMP) and discuss DEP's role in it. The 1997 Watershed Memorandum of Agreement (MOA) identified 22 watershed communities in need of wastewater solutions. The New Infrastructure Program (NIP) administered through the New York State Environmental Facilities Corporation (NYSEFC) was established to address the needs of communities 1-7 (Hunter, Fleischmanns, Windham, Andes, Roxbury, Phonecia and Prattsville). Six of the seven communities participated in the NIP and their wastewater needs were addressed through wastewater treatment plants (WWTP). The CWMP is a continuation of the NIP and is administered by the Catskill Watershed Corporation (CWC) to address the needs of the remaining 15 communities. Projects have included septic maintenance districts (SMD), community septic systems (CSS), WWTP's and connections to existing WWTP's. The CWMP has completed projects in ten of the communities to date totaling $55,000,000. Designs are currently being developed to address the needs of the remaining five communities

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Public Health Surveillance for Detecting Drinking Water Contamination: How does NYC's WDRA Program Compare Nationally?

Anne Seeley, NYC Department of Environmental Protection; Jonathan Yoder, Centers for Disease Control and Prevention

The monitoring of various public health indicators can serve a number of important functions – for medical care providers, public health officials, municipal managers, emergency managers, and policy makers. Public health surveillance as a tool for helping assess the ongoing safety of public drinking water supplies is one function that has gained traction in recent years. New York City implemented public health surveillance for water supply assessment purposes beginning in 1993, via a partnership program between the City's water utility (DEP) and the City's Department of Health and Mental Hygiene (DOHMH). NYC's program is known as the Waterborne Disease Risk Assessment Program (WDRAP) and in the years since 1993, the program has evolved significantly. In 2018, NYC conducted a literature search and a survey of selected U.S. cities to learn what public health monitoring programs are currently in place around the country relevant to assuring the safety of drinking water supplies, and to determine whether any new or modified program elements should be considered to further enhance NYC's WDRAP surveillance programs. This presentation will provide: an introduction to public health surveillance for water supply microbial contaminant assessment, an overview of the NYC program (describing disease surveillance and four different syndromic surveillance program components), and a summary of findings from the literature search and survey. A general qualitative comparison will be made of NYC's system to systems in place elsewhere, and "lessons learned" will be discussed.

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Evaluating Suspended-Sediment Dynamics and Turbidity in the Upper Esopus Creek Watershed: A Comprehensive Study

Jason Siemion, Michael R. McHale, Matthew Cashman, US Geological Survey; Dany Davis, NYC Department of Environmental Protection

The Ashokan Reservoir provides up to 40% of New York City's drinking water supply as part of the West-of-Hudson (WOH) water supply system. The NYC Department of Environmental Protection (NYCDEP) currently operates the WOH water supply system under a recurring Filtration Avoidance Determination (FAD) issued by the NYS Department of Health. The Esopus and Schoharie Creek watersheds are the source waters for the Ashokan Reservoir, both of which have elevated concentrations of suspended-sediment and turbidity values during large storms. High turbidity events can limit the use of Ashokan Reservoir water. Current FAD requirements include studying turbidity watershed source conditions and funding and evaluating the effectiveness of stream sediment and turbidity reduction projects (STRPs) in the Ashokan watershed. NYCDEP and

US Geological Survey are in the first phase of a 10-year study of the suspended-sediment source dynamics and associated turbidity in the Upper Esopus Creek watershed. The study includes extensive discharge, suspended-sediment and turbidity monitoring, spanning stream reach to reservoir watershed scales. In the Stony Clove watershed, repeated mapping of stream channel geologic and geomorphic sediment sources, bank erosion monitoring, and sediment source fingerprinting (SSF) are used to correlate watershed sediment dynamics to measured suspended-sediment and turbidty values. The highest turbidity values occur where fine-grained lacustrine material is in contact with the stream. Sediment source fingerprinting is used to identify the geologic sources (lacustrine, till, alluvium, or colluvium) of suspended-sediment within the Stony Clove basin. The SSF and reach scale mapping and monitoring results will help guide the selection of locations for future STRPs. Preliminary results indicate that (1) Stony Clove and Woodland Creeks are currently the largest sources of suspended-sediment and turbidity in the upper Esopus Creek watershed, and (2) STRPs have reduced suspended-sediment yield and turbidity in the upper Esopus watershed – for the streamflows and time periods monitored.

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Development of a NYC Stream Protection and Management Framework

Rebecca Swadek, Marit Larson, Emily Stephan, NYC Department of Parks and Recreation

Less than 20% of historic streams that once existed in New York City remain, and those left experience adverse effects of urbanization. As development continues and climate change leads to more intense rainfall events, stormwater will increasingly impact the quality and stability of streams. NYC Parks manages about half of the City's remaining wetlands and streams. A framework for managing these resources is crucial in guiding decisions in the face of increasing stressors.

In assessing appropriate management strategies for urban streams, it is critical to evaluate current conditions, causes of degradation, opportunities for restoration, and potential future impacts, particularly from stormwater runoff. To do this, we conducted a rapid assessment of stream conditions, at 176 reaches, in over 20 catchments, focused on channel, biotic, riparian buffer, infrastructure and watershed attributes at both the field and landscape scale. We selected metrics from these assessments that could serve as indices (or scores) of relative stream reach condition and relative potential threat.

A streams' relative condition and impact score compared to the range of scores for streams across the city provides a basis for setting management priorities at both the individual reach and watershed scale. For example, protection is required for streams that are in good condition with few threats. Protection actions may include expanding riparian buffers or preventing any increase in upstream impervious area. Streams that are highly threatened and in poor condition may require management strategies such as channel reconstruction to re-establish a floodplain connection, tracking of illicit discharges, or installation of green infrastructure to reduce and treat stormwater runoff. The categorization of streams throughout NYC allows for grouping management strategies, and targeting efforts to maintain or attain the best possible stream conditions considering our highly urbanized landscape.

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Cyanotoxin Monitoring in the New York City Water Supply

Richard Van Dreason, Lori Emery, NYC Department of Environmental Protection

The New York City water supply consists of nineteen reservoirs and three controlled lakes located in New York's' Catskill Mountains and in Putnam and Westchester counties east of the Hudson River.

In 2015, EPA issued 10-Day Drinking Water Health Advisories (HAs) for microcystins (0.3 µg/L for <6 years old; 1.6 µg/L for 6 years and older) and cylindrospermopsin (0.7 µg/L for <6 years old; 3.0 µg/L for 6 years and older. In July 2015, the New York City Department of Environmental Protection (NYCDEP) initiated a monitoring program to determine the occurrence of cyanotoxins: anatoxin-a, cylindrospermopsin, nodularin and 6 variants of microcystin in the water supply. Samples were collected on reservoirs and at critical reservoir outflows (i.e., keypoints) based on the sum of counts from 10 cyanobacteria genera known to produce cyanotoxins. Additional monthly baseline samples were collected from keypoints in 2017. Visible surface blooms were sampled as well and reported to the New York State Department of Environmental Conservation (NYSDEC) via the agency's Harmful Algae Bloom website: HABsInfo@dec.ny.gov. To date no cyanotoxins have been detected at keypoint locations while microcystins and anatoxin-a have been found in mostly localized areas in several reservoirs. In this presentation, we will provide more details of the monitoring plan; discuss cyanotoxin results through 2017 as well as plans to improve our monitoring capabilities.

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Establishing a Water Quality Baseline Prior to a Large-Scale Construction Project Near Belleayre Mountain

David Van Valkenburg, NYC Department of Environmental Protection

The New York City Department of Environmental Protection (DEP) evaluates proposed development within reservoir watersheds, which supply drinking water to more than 9 million consumers, to minimize potential impacts to water quality. In 2000, DEP established a sampling program near Belleayre Mountain to determine preconstruction water quality conditions and this monitoring continued through 2011. Headwater stream sampling locations were chosen to evaluate multiple points draining the proposed project area as well as a stream expected to not be impacted for the duration of the project. At these locations, routine and storm event monitoring occurred and the water quality data established baseline conditions for comparison with any future construction and post-construction water quality monitoring results. Monitored constituents for these locations included nutrients, coliform, physical parameters, anions, and cations. The goal of such assessments is to be able to determine if quantifiable changes have occurred in the streams draining the project area and whether or not such changes are part of a regional shift.

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Strategies to Address the Regulatory Overlap of UCMR4 and EPA's Cyanotoxin Health Advisory

Ben Wright, P.E., Tina Nelson, Hazen and Sawyer; Mike Usai, Meredith Taylor, NYC Department of Environmental Protection

Hydrilla verticillata (hydrilla) is a federally listed aquatic invasive species that has the potential to cause significant economic and environmental impacts once established. Introduced decades ago in Florida and the Mid-Atlantic states, hydrilla has continued to spread through much of the US. Hydrilla is a high priority risk for reservoir systems as it can impact water quality, aquatic habitat, and recreational uses. Control of hydrilla is expensive, but without management, Hydrilla can take over and can make lakes nearly unusable. As with other aquatic invasive species, once a population is established, management alternatives consist of chemical, biological, physical, or mechanical/manual methods. However, hydrilla's ability to reproduce from plant fragments, turions and tubers, has made chemical management with herbicides one of the most common methods of control.

For a utility or water manager to decide to add chemicals to a source of drinking water, they must be assured that those chemicals are not going to cause harm to the general public. As hydrilla continues to spread, it will inevitably affect more sources of drinking water. Therefore, the Water Research Foundation, in partnership with the New York City Department of Environmental Protection (DEP), funded this project to:

- assess the state of knowledge of herbicide application for the management of hydrilla in drinking water reservoirs and its impacts on treatability, water quality, and human and environmental health;
- review lessons-learned from prior hydrilla management efforts;
- provide recommendations for mitigation of impacts associated with hydrilla management; and
- sevelop communications resources for public outreach.

This presentation will provide an overview of the project findings, which will help the audience obtain a better understanding of the potential risks from hydrilla and communicate those risks to stakeholders, so utilities can respond quickly and effectively to hydrilla infestations.

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A Multivariate, Stochastic Approach to Generating Daily Precipitation Series at Ungauged Locations in Catskill Mountain Region

Chris Yeo, Ph.D., Rakesh K. Gelda, Ph.D., NYC Department of Environmental Protection; Allan Frei, Hunter College

Information on the variability of precipitation in time and space is critical for a large number of water resources projects. However, in most practical applications, precipitation records at the location of interest are often either limited or unavailable due to the lack of adequate network of rainfall measurements. To address this need, regionalization methods have been frequently employed to understand the spatial behavior of precipitation and to transfer precipitation information from one location to the other where records are scarce. However, most conventional regionalization approaches are based on precipitation amounts or extreme rainfalls but do not include information on spatial variation in precipitation occurrence (wet/dry-day). This study proposes a stochastic weather generator for

estimation of missing daily precipitation time series data in mountainous regions based on a novel, multivariate regionalization method that uses both precipitation amount and occurrence. This approach includes two steps: (i) the combination of Principal Component Analysis (PCA) and Ordinal Factor Analysis (OFA) is implemented for identifying regions of homogeneous precipitation, and (ii) the implementation of a stochastic model for constructing daily precipitation events at ungauged locations. The method is calibrated and validated using rain-gauge stations in Catskill Mountains region, which typically produces 90% of the drinking water for the New York City Water Supply System (NYCWSS).

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