

Above: The pilot plant used by George Warren Fuller to determine the optimal treatment of Ohio River water at Cincinnati. Right: Named after former Greater Cincinnati Water Works director and AWWA past president, the Richard Miller Treatment Plant provides water to 1.1 million customers.



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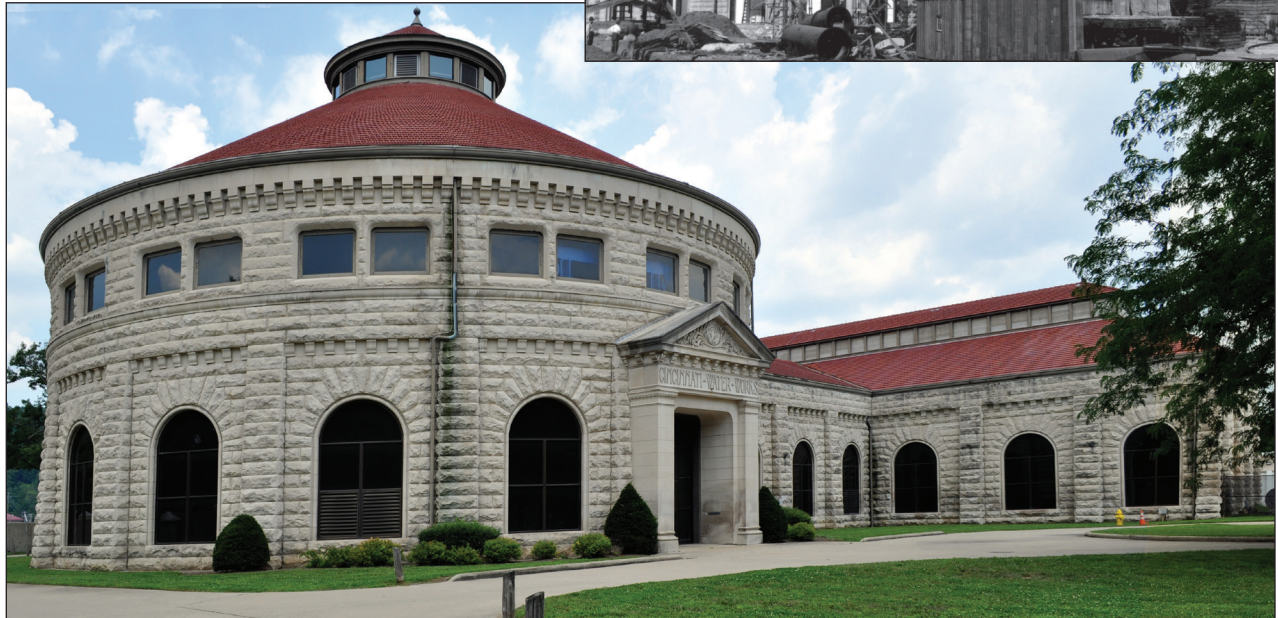
Cincinnati's Richard Miller Treatment Plant: Setting the Foundations for the Future

THE RICHARD MILLER TREATMENT PLANT, WHICH STARTED OPERATION MORE THAN 100 YEARS AGO, IS THE CROWN JEWEL OF THE GREATER CINCINNATI WATER WORKS AND THE PRIDE OF THE ORGANIZATION THAT HAS A HISTORY OF INNOVATIVE RESEARCH AND AN EYE TOWARD THE FUTURE OF WATER TREATMENT AND PUBLIC HEALTH.

Very possibly no other department of the City of Cincinnati possesses a more interesting history than the Water Works: not only from its special record, but because it is more closely connected with the development of the city, and illustrates its progress to a better advantage. This quote from Thomas J. Bell, assistant superintendent of the Cincinnati Water Works (CWW), Ohio, is certainly as accurate today as it was when originally published in CWW's 1880 *Annual Report*. It is reflective of how the history of this great utility has combined the innovation of its employees, cutting-edge research, and state-of-the-art facilities like the Richard Miller Treatment Plant (see the right-hand photograph on this page) to refine and improve treatment processes for the benefit of its water customers.

PUBLIC HEALTH AND THE NEED FOR CHANGE

At the end of the 19th century, Cincinnati was already a vibrant river city and a major hub of commerce in the Midwest. The nickname "Queen City of the West" truly fit, and according to the 1900 census, Cincinnati's population of 325,902 placed it among the top 10 largest cities in the United States at the time (Bureau of the US Census 1998). Despite the fact that the city was



Top left: The utility name and city seal are mounted at the entrance of the River Station. Top right: Construction of the River Station's conical steel roof. Bottom: Although the steam-driven pumps are no longer in use, the River Station is still a functioning raw water pumping station and supplies much of the Ohio River water for the Richard Miller Treatment Plant.

served by the oldest municipally owned water system in Ohio, water-borne disease was prominent, and outbreaks of typhoid (Ferrie & Troesken 2008) and cholera (Daly 2008) were commonplace in Cincinnati as well as most other large cities in the United States (Haines 2001). Figure 1 depicts the identified cases of typhoid in Cincinnati in the early 1900s and the number of deaths each year from the disease. As can be seen from the graph, before 1907 thousands of cases resulting in hundreds of deaths occurred each year. This public health tragedy, however, was about to change.

Public debate. The Ohio River formed the backbone of the city, and

the city relied on it as a source of commerce, transportation, and drinking water. In the late 1800s, basic sanitation concepts had not yet taken hold in most of the country, and the citizens did not yet fully understand the role that water has in the proliferation of disease. Raw sewage entered the waterways from upstream cities and from the growing eastern suburbs of Cincinnati and flowed into the river upstream of Cincinnati's intake (O'Toole 1990). Ever since the 1850s, there had been public debate about the role that the river played in transporting disease, with some advocating the need to move the intakes above the pollution and to provide

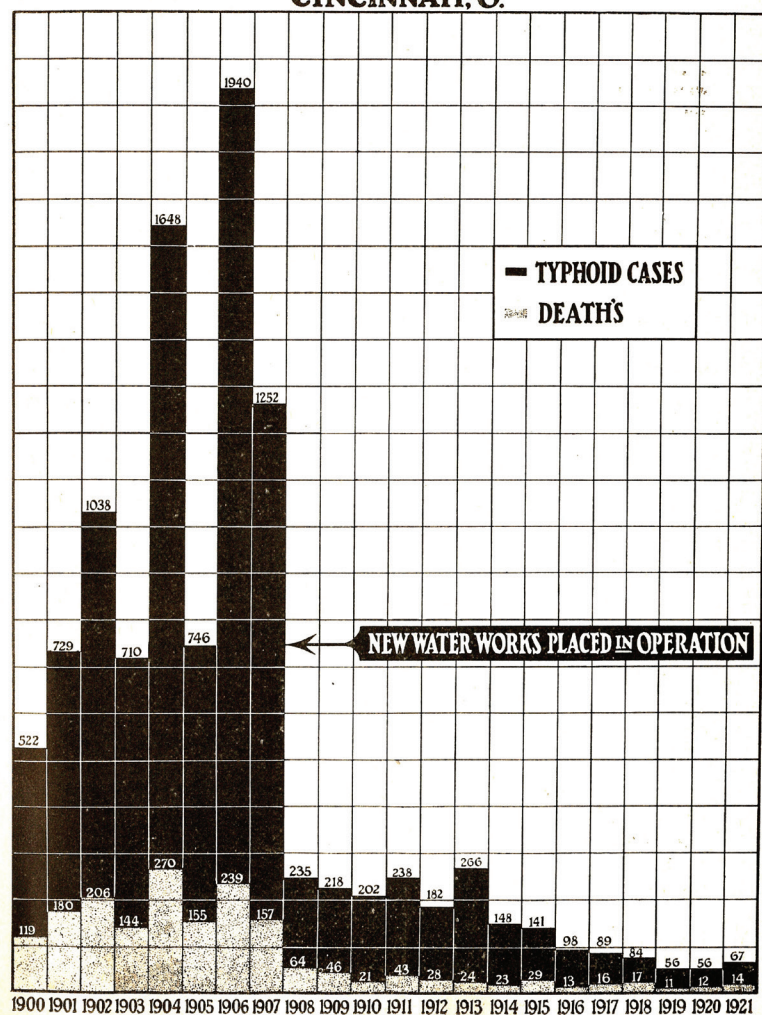
treatment to the water. Others contended that the Ohio River was as "pure as snow" and that the disease was a result of living conditions and vapors in the air (Ferrie & Troesken 2008, O'Toole 1990).

Finally in 1895 an evaluation conducted by the Ohio State Board of Health and the Cincinnati Academy of Medicine recommended constructing treatment works well upstream of the downtown area and conducting studies of the most effective settling and filtration system for use at the plant (Benzenberg 1909). In 1896 the chief engineer of the CWW submitted plans for the construction of the treatment works to the Ohio State Board of Health for

FIGURE 1 Typhoid occurrence in Cincinnati before and after the opening of the Richard Miller Treatment Plant in 1907

DIAGRAM SHOWS THE NUMBER OF CASES AND DEATHS FROM TYPHOID FEVER FROM 1900-1921

CINCINNATI, O.



approval. These plans included a raw water pumping station, mains, and an open clearwell, but detailed plans for the filtration system were not included at the time, pending the conclusion of filtration studies. Nevertheless, construction began on the plant in 1898.

Fuller's pilot studies. The "English system" of filtration (what we now call slow sand filtration) was used in many cities in the United States and

Europe (Stein 1919), but it was recognized that the "Ohio River water at Cincinnati differs materially in its characteristics for about six months in the year" compared with waters that were successfully treated by this process (Fuller 1899) and that intensive studies were needed to determine the most effective and efficient means of treating the water. On Dec. 3, 1897, George Warren Fuller was appointed to take charge of these

studies and oversaw the construction of a 100,000-gpd pilot plant in Eden Park, overlooking downtown Cincinnati (see the left-hand photograph on page 46).

The pilot plant consisted of four 100,000-gal steel sedimentation basins, 15 11.8-ft-diameter wooden tanks for filters, and a laboratory. The plant was supplied with raw Ohio River water from the same pumps that pumped untreated river water to the city. This pilot plant allowed Fuller's team to examine different types of sand, bed depths, and flow rates, as well as pretreatment configurations for coagulation and sedimentation of water in preparation for filtration. These studies commenced on Mar. 28, 1898, and ran until Jan. 25, 1899. A full report was submitted in February 1899 with the conclusion that a mechanical filtration system (also called the American filtration system at the time but now known as rapid sand filtration) was the most efficient and effective treatment system for treating Ohio River water at Cincinnati (Fuller 1899). These recommendations were accepted by the board of trustees of CWW, and plans for this filtration system were approved for inclusion in the plant that was already being constructed. The total cost of construction and operation of the pilot plant was \$38,260.29, which is equivalent to approximately \$1,093,000 in 2015 dollars.

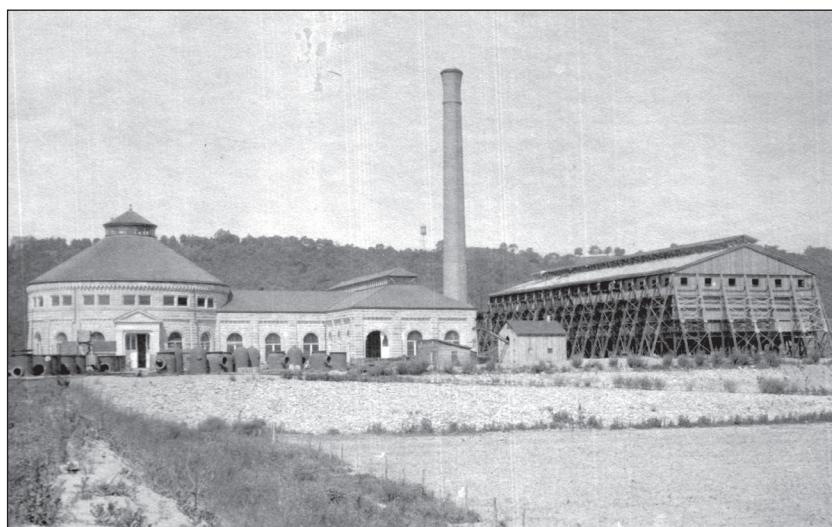
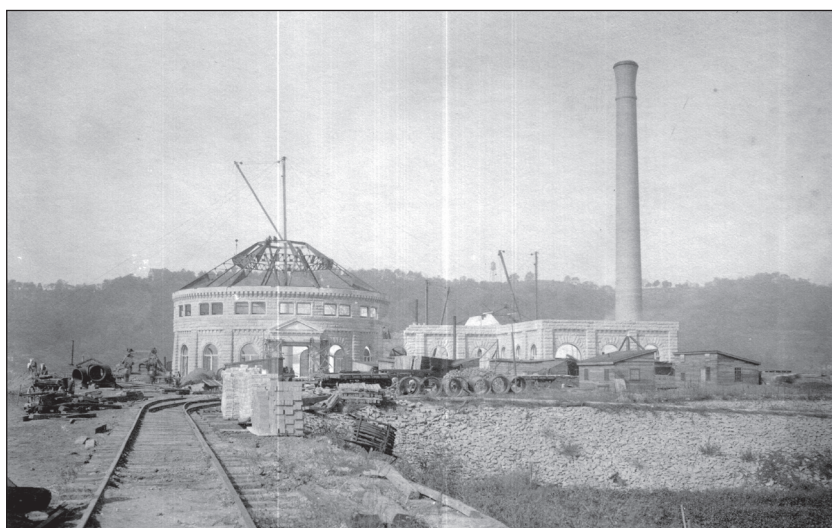
THE NEW WORKS

With the completion of Fuller's studies, the final design element of the plant was included in the plans. In total, construction of the "New Works" was a monumental task, overseen by one of Cincinnati's prominent architects, Gustave W. Drach (see the sidebar on page 50). The location of the plant, approximately 10 mi upstream of the city, necessitated construction of several new distribution and pumping facilities at the same time. To follow is a partial list of what was included in the construction of the New Works:

- The River Station (see the photographs on page 47 and the top and center photographs on this page), a raw water pumping station with a design capacity of 120 mgd connected to a 7-ft-diameter tunnel founded in bed-rock to an intake pier on the Kentucky side of the Ohio River (see the bottom photograph on this page and the photographs on page 50); the four triple-expansion steam engines are the largest of their type at more than 104 ft high and more than 1,400 tons each (see the top photograph on page 51).
- Two 60-in.-diameter cast-iron force mains to deliver river water to two settling reservoirs with a total capacity of approximately 330 mil gal.
- Three secondary coagulation and sedimentation basins to condition the water for maximum filtration efficiency.
- A rapid sand filtration facility with 28 rapid sand filters, each with a hydraulic capacity of 5 mgd (see the bottom photograph on page 51).
- A 20-mil-gal open clearwell.
- A brick-lined 7-ft-diameter gravity tunnel founded in bed-rock to convey treated water to a new pump station located about 4.2 mi toward the city.
- The new Main Pumping Station with four 25-mgd low-service pumps and four 12-mgd high-service pumps.
- The new Western Hills Pumping Station with four pumps that pushed water to the higher elevations west of downtown.
- All of the necessary distribution mains to distribute water from the new pump stations to the service area.

These facilities were finally completed, and all were in operation during the last half of 1907.

The impact on public health from the New Works was dramatic and immediate. Waterborne disease in the city decreased immediately, as



Top: Workers carefully lay one of the oolitic dimensioned Bedford limestone blocks in place during construction of the River Station. **Center:** In 1903, construction was about to begin on the roof, covered with American red vitrified "S" tile for the River Station. The conical building housed the steam pumps, and the rectangular building to the right was to enclose the steam boilers to provide the steam to run the pumps. **Bottom:** The finished pumping building, boiler building, and coal storage building circa 1906.



Left: The intake structure is located just off of the Kentucky bank of the Ohio River and is connected to the pumping station on the Ohio side via a 7-ft-diameter tunnel in bedrock below the river. **Above:** While in operation, the original raw water pumping facility required a crew of nine staff members per shift. The name plate is stamped with “1908,” but the pumps operated from October 1906 to May 1963.

demonstrated by the impact on typhoid fever that can be seen in Figure 1. The disease rate remained low, and in 1918, when continuous chlorination was implemented, incidence of this disease was virtually eliminated.

The cost of the New Works was \$11,137,400 (\$278,435,000 in 2015 dollars) when finished and probably represents the most important investment ever made by the city. Not only did this investment

result in significant improvements in public health, but most of the facilities constructed are still being used today, more than 108 years later. Even the filters that Fuller designed are still in operation, with only slight modifications since the original construction.

INNOVATION CONTINUES

Bell’s words from 1880, quoted at the beginning of this article, continued

to ring true as CWW progressed through the 20th and into the 21st century. CWW expanded its service area to include the city of Cincinnati, most of Hamilton County, and much of southwest Ohio, and it has constructed a pipe under the Ohio River to serve most of Boone County, Ky. With this expansion, CWW changed its name to the Greater Cincinnati Water Works (GCWW) to highlight its service to the region.

Gustave W. Drach (1861–1940)

Gustave Drach designed a variety of buildings in Cincinnati, Ohio, both residential and commercial. Among others, he designed the Woodward High School, the Hotel Gibson, and Good Samaritan Hospital. He also designed the city’s New Water Works buildings.

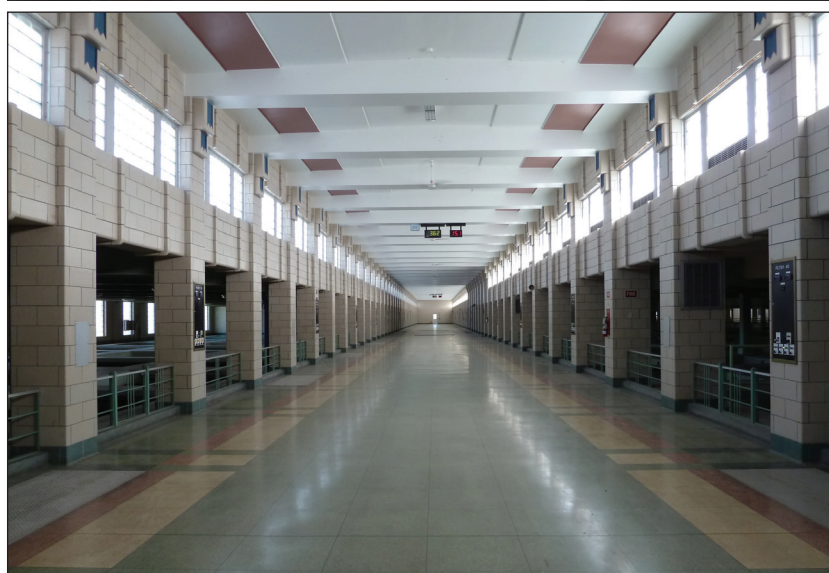
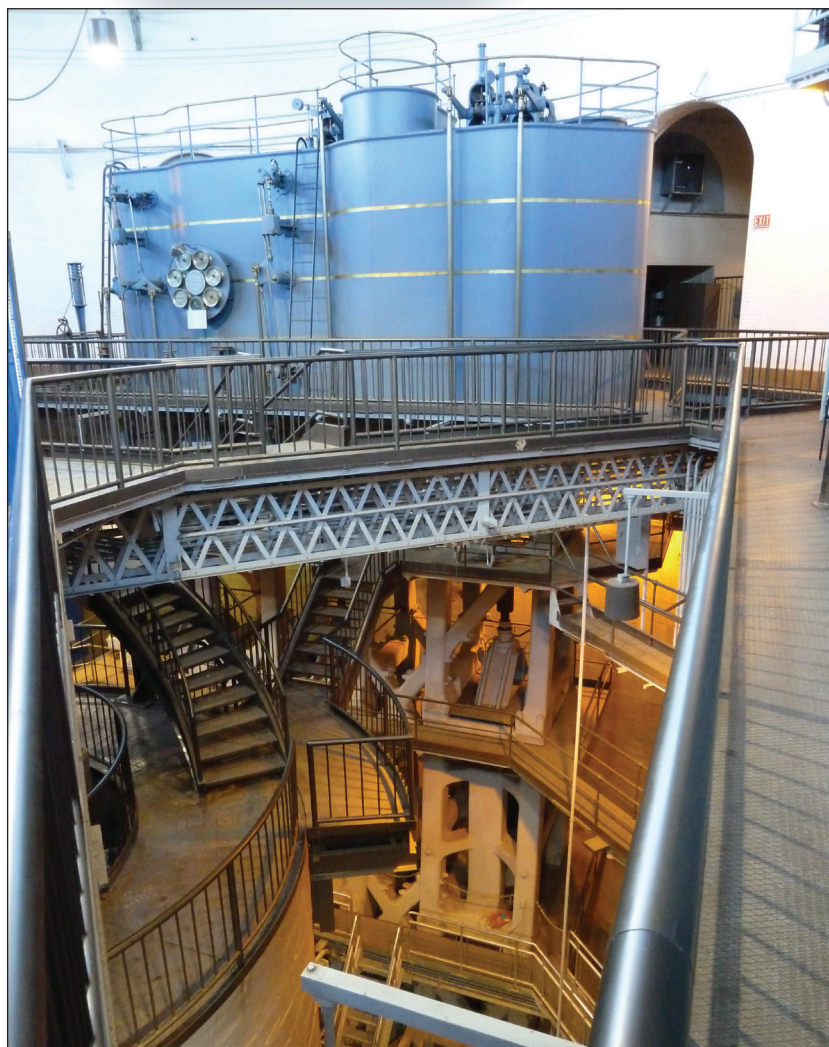
A product of the public school system in Cincinnati, Drach went on to study at the Ohio Mechanics Institute and then attended the Boston Institute of Technology (Boston, Mass.), where he studied architecture. After graduating in 1883, Drach worked for several firms—including Cummings & Sears (Boston), Herter Brothers (New York), and George W. Rapp (Cincinnati)—before venturing out on his own in 1885.

Many of Drach’s projects were large as well as functionally and/or technologically innovative, with a restrained style. Said to be one of the most respected and “balanced” architects in Cincinnati (in terms of his clientele and types of projects), Drach proposed “Canal Improvements” for the 1910 Ohio Valley Exposition and is believed to have chosen the moniker for the fashionable suburb of Hyde Park.

Sources: AFC 2008, Hover et al. 1920.

The Ohio River has proved to be a very plentiful supply, but along with the supply comes the challenges associated with an industrial river. Largely because of spills and industrial discharges into the river, in 1992 GCWW began operation of what was at the time the world's largest granular activated carbon (GAC) drinking water facility with onsite reactivation (see the bottom-left photograph on page 52). The opening of this facility followed 15 years of bench and pilot investigations into the potential of GAC to protect against industrial threats (see the top-left photograph on page 52). Like Fuller's studies almost a century earlier, the research demonstrated the ability of the technology and yielded critical information necessary for designing the full-scale contactors (see the bottom-right photograph on page 52) as well as the onsite reactivation process (Westerhoff & Miller 1986, Miller & Hartman 1982). Since the startup of GAC treatment, the consumers of GCWW's water have greatly benefited from protection from spills, industrial discharges, pesticides, and nonpoint pollution; lower disinfection by-products (DBPs); and the removal of the trace emerging compounds of interest (e.g., pharmaceuticals, algal toxins).

GCWW reasoned from the GAC studies that moving the chlorination step to after the filters and contactors would yield several treatment advantages, such as decreasing chlorine demand and DBP formation, as well as eliminating the production of dioxins during the reactivation process (DeMarco & Miller 1985). This was somewhat of a change of thought in the 1980s, as biological filtration was not yet a widespread practice in the United States. Concerns arose about biological growth and its impact on GAC and on the Fuller-designed sand filters, so CWW conducted full-scale studies by isolating a portion of the sand filters and providing these filters with non-chlorinated water as a pretreatment



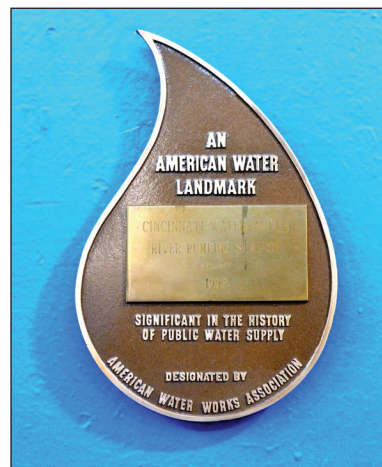
Top: The largest ever built, each of the four triple-expansion steam engines is 104 ft tall, weighs 1,400 tons, and has a 24-ft-diameter flywheel. The entire operation had a coal-to-water efficiency of 22%. **Bottom:** The Greater Cincinnati Water Works sand filter gallery features 47 rapid sand filters, 28 of which are part of the original New Works construction designed by George Warren Fuller and are still in use today.

to a pilot GAC process. Among other things, these studies proved that biological growth would not cause treatment problems and would significantly reduce DBPs and chlorine demand (Hartman et al. 1991, Himmelstein et al. 1990). As a result,

GCWW decided to cease the practice of prechlorination with the initiation of the GAC process in 1992.

Since that time, GCWW has performed or participated in many research studies looking at the impact of biological filtration.

Results have shown that the biological component of the filters is very successful in removing total organic carbon, taste-and-odor compounds, and trace organics, and in general has made the GAC process more effective and efficient to



Top left: The granular activated carbon facility was the culmination of more than 15 years of bench and pilot research. Bottom left: Onsite reactivation furnaces made it economically feasible to use granular activated carbon as a post-filter adsorber at Greater Cincinnati Water Works. Top right: The River Station is a registered AWWA American Water Landmark. Center right: Eight 48-in. medium-pressure ultraviolet reactors provide 4-log reduction of *Cryptosporidium* at a 240-mgd design rate. Bottom right: One of 12 carbon contactors provides protection not only from industrial spills but also from trace contaminants and is effective in reducing disinfection by-product precursors.

operate (Zearley & Summers 2012, Metz et al. 2009).

In 2013 GCWW added the most recent jewel to its treatment crown by starting operation of an ultraviolet (UV) disinfection facility designed to achieve 4-log inactivation of *Cryptosporidium* at a flow rate of 240 mgd (see the center-right photograph on page 52). This facility was also the culmination of careful planning and study by GCWW to select the most effective, efficient, flexible design possible. With the addition of this UV disinfection facility, the Richard Miller Treatment Plant is capable of 7-log reduction of *Cryptosporidium* and removing a host of other waterborne pathogens. The UV facility was also designed to allow for the potential of limited advanced oxidation if needed.

FUTURE DIRECTION

GCWW's River Station is a registered AWWA American Water Landmark because of its significance in the history of public water supply (see the top-right photograph on page 52). Producing a plentiful supply of high-quality water in a cost-effective manner will continue to require the concerted efforts of all of the GCWW staff. Although many of the challenges of the past such as typhoid have been overcome, the future continues to pose both understood and unforeseen challenges. As issues like aging infrastructure, workforce turnover, energy costs, and customer expectations become more and more important, it is the spirit of innovation and discovery that will guide the utility to new understandings and to develop solutions to meet those needs well into the future.

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IN THE SPOTLIGHT

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