Silver & Green

North Carolina water utility ups its capacity with advanced process technologies

By Steve London

In February 2010, the Dempsey E. Benton Water Treatment Plant (WTP) added 16 million gal per day (mgd) of capacity to the water utility operated by the city of Raleigh, N.C. The project, situated on 55 acres in the neighboring town of Garner, N.C., represents a milestone in the utility's history.

It presents a model of multiple advanced process technologies that include two-stage filtration and triple disinfection in a contemporary building designed for Leadership in Energy and Environmental Design (LEED) Silver certification by the U.S. Green Building Council. The new facility supplements the 86-mgd capacity of the conventional-style E. M. Johnson WTP in serving 175,000 service connections in Raleigh and six neighboring municipalities in eastern Wake County. The plants offer a total of 102 mgd, but this will increase with envisioned expansions.

"It seemed that Raleigh started changing overnight in those years before the new plant," said Kenneth Best, superintendent of Raleigh's two WTPs. "Drought conditions between 2005 and 2008 really changed our daily peak demand, and it was evident that our one WTP was being challenged, especially during summer months. We started working with our engineering consultants to design the second plant. Particularly valuable input came from our program heads and operator staff by way of open panel discussion about all issues experienced at the existing plant to ensure these would be avoided in the new facility's design."

Award-Winning Work

The Dempsey E. Benton WTP, which can be expanded to 40 mgd, was designed by architectural and engineering teams within Arcadis G&M of North Carolina Inc. Archer Western Contractors, part of the Chicago-based Walsh Group, built the project between April 2007 and February 2010. The project scope included the plant, a 5-mgd water storage reservoir, renovation of a 1950s pump station, a backwash storage tank, standby generator facilities and modification to an existing gate control structure.

The disciplined project management was honored as the Best Utility Project in 2010 by the Carolinas Associated General Contractors. The exemplary teamwork under the leadership of Archer Western completed the $97.5-million project on schedule and $7 million under budget. The award specifically cited the project's 524,000 man-hours without a lost-time incident and Archer Western's reduction of the original bid from $105 million to $90 million, which helped the city maintain the desired bond rates.

The teamwork delivered yet another dividend two years into construction. With design and specifications complete and construction underway, the utility added a newly enacted LEED certification requirement to the main building. It is now a showcase demonstrating then-newly adopted energy conservation and environmental initiatives for all city-owned buildings. A 250-kW solar energy system at the already existing E. M. Johnson WTP presents another example of the municipal commitment to green operations.

The construction of a second treatment facility delivered two benefits to the water utility. In step with the increased capacity, the utility gained another reliable raw water source in a separate watershed. The plant can tap the combined usable raw water in Lake Benson, the primary source, and Lake Wheeler, located upstream and capable of recharging the smaller lake downstream. This creates an operational backstop against extended drought or other emergencies.

The city was fully acquainted with Lake Benson as a raw water source. The utility had drawn from the 500-acre lake for its first WTP, which operated for more than 30 years. In 1987, the plant closed in favor of expanding the newer E.M. Johnson WTP, which draws from a different reservoir and watershed. The city, however, wisely preserved the water supply classification of the Swift Creek/Lake Benson watershed for future contribution to the municipal water supply system. The storage in Lakes Wheeler and Benson totals an estimated 2.3 billion gal.

"We learned a lot during the design of the Dempsey E. Benton WTP project," Best said. "Farsighted planning is a must because it takes several years of environmental assessments. Management here continues to prepare for yet a third water source called Little River. We are concerned about the watersheds contributing to our source water because polluted runoff can add extremely high costs for treatment and regulatory compliance."

Therefore, the utility's in-house lab consistently tests the quality of its current and projected sources, Best said. The resulting database helps to identify factors affecting any changes in source water quality that might affect the design of a future treatment process.

The Dempsey E. Benton facility is considered the cornerstone of the city's initiative to build environmentally conscious buildings. The design criteria was upgraded to LEED Silver Certification by the U.S. Green Building Council when already underway.

Left: The ozone system consists of two ozone generators. The units alternate in operation with one duty unit online while the other remains on standby. Right: The use of UV technology for drinking water disinfection represents a trend away from reliance on chemical disinfection and will enable the new plant to comply with more stringent federal disinfection byproduct rules.

Population Growth

Best has seen a lot of changes during his 22 years in the field. The Raleigh service area includes the Research Triangle, a name forged into the public consciousness with the creation of Research Triangle Park in 1959. The three research-oriented universities in the area have attracted numerous high-tech and pharmaceutical companies, and other enterprises to the region. The population in Raleigh and the surrounding Triangle, now at more than 400,000, ranks among the nation's fastest-growing metropolitan areas, with a 97% population growth expected by 2025.

Urban runoff contributes contaminants, organics and high turbidity to the relatively shallow Lake Benson. The turbidity can reach 120 NTU, which played a major factor in the selection and exclusion of the plant's process technologies, according to Shannon Dorsey, P.E., associate project manager with Arcadis. The process train begins with ozonation, a technology also in place at the existing plant, passes through two-stage filtration and ends with ultraviolet (UV) disinfection and chlorination at release into the distribution system.

Water Treatment

ITT Water & Wastewater supplied Wedeco-brand ozone and UV systems. The first link in the chain applies a high-performance ozone system as an extra treatment barrier, reduces the amount of chemicals in the process, facilitates TOC removal by the two-stage filtration, and oxidizes iron and manganese in the raw water.

Although not as widely accepted yet as in Europe and Asia, the use of ozone for water treatment has gained increased application in North American plants that draw their raw water from surface sources such as rivers, reservoirs, canals and smaller lakes subject to seasonal taste and odor (T&O) or other indigenous quality issues. With the debunking of misperceptions about operational issues, including higher cost and complexity, ozone systems have steadily gained interest from the water treatment industry over the past 15 years. Much of this can be attributed to advancements in electrical power supplies, optimization of ozone systems to reduce operation and maintenance costs, and technological advancements in the equipment that can produce ozone from concentrated oxygen feed gas more efficiently than the treated ambient air feed gas used in the past.

The ozone system at the new plant consists of two ozone generators rated at 700 lb per day, each at 10% weight concentration with nitrogen boost and at 8% weight concentration without it. The units alternate in operation, with one as the online duty unit and the other in standby status. The incoming water receives a design dose of 4 mg/L at 20 mgd. There are two 62,380-gal pre-ozone contactors and twin 9,000-gal LOX tanks. An in-line flash reactor transfers ozone gas to the plant influent via sidestream solution injection with dispersion nozzles. Two contactor off-gas ozone gas destruct units—one active and one reserve—also are components of the system.

The system brings the raw water to 0.07 NTU combined filter turbidity versus the state maximum of 0.30 NTU.

Coagulation & Clarification

Following pre-oxidation with ozone, the water is coagulated with ferric sulfate to bind particles and organic material in the water. The coagulated material then is subjected to a high-rate solids clarifier technology that combines flocculation and clarification in one basin. The system combines the principles of a sludge blanket and solids contact system that enhances removal of turbidity, color, TOC and other undesirable constituents. After the pretreatment clarification process, the water advances to filtration.

Filtration

The high turbidity of the source water and maintenance and life-cycle constraints imposed on microfiltration led to the inclusion of granular activated carbon (GAC) roughing filters ahead of the final filtration. The two-stage design at the Benton plant removes more iron, manganese, fine particulates and pathogens, according to Jessee Walker, facility manager at the new plant. Removing TOC reduces disinfection byproduct formation or total trihalomethanes (THMs), which average 24.35 µg/L versus the maximum 80 µg/L regulatory requirement. An average of 82.8% of the TOC is removed versus the 45% removal mandated by the state. HAA5 removal is registering 13.15 µg/L versus 60 µg/L to comply with state water quality rules.

"Consistently averaging 75% or higher TOC removal—and an average of 65% removal at our other plant—are critical in meeting state and federal regulations in the distribution system when you start looking at water age and other factors," Walker said.

He added that the Dempsey E. Benton WTP facility is the first in the nation to utilize the gravity upflow design intended to minimize pressure loss in the media and thereby conserve energy. The applied concept consists of upflow GAC filters followed by the traditional final filters with concrete bottoms, 12 in. of varied-size gravel overlaid with 12 in. of silica sand and a 15-in. top layer of anthracite coal.

Casting Light on Pathogen Removal

The Wedeco UV was only the second UV system installed in a North Carolina drinking water plant. This added barrier was included because of the technology's ability to kill microorganisms in the water by destroying their DNA. Although in operation at the new plant, North Carolina does not extend disinfection credits for UV as some other states do. The utility is hoping to change that rule in North Carolina.

"The design, assuming the state's acceptance of UV, was to then introduce chloramines in the 5-million-gal clearwell to reduce THMs and HAA5s," Dorsey said. "Once North Carolina credits UV disinfection, the chloramines will be introduced before the clearwell to reduce the potential formation of disinfection byproducts leaving the facility. Until then, free chlorine is used in the clearwell with a post-clearwell ammonia feed to form chloramines."

The plant has three trains (one a standby) rated at 10 mgd each, configured as five rows with 12 UV lamps in each row. The adoption of UV technology and movement away from exclusive reliance on chemical disinfection also will enable the plant to comply with the more stringent federal disinfection byproduct rules.

LEED Landmark

As previously noted, the plant building was two years into construction when the city decided to certify the building to LEED Silver standards. With this certification, the Dempsey E. Benton WTP could become the cornerstone of Raleigh's commitment to sustainable design in its future building programs.

This building is easily admired for the eye-riveting geometry of its arched standing seam metal roof and abundant glazing to admit natural daylight. The walls and roof are heavily insulated to complement the operation of the heating and air-conditioning system. Recycled materials found new life in the building's construction and in the waste products that were gathered, sorted and hauled away for remanufacture rather than disposal in a landfill. The building's interior provides a healthy work environment due to low-vapor finish materials, balanced lighting and temperature control. Environmental awareness even extends outside to the LED site lighting.

The new plant is the latest component of Raleigh's long-range water plan, including a planned expansion of the 86-mgd E. M. Johnson plant to 100 mgd and the potential for expansion of the new Dempsey E. Benton facility. A 10-mgd reuse system is under development for use in irrigation and industrial cooling towers. WWD

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