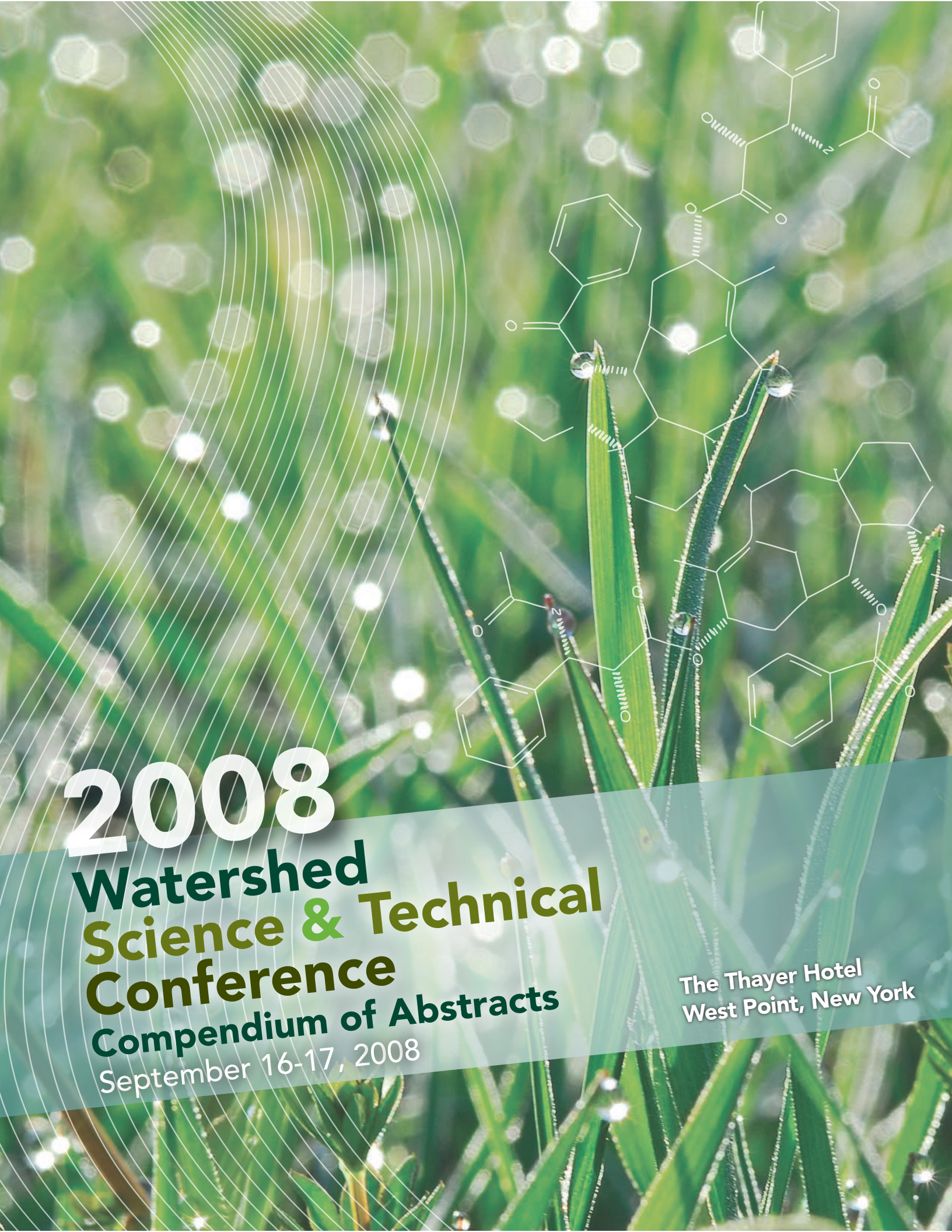

2008 Watershed Science & Technical Conference

Compendium of Abstracts

September 16-17, 2008

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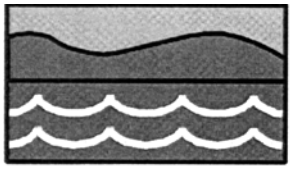

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INTRODUCTION AND ACKNOWLEDGMENTS

Dear Conference Participants,

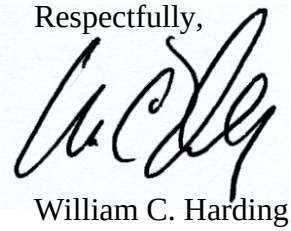
In 1997, the signatories to the historic New York City Watershed Agreement formed an enduring partnership to protect and enhance the City's Watershed and the scores of communities living within it. Underlying this complex social and political undertaking has been an unprecedented technical initiative 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.

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 the 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 9 million New Yorkers.

Respectfully,



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Giardia and Cryptosporidium Monitoring in the New York City Watershed : A Retrospective

Kerri Alderisio, NYC Department of Environmental Protection

It began June 16, 1992. A Department of Environmental Protection employee walked into the Delaware effluent chamber of Kensico Reservoir, set up sampling equipment, and collected the first sample for monitoring the New York City water supply for protozoa. Specifically, the sample analysis targeted Giardia spp. cysts and Cryptosporidium spp. oocysts. These organisms are parasitic protozoa that have the ability to cause intestinal illness in humans and animals, and they are monitored for the reason that they can be transmitted through water. Over the past sixteen years there have been changes to the collection and analytical methods, as well as changes in the laboratories performing these analyses. Initially, the ASTM Method (#) was performed at the New York State Department of Health Wadsworth Center for Laboratories and Research in Albany, then Erie County Water Authority handled the contract for this work. Eventually, the New York City Department of Environmental Protection Pathogen Laboratory took over analysis using the ICR methodology in 2001, and then the US EPA Method 1623 from 2002 to the present. Along the way we have learned a lot of information concerning the occurrence and trends of these organisms at both aqueduct locations and streams and releases in the watershed.

Additionally, we have participated in many studies, both internally and with outside agencies, to improve methods and the recovery of these protozoa from surface water. Ultimately this monitoring has provided valuable information that has allowed the New York City Department of Environmental Protection to better examine these organisms, determine how the data may compare to other water supplies across the country, and determine how those same data compare to the Cryptosporidium threshold indicated in the Long Term 2 Enhanced Surface Water Treatment Rule. This retrospective is a summary of the history of the methods, and the data, for anyone not familiar with the past activities that have brought protozoan monitoring in the water supply to where it is today. Above all, it is clear that significant improvements have been made along every step of this journey, yet there is still room for advancement in this area of science.

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Northern Westchester Watershed Committee Highway Deicing Task Force Report

Christina Anderson, Westchester County

About 40% of Westchester County's land is within the Croton Watershed, an important component of the New York City Water Supply System. Most of the residents who live in this watershed are served groundwater supplies which are recharged by water passing through the watershed and infiltrating into the ground. Many threats to surface water supplies, such as salt from winter roadway maintenance, impact groundwater.

In June 2006, County Executive Andrew Spano met with both the Northern Westchester Watershed Committee (NWWC), a forum which oversees and discusses issues within the New York City Croton Watershed, and Alex Matthiessen, President of Riverkeeper, a non-profit environmental advocacy group, to discuss the impacts of road salt on water quality. During this meeting, all agreed that road salt can degrade water quality and that action should be taken to decrease the use of road salt within the Croton Watershed. As a result of this meeting, the NWWC created a task force, NWWC Highway Deicing Task Force (Task Force), to evaluate existing deicing practices in the watershed and propose strategies to reduce the environmental impacts of highway deicing. The Task Force includes representatives of local highway officials, NYCDEP, NYSDOT, NYPIRG, Riverkeeper and Westchester County. For about a year following its induction, the Task Force reviewed existing deicing practices within the Croton Watershed, researched deicing alternatives, and discussed possible solutions to salt reduction.

The Task Force summarized their findings and strategies in a report entitled the NWWC Highway Deicing Task Force Report (Report), which was released in November 2007. The Report discusses environmental impacts of road salt, describes alternative deicers and provides best management practices and strategies to decrease impacts from road salt. The report was prepared for communities in the Croton Watershed, but the strategies and guidelines are applicable for all communities in Westchester County and New York State. Westchester County sent a copy of the Report to all 45 highway officials within Westchester County. The Report is available at the County website for anyone to access by clicking on the Stormwater Education link on the left hand tab at: www.westchestergov.com/planning/environmental/.

The highway deicing practices presented in the report also relate to the NYS DEC Stormwater Permit program, which requires Westchester municipalities to develop and implement a stormwater management program as a means to reduce the discharge of pollutants and protect water quality. Identified pollutants of concern include deicing chemicals such as road salt. The Deicing Report highlights the importance of educational outreach programs for property owners and the driving public, and outlines best management practices (BMPs) such as monitoring and record keeping, new deicing technologies and highway personnel training. In addition, television and radio Public Service Announcements regarding homeowner salt BMPs are scheduled for production under the MS4 Phase II Stormwater Education and Outreach Program.
In February 2008, the American Public Works Association awarded the Westchester County Department of Public Works an award for Excellence in Snow and Ice Control as a result of the Final Report.

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Kensico Action Plan's Dual Strategy of Offense and Defense to Protect Water Quality

Guy Apicella , HDR Engineering, Inc. and Dale Borchert, NYC Department of Environmental Protection

In March 2006, DEP retained HDR to develop the Kensico Action Plan (KAP) for the continuing watershed management and protection of the drinking water supply. The project entailed the application of stormwater models to evaluate the discharges and pollutant loadings to the reservoir. Model results along with drainage and stream condition issues, which DEP brought to the attention of HDR, were evaluated to recommend four stormwater pollution remediation practices for designs. The KAP produced designs of four BMPs that will be constructed and add to the water quality protection provided by the existing 44 BMPs in the watershed. Two of the KAP designs feature concepts that are new to the Kensico watershed: an off-line extended detention basin in sub-basin N12 and stream stabilization using grade control in the Whippoorwill Lake sub-basin. In addition to the BMPs, the KAP used the strategy of water quality risk assessments to investigate potential sources of pollution or water quality impairment. Three potential pollution sources investigated by the KAP were: Westchester County Airport, turf management chemicals in the N5 sub-basin and the Swiss Re office complex. The qualitative risk assessments concluded that these areas were not pollution sources to the Kensico reservoir and sequential assessments of human health exposure were not recommended. The presentation will provide the details concerning the development of the innovative BMP designs and the methodologies used in the risk assessments.

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Watershed Protection Planning for Metropolitan Boston Water Supply

Patricia Austin, P.E., Massachusetts Department of Conservation and Recreation

The Massachusetts Department of Conservation and Recreation, Division of Water Supply Protection, Office of Watershed Management (DWSP) manages and protects the watersheds that provide drinking water for approximately 2.2 million Massachusetts residents. DWSP partners with the Massachusetts Water Resources Authority (MWRA) to deliver water to the user communities. MWRA is responsible for treatment and transmission of the water.

DWSP, with MWRA, is regulated as a Public Water Supply by the U.S. Environmental Protection Agency and the Massachusetts Department of Environmental Protection. The system has a waiver from the filtration requirements of the Surface Water Treatment Rule. Watershed Protections Plans, as required by the Surface Water Treatment Rule, were first written in 1991. The original plans were developed following guidance developed by Massachusetts DEP. Since then, plans have been updated twice. Watershed Protection Plans guide the work of the Division. The current Plans run out in December of 2008.

This paper describes the process taken to update the plans, and summarizes the major findings of the assessment conducted as part of the update.

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Start-Up of Largest Wastewater Treatment Plant in NYC Watershed

Robert Carr, P.E., Jan S. Salzman, P.E. Robert Butterworth, P.E., Stearns & Wheler, LLC and Sharon Robinson, P.E., Town of Yorktown

The decision to divert Yorktown's Water Pollution Control Plant (WPCP) 1.5 mgd flow to Peekskill or to treat the flow to NYCDEP watershed requirements took a decade to make. Yorktown's WPCP is the largest treatment plant that discharges into the NYC watershed. Diversion of Yorktown's treated effluent out of the watershed was the initial engineering recommendation. Diversion was not the selected option since years went by and the required approval of multiple governmental agencies was not obtained, and costs for diversion were higher than originally thought. Thus, upgrading the existing treatment facilities to meet NYCDEP watershed requirements was the selected option. This option was "inspired" by a consent order from NYSDEC that required a final study of both alternatives and immediately followed by design and construction via the Consent Order schedule. This presentation describes final design and approval process, innovative design aspects such as equalization tank and other methods to handle peak flows. Start-up of treatment plant equipment was initiated in May 2008. Process sampling data will be presented to show the improvements in water quality.

The Town of Yorktown had been trying for years to obtain a final decision on whether flow from its treatment plant could be diverted out of New York City's watershed to the Peekskill Treatment Plant, or if the treatment plant should be upgraded to meet New York City Watershed improvements. Diversion was initially thought to be the most appropriate option. Diversion ran into several regulatory and public opinion roadblocks so a final decision on that option was delayed. Following evaluations identified upgrading the treatment plant to meet New York City Watershed requirements and NYSDEC SPDES permit limits as the most appropriate solution. Frequent meetings with regulating agencies, Town Officials and Stearns & Wheler allowed for a streamlined decision making and approval process. Two projects were designed and constructed at the same time:

1. Install a 2 million gallon equalization tank to capture peak storm flows. Replace existing sand filters, install microfiltration equipment, and replace chlorination/dechlorination with ultraviolet disinfection.

2. Install RBCs to remove ammonia and upgrade other treatment plant equipment to provide reliable operation for the next 20 years.

Frequent meetings provided for regulatory input during the design process and allowed for expedited reviews. This process resulted in a design that met regulatory and Town requirements. The completed upgrade construction provides advanced treatment methods, greatly increases the reliability of process equipment, eliminates disinfection byproducts from chlorination, stores peak flows for later treatment, and will help protect the NYC Watershed in the long term.

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Water Reuse Advancements - Protecting Our Valuable Resources

Richard Cisterna, P.E. and Enrique Vadiveloo, Hazen and Sawyer

Wastewater reuse can be an important component of a comprehensive watershed protection plan. Removing wastewater streams from surface water bodies can reduce pollutant loads to these receiving waters. The wastewater can be treated to a higher level and reused beneficially. Another important benefit is that that wastewater reuse also reduces water demands that potable supplies otherwise would have served. This paper will describe some case studies regarding cutting edge water reuse programs in the country and will present concepts that may be of value to utilities in the northeast that may be considering similar issues. A few examples in Florida are described below:

South Florida is experiencing significant population growth, coupled with natural climatic variability and the water demanding task of Everglades restoration. Use of the historic sole source water supply (Biscayne Aquifer) has been capped by regulators and all new water must come from alternative water supply sources. Utilities must find synergistic solutions such as water conservation, wastewater recycling, and new water sources such as brackish aquifer or seawater.

This paper will focus on a few of the more advanced wastewater reuse programs that apply state of the art dual membrane (microfiltration and reverse osmosis) technology for challenging applications such as indirect potable reuse that would recharge the Biscayne Aquifer and provide spray irrigation using brackish water sources.

City of Plantation Reverse Osmosis Reuse Pilot Plant

This program assessed the following technologies: denitrification filters, membrane bioreactors (MBR), reverse osmosis (RO), and Ultraviolet (UV) light disinfection.The primary effluent requirements are:" Total Nitrogen < 1.5 mg/L" Un-ionized ammonia <0.2 mg/L" Total Phosphorous < 0.02 mg/L.

Miami Dade County, Florida

Miami Dade County, Florida is embarking on one of the largest water sustainability programs in the country. This program envisions over 100 mgd of wastewater reuse projects. The Central District WRF will provide over 2 mgd of advanced membrane treatment to reduce chlorides below 400 mg/L for irrigation application.

The South District WRF will recharge it’s drinking water wellfield with highly treated wastewater that treats well beyond drinking water standards. In addition to dual membrane technology, this project also envisions using an ultraviolet light advance oxidation process to destroy microconstituents such as pesticides, herbicides, and hormones.

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Using Advanced Technology to Manage Emerging Contaminats in Wastewater

Richard Cisterna, P.E. and Joyeeta Banerjee, Hazen and Sawyer

Many utilities are beginning to evaluate the presence, fate and effect of emerging contaminants in wastewater effluents, receiving water bodies and reclaimed water application sites. There is growing interest in methods to controlling or even eliminating endocrine disrupting compounds (EDCs) and pharmaceutically active compounds from wastewater effluents that discharge into senstive water bodies. The main focus has been where wastewater is applies directly or indirectly into potable sources of water. The focus of this paper will be to review some applicable case studies and discuss the primary methods of controlling emerging contamints in wastewater and reclaimed water.

One such example is described below:

Southeast Florida water utilities are facing some of the largest and most challenging issues they have ever seen. Utilities are being asked to find synergistic solutions to water supply and wastewater effluent disposal and reuse issues. This type of effort has been undertaken in California and is now being seriously evaluated in Florida. In Florida the traditional water supplies have been capped and all new water sources must come from alternative water supplies.

The South Florida Water Management District (District) approved the proposed Regional Water System Availability Rule, which is aimed at preventing increased reliance on Everglades and Loxahatchee River watershed water bodies by restricting new/increased withdrawals over a base condition that would cause seepage or direct withdrawals from the Regional System. With implementation of the Regional Water Availability Rule, the volume of water available from Southeast Florida s primary source has been quantified and capped for utilities. As a result, Southeast Florida utilities are seeking alternative sources of water.

As an ongoing regional effort to finding alternative water supplies, the City of Plantation and the District entered into a cooperative agreement to evaluate recharging the Biscayne Aquifer with highly treated reclaimed water through surface water discharge. The effluent criteria required are some of the most stringent in the nation and include:

*TN < 1.5 mg/L *TP < 0.02 mg/L* Uninonized Ammonia < 0.2mg/L

The following process schemes were evaluated and piloted:

A. Process Scheme 1: Primary effluent, membrane bioreactor (MBR), reverse osmosis (RO), and UV disinfection.

B. Process Scheme 2: Nitrified secondary effluent, tertiary clarification, denitrification filter, ultrafiltration (UF), RO, and UV disinfection.

Both processes were shown to be a viable approach to meet the very stringent effluent requirements for surface water discharge.

Other advanced testing included toxicity, emerging contaminant removal (including EDCs and pharmaceuticals) and hormonal impacts of the treated wastewater.

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The Development of a Remote Data Communication System for Storm Sampling in New York City Watershed Streams

Steven DiLonardo and James C. Alair, NYC Department Environmental Protection

Sampling storm events offers many challenges; however, technological advances have significantly facilitated and reduced the time and effort necessary to sample multiple streams at various sites, thus allowing for a more complex and widespread storm sampling program. Through grants such as the Water Resource Development Act (WRDA) and the Safe drinking water Act (SDWA), DEP has developed the infrastructure for simultaneous automated sampling of several streams for a given storm event. Recently, DEP has developed a data communication system allowing for the remote acquisition of flow data as well as setting an arbitrary flow based trigger and time based programming of storm events in Kensico Reservoir stream sample stations. This has been achieved through modem communication with on-site data-loggers, which transfer data onto the Water (WISKI) software system (KISTERS North America, Inc.). In addition, the WISKI software system establishes a database (that includes up to the hour flow information), which allows field staff to determine if storm sampling was triggered according to the preset criteria, as well as determine if on-site flow data is correctly being recorded, without having to travel to the field site. In addition, end users can query data according to their needs by simply clicking on a map icon. This remote data communication system can be used to monitor other parts of the watershed and has the capability for added parameters (*i.e.,* meteorological conditions, turbidity), to further enhance the application of this system.

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Development of a Regional Model to Predict the Impact of Bacterial and Conservative Discharges

Charles Dujardin, P.E., HydroQual and Peter Sattler, Interstate Environmental Commission

During June 1997, a force main failure under Eastchester Bay in western Long Island Sound initiated the closing of public and private beaches in the Bronx, adjoining Westchester County and Connecticut (~10 miles to the east). The necessity to close beaches in the vicinity of the sewage release for the public welfare was paramount, but it became obvious that there was a need to be able to predict which beaches and shellfish harvest waters may be affected by a sewage spill, and to establish a regional protocol to notify responsible authorities of potential threats to these sensitive areas from unplanned sewage releases. This incident, in conjunction with several other sewage releases, stimulated environmental and health officials to assess the notification process among the agencies and to the public.

In July 1997 a meeting of New York and Connecticut environmental and health officials, as well as the Interstate Environmental Commission, was convened to discuss unplanned sewage bypasses that resulted in beach closures in New York and Connecticut. A modeling work group representing 15 agencies --federal, state, local and interstate-- was formed to discuss modeling scenarios/strategies for unplanned sewage bypasses. These discussions led to the framework and development of the original Regional Bypass Model. The model enables quick predictions of whether a discharge occurring at certain point will affect another area, and if there should be concern as to whether a beach or a shellfish area should be closed. However, the original version of the model was limited to the number of discharge locations and the number of receptor cell locations. Other limitations include the duration of the discharge, and the time of the spill within a tidal cycle. The old version was also based on total coliform kinetics

In 2008, an upgrade to the model was completed. The new version includes enterococci kinetics, has the ability to input multiple discharges, discharges can be input to any segment of the model domain, and model results can be viewed in any model segment. Results of a simulation are viewed in a color coded anaimation. The user wathches the spread of the bypass/spill and its dissipation. The user can also easily produce a graph of concentration versus time in any model segment. Since the model refinements allows for discharges into any model segment, the spatial domain for assessment is not limited to NY-NJ Harbor; the assessment domain now includes all of Long Island Sound and the New Jersey Coast.

The upgrade also includes a conservative tracer option as a representation for other parameters of concern (*e.g.*, metals). Although the detailed kinetics of these substances are not included, the conservative substance option will give the user an estimate of the dilution characteristics in the system.
Since the model platform is GIS based, geogrphical information layers are also included (*i.e.* CSO and stormwater outfall locations, designated beaches, shellfish areas, and more).

The model is currently being used by State and muniipal agencies, beach managers, shellfish managers in New York, New Jersey, and Connecticut.

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Climate Mitigation via Sequestration of CO2: Technical Challenges and EPA's Regulatory Approach

Robert Ferri, U. S. Environmental Protection Agency

Carbon dioxide (CO2) from combustion of fossil fuels is considered a principal factor contributing to global climate change. A measure to reduce the amount of CO2 released into the atmosphere involves injection of supercritical CO2 into deep geologic formations. Subsurface injection of potentially endangering fluids into formations underlying Underground Sources of Drinking Water is regulated by EPA's Underground Injection Control (UIC) Program. The scale of the operations is such that EPA is developing new proposed regulations for injection of CO2. Technical issues and unique challenges posed by injection of supercritical CO2 for long term subsurface storage, and issues related to the regulation of CO2 injection will be presented for the New York/New Jersey area including some notes on sub-seabed sequestration of CO2.

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The Bedded Pack Management System - A Case Study

Daniel Flaherty, Brian LaTourette, Watershed Agricultural Council and John Thurgood, Delaware County Cornell Cooperative Extension

In 2004, a Whole Farm Plan was developed identifying several water quality issues on a small dairy farm in the Arkville, NY. A barnyard feeding area was less than 100 feet to a watercourse, because of the close proximity to the watercourse and the topography of the farm, the traditional Best Management Practice (BMP) was to install a covered barnyard or concrete barnyard with a pump system. Manure storage was also identified. The steep slopes of the meadows prohibited spreading during winter. The traditional BMP would have been a waste storage facility.

Because of site constraints and high construction costs of manure storages and covered barnyards, another solution was explored. In Vermont, Bedded Pack barns were constructed as manure storages to comply with the prohibition of winter spreading. These also served as a covered barnyard/feeding area. The result was a manure storage system that farmers could manage with existing equipment with minimal odors and a barnyard that has no runoff because the animals are fed daily under cover. The modern hoop structure with plastic cover has allowed the possibility of this innovative BMP.

In 2006, a USDA Conservation Innovation Grant along with funding from the Watershed Agricultural Council funded the construction of the Bedded Pack facility. The facility was a coverall structure 100 X 50 feet to accommodate 50 milking cows. The sidewalls were 10 feet high to account for manure and bedding accumulating during the 6 month storage period.

The farmer moved his herd into the facility in late 2006 and has gone through two winters. After completion of the construction of the project, improvement in animal comfort has been observed. All barnyard runoff from the loafing and feeding areas was eliminated. The facility effectively contains all the winter's manure from the dairy herd. The overall use of bedding has increased over the prior system. The farmer uses straw bedding from which costs nearly $10,000. Excellent udder health and milk quality has continued in the Bedded Pack. The somatic cell counts before and after the Bedded Pack has averaged 150,000.

As part of the project, a time and electrical usage study was conducted by Cornell Cooperative Extension comparing the Bedded Pack to a conventional dairy farm. There was a daily time savings in the winter, because there was no manure to spread. On average it took 1.5 hours less to do daily chores in the winter on the Bedded Pack. However it took 160 hours to clean out the Pack and take to the compost site. Electrical usage in winter was less in the Bedded Pack, but diesel fuel to move round bales and straw could offset lower energy use. It took 30 minutes per day to feed and bed the animals in the Bedded Pack compared with 1 hour and 15 minutes in the conventional barn.

The Bedded Pack is a viable option to store manure over the winter and can be utilized as a feeding area for the dairy herd.

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The Green Lie: Development on Private Forestland and Forest Cover Complacency Syndrome in the New York City Watershed

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The Catskill/Delaware watersheds of the New York City water supply system deliver approximately four billion liters of water to the City each day. Between 1984 and 2000, the parcelization of private land resulted in approximately 8,000 new parcels and a decline in average parcel size from 19 to 16 acres. Despite parcelization, net forest cover has been stable or increasing in this region over the last thirty years. The idiom Athe Green Lie@ has been used to refer to forests that are full of trees, but are in poor condition from a silvicultural perspective. In the case of water resources, forested watersheds are associated with high water quality. In the urbanizing environment such as the Croton system, negative water quality effects are closely linked to runoff from impervious surface cover. But low-density, rural residential development has also been linked to significant negative water quality impacts, including non-point source contamination from lawn chemicals and fertilizers, septic systems, sump pumps, and fecal contamination, which can be intensified by impervious surface area. Furthermore, research indicates that low density patterns of development can be associated with higher impervious surface area per housing unit. Low density rural residential development can bring potential for water quality degradation, even if the landscape retains high forest cover. At its core, the Green Lie embodies the idea that people’s perceptions of forested land are highly visual, but often the functional relationships that characterize ecosystem processes are hidden from view. This study quantifies forest cover and impervious surface area on new parcels resulting from subdivision in the Watershed, and compares subdivided parcels to parcels that remained intact over the study period. Results show that subdivided parcels are being developed to nearly the same intensity as intact parcels. Projections from these data indicate that residential development on new parcels added nearly 1,000 acres of new impervious surfaces on private property since 1984, apparently without being accompanied by observable net reductions in forest cover at the landscape level. In this light, robust efforts to encourage the implementation of Best Management Practices on private residential properties may be critical in avoiding water quality degradation from development in the Watershed.

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Five estimates of future development growth in the NY City West of Hudson Watersheds and their implications for Water Quality

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Water quality models currently used by the NY City DEP predict future land use change as a function of population growth. While population is generally thought to be the major driving factor of land development one-half of the private watershed parcels belong to people whose census information is gathered elsewhere. In this study we explored five data sets whose extrapolation creates five different development scenarios between 2002 and 2022. They include 1) a 1975 - 2002 remotely-sensed time series of classified satellite images, 2) in-depth on the ground visits conducted in 2005 of 138 private properties parcelized or not parcelized since 1984, 3) a compilation of the changing number of private parcels per watershed town from1996 to 2007 using the NY State Office of Real Property data base, 4) building permits from 1980 to 2007, and 5) an evaluation of population growth versus development in each town from 1990 to 2006. First, we found much less forest cover than other satellite-based estimates. The fastest growth rate is derived from the building permit history and extrapolated linearly would result in 5760 more acres of impervious surface by year 2022, whereas the slowest growth rate is found in the population data. The fastest growing towns in terms of land use change are Windham and Hunter. This development pressure in spite of moderate population growth, reforestation, farm abandonment, and City land acquisition, will place additional burdens on NY City's DEP to maintain a safe and aesthetic drinking water supply.

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Low Impact Development (LID): A Timely Watershed Protection Tool

Scott Horsley, Horsley Witten Group

Low-impact development (LID) is an alternative approach to site planning, design and building that minimizes impacts to the landscape and preserves the natural hydrologic cycle and mitigates water quality impacts. LID is accomplished as a two step process:

"better site planning; and" implementation of best management practices (BMPs).

This approach results in reduced impervious surfaces, smaller lawns and more natural landscaping. Therefore it is commonly less costly to construct, requires less maintenance and is more attractive, which enhances real estate values.Thoughtful site planning begins with an approach first publicized by the planner and landscape architect Ian McHarg which identifies critical site features such as wetlands, or drinking water protection areas that should be set aside as protected open space. Natural features, such as vegetated buffers and view sheds also play an integral role in any LID planning exercise. After the critical open space areas are identified and preserved, sustainable development areas are then identified as "building envelopes." Within the delineated building envelopes, a broad range of design techniques or BMPs, such as shared driveways, permeable pavers, and stormwater treatment by bioretention are used to reduce the level of impervious cover and improve the quantity and quality of stormwater drainage. Other LID design techniques include green roofs, rain barrels, rain gardens, grassed swales, stormwater infiltration systems, and alternative landscaping. Through these techniques, natural drainage pathways are conserved, open space is preserved, and the overall impact from development is significantly reduced.

This paper will present the LID planning process and will describe a wide range of BMPs. Case studies will be used to illustrate how LID is implemented to achieve watershed protection goals.

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Climate Change Issues and Planning for New York City's Water Supply Watershed

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The water supply system for New York City (NYC) is one of the largest metropolitan water supplies in the world. Its development was regarded as a major engineering feat which required the construction of 19 reservoirs and 480 km of interconnecting aqueducts and tunnels. This system supplies an average of 1.3 billion gallons per day of clean drinking water to the City from a watershed of nearly 2,000 square miles. This system is also known for the abundant and excellent water quality it provides to more than 9 million consumers. The high quality of the source water allows it to remain one of the few, large unfiltered systems in the nation. The City's goal is to retain the status of "unfiltered" through an anti-degradation policy that employs intensive watershed protection and partnership programs with watershed communities. The robust nature of the system is bolstered by these watershed protection programs, and they will serve the City well in the future by adding stability to water quality. However, the potential effects of the projected changes in the climate on the maintenance of a safe and reliable supply have yet to be determined. How will climate change affect the water supply? The prediction is for an increase in hydrological extremes (*i.e.*, droughts, severe storms, and floods). Hydrological extremes are typically the times of greatest challenge to those responsible for providing a safe and adequate water supply. At the present, extremes are dealt with through routing operations to optimize quantity and quality, and through the application of watershed protection programs. The question is how potential changes in climate may impact existing methods of operating the water supply and current watershed protection. This presentation begins with a brief description of the current water supply system for NYC followed by a review of the climate change trends and projections for the NYC watershed. It then discusses some of the water quantity and quality issues faced by water supply managers, introduces some of the programs established to deal with these issues, and explains how the City plans to cope with the projected impacts of climate change. The NYCDEP's Climate Change Task Force (CCTF), established in 2004, began evaluation of vulnerabilities and recently completed its first Action Plan to provide guidance for water resources planning. Concluding remarks explain how this strategy was developed and how the Task Force is approaching the challenge of planning for climate change in the watershed.

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Pressurizing the Catskill Aqueduct to Increase New York City's Water System Reliability

Roopesh Joshi, P.E., Hazen and Sawyer, David Tanzi, CDM, Leszek Glodkowski, Jenny Engineering Corporation, Paul Smith, NYC Department of Environmental Protection

The NYCDEP is constructing an Ultraviolet Light (UV) Disinfection Facility at the Eastview site in Westchester County, NY, owned by the City, to treat the City's Catskill and Delaware (Cat/Del) water supplies, which provide approximately 90 percent of the City's water supply. Only the Delaware Aqueduct, which runs beneath the eastern portion of the site, has sufficient pressure to supply the 2-BGD water to the UV Facility. To use the 90-year old Catskill Aqueduct as a source of gravity supply requires a 2.5 mile segment, from the Kensico reservoir to the UV Facility, to be pressurized by over 40 feet of head to enable it to convey raw water to the Facility. There are several advantages to maintaining the service of this segment, one of which is to continue to use the aqueduct without changing to a pumping system. Pressurization would increase the hydraulic capacity of this aqueduct segment by an additional 300 MGD and allow for reservoir bypass when needed, which provides advantages in system flexibility and operations. To establish the optimum approach for continuing to utilize this segment of the aqueduct a study was performed to determine the measures needed for pressurization, which included seven separate inspections of the aqueduct segment. Because the aqueduct is an active water supply to NYC and many other communities, each shutdown was limited to 24 hours, using procedures to yield the most information in the shortest possible time.

This project, one of a few of its kind, sets a precedent: it represents one of the largest aqueduct pressurization projects in the world for water supply. The conceptual design was developed taking into consideration several rehabilitation options for each section of the aqueduct segment, while carefully balancing considerations of costs, schedule and allowable leakage goals. The complexity of the design was increased because the aqueduct's configuration is not homogenous. It is circular in some sections and horse-shoe shaped in others; some sections were constructed by cut-and-cover techniques, while others traverse rock. Because of these structural variations, each section requires different rehabilitation measures for pressurization. Therefore, a variety of materials for strengthening and waterproofing the aqueduct, and an extensive grouting program was developed.

This paper provides an overview of the approach taken for the inspections, the study of alternatives, and the conceptual design of rehabilitation for the Catskill Aqueduct, its existing structures and the new structures needed for pressurization of the 2.5 mile segment.

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Assessment of Continued Manipulation of Nutrients in a Catskill Forest

Gregory Lawrence, Ph.D. and Douglas Burns, U.S. Geological Survey, Laura Heath and Don Leopold, SUNY Environmental Science and Forestry

Nitrogen, long considered a growth-limiting nutrient for northern forests, is likely to be available in excess of that needed by the Catskill forests a result of acidic deposition. Concentrations of nitrate, which have been elevated in Catskill streams for over two decades, are showing further increases in some streams since 2000. In addition, calcium and magnesium, also important nutrients, have been leached out of soils by the acidity in atmospheric deposition. Related research in Pennsylvania showed that deficiency of calcium and magnesium resulted in greater susceptibility of sugar maple trees (Acer saccharum) to crown dieback and increased mortality when exposed to defoliation outbreaks. To evaluate a possible imbalance in the availability of nitrogen and calcium (and possibly magnesium), a long-term study was initiated in the fall of 2003, in which forest plots in the Neversink River valley were fertilized with dolomite (limestone that contains both calcium and magnesium) and/or nitrogen. This experiment is a component of the USGS Nutrient Controls Study that is evaluating the effects of forest harvest intensity on water quality. Three plots received dolomite, three plots receive dolomite plus nitrogen, three plots received nitrogen only, and three plots served as untreated controls. Fertilization effects on soil and soil water chemistry are being monitored in conjunction with the response of canopy trees and understory. The goal of this experiment is to determine the degree to which soil conditions are controlling tree growth and health, which plays an important role in protecting water quality.Data on the response of overstory trees are not yet available, but the response of sugar maple seedlings provides preliminary indications of how nutrient relations are linked to growth of this species. Dolomite was added once in October 2003. Annual nitrogen additions were begun in early May of 2004. Mast seed production in the fall of 2003 resulted in an increase in numbers and biomass ($p < 0.01$) of sugar maple seedlings in all treatments (including control plots). By 2005, seedling biomass in the control and nitrogen treated plots returned to levels measured in 2003. By 2006, only the dolomite treated plots had seedling biomass higher than levels in 2003 ($p < 0.05$). Concentrations of calcium and magnesium, and pH, in the uppermost soil horizon (Oe), were positively correlated with the relative growth rate of the sugar maple seedlings in 2005. Lack of a growth response to nitrogen addition indicates that nitrogen availability is not the primary growth control of sugar maple seedlings. Increased growth from additions of dolomite and dolomite plus nitrogen, do suggest, however, that calcium and magnesium are limiting growth of sugar maple seedlings. However, the initial seedling response has not been sustained, possibly because the calcium availability was not sufficiently improved in the B horizon. As the seedlings grew, their root systems extended down into the B horizon where concentrations of calcium remained relatively low in the first 3 years following treatment. Baseline data collection continues in this study to enable sufficient data to evaluate the response of overstory trees.

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Simulating multiple functional groups of phytoplankton in Cannonsville Reservoir

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The 1-Dimensional (vertical resolution) hydrothermal water quality model (UFI 1-D) was created by Upstate Freshwater Institute (UFI). The model has a well developed hydrothermal and water chemistry formulation, includes a single phytoplankton group, and has been used to simulate nutrients and phytoplankton concentrations in reservoirs belonging to New York City Water Supply.The PROTECH (Phytoplankton RespOnse To Environmental CHange) model was created by Reynolds et al. (2001). It is a model focused on the biology of multiple phytoplankton functional groups, where each group has a set of characteristics allowing them to express complex behaviors similar to what is found in nature. Light, temperature and nutrient availability determines whether the different phytoplankton groups will settle, float, swim, or fix molecular nitrogen. Growth rates for each functional phytoplankton group are derived from phytoplankton size and volume characteristics together with light, temperature and nutrient availability in the reservoir.In this paper a hybrid model is described that was created by merging the UFI 1-D model with the formulation of phytoplankton functional groups in the PROTECH model. The resulting hybrid model combines a sound physical and chemical foundation with an advanced phytoplankton description.The hybrid model was compared to the UFI 1-D model. We found that the two models equally well simulated seasonal variations in total phytoplankton biomass. The hybrid model successfully simulated occurrence of major functional groups in the Cannonsville Reservoir.

Reynolds, C. S., A. E. Irish, and J. A. Elliott. 2001. The ecological basis for simulating phytoplankton responses to environmental change (PROTECH). Ecological Modelling 140:271-291.

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Implementation of the USEPA Methods Update Rule to 40 CFR 141: Field Filtration and Preservation

Gerard Marzec, James Broderick and Karen E.B. Moore, Ph.D., New York City Department of Environmental Protection

A study is being conducted to assess the impact of field preservation and filtration as required by the USEPA Methods Update Rule (40CFR 141 et al. 3/12/07). The rule modifies the testing procedures for sampling and analysis under the Safe Drinking Water Act and the Clean Water Act. Samples must be preserved and filtered within 15 minutes of collection where appropriate, as compared to the current practice of filtering and preserving samples upon arrival at NYCDEP Laboratories. These methods changes could be potentially significant with regard to the interpretation of historical data. Field conditions, such as filtration during anoxia in reservoir samples, could make comparisons with historical data difficult. An assessment of an appropriate field filtration procedure and an adequate number of side-by-side samples was performed. Filtration equipment was researched and tested to assure safe and efficient performance, and minimal background contamination under field conditions. Statistical methods were used to determine the appropriate sample size for the side-by-side comparisons. The variability within the existing data for each analyte was used to predict the number of samples needed, and to estimate the expected difference that could be determined between the laboratory filtered and the field filtered samples. By the end of the year, approximately 6000 samples for 13 analytes will be filtered from streams, reservoirs, releases and aqueduct monitoring sites. Sub-samples for reservoir and stream matrices will then be compared. Preliminary results will be discussed to illustrate some of the comparisons found to date.

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DEP's Watershed Water Quality Monitoring Program

James Mayfield, New York City Department of Environmental Protection

The 2007 Filtration Avoidance Determination (FAD) recognizes that New York City's Department of Environmental Protection (DEP) must periodically review and update its watershed water quality monitoring program. The FAD specifically states that: "As watershed protection programs develop and analytical techniques for key parameters change, it is necessary to reassess the monitoring program to ensure that it continues to support NYCDEP's watershed management program and that it can be used to evaluate the effectiveness of programs established under the FAD and MOA." DEP is currently in the process of reviewing its monitoring program and will produce an updated Watershed Water Quality Monitoring Plan in 2008.

The goals of DEP's Watershed Water Quality Monitoring Plan include providing an up-to-date, objective-based monitoring plan to help assess compliance and provide comparisons with established benchmarks. In addition, monitoring data will help evaluate the source and fate of pollutants and the effectiveness of watershed protection programs. Also, the plan must allow for a comprehensive evaluation of watershed water quality status and trends to support assessment of the effectiveness of watershed protection programs.

The 2009 Watershed Water Quality Monitoring Plan will be a comprehensive program, encompassing all areas of watershed monitoring, including aqueduct monitoring sites, streams, and reservoirs. Major areas of concern will include compliance sampling, FAD program evaluation, surveillance monitoring, and monitoring to support DEP's modeling efforts. The plan will be organized by specific objectives within these major areas. Historical data will be used to help guide the development of the plan.

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Chautauqua Lake Management Commission 2007 Lake Action Plan

David McCoy and James Rupert EIT, TVGA Consultants

Chautauqua Lake is a significant environmental and economic resource for Chautauqua County, and for Western New York. Chautauqua Lake is a Class A water body that serves as the drinking water supply for the Chautauqua Institution and a number of small public and private water systems. The health of the lake has been negatively impacted by excess sedimentation, excess nutrient levels and submerged aquatic vegetation. The Chautauqua Lake Management Commission selected TVGA Consultants (TVGA) to provide watershed assessments, programmatic and site specific measures to reduce controllable erosion and sedimentation, sources of nutrients and improve stormwater management practices within the Chautauqua Lake watershed. The work was divided into subtasks, which included:

TVGA worked with local government (towns and villages within the Chautauqua Lake watershed) and used GIS data collection techniques to assess streams in over 375 locations within the 180-acre Chautauqua Lake Watershed. Each of the twelve major drainage sheds that compose the Chautauqua Lake Watershed were assessed.

Following a review of the areas of erosion problems, TVGA prioritized these areas based upon a number of factors including the magnitude of the problem, the feasibility of and timetable for implementing corrective actions, and the probable order of magnitude cost of said actions. TVGA then prepared preliminary design plans for stream restoration, bank stabilization and wetland augmentation projects. Projects involved utilization in-kind municipal and volunteer services for construction where possible.

A model inter-municipal agreement to facilitate the provision of technical support to local government was developed by TVGA. TVGA assisted with the implementation of the agreements and designated an engineer and scientist to work with each municipality during the design, review and construction phases of private developments and public works projects.

TVGA presented a series of educational seminars for local government representatives including highway department personnel, code enforcement officials, and review boards. These seminars focused on best management practices for erosion and sediment control, stormwater management and pollution prevention/good housekeeping for municipal operations, roadway deicing and ditch restoration techniques. TVGA worked with local government to coordinate and oversee storm water and erosion control demonstration projects. This included the review of previously developed plans and/or the development of preliminary designs for new projects, and the coordination and oversight of construction activities to be performed by municipal, volunteer or public/private partnerships.

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Trends in Deposition and Stream Water Chemistry in the Catskill Mountains

Michael McHale, Ph. D., Douglas Burns, Gregory Lawrence, Ph. D. and Peter Murdoch, U.S. Geological Survey, Angelika Winner, University of Freiburg

The Catskill Park in the southeast of New York receives some of the highest rates of acid deposition in the United States. Consequently streams in the region have low acid neutralizing capacity (ANC) and experience episodic acidification and in some cases are chronically acidified. Although acid deposition has decreased during the last two decades, there has been no corresponding increase in stream water pH. This study was conducted to identify trends in stream water, soil water, and deposition and investigate interactions among chemical species that might shed light on the apparent disconnect between trends in atmospheric deposition and stream water concentrations. The period of study included water years 1991 to 2007; the water year is defined as (Oct 1 - Sept. 30).Five watersheds were included in the study, Winnisook, Biscuit Brook, and Tison's Creek, all tributaries of the Main Branch watershed, and Rondout Creek (RC), a small watershed adjacent to Tison's Creek. The Neversink River watershed is characterized by steep slopes, thin till and soil cover, a slow rate of bedrock weathering, and a short growing season. These watersheds are 99% forested; vegetation is dominated by American Beech, Sugar Maple and Yellow Birch.There was no significant decrease in the sum of base cation concentrations for most of the study sites (significant for magnesium and potassium, but not for calcium and sodium) and there was no significant increase in ANC for four of the five study sites. In addition, no significant trend was observed for nitrate concentrations in precipitation or in stream and soil water. These results contrast with previous studies which showed increasing trends in ANC and decreasing nitrate concentrations for Catskill streams. The addition of more recent data appears to have negated those trends. Trends in stream water magnesium and silica concentrations, as well as relations between mean annual concentrations of those solutes suggest that there has been a decrease in the weathering rate as a result of decreases in sulfate deposition.

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An Evaluation of BMP Removal Efficiency in the Kensico Reservoir Watershed

Paul Muessig, Michael Powell, Jon Trombino, EA Engineering, Scinece, & Technology, John Canning, NYC Department of Environmental Protection

Removal efficiencies of total suspended solids, turbidity, total phosphorus, and fecal coliform were evaluated for four Best Management Practice structures (BMPs) in the Kensico Reservoir watershed. The evaluation was conducted using paired influent and effluent monitoring data collected during at least 10 storm events. The BMPs consisted of two retention ponds, a wetland meadow, and a sand filter. The evaluation followed guidance provided in U.S. EPA's Urban Stormwater BMP Performance Monitoring guidance, including paired statistical comparisons of influent and effluent concentrations, Efficiency Ratios, and Effluent Probability Plots. In general, all four BMPs demonstrated a significant reduction in total suspended solids, turbidity, and phosphorus concentrations between the influent and effluent. For most constituents, the removal efficiency was limited at low influent concentrations, but improved as influent concentration increased. The retention ponds, and wetland meadow BMPs were found to be effective at fecal coliform removal, but only for influent concentrations exceeding 100 cfu/100 mL. The sand filter BMP was found to be ineffective at fecal coliform removal. For all four BMPs, fecal coliform concentrations in the effluent generally increased when influent concentrations were less than 100 cfu/mL.

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Potential Effects of Climate Change on New York City Water Supply Quantity and Quality: An Integrated Modeling Approach

Donald Pierson, Ph. D. Elliot M. Schneiderman and Mark S. Zion, NYC Department of Environmental Protection

NYC DEP is taking an integrated modeling approach to estimate the effects of future climate changes on the quantity and quality of the New York City Water Supply. The modeling project utilizes climate change projections as input to an integrated suite of models including watershed hydrology and water quality models, a water system operations model, and reservoir hydrothermal and water quality models.
At this time, predictions of future climate for the northeast U.S. generally indicate greater annual precipitation and increased temperatures compared to current climate conditions. These climate changes could potentially produce longer growing seasons, longer periods of summer low flow, earlier snowpack melting, greater frequency of high streamflow events, differences in proportion of streamflow due to overland flow, shifts in the timing of sediment and nutrient delivery to the reservoirs, and changes in the timing and intensity of reservoir thermal stratification.

The integrated modeling approach is used to better understand how the interplay of these potential changes will effect the NYC Water Supply System. Various future greenhouse gas levels and different climate models are used to produce a range of possible future climate scenarios. These scenarios provide input to the modeling system. Integrated models incorporate feedbacks between watershed, reservoir, and system operations, and thus provide a framework for quantifying and better understanding the interdependent effects of climate changes on flows and loads entering the reservoirs, reservoir water quality, and water system demand and operations.

Three initial areas of investigation include: overall quantity of water in the West-of-Hudson water supply, turbidity in the Schoharie Reservoir and eutrophication in the Cannonsville Reservoir. Preliminary model simulations are presented that demonstrate how the integrated models are used to investigate climate change effects. To place the results in the context of DEP_s water supply concerns, various measures of water system quantity and quality include statistics of drought indicators, frequency of occurrence of turbidity limits and frequency of threshold chlorophyll and phosphorus concentrations.

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Advanced Modeling Tools for Evaluating Catskill Turbidity Control Alternatives

Grantley Pyke, P.E., Hazen and Sawyer ,Steve Effler, Ph.D., P.E. , Upstate Freshwater Institute, Daniel Sheer, Ph.D., P.E., HydroLogics and David Warne, NYC Department of Environmental Protection

In order to protect and improve the quality of its unfiltered drinking water supply, NYCDEP has undertaken the Catskill Turbidity Control Study. Though the Catskill watershed generally provides very high quality water, peak runoff events mobilize natural clay deposits in stream banks and channels, and contribute to periodically elevated turbidity levels in Schoharie and Ashokan Reservoirs.

Phase III of the study includes conceptual design and evaluation of a wide range of structural alternatives at Ashokan Reservoir, including improvements to existing intake facilities, a new intake facility, an in-reservoir baffle wall, and operable weirs. In addition, operational measures for optimizing management of the multi-reservoir system to meet water supply and water quality objectives are also considered. This presentation focuses on the innovative reservoir modeling framework that was developed to evaluate the water quality benefits of these alternatives.

The modeling framework consists of water quality models of Schoharie, Ashokan, and Kensico Reservoirs, linked with a system model of the entire NYC reservoir system and Delaware River basin. The water quality models (CE-QUAL-W2, Upstate Freshwater Institute) are rigorously tested two-dimensional hydrothermal models that explicitly simulate turbidity levels in the reservoirs. The system model (OASIS, HydroLogics, Inc.) simulates the daily routing of water throughout the reservoir system, subject to release requirements, physical constraints, and operating rules.

The linkage between water quality models and a system model allows the water quality benefits of structural alternatives and modified operating rules to be simulated over a long (57-year) period, thus capturing a wide range of environmental forcing conditions and providing a robust analysis of long-term performance. This modeling framework also accounts for the dynamic interaction between how a reservoir is operated and the water quality that is available for withdrawal.

This presentation reviews the modeling framework and demonstrates how it is a valuable tool for evaluating major structural alternatives and for developing reservoir operating rules that improve raw water quality while balancing water supply reliability and environmental release objectives.

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Economic Impact to the NYC Watershed Community by the NYCDEP Wastewater Treatment Plant Upgrade Program

Robert Ravallo, New York City Department of Environmental Protection

As part of the MOA, the City agreed to fund the eligible costs of designing, permitting and constructing upgrades of all non-City-owned wastewater treatment plants (WWTPs) in the watershed. For the purposes of this program, "Upgrades" mean equipment and methods of operation that are required solely by the WR&R, and not by federal or State law. The City further agreed to pay the annual costs of operation and maintenance of the upgraded facilities.

The capital portion of this Program is over $400 million. The annual cost for operation and maintenance (O&M) of the upgraded facilities once all are upgraded is over $16 million.

Both of these activities, capital and O&M, have had an impact on the local economies in the NYC Watershed Community.

The presentation will quantify where dollars have been spent/where jobs have been created.

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Emergency Flood Response Holliday Brook Stream Restoration

Christakis Roumbas, Tiffany Bright and Sandeep Mehrotra, Hazen and Sawyer, P.C.

On June 20, 2007 flash flooding in Upstate New York, specifically in the NYCDEP operated New York City watershed, the principal supply source of NYC's water, caused an unprecedented level of water in the Pepacton Reservoir watershed. Post-storm, NYCDEP inspections of these roads and streams revealed that flood waters overflowing Holliday Brook stream caused severe bank erosion that washed-out parts of the road and adjacent roadway embankment at Holliday Brook Road (a.k.a. NYC Road 2D). More concerning, was the substantial degradation of Holliday Brook's natural channel and floodplain as well as deposition of significant debris and potentially hazardous material in and around the channel, thus contributing to the degradation of waters entering the New York City's water supply system at Pepacton Reservoir
The debris and potentially hazardous material located in and around the channel posed a direct environmental danger to the local wildlife, especially fish which travel through this brook. Also, the location and quantity of the debris along with the potentially hazardous material could pose a potential health threat to the New York City drinking water supply by contaminating the Pepacton Reservoir. To help reduce the pressing environmental and health hazards, on June 21, 2007 NYCDEP in coordination with Delaware County and National Guard, started to remove and stockpile the debris from the stream channel. Realizing the full extend of the damage and the associated negative environmental, health and safety effects, on June 25, 2007 NYCDEP Commissioner, Emily Lloyd, commissioned a Declaration of Emergency for the road and stream located at Holliday Brook. The Declaration of Emergency was not only justified by the extensive damage to Holliday Brook, but by the amount of debris and potential structural and environmental damage that would have resulted from nonintervention. Holliday Brook flows directly into the Pepacton Reservoir via a culvert under NYS Route 30. Without immediate debris removal, as well as channel and bank stabilization, undermining of the roadway pavements and potential damage to NYS Route 30 would off resulted. Further damages to NYS Route 30 would have rendered the road unsafe for use creating significant danger to drivers that access the roadway. However, the primary and most immediate concern was the environmental impact on not only Holliday Brook and NYC's water supply. The flood caused substantial degradation to Holliday Brook's natural channel and floodplain and deposited significant amounts of debris and potentially hazardous material in and around the channel. If immediate debris removal and restoration were not performed, the stream would continue to erode, causing increased turbidity flowing directly into Pepacton reservoir, thus degenerating water quality. This situation could have been exacerbated in the event of another flash flood.

In response to the Declaration of Emergency, NYCDEP accelerated design efforts and preparation of contract documents to reconstruct Holliday Brook and refurbish the Holliday Brook Road .

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