Clearwell project leads to system-wide operational advantage

As part of the Miramar Clearwell Improvement Project, the new disinfection system enhances water quality in San Diego's distribution system. **Simon Wong**, **Larry VandeVenter**, and **Edward Matthews** of Kleinfelder and **Iraj Asgharzadeh** and **Anh Nguyen** of City of San Diego explain how a new chlorine contact chamber eliminates the addition of chlorine to the filters and converts filtration to a biological mode.

A few years ago, the City of San Diego's Public Utilities Department initiated a major planning study for the upgrade of the clearwells at one of its major water treatment plants. During the evaluation and design process, the program expanded considerably as the city looked to replace aging infrastructure and add more features to improve efficiency and overall system redundancy to meet growing demand and tightened regulatory requirements.

San Diego's population, currently approximately 1.37 million, is expected to rise to 1.54 million by 2020, 1.69 million by 2030, and 1.95 million by 2050. The Miramar Water Treatment Plant (WTP) is the primary drinking water resource to residents living and working in the northern parts of the city.

San Diego's Public Utilities Department initiated the six-year, US$85-million Miramar Clearwell Improvements Project, which has since become the city's largest capital improvement program – with a scope that goes far beyond just replacing the aging clearwells.

Planning for the future

The Miramar WTP, first constructed in 1962, is one of the city's three WTPs for drinking water. When it was first built, the plant and its associated Clearwell No. 1 served the newly developed regions of San Diego. In 1974, the Miramar WTP was expanded to approximately 378.5 million liters per day (Mld) and Clearwell No. 2 was built. In the 1980s, the plant was expanded to approximately 530 Mld, and then expanded again early in the new millennium to approximately 814 Mld. Currently, actual plant capacity has been limited to approximately 545 Mld at the approved filter-loading rate of 14.7 m/hr. The maximum hydraulic capacity of the plant is approximately 814 Mld if the filters are re-rated to 22.0 m/hr.

Now, both clearwells are approaching the final stretch of their service lives, with neither meeting today's more stringent seismic codes. Subsequently, the city completed some local structural modifications to lengthen the service life of both clearwells. The criticality of the clearwells, a desire to bring the clearwell volumes in line with the ultimate capacity of the treatment plant, and the on-going concern about structural stability prompted the city to replace both clearwells.

In 2011, the city of San Diego initiated the design of two new rectangular-shaped clearwells, with a combined capacity of 221 Ml, bottom elevation at 209 meters, and a maximum water surface elevation of approximately 217 meters that conforms to the distribution zone. During the original clearwells planning process, city engineers noted the need for further redundancy in case of power outage affecting the ozone disinfection process, as well as the need to upgrade hydraulics to support the 814-Mld flows when assuming re-rating of the filters from 14.7 to 22 m/hr.

As the project evolved, the city added four more components. The first component added a chlorine contact chamber (CCC); the second added a 814-Mld lift station within the process to pump filtered water to the CCC and satisfy hydraulic requirements for ultimate capacity; the third element included an approximate 1,830-square-meter operation and maintenance facility; and the fourth component was the addition of a 1-megawatt, photovoltaic solar system to the roof of the clearwells. The city selected Kleinfelder (then known as Simon Wong Engineering) as the prime consultant.

Disinfection upgrades

Key in the Miramar Clearwell Improvement Project is the construction of a new CCC. To meet and exceed the US Environmental Protect Agency's drinking water standards, the Clearwell Improvement Project includes the design and implementation of a disinfection system that encompasses all conceivable water quality and operating conditions to provide a high level of reliability and drinking water quality to its constituents. The objectives of the CCC is to add redundancy and reliability to the current o zone system by using free chlorine disinfection within the CCC, thus eliminating the addition of chlorine to the filters and converting filtration to a biological mode. This proactively enhances the water quality in the distribution system with respect to increasingly stringent regulations.

The existing ozonation system is designed to achieve 0.5-log inactivation of Giardia, but is capable of providing 1.0-log inactivation. Under degraded, raw-water quality conditions, the California State Water Resources Control Board Division of Drinking Water (formerly the California Department of Public Health) requires an additional 1.0- or 2.0-log inactivation. The CCC is designed to handle the 814-Mld flow and provide 0.5-log Giardia inactivation at a 2.5-milligrams-per-liter chlorine residual, and a baffling efficiency factor of 0.8. The clearwells are designed to a baffling efficiency factor of 0.8 to achieve 1.0-log Giardia inactivation with

Rendering of Miramar Clearwell Improvements Project with solar panels on one clearwell. Photo by Kleinfelder chloramination. Both the clearwells and CCC baffling curtain designs were optimized using computational fluid dynamics modeling.

With the addition of the CCC and baffling curtains of the new clearwells, the disinfection system becomes much more reliable and flexible under various types of water quality conditions. Under normal water quality conditions, the ozone system, CCC, and clearwells can individually achieve the 0.5-log inactivation of Giardia. Under degraded water quality condition, the requirement becomes 1.5-log, which all three components work together to achieve. If either the ozone or the CCC is offline, the clearwells provide the needed 1.0-log inactivation.

For extremely degraded water quality condition, the system must achieve 2.5-log inactivation and all three systems are needed with both the ozone and clearwells providing 1.0-log inactivation each.

The CCC includes the construction of a dual-train configuration with an ammonia diffusion system for chloramination at the outlet of the CCC and flow control valves that maintain CCC water level and split the flow equally between both clearwells. The internal baffle walls are reinforced concrete serpentine channels of 3.05-meter widths supported by a concrete spread foundation and roof structure. The ammonia addition stops the further formation of disinfection byproducts in the clearwells and distribution system.

The Miramar WTP is one of the city's three WTPs for drinking water.

To address desired hydraulic operating conditions, the city added additional program scope for the design and construction of a 814-Mld lift station to pump filtered water to the new CCC. The lift station will provide reliability to maintain the top water surface at the clearwells to 217 meters elevation regardless of the flow. The pump station is located upstream of the CCC and will have the ability to pump flow from approximately 151 to 814 Mld. Initially, installing four pumps for flows up to approximately 644 Mld, the fifth pump will handle the ultimate 814-Mld flow. The exposed pump motors (designed for ease of maintenance) are equipped with variable frequency drives to provide continuous flow over the various conditions. Also, the design team commissioned a scaled, physical model hydraulic testing in a research laboratory and identified design improvements to alleviate potential pump problems.

Clearwell improvements

The new seismically compliant clearwells working as part of the disinfection system helped reduce the size of the chlorine contact chamber. The benefits to the city include: more storage capacity; reduced ongoing maintenance costs; better control for steady distribution for the 217 meter zone; less production fluctuation impact to the WTP operations; and critical inactivation functionality through chloramines in various water quality conditions, especially when both the ozone and CCC are offline together. The meter zone refers to hydraulic elevation designation for a hydraulic distribution zone as defined by the city.

The existing unequal-sized rectangular clearwells are buried hopper-bottom, concrete liner structures with only the flat concrete roofs exposed. They share the same widths in the north-south direction and lie in tandem longitudinally in the east-west direction. Miramar Lake – the forebay of the WTP – is located to the north and the south side and is bounded by an embankment sloping back down to a roadway.

Due to the increased ultimate capacity of 814 Mld, the total clearwell volume will also increase approximately to 221 million liters from the current 197 million liters. The new clearwells will be identical in volume to each other with a combined overall dimension of approximately 257-meters by 118-meters, with a host of custom flow features on the south and north side.

The south-side clearwell flow will be primarily buried within the embankment and through 137-centimeter (cm) outlet pipes, 107-cm overflows, and 40.6-cm drain pipes discharging to a 137-cm storm pipe are included with an underdrain system below the floor salby for leak detection All these elements are ultimately connected to the Miramar pipeline, which serves the 217-meter zone distribution system.

Flows from each clearwell to the north side was designed for reliability and flexibility and is an outlet system

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made up of 152-cm pipes installed on the north side and connected to the Miramar 2A pipeline, which ultimately merges into the Miramar pipeline.

The top of the original concrete liner hopper was constructed level with the exterior grade of the embankment. For the new clearwells, engineers designed an approximately 5.5-meter-tall vertical perimeter walls positioned before the concrete liner hoppers. California Division of Safety of Dams requires the clearwells to be standalone structures should the south embankment sustain any damage during a major earthquake. For overall stability, lean concrete or controlled low-strength material is used under the foundation until it firmly bears on the stadium conglomerate strata. This system optimizes the wall thickness and maximizes the storage volume for greater overall system efficiency.

The clearwells are designed to the highest current seismic code and the clearwells' water-bearing reinforced concrete structures can resist the inertial forces generated by a fully filled reservoir. The roofs are designed as horizontal diaphragms to transfer seismic loads to the shear walls. The wall foundations are designed to dissipate seismic forces within acceptable bearing pressure of the soil.

Construction sequencing

Several construction sequencing challenges emerged during the design of the WTP upgrades.

The construction of the new clearwells will require the loss of one operating clearwell for a significant period of time, which will be a significant challenge for operations. Therefore, carefully planned construction sequencing for clearwell construction and piping has been developed to be able to maintain operation of one clearwell at all times.

The WTP operators also defined a maximum 12-hour shut down duration of plant during construction. The sequencing includes the independent isolation of the clearwells for pipeline and vault construction, with shoring for protection of pipelines and the remaining clearwell during construction. In addition to the multiple challenges – such as seasonal WTP demand and limitation – the sequence of construction (a critical risk management issue) is organized to maintain the availability of at least one continuously operating clearwell at all time.

As one of the clearwells is being demolished or constructed, the remaining one needs to remain intact with enough structural stability to meet surrounding construction loadings. Careful planning needs to be considered for additional updated condition assessment and repair, mandated shoring at certain locations, all inlet and outlets, pipeline, appurtenances, and all temporary shutdowns for the tie-ins. Additional redundant construction procedures are planned, and to aid contractor's understanding of the project, a three-dimensional, computer-generated construction phasing animation video was developed as well as a complete informational critical path methodology and construction schedule.

The Miramar Clearwell Improvement Project to enhance water quality in San Diego's distribution system will go out to bid by mid-year 2015, with construction set to begin in 2016.

Authors' Note

Simon Wong is the Kleinfelder project manager of the Miramar Clearwell Improvements Project, and a vice president of Corporate Business Development. Edward Matthews is a senior water and wastewater engineer at Kleinfelder. Both Wong and Matthews are based in Kleinfelder's San Diego, California headquarters. Larry VandeVenter is vice president of Water Treatment with Kleinfelder's Boston, Massachusetts office, also in the United States.

Iraj Asgharzadeh is senior civil engineer with City of San Diego, California. He has managed multiple treatment plant upgrades and expansions including the Miramar Water Treatment Plant Upgrade and Expansion Project for the last 12 years. Anh Nguyen is an associate civil engineer and a project manager with City of San Diego for the design of facilities within the Miramar Water Treatment Plant.

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