COMPENDIUM OF ABSTRACTS

Water Quality Issues in the NYC Watershed and Beyond

NYC Watershed Science Technical Conference & Exhibition

NYWEA
LEADING THE WAY IN WATER QUALITY MANAGEMENT

September 13, 2017

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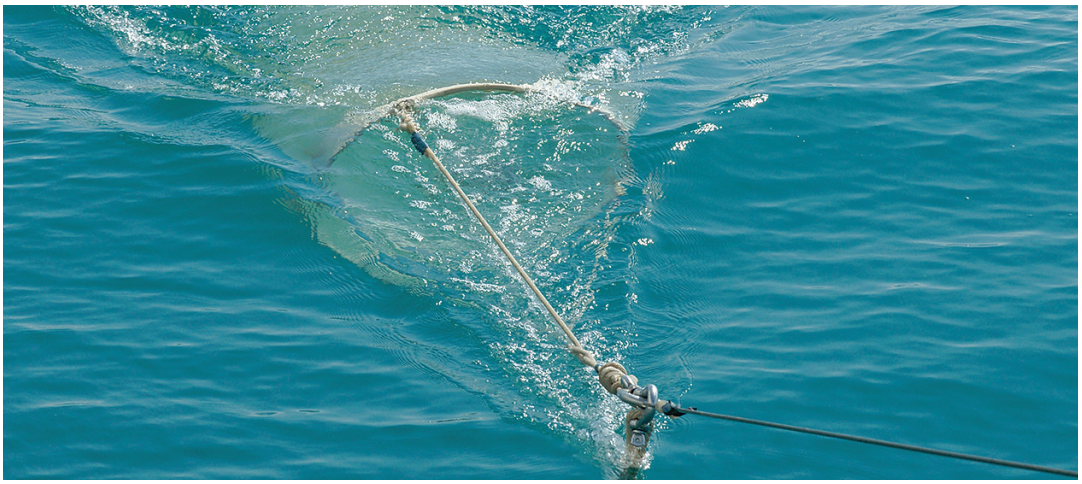

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INTRODUCTION AND ACKNOWLEDGMENTS

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 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
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

Application of Microbial Source Tracking Using Bacteroides spp. in a Watershed Stream: The N5 Case Study, Part II

Kerri Alderisio, Kurt Gabel, David M. Alderisio, NYC Department of Environmental Protection

Previously, data were presented indicating the initial results of Microbial Source Tracking (MST) from two streams in the New York City Watershed. Since 2015, additional data have been gathered to help identify the source of fecal indicator bacteria. The New York City Department of Environmental Protection (NYC DEP) routinely monitors the water quality of streams, reservoirs and aqueducts in the watershed for indicator organisms. Fecal coliform bacteria in particular are used as indicators of fecal pollution, and by association, indicate the potential presence of more resilient microbes. Ultimately, with the mission of providing drinking water of the highest quality, it is a goal of the NYC DEP to identify the source of these organisms and implement, where practical, management practices that will eliminate the source. The application of MST is a way to help identify sources of microbes, and there are many approaches and techniques available. Most recently, NYC DEP has used the analysis of Bacteroidales through the use of quantitative Polymerase Chain Reaction (qPCR) to assist in the identification of microbial sources. This MST testing led to the repeated identification of molecular markers that are normally associated with humans rather than animals, which is extremely rare in the watershed. Through collaboration with Water Quality and Watershed Protection Programs staff, numerous samples were collected for fecal coliform analysis, a sanitary survey walk through of the area was performed - which included house-to-house surveys to determine which houses were on septic or sewer - and a helicopter survey was performed. This presentation will review the follow up monitoring conducted since last year and discuss the MST results as they pertain to identifying the source(s) of the molecular markers.

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Feasibility of Remote Sensing for Comprehensive Assessment of Trophic Status of Lakes: Case Study in New York

Kirk Barrett, Ph.D., James Curra, Manhattan College

This project assessed the feasibility of using remote sensing for continual, routine assessment of tropic status of lakes. New York, and other states, devotes great effort to assess the quality of its freshwater lakes, with trophic status as a primary indicator of water quality. The costs of conventional water sampling and analysis are too large to permit comprehensive spatial and temporal assessment. Instead, lake water quality is typically measured at only one or a few points and at only a few to several times per year. Many lakes are not measured at all. Remote-sensing (RS) methods enable comprehensive monitoring because of their frequent collection, low cost, large spatial extent, and detailed spatial resolution. Satellite-based sensors, such as Landsat Thematic Mapper (TM) sensors, detect different bands of light wavelengths reflected by lakes. Previous work has verified that reflectances can be well correlated to ground-based trophic indicators, but these methods are not widely applied. This project applied a published equation to correlate Landsat data and ground-level Secchi disk depth in 35 lakes in NY of varying trophic states. We assessed whether a single set of coefficients for each lake would be useful in predicting Secchi disk depth. Correlation between spectral data and the ground measurements via the published equation was poor for most lakes, with 75 percent giving R^2 values of less than 0.28. Neither physiographic region nor trophic status affected the success of the equation. Based on the methods and scope of this study, using remote sensing for accurate, routine, continuing assessment of trophic status appears infeasible with current methods.

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Per- and Poly-Fluoroalkyl Substances (PFAS): An Overview

Elizabeth Denly, Michael Eberle, TRC

There has been considerable coverage lately of the detection of several “emerging contaminants” in groundwater and public water supplies. States are setting standards and criteria for several per- and poly-fluorinated alkyl substances (PFAS) that have shown up in the environment and water supplies. New York’s Department of Environmental Conservation finalized a rule in March 2017, adding to the state’s list of hazardous substances at 6 NYCRR section 597.3 perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), in both the acid and salt forms.

PFAS are a diverse group of man-made chemicals that are resistant to heat, water, and oil. The most prominent PFAS include PFOS and PFOA. An increasing number of studies indicate PFAS are widespread globally. Their persistence and ability to transport are becoming an increasing area of concern. Resistance to natural attenuation processes in groundwater is a cause for concern for long-distance migration in plumes. Because of this, demand for PFAS testing and analysis has increased. PFAS are also ubiquitous, which presents both a sampling challenge and an important consideration in source attribution by regulators.

This presentation is designed to provide an overview on the many issues associated with PFAS including the following: history and sources of PFAS; regulatory status and future implications; the unique chemistry of PFAS, including precursors, the basic definitions and physical/chemical properties; exposure, health effects, and toxicity; and sampling and analytical challenges, limitations, and options.

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Fingerprint Evaluation of PFAS Source, Identification of Surface Partitioning, and Associated Remedial Implications

Michael Eberle, Elizabeth Denly, Kenneth Quinn,TRC

Per- and Poly-fluorinated Alkyl Substances (PFAS) are strategic chemicals that have been used extensively in a variety of products due to unique physicochemical properties including use in Aqueous Film-Forming Foams (AFFFs), oil and water repellant clothing, furniture, and rugs, and numerous industrial applications. The subject site involves PFAS impact to a drinking water supply reservoir in the northeast United States. Based on reported AFFF usage in the Site vicinity and known releases, five areas were identified as potential sources to the reservoir. Some of the suspected sources included a local airport and a military installation. After confirming the presence of residual PFAS mass in four of the five areas, characteristic PFAS fingerprints were generated for each area and the patterns were used to clearly identify the source of PFAS impacts to the reservoir. During the forensic evaluation, the specific source areas and discharge pathways were identified for the airport sources. During the forensic investigation a new and unanticipated property of low concentration PFAS solutions was identified. The forensic evaluation results also provided sufficient source characterization information to complete the preliminary design of remedial measures.

A key observation made during forensic environmental sampling activities involves identification that due to the tensioactive properties of PFAS, the compounds appear to partition from very dilute concentrations dispersed in stagnant or still water bodies into a thin layer on the surface of the water. This partitioning property which can be described as an invisible sheen, can bias surface water sampling results with extremely high concentrations present in the surface layer that may not be representative of a majority of the water body. Development of potential remedial strategies are being formulated to attempt to take advantage of the partitioning that may occur under similar water body circumstances.

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Water Quality Protection and the Flood Hazard Mitigation Efforts in the NYC West of Hudson Watershed

Phillip Eskeli, NYC Department of Environmental Protection

The focus of flood hazard mitigation by the Federal government is the reduction of recurrent flood damages, protection of lives and the increased resiliency of flood communities. While federal efforts to expand the benefit cost analysis to account for unvalued benefits such as environmental protection have increase in recent years, water quality benefits are not considered when accounting for flood hazard mitigation project benefits. The NYC funded flood hazard mitigation program is documenting the anticipated water quality benefits of mitigation actions through the Local Flood Analysis process. Flood hazard mitigation projects will be evaluated for their water quality benefits resulting in a better understanding of the city's investment in water quality protection. The presentation, by Phil Eskeli, Certified Floodplain Manager and coordinator for DEP's flood hazard mitigation programs, will describe the nature of flood related water quality threats from a landscape perspective and the extent to which a variety of mitigation actions may address these threats using examples from communities involved in the program.

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Development and Testing of a Turbidity Model for Neversink Reservoir

Rakesh Gelda, Ph.D., NYC Department of Environmental Protection

Neversink Reservoir is one of New York City's (NYC) 19 water supply reservoirs, located approximately 80 miles northwest of the city. The reservoir has available capacity of 35 billion gallons and supplies 110 million gallons per day on average (1987-2015), or about 10 percent of the average daily consumption, to NYC consumers.

The primary tributary of the reservoir, Neversink River, is gauged at Claryville, NY, capturing runoff from 74 percent of the mostly forested watershed. Outflow from the reservoir occurs via an aqueduct (Neversink Tunnel) that discharges into Rondout Reservoir, through release works located in the Dam, and over the spillway. Water withdrawn from Rondout Reservoir enters an aqueduct for conveyance to a further downstream reservoir where it mixes with water from other parts of the system in Kensico Reservoir before disinfection and supply to NYC, without filtration.

An important water quality parameter of concern for the City's water supply is turbidity. Turbidity in Neversink Reservoir is less than 5 NTU 92 percent of the time (1987-2014), however, higher turbidities have been observed during extreme runoff events, exceeding 20 NTU 1 percent of the time. Mathematical models of turbidity are desired for such situations to predict transport and fate of turbidity-causing particles and to guide reservoir operations.

Here we adopt a two-dimensional, multi particle size class, dynamic turbidity model for this reservoir based on the transport framework of CE-QUAL-W2. The same approach for developing, testing, and applying turbidity models for other NYC reservoirs had been successfully used in earlier turbidity modeling studies. Model calibration is performed using data from 2015, and validation using data from 2013-2014. Extended validation of the model is performed for 1987-2012 interval (26 year). The model performed satisfactorily in simulating turbidity in the reservoir and in the withdrawal. The model may be integrated into NYC DEP's Operations Support Tool (OST) in the future.

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Ontario's Drinking Water Source Protection Program: A Decade of Learning and Success

Chitra Gowda, Conservation Ontario

The Clean Water Act, 2006 is part of the multi-barrier approach of the Government of Ontario to ensure clean, safe and sustainable drinking water for Ontarians, by protecting sources of drinking water including our lakes, rivers and well water. Under this legislation, the drinking water source protection program was established with funding from the Government of Ontario. This resulted in the development of science-based assessment reports and local source protection plans by multi-stakeholder source protection committees, who are supported by Ontario's 36 conservation authorities, the Severn Sound Environmental Association and the Municipality of Northern Bruce Peninsula. Conservation authorities operate on a watershed basis, bringing together stakeholders across various political boundaries to contribute to the health of rivers, lakes, and groundwater, thus supporting public health. Implementation of the 22 source protection plans is well underway across the province of Ontario, by various implementing bodies including municipalities, provincial ministries and conservation authorities. Some of the highlights of Ontario's program protecting the quality and quantity of sources of municipal drinking water are: collaborative approach involving multiple stakeholders, risk management plans containing measures to mitigate risks to municipal drinking water sources, municipal official plan updates and new land use planning policies, new standard operating procedures for the review and approval of permits and approvals by provincial ministries, installation of road signs that identify drinking water protection zones across Ontario, mandatory maintenance inspections of septic systems in certain areas, road salt management, and addressing activities on the landscape that could contribute to water quality issues such as nitrate in municipal wells and surface water intakes. Join opening panel speaker Chitra Gowda of Conservation Ontario to walk through over a decade of successes and challenges of one of Canada's flagship programs supporting public health in Ontario.

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Upscaling the Application of SWAT-HS to Simulate Hydrology for the Cannonsville Watershed, New York

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SWAT-Hillslope (SWAT-HS) is a modified version of the Soil and Water Assessment Tool (SWAT) watershed model developed to improve predictions of saturation-excess runoff and is suitable for humid vegetated areas like the New York City watersheds where this type of runoff is dominant. Initial testing of SWAT-HS at Town Brook, a 37 km2 headwater watershed draining to Cannonsville Reservoir used a single sub-basin model setup and showed good agreement between simulated and modeled streamflow with Nash-Sutcliffe Efficiencies (NSE) of 0.68 and 0.87 at the daily and monthly time steps respectively. More importantly, it predicted the spatial distribution of saturated areas accurately. Based on good model performance in the Town Brook watershed, we scaled up the application of SWAT-HS to the 1160 km2 Cannonsville watershed utilizing a setup of multiple sub-basins. The model performance on flow simulation was evaluated at seven gauging stations distributed across the watershed. Results show that SWAT-HS can make good predictions of daily streamflow at the calibrated station with NSE values of 0.85

and 0.79 during the calibration and validation periods, respectively. Daily streamflow predictions at the other six stream gages also yielded NSE values ranging from 0.56 to 0.82 for the calibration period which corresponds with satisfactory to very good model performance. Lateral flow that transports water from upland areas to near-stream saturated areas is the most significant flow component while saturation-excess runoff only occurs at high rainfall events. Building on the good performance of the hydrology model, the SWAT-HS model will be used to predict water quality in the Cannonsville watershed, and in the evaluation of watershed protection programs.

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Advancements in Phytoplankton Methodologies at NYCDEP

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Phytoplankton species composition and biomass are important to management of water supplies because of their potential impact on taste and odor, chlorine demand, disinfection by-product formation potential, and in rare instances, toxin production. Since the DEP limnology program began in the late 1980s, we have tracked phytoplankton species and relative density using a sand-filtration and Sedgwick-Rafter method, originally designed to determine when sand filters might clog. This laboratory method reports algal presence in areal standard units (ASU) and only includes large cells or colonial forms. More recently, we have begun to apply the Utermöhl technique, which includes all cell sizes and species, examines a larger portion of the sample that the other method, and estimates biomass. It offers the benefit of added information on species composition and biomass, but the analysis is time consuming. Improvements in efficiency may be possible by combining automated biomass calculations and imaging techniques. In the field, DEP has employed high frequency measurements by optical sensors for chlorophyll and phycocyanin on water quality monitoring buoys. The buoys have demonstrated the localized nature of phytoplankton distribution. Utermöhl enumeration of such localized populations will give us better information on species composition, concentrations, and conditions in which they thrive. It will allow us to develop the relationships necessary to interpret the optical sensor signals and promote the use of these signals for modeling phytoplankton growth and their role in disinfection by-product formation potential under various conditions.

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Making Sense of Optical Water Quality Sensor Data: Correcting for Interferences

Emily Kinne, Paul Brown, Ph.D., Karen Moore, NYC Department of Environmental Protection; Bruce R. Hargreaves, Lehigh University

Advances in optical sensor technology have made high-frequency monitoring of dissolved organic matter and other water quality constituents possible. NYCDEP is using submersible fluorometers on reservoir and stream sites to characterize dissolved organic matter and reservoir algae. Among the challenges of monitoring water quality with optical sensors in unfiltered water is accounting for interferences from suspended particulate matter. Suspended particles can both scatter and attenuate light transmission and consequently increase or reduce the sensor signal. Instrument response also depends on the make and model of the sensor. To address this issue for equipment deployed in NYC reservoirs and streams, some simple performance tests were run to evaluate interferences and linearity of the latest models of YSI fluorescent dissolved organic matter (fDOM) and total algae (chlorophyll and blue-green algae) sensors. This was a first step to assess the importance of correcting for interference in the fluorescence signal using turbidity of a non-fluorescent suspension of bentonite clay and a live algal culture of Nannochloropsis as surrogate measures of suspended particulate matter. Our presentation will focus on some simple steps to evaluate sensor performance and our approach to correct for interferences that affect data interpretation.

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Traditional Source Water Protection Enhanced by Water Conservation (WaterSense) and Improvements in Water-System Resiliency

Andrew Kricun, Camden County Municipal Utilities Authority

The Camden County Municipal Utilities Authority is responsible for treating the wastewater generated by the 500,000 residents and businesses of Camden County, NJ. During storm events, the additional stormwater entering the system from the combined sewer systems from some county municipalities exceeds plant treatment capacity and results in street flooding and overflows in its host community, Camden City. In addressing these problems, CCMUA has looked toward ways of increasing treatment effectiveness and efficiency, and also recognized its responsibility to Camden to improve the quality of life in the city. Green infrastructure is part of the Camden SMART Initiative and is something CCMUA is implementing aggressively. Engaging numerous stakeholders and community partners, collaborative efforts have produced a number of green infrastructure approaches to manage stormwater, including rain gardens, park creation, a rain barrel program, and depaving. With operating efficiency in mind, CCMUA has a net-zero energy goal for 2020 to reduce its carbon footprint and increase its climate resiliency. Besides promoting an energy-conserving culture in operations, the treatment facility takes advantage of its solar panels array to power 10% of the plant. Other technologies being implemented include combined heat and power derived from process sludge.

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Correlation of Traditional Water Quality Parameters with Metal Concentrations in Permeable Pavement Infiltrate

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EPA constructed a 4,000-m2 parking lot for research and demonstration of three permeable pavements [permeable interlocking concrete pavers (PICP), pervious concrete (PC), and porous asphalt (PA)] at the Edison Environmental Center in Edison, NJ in 2009. Infiltrate samples from each permeable pavement were analyzed for 22 metals along with traditional water quality parameters [pH, chloride (Cl), total organic carbon (TOC), and suspended solid concentration (SSC)] from January 2010 to October 2015. Regression models were calculated to determine whether metal concentrations in permeable pavement infiltrate were associated with water quality parameters.

Most metal concentrations in the permeable pavement infiltrate had limited or no association with water quality parameters. However, some of metals did associate with specific parameters: Al and Mg concentrations (dissolved) showed relatively strong association with pH. Dissolved Ba, Ca, Cr, K, and Sr concentrations in all three permeable pavement infiltrates, and Mg concentrations in PICP infiltrate were moderately associated with Cl concentrations, whereas Na concentrations (dissolved) in all permeable pavement infiltrate were strongly associated with Cl concentrations. The association between dissolved metal and Cl concentrations was weaker for PC infiltrates than PICP or PA infiltrates. Ba, Cr and K were not detected in deicing salts applied in this research. Total concentrations of Cr, Cu, K and V in PA infiltrates, and of Cr, Si and V in PC infiltrates showed moderate association with TOC concentrations. Al and Fe concentrations (total) in surface runoff had strong association with SSC while Al, Cu, Fe, Mg, Mn, Si in PICP infiltrates, and Al, Ca, Sr in PA infiltrates had moderate association with SSC.

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Using Reference Wetlands to Improve the Outcome of Wetland Establishment and Restoration Projects

Laurie Machung, Frank Parisio, Maria Tupper-Goebel, NYC Department of Environmental Protection

Among many applications, reference wetlands provide information to support science-based decision making in the design and evaluation of wetland construction projects. For over a decade, DEP has monitored the vegetation, soils, and water levels from 20 reference wetlands comprising 117 acres throughout the Catskill and Delaware Watersheds. Data collected from these reference sites were analyzed to describe the range of conditions in hardwood, hemlock hardwood, scrub-shrub, and emergent wetland types included in the monitoring program. Frequency and abundance of 214 native wetland plant species across 129 plots were characterized by wetland type. Soil organic matter, nutrient, and pH levels were summarized for 50 soil samples, and descriptors of the depth and duration of wetland saturation or inundation were provided from approximately 15,000 growing season measurements recorded at 35 wells. This information has guided DEP's design, construction, adaptive management, and assessment of wetland construction projects. These data have provided a benchmark for evaluating and revising topsoil specifications, and have guided the selection of topsoil for

individual projects. Reference vegetation data guides the development of planting plans, while water table data provides insight on designing hydrologic regimes to support specific habitats. Reference data can also be used to establish and evaluate performance standards for wetland establishment and restoration projects. Long-term wetland monitoring has provided a valuable benchmark of the conditions of wetlands in the New York City Watershed to improve the outcomes of wetland establishment and restoration efforts.

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20 Years of On-Site Wastewater Treatment Programs in the NYC Watershed – Lessons Learned and Status Update

Michael Meyer, NYC Department of Environmental Protection

For more than 20 years, DEP has worked cooperatively with a number of watershed partners including Catskill Watershed Corporation, NYS Environmental Facilities Corporation, counties, municipalities, and private entities to develop and implement a number of programs that reduce the potential water quality impacts associated with improperly treated wastewater in the upstate water supply watershed. Collectively, these programs have resulted in nearly 9,000 on-site wastewater treatment systems (OWTS) that have either been repaired, rehabilitated, or connected to a centralized wastewater treatment system.

Ultimately, these programs improve the quality of the drinking water supplies within the NYC Water Supply System and are a critical component to DEP's Long-term Watershed Protection Strategy. The repair or conversion of these OWTSs is equivalent to millions of gallons of wastewater flow per day that is now properly treated before discharge into the water supply watershed. Since the 1997 Watershed MOA, the overall contribution by DEP to implement the extensive OWTS rehabilitation or conversion programs is approximately $300,000,000.

The presentation will provide an overview of the various DEP-funded programs that have been implemented to reduce the potential water quality impacts associated with improperly treated wastewater. The DEP-funded programs that have been implemented to reduce the impacts from OWTSs include septic repairs, new sewage collection systems, and new or expanded wastewater treatment systems. The presentation will conclude with a discussion on the cost-effectiveness of the various protection programs that DEP has implemented.

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Long-term Water Quality Evaluation for NYC Reservoir Inflows

Karen Moore, Ph.D., Jim Mayfield, NYC Department of Environmental Protection

Significant effort and resources have been invested in watershed protection for the NYC Water Supply watersheds over the past two and a half decades. We use data from NYC's long-term water quality monitoring program to evaluate the effectiveness of these watershed protection programs. We offer a supplemental approach to the periodic assessments of water quality based on a statistical model developed by United States Geological Survey scientists. We applied the "Weighted Regressions on Discharge, Time, and Season" (WRTDS) approach (Hirsch and De Cicco, 2015) to understand the changes observed in nutrient inputs to the main river inflows to New York City's upstate water supply reservoirs. The statistical model can produce a history of annual concentrations and loads along with a flow-normalized version of the history that minimizes variations due to river flow. Along with constructing the histories of concentrations and fluxes for nitrogen, phosphorus, carbon, and suspended sediment, we tested the sensitivity of the method for different sampling frequencies to assess the importance of storm event sampling.

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A Framework for "Bottom-Up" Based Climate Change Impact Assessment for NYC Watersheds

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

The New York City water supply is currently the largest unfiltered drinking water utility in the United States serving over 9 million consumers. Historically about 90 percent of this water is delivered from the Catskill/Delaware System West of Hudson (WOH) watersheds. Recent studies have reported increasing trends in total precipitation, and in the frequency and magnitude of extreme precipitation events in WOH watersheds. The Northeast in general has experienced the greatest increase in extreme precipitation in recent years than any other region in the United States. The potential effects of these trends may pose challenges for both water quality (such as increased sediment and nutrient loading, and formation of disinfection byproducts) and quantity (such as reservoir storage and management).

The NYC DEP Climate Change Integrated Modeling Project (CCIMP) is exploring climate impacts on water resources by evaluating the effects of future climate change on the quantity and quality of water in the NYC water supply, and to evaluate how such effects could influence the use and operation of the water supply. Phase I of CCIMP followed a "top down" approach with the goal of making an initial estimate of climate change impacts using available General Circulation Model (GCM) output and DEP's available suite of watershed, reservoir, and system operation models. The general findings of Phase I included a projected shift in the timing of spring snowmelt from a distinct peak in late March and April to a more consistent distribution throughout the winter and autumn.

The ongoing Phase II of CCIMP is using "bottom up" or vulnerability based methods to explore climate impacts on water resources with a focus on extreme hydrologic events. Stochastic weather generators (SWGs) are an integral component of the bottom up approach. A framework for bottom up based climate change impact analysis incorporating SWGs will be presented.

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A Model of the Internal Seiche in Schoharie Reservoir

Emmet Owens, NYC Department of Environmental Protection

Internal waves, or internal seiches, are common in stratified lakes and reservoirs. While sudden changes in inflow such as a runoff event, or abrupt changes in outflow can induce internal waves, the most common driving force is wind stress on the water surface. The vertical movement of water layers associated with internal waves can contribute to significant fluctuations in temperature and water quality observed at a fixed location. In the water column of Schoharie Reservoir, episodes of elevated turbidity are associated with runoff events. During such episodes, the turbidity of water diverted through the intake structure may exhibit significant fluctuations that are believed to be associated with internal wave motion. The temperature of releases from the reservoir may fluctuate in a similar manner. Understanding the causes of seiche-induced turbidity and temperature fluctuations, and the impact of drawdown and stratification on these, is an important step leading to the development of strategies to minimize their impact on water supply. This study describes a model for the internal seiche in a thermally-stratified reservoir. This model uses the same description of reservoir bathymetry used in CE-QUAL-W2, the two-dimensional model that is the water quality component of NYCDEP's Operations Support Tool (OST). The model considers the effects of reservoir drawdown and thermal stratification on characteristics of the internal seiche: the period of oscillation, and the pattern of the vertical displacement of

water along the length of the reservoir. The variation of these internal seiche characteristics using the history of reservoir drawdown and stratification from recent years is evaluated. In addition, the amplitude of internal waves in Schoharie Reservoir can be estimated from an observed time series of turbidity in the diversion. This analysis provides confirmation that the internal seiche is the source of the observed fluctuations in turbidity.

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Time Scale Evaluation for the Detection of Trends in Protozoan Occurrence within the New York City Watershed

Christian Pace, Kerri A. Alderisio, NYC Department of Environmental Protection

New York City Department of Environmental Protection (DEP) has monitored watershed streams and reservoirs for protozoans since 1992. Monitoring continues at 24 sites with a period of record greater than 10 years. With more than 7,000 samples from those sites, DEP has an impressively large protozoan dataset. Aside from ensuring the microbial quality of drinking water, one of the focuses of data assessment is to help guide DEP's watershed protection programs in the future. However, even with a robust dataset statistical assessment can be complex with multiple factors influencing each sample. In addition to the abundance or concentration of (oo)cysts in the watercourse, climatic variables (hurricanes, floods, droughts, etc.) and analytical method changes can influence protozoan results. Despite this potential variability, it is often necessary to pool results from multiple years to evaluate long term data trends and potential changes resulting from the implementation of watershed protection programs. Additionally, larger data sets offer increased statistical power and can help create meaningful correlations.

During this presentation, protozoan data from streams, upstate reservoir outflows, and source waters will be grouped in varying time scale scenarios to determine potential trends (step, monotonic, seasonal). Statistical smoothing methods will be utilized. Environmental factors and analytical method changes will be considered where applicable and compared for statistical significance as they may underlie or influence the trends discovered.

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Bayonne, NJ CSO Treatment Demonstration Project - Disinfection Results

Jurek Patoczka, Ph.D., Mott MacDonald

The following existing manufactured systems were selected for the demonstration project for Bayonne Municipal Utilities Authority (BMUA):

- Hydro International's Storm King® with Swirl Cleanse
- Terre Kleen TK-09
- WETTCO's Flex Filter™
- PeraGreen's INJEXX™ Per Acetic Acid (PAA) unit
- Trojan's UV3000Plus™
- Aquionics Inline 250+W Medium Pressure UV

A total of nine Test Runs were executed in various equipment configurations and flow rates. The bacterial indicators tested were fecal coliforms, E. coli and Enterococci.

A 12 percent solution of PAA was used during all runs at HRT ranging from 3 to 6 minutes. The target PAA residual was in the range 1 to 2 mg/L. Disinfection efficiency was best predicted by the applied PAA dose normalized with respect to sample COD. The normalized dose correlates well with the log reduction for all three pathogen indicators. The PAA dose of 0.01 mg/L of PAA per mg/L of COD typically results in 3 log reduction of fecal coliforms, with slightly higher effectiveness for E. coli and slightly lower for Enterococci.

Low pressure UV unit performed better than the medium pressure UV unit at the same UV dose (as calculated by the manufacturer). The disparity in performance could be a result of differences in the validation procedure and effective dose calculation, or it could be related to the lower efficiency of medium pressure lamps versus the low pressure lamps. The relatively low log reduction of bacterial densities achieved by the UV units is the result of inadequate UV dose caused by low transmittance of the wastewater which ranged from single digits to 60 percent, with majority clustered in the 20 to 50 percent range. The correlation between UVT and total CBOD5 and COD are even better than with TSS, attesting to the contribution of soluble organics to the UV absorbance.

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Evolution of Cooperative Policy Development on NY's Esopus Creek: The Ashokan Release Working Group

William Richardson, NYC Department of Environmental Protection

The Ashokan Releases Working Group, a cooperative, collaborative, stakeholder group brings together involved agencies with local municipalities and other stakeholders to foster communications and policy discussion on Ashokan Reservoir releases to the historically bisected Esopus Creek. With no formal leader, the group is facilitated by New York City Department of Environmental Protection (DEP) and New York State Department of Environmental Conservation (DEC) officials as well as representatives from Ulster County, the Towns of Marbletown, Hurley, Ulster, Saugerties, Saugerties Village, City of Kingston, Riverkeeper, RCAP Solutions, other local and regional stakeholders and New York State Department of Health (DOH).

Beginning in 2011, the group has met at least quarterly, building open communications and information exchange regarding policy and management decisions as well as DEP's water supply operations under a DEC consent order impacting the 32 mile long Lower Esopus Creek. Special topics of significant stakeholder interest, watershed management concepts, and the relation to mandated and un-mandated programs, help focus the group's dialogue. Presentations are made summarizing hydrologic conditions, operational variables, and water quality results of the Ashokan Reservoir and its impacts to Lower Esopus Creek and the communities from the reservoir to its confluence with the Hudson River. The group also monitors the DEP's implementation of the "Interim Release Protocol", provides feedback on the development of an Environmental Impact Statement, and reviews water quality/quantity in the context of economic, recreational, municipal and ecological interests and uses of concern.

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Impact of Forest Harvesting on Streamflow in Neversink Reservoir Streams

Kyongho Son, Ph.D., Hunter College, City University of New York; Elliot Schneiderman, Emmet Owens, NYC Department of Environmental Protection; Laurence Lin, Institute for the Environment, UNC-Chapel Hill

Forest harvesting is the felling and removal of trees, and is a common forest management practice. The impact of harvesting on water yield varies depending on the extent and intensity of harvesting, climate variability and natural forest succession during the recovery period. However, the availability of forest recovery data over large areas and long time periods is limited. This study focused on utilizing remotely sensed vegetation indices to detect forest leaf recovery patterns in Shelter Creek (Neversink River basin) following spatially-varying forest harvesting. In addition, this study used a paired watershed approach (control vs harvested) and process-based modeling approach (using RHESSys) to estimate the impact of forest harvesting on streamflow. Our preliminary analysis of the vegetation indices showed that leaf cover in partial forest cutting site recovered within a year, but for the clear cut site, recovery patterns of forest leaf varied among the indices; the analysis of vegetation indices suggests that forest leaf fully recovered in 3 to 5 years. As expected, the paired watershed approach showed that forest harvesting increased annual and monthly flows due to reduction in evapotranspiration. In the recovery periods, these flows decreased. However, annual flow was not predicted to recover to pre-harvesting conditions even though the forest leaf (based on vegetation indices) did fully recover. Similarly, RHESSys was applied to forest harvesting areas to quantify the flow changes following forest leaf recovery. This study has improved our understanding of the relationship between forest changes and streamflow.

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Diversity of Programs in Land Acquisition

Dave Tobias, Ira Stern, NYC Department of Environmental Protection

New York City's watershed is one of the largest managed surface water supply systems in the world. At over one million acres (almost 2,000 square miles / 5,180 square km), the watershed is larger than 65 of the world's 200+ sovereign nations, supplying water to 9 million consumers in one of the largest metropolitan / urban centers in the world. NYC acquires conservation easements and land in fee simple under programs specifically tailored to protect eligible land to protect water quality. Each program is guided and controlled by its own set of complex requirements, policy parameters, process requirements, and rules. Together the programs must satisfy myriad stakeholders in the context of a working landscape that includes 250,000 residents.

Once a transaction is complete, newly-acquired properties are protected from development, impervious surfaces, and pollution, while the vast majority of land acquired in fee simple is opened for compatible public access and recreational uses. However, the City's responsibilities as a landowner go well beyond to include the following

activities that help to ensure long-term land management, ecosystem protection, and water quality benefits:

- Provision of compatible recreational opportunities for public use;
- Inventory and monitoring of natural resources to understand the resource base, trends, and restoration needs;
- Active management of forests in order to promote diversity of age and species, vigorous growth, resiliency, and nutrient uptake;
- Facilitating deer management programs to reduce forest damage;
- Leasing of land for low-impact agricultural uses to maintain diverse landscapes and integrate with local economies; and
- Review of land use permit applications as we seek to accommodate community and neighbor needs in a working landscape

This presentation, by two DEP staff who oversee the Land Acquisition and Natural Resource programs throughout the City's watershed, will address the programs and efforts described above as well as successes and obstacles encountered.

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Potential for Wetland Creation through Small Dam Removal or Modification

Maria Tupper-Goebel, NYC Department of Environmental Protection

Consistent with national and regional trends, a recent study has revealed that the New York City Water Supply West of Hudson Watershed has seen a net gain in the acreage of freshwater ponds. There was total gain of 212 acres of pond in the West of Hudson Watershed between 2001 and 2009, 167 acres of which occurred in wetlands or watercourses. The greatest gains in pond acreage occurred in the Schoharie and Cannonsville Reservoir Basins. To date the city has acquired 67,777 acres of land within these basins combined. These holdings contain approximately 55 ponds created by small dams. DEP is developing a screening protocol to evaluate and prioritize all small dams in these basins for the potential to create wetlands through dam removal or modification. Dam type, soils, topography, and adjacent land use are some factors included in the evaluation. Once selected, sites may be restored through third party mitigation or other partnership programs. Replacing open water habitat with vegetated wetland will help offset the historic loss of vegetated wetlands and their functions.

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Suspicious Algal Bloom Monitoring in the New York City Water Supply

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

Research has indicated that toxin producing cyanobacteria blooms are occurring in freshwater with increasing frequency. Increased water temperature, nutrient loads and longer periods of stratification are often cited as contributing factors. In 2014, the U.S. Environmental Protection Agency (EPA) included three algal toxins (anatoxin a, cylindrospermopsin and microcystin LR) on the Contaminant Candidate List (CCL). 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 2016, EPA issued draft Human Health Recreational Ambient Water Criteria for microcystins (4 µg/L) and cylindrospermopsin (8 µg/L). EPA has also made recommendations on how utilities can monitor and treat drinking water for algal toxins and notify the public if drinking water exceeds protective levels. While cyanobacteria blooms are not frequent in most of NYC's water supply, blooms are common during the summer months in the Croton System Reservoirs located east of the Hudson River. Based on EPA recommendations, the New York City Department of Environmental Protection (DEP) initiated a monitoring program in 2015 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. 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. In this presentation we will provide more details of the monitoring plan, discuss results through 2016 and discuss future plans to improve our monitoring capabilities.

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What can we learn from the visualization of Automated High Frequency Reservoir Monitoring?

David Van Valkenburg, NYC Department of Environmental Protection

Automated High Frequency Monitoring (AHFM) of New York City Department of Environmental Protection (DEP) reservoirs have provided DEP with the ability to measure important water quality constituents throughout the entire water column multiple times every day. These AHFM measurements can be utilized to supplement routine monthly monitoring and provide a clearer picture of what is taking place between routine monitoring. The AHFM buoy systems can utilize some or all of the following sensors: temperature, specific conductivity, turbidity, depth, and optical probes for Chlorophyll, Blue-Green Algae, Dissolved Oxygen, and fluorescent Dissolved Organic Matter (fDOM). Visualization of these water quality constituents, using the statistical package R, will focus on West of Hudson reservoirs and has allowed for the examination of how characteristics can change over the entire monitoring season or in much shorter time steps. Some of these characteristics include how the AFHM data relates to the thermocline, showing features not previously observed by monthly fixed frequency monitoring in the reservoir, how withdrawal elevations relate to profile observations, compare laboratory and in situ measurements differences, and provide a more complete picture of processes occurring within the reservoir water column.

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Confronting Climate Issues in New York State

Mark Wysocki, Cornell University

New York State covers a wide range in topographical, coastal features, and climate zones. Current trends in precipitation across New York State indicate a decrease in annual snowfall and an increase in extreme rainfall events (≥1.0") since the 1950's. The frequency of moderate and extreme droughts across the Northeast are also declining since the early 1970's. Increased moisture in the atmosphere due to global warming and increased flood plain development are shifting the odds in favor of more extreme floods occurring more often. Sea levels are rising at a rate of 3.3 mm yr-1 and with 53 percent of the U.S. population residing in 673 coastal counties, this has placed a stress on coastal management resources. All these events are having and will continue to have a large impact on the quality of life and the economic well being of New York State. Specific trends by climate region will be presented along with the challenges for decision makers during a changing climate.

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Drinking Water Quality and Source Water Protection

Lloyd Wilson, Ph.D., NYS Department of Health

There are approximately 9000 public water systems in New York State. The Bureau of Water Supply Protection (BWSP) implements Safe Drinking Water Act regulations by providing guidance and technical resources to County and State District office staff who directly oversee the water systems. In recent years drinking water quality has become of heightened concern given the lead contamination at Flint Michigan, the Toledo Ohio contamination with harmful algal bloom toxin, and the West Virginia spill of 4-methylcyclohexanemethanol. In New York, the experience with the unregulated perfluorinated compounds (PFCs) at various locations including Hoosick Falls, harmful algal bloom toxin in Owasco Lake, and other unregulated compounds like 1,4-dioxane tested under the U. S. Environmental Protection Agencies (EPA) unregulated contaminant monitoring rule (UCMR 3) all have raised concerns about drinking water quality. Efforts to strengthen the drinking water program to address these concerns will be discussed.

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