New York City UV - The Light before the End of the Tunnel

Donna Potorti, P.E., DEE,* Christopher R. Schulz, P.E., DEE*, Richard J. Fahey, P.E., DEE†, Michael Borsykowsky, P.E., Deborah E. Keesler, P.E.‡, and Paul D. Smith, P.E.‡.

*Camp, Dresser and McKee; †Hazen and Sawyer, P.C.; ‡New York City Department of Environmental Protection

* Corresponding Author: Christopher Schulz, SchulzCR@cdm.com

ABSTRACT

New York City is moving forward with the design of the world's largest drinking water disinfection facility – a 2 billion gallon per day ultraviolet light (UV) facility to treat unfiltered water from the Catskill and Delaware reservoir systems. The UV facility will be designed to provide up to 99.9 percent (3-log) inactivation of *Cryptosporidium* to meet future regulatory requirements for unfiltered water supplies. This paper presents an overview of how UV was selected for this water supply and highlights the key design issues for the project including: UV system design criteria, technology selection, performance validation requirements and site selection.

INTRODUCTION

New York City has the largest unfiltered surface water supply in the world. Every day, about 1.3 billion gallons (4.9 billion liters) of water from this vast system is delivered to 9 million consumers - 8 million New York City residents and 1 million upstate consumers. New York City is fortunate to possess what is arguably the greatest metropolitan water supply system in the world.

Foresight by our predecessors, as far back as the mid-1800s, has provided a system with exceptional source water quality, and is almost entirely supplied by gravity. The New York City water supply includes three upstate reservoir systems: the Croton, Catskill (Figure 1), and Delaware. Together these supplies include 19 reservoirs and three controlled lakes, with a total available storage capacity of approximately 580 billion gallons (2,195 million liters).

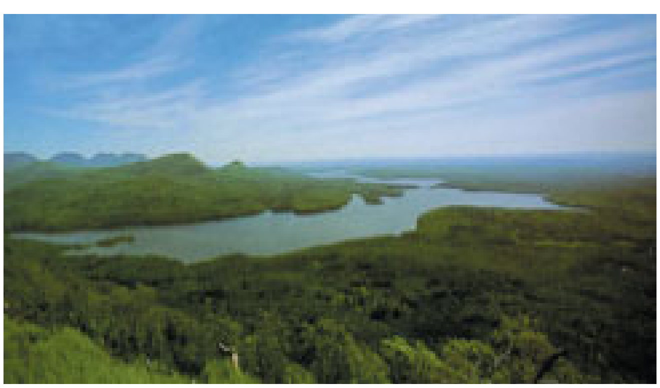

Figure 1. Ashokan Reservoir of the Catskill System

The New York City water supply system (Figure 2) includes a 1,969-square-mile (5,100-square-kilometer) watershed across eight counties north and west of the City. The three water systems were designed and built with various interconnections to increase flexibility by allowing the exchange of water from one system to another. Water is conveyed to the City from the Croton, Catskill, and Delaware reservoirs by gravity through large aqueducts and two balancing reservoirs. Water is distributed to the City through three tunnels and distribution reservoirs. Overall, the New York Water Supply system contains 300 miles (480 km) of aqueduct and tunnel.

EXISTING TREATMENT

Historically, the water supply from all three of New York City's reservoir systems is of high quality and has received minimal treatment (primarily disinfection with chlorine). The City is currently under a Consent Decree with the United States Environmental Protection Agency (EPA) to build filtration facilities for the Croton System, which provides 10% of the normal daily supply. In 1993, the EPA issued a Filtration Avoidance Determination (FAD) to New York City for the Catskill and Delaware systems, which provide 90% of the City's daily demand. The determination was related to compliance with federal drinking water regulations, and allowed the City to extend its filtration avoidance program for the Catskill and Delaware water systems.

Under the terms of the Catskill and Delaware determination, the City was required to pursue both a comprehensive watershed protection program and planning/design of filtration facilities, on parallel tracks to comply with Surface Water Treatment Rule (SWTR) requirements. In response, New York City entered into an agreement with the joint venture (JV) of Hazen and Sawyer/CDM and developed a program for meeting the goals of the SWTR. The program includes both non-filtration activities to ensure filtration avoidance, and an agreement to plan for the world's largest filtration facilities, should there be a future need for a water treatment facility.

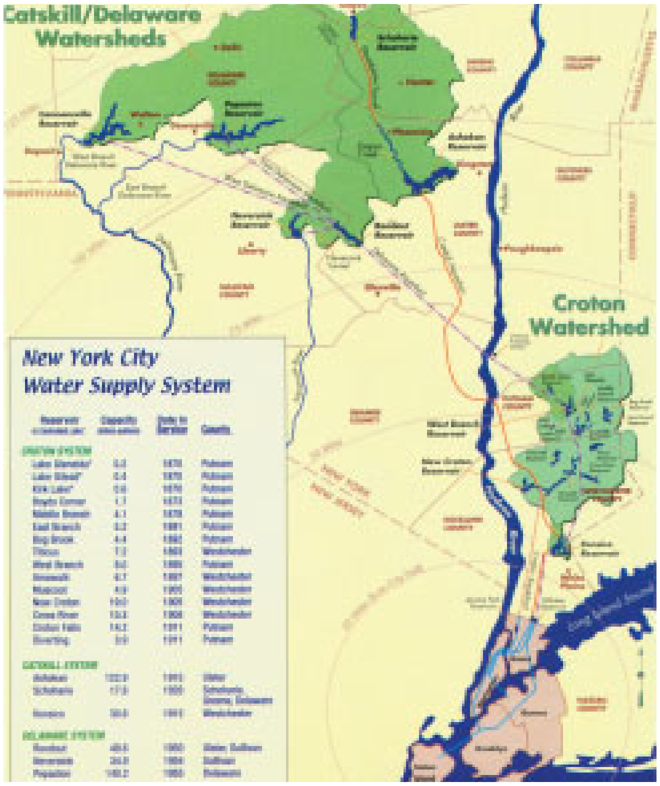

Figure 2. New York City Water Supply System.

As a result of the ongoing success of the watershed protection program and continued excellent water quality of the Catskill and Delaware systems, EPA has granted New York City relief from the remaining filtration planning/design requirements of the FAD, including the completion of the filtration facility's final design. In place of this deliverable, the City committed to initiating an in-depth look at UV disinfection as a possible alternative to filtration for the Catskill and Delaware water systems.

In 2001, the City completed a feasibility study and determined UV disinfection to be appropriate for providing disinfection levels necessary to meet anticipated regulations. EPA has concurred that UV disinfection is feasible for the Catskill and Delaware systems, and the City is presently implementing the preliminary design of a UV disinfection facility for both systems.

MAJOR DESIGN CONSIDERATIONS

The City has been faced with many design challenges - UV equipment capacity, lamp technology, electrical system reliability, and performance validation - in addition to regulatory compliance without clear targets for dose requirements. UV disinfection has never been used at a capacity even within an order of magnitude of 2 billion gallons per day (bgd) [7.6 billion liters per day (bld)]. In order to reduce the size, construction cost, and operational difficulties, the City decided to evaluate UV units larger than any that had been built at the inception of the project. Each UV unit will be sized to handle 40 million gallons per day (mgd) [150 million liters per day (mld)] - more than twice the size of any existing UV unit, and comparable in size to many of the largest existing UV facilities. Not surprisingly, UV units of this size also present a challenge for performance validation.

UV SYSTEM DESIGN CRITERIA

Given the planning horizon for a project this size, the City has continuously been faced with making treatment decisions amid an ever-changing myriad of regulations, technologies, and public perceptions. The inactivation of viruses and waterborne pathogens such as *Giardia* and *Cryptosporidium* is an essential component of New York City's overall drinking water treatment process. Currently, the City utilizes free chlorine as both a primary and secondary (residual) disinfectant. While chlorine does provide inactivation of *Giardia* and viruses, it is not effective against *Cryptosporidium* and other chlorine-resistant pathogens.

The proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) will require more stringent inactivation treatment for *Cryptosporidium* for unfiltered water supplies. Unfiltered systems, such as New York City's will be required to continue to meet filtration avoidance criteria and provide treatment to achieve 4-log virus, 3-log *Giardia*, and 2-log *Cryptosporidium* inactivation using a minimum of two disinfectants. The Catskill and Delaware UV disinfection facility will be designed to meet these requirements with UV and chlorine as the two required disinfectants.

New York City has previously established conservative *Cryptosporidium* removal/inactivation goals as part of the filtration planning and preliminary design. Similarly, the City has adopted a conservative dose of 40 mJ/cm^2 to achieve at least 3-log inactivation of *Cryptosporidium*. This goal will provide flexibility should greater inactivation be desirable in the future either for *Cryptosporidium* or other emerging pathogens.

EQUIPMENT CAPACITY

An evaluation was performed to determine the optimum capacity of individual UV units to disinfect the Catskill and Delaware water systems. Unit capacities ranging from 20 mgd (75 mld) to more than 100 mgd (380 mld) were considered in the evaluation for systems containing either low pressure high output (LPHO) or medium pressure (MP) UV lamps. The evaluation concluded that significant cost benefits existed with 40 mgd (150 mld) units as compared to 20 mgd (75 mld) units, while reduced cost benefits were apparent for units larger than 40 mgd (150 mld) (see Figure 3). Full-scale validation of UV units was also an important factor in evaluating a

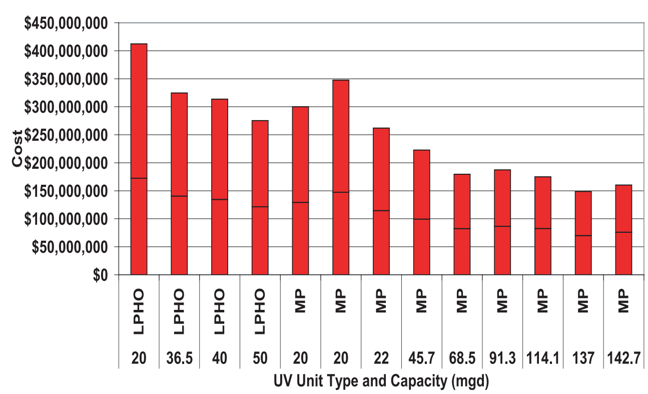

Figure 3. Cost Comparison by Unit Capacity

preferred capacity, since the art and complexity of performing full-scale validation of a unit increases with capacity. The ability to manufacture the large units was also a concern. Based on the equipment analysis and discussions with several major UV equipment suppliers, a capacity of 40 mgd (150 mld) was selected for the UV units. A total of 56 UV units are required for the Catskill and Delaware UV disinfection facility.

EQUIPMENT TECHNOLOGY

A major challenge has been to identify manufacturers capable of producing a UV system with a unit capacity of 40 mgd (150 mld), a size which, up to the start of the Catskill and Delaware design, had never been commercially available. During the UV facility's conceptual design, both LPHO and MP systems were evaluated and determined feasible for providing the disinfection level needed to meet anticipated regulations for *Cryptosporidium* inactivation. Considerable research and evaluation was conducted on the relative merits and drawbacks of the two systems. The evaluation process included a series of meetings with potential manufacturers and site visits to large operating facilities. For the Catskill and Delaware systems, MP and LPHO systems were considered to be about equal with respect to disinfection effectiveness, proven experience, space requirements (overall footprint), procurement flexibility and hydraulics, although each system offered its own unique set of advantages and disadvantages.

As part of the decision-making process, non-economic categories were tabulated and relative weights were applied in proportion to their importance. Within the non-economic criteria, maintenance efforts (lamp cleaning/replacement and electrical equipment replacement/testing), procurement flexibility, and sensor coverage/reliability (monitoring dose and lamp failure) were considered to be the most important with respect to evaluating the advantages and disadvantages of UV systems. Maintenance efforts involve long-term staff commitments and recurring costs, while sensor coverage and reliability affect regulatory compliance and the ability to keep a unit in service.

An economic evaluation was conducted to compare 30-year life cycle costs (capital and operations and maintenance) for both UV technologies. Weighing factors were applied to both the economic and non-economic criteria, and each type was scored against the weighted criteria. Input was solicited from several bureaus within the New York City Department of Environmental Protection (NYCDEP) to confirm the relative importance of the criteria from the NYCDEP's standpoint. The economic advantage of LPHO and its lower operating cost weighed in favor of LPHO, with non-economic factors being comparable. Overall, the decision for selection of one system over the other was very close, and it was necessary for the City to proceed with one system to avoid delays, additional design costs, and procurement difficulties. Although the LPHO system requires a greater number of lamp changes than a MP system, LPHO lamps are easier to replace. Additionally NYCDEP determined that this operation is routine, making it possible to readily train operators. The MP system on the other hand, requires less lamp replacement activity, but would involve other tasks that require more specialized personnel (such as electrical maintenance tasks and the operation/exercising of standby generators). A MP system also has higher operating costs and electrical power requirements (about 5 to 8 MW higher for the Catskill and Delaware system). Therefore, NYCDEP determined that the LPHO system was a better selection for the City.

To confirm the decision for LPHO, site visits to facilities with 20 mgd (75 mld) UV units of both types were conducted to gain further information and a better understanding of how both systems operate. Lamp and ballast replacements, access to units, and cleaning systems were observed. Many of the maintenance issues originally understood to require more effort for LPHO systems no longer appeared to be as critical. The site visits and NYCDEP's available manpower with respect to lamp/sleeve/ballast replacements (in comparison to electrical facility maintenance), reinforced the decision to proceed with the LPHO system.

Arrangements are presently being made to purchase UV units from two or possibly three manufacturers for full-scale validation at an independent validation facility in Johnstown, N.Y. Selection of one UV manufacturer will be made following the validation testing and will be dependent on successful testing combined with costs and non-economic factors.

PERFORMANCE VALIDATION

The performance of UV units requires verification that the appropriate level of pathogen disinfection will occur within a given set of operating parameters. For most commercially available UV units, the use of biodosimetry (bioassay) testing can be used to confirm the delivered UV dose of the unit under varying flow and water-quality conditions. At the start of the Catskill and Delaware facility's design, logistical difficulties existed in performing full-scale bioassay testing of UV units greater than 20 mgd (75 mld), and larger-scale UV units were unproven as to inactivation effectiveness. For this reason, the City considered additional methods, such as computer modeling to validate the performance of larger UV units.

The goal of the computer modeling is to demonstrate that integrated models of UV light intensity distribution (LID) and computational fluid dynamics (CFD) used to simulate the distribution of flow through the UV units will effectively predict UV unit performance (see Figure 4). The coupled LID and CFD models will predict performance of 20 mgd (75 mld) UV units based on a comparison with biodosimetric results. Calibrated models will then be used to predict the performance of 40 mgd (150 mld) UV units, which have not yet been validated with biodosimetry.

However, with the increasing appeal of UV disinfection technologies for drinking water applications, performance validation has quickly become a requirement for acceptance of commercial systems. HydroQual, Inc. operates a centralized UV validation facility at the Gloversville-Johnstown joint wastewater treatment facility in Johnstown, N.Y., funded by the New York State Energy Research and Development Authority and several subscribing UV manufacturers. The City has selected the Johnstown facility as the location to perform its anticipated validation testing. More than one LPHO unit will be validated at this facility, and only one manufacturer will be selected to proceed with the construction of the additional units required for the full-scale UV disinfection facility. Selection will be based on system performance and several evaluation criteria. A correlation of model predictions and bioassay testing will be evaluated for the selected system once the testing is complete.

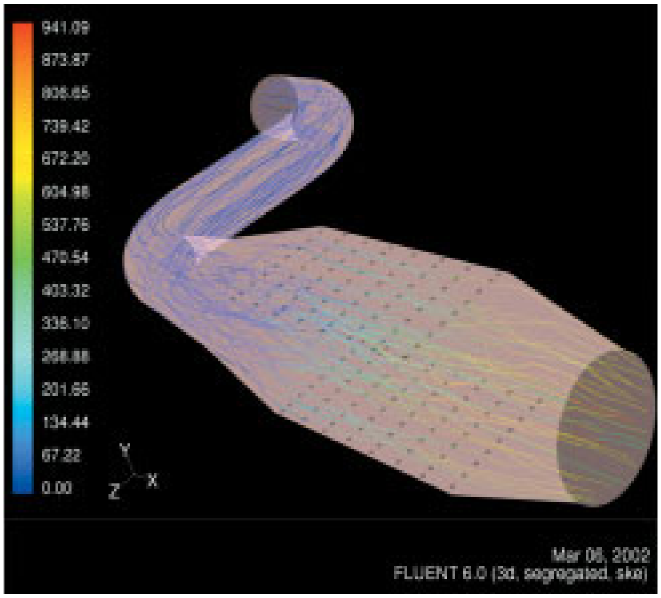

Figure 4. Model Output Showing Particles Tracked Trough UV Unit to Calculate Applied UV Dose.

UV FACILITY SITE

The proposed site for the UV facility is on city-owned property within Westchester County, N.Y. The City purchased the property in the early and mid-1900s and constructed the Catskill and Delaware aqueducts with connections in anticipation of the potential future need for a water treatment facility. To increase the dependability of the New York City water supply system, a 2.5 mile (4 km) section of the Catskill Aqueduct upstream of the UV facility will be pressurized so that it can serve as a second raw water conduit (in addition to the Delaware Aqueduct). Pressurization of the Catskill Aqueduct may also permit increased future flow to the UV facility.

To determine the feasibility of pressurizing the Catskill Aqueduct, the City performed an intensive aqueduct inspection program, which included non-destructive testing (seismic/ultrasound, electro-magnetic resistivity, ground penetrating radar), core boring and testing with fiber-optic probing of bore holes, and other appropriate inspection techniques. After evaluating possible methods, such as grouting and inserting a lining, a pressurization program will be formulated. The program will include the design and implementation of selected methods for converting the gravity, non-pressurized aqueduct to a pressurized tunnel.

TEAMWORK LEADS TO SUCCESS

By applying recent scientific findings on the effectiveness of UV disinfection in drinking water applications, coupled with innovative design decisions, the City and the JV have significantly contributed to protecting the public health of 9 million consumers. The City has received the New York Association of Consulting Engineers Diamond Award (First place) for the planning and conceptual design of the world's largest UV disinfection facility.