Wastewater Chlorination Systems: A Holistic Approach Toward Design and Construction

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The Miami-Dade County Water and Sewer Department (WASD) currently operates three wastewater treatment plants that serve one of the largest metropolitan areas in the United States. On any given day, WASD provides water and wastewater service to nearly 2.3 million residents and thousands of visitors throughout the county. The largest facility at WASD is the Central District Wastewater Treatment Plant (CDWWTP), which was constructed in 1956. Currently, CDWWTP is a secondary treatment facility consisting of headworks, high-purity oxygen activated sludge biological treatment facilities (oxygen-generating system, oxygen train tanks, final clarifiers, and return activated sludge [RAS] pumps), and disinfection. Miami-Dade County entered into a consent decree with the U. S. Environmental Protection Agency (EPA), which has mandated improvements to a variety of processes throughout WASD's wastewater infrastructure.

Among WASD's assets identified for improvements were the chlorine gas disinfection facilities at CDWWTP and it elected to replace the existing chlorine gas disinfection system with a liquid sodium hypochlorite (NaOCl), or bleach, system that is safer to handle than gas or liquid chlorine and will improve overall plant health and safety. The NaOCl will be transported by delivery trucks to CDWWTP, where it will be stored in a main bulk storage building. Metering pumps at the main facility will serve as part of the NaOCl feed system for various injection points throughout the plant. The NaOCl storage system will also include a second ancillary site for additional storage.

The CDWWTP chlorination project provides an example of the design and construction challenges of transforming an existing chlorine gas disinfection system to a NaOCl dosing system. The design and construction process was a collaborative effort among the design team, construction team, and WASD staff. Design challenges included providing a functional design layout of the NaOCl storage and feed system, which considers adequate storage and accommodates system maintenance. The building layout and yard piping were some of the most important design elements of the project. During construction, equipment testing and integration of the process control equipment and instrumentation were some of the greatest challenges. The CDWWTP chlorination project will provide the design teams with a holistic approach toward designing chlorination disinfection facilities and an overview of the project.

Figure 1. Central District Wastewater Treatment Plant *(2012 Existing Conditions Report)*

Background

In 2013 Miami-Dade County initiated execution of an aggressive program schedule identified in the federally mandated consent decree, with EPA and the Florida Department of Environmental Protection (FDEP) committing to rehabilitation and improvement projects of the county's wastewater collection, transmission, and treatment systems. This includes improvements at each of the wastewater treatment plants (WWTPs) owned and operated by WASD.

Three WWTPs (North District, Central District, and South District) are currently operated by WASD, and CDWWTP, located in Virginia Key, is its oldest existing WWTP. The plant has undergone numerous expansions and upgrades from its original permitted capacity of 47 mil gal per day (mgd) as a modified activated sludge process to its current configuration as a 143-mgd high-purity oxygen activated sludge facility. The raw wastewater that is pumped to the central plant is hydraulically split into two treatment plants: Plant 1 and Plant 2. Plant 1 has a treatment capacity of 60 mgd based on annual average daily flow (AADF), and Plant 2 has a treatment capacity of 83 mgd based on AADF. Although the treatment capacities are different, the treatment processes used are identical. The treatment process used at the central plant consists of pretreatment (grit removal), high-purity oxygen activated sludge process, secondary clarification, and basic disinfection using chlorine. An aerial view of CDWWTP is shown in Figure 1.

The original chlorine facilities, one at each plant, consisted of one-ton cylinders, chlorinators, and evaporators. Liquid chlorine was pulled from the cylinders to chlorine evaporators, where the liquid chlorine was converted to chlorine gas. The chlorine gas was then fed to the chlorinators, which regulated dosing and contained the ejectors where the chlorine gas was mixed with a small flow of secondary clarifier effluent. The CDWWTP holds a domestic wastewater facility permit issued by FDEP that requires the effluent to meet basic disinfection requirements, which is a minimum chlorine residual of 0.5 mg/L after a contact time of 15 minutes. The NaOCl feed system was designed to meet these permit requirements.

In 2012 MWH (now Stantec) completed an evaluation of CDWWTP that documented the existing condition of assets throughout the facility. The 2012 report indicated that there was a need for converting the chlorination facilities from chlorine gas to NaOCl in order to improve overall plant health and safety constraints, as well as equipment that was nearing its useful life. Failure of the existing chlorine gas storage system could lead to an unregulated discharge of chlorine gas and expose plant personnel and the public to chlorine gas. In 2015 Gannet Fleming developed a basis of design report (BODR) for the new chlorination facilities that provided a summary of the equipment and NaOCl injection points. The following unit processes were identified in the BODR as injection points utilizing 10.5 percent NaOCl:

- Disinfection of effluent from Plant 1 and Plant 2
- Filamentous control (RAS dosing) for Plant 1 and Plant 2
- Flushing water for Plant 1 and Plant 2
- Scum wells on the final clarifiers at Plant 1 and Plant 2
- Digester gas scrubbers at Plant 1 and Plant 2

The BODR provided a basis for the required chlorine dosage for each injection point, siting of the new facilities, and overall operation of the new chlorination facilities. The BODR also established requirements for the size and material of the NaOCl storage tanks, pump selection for the NaOCl feed system, and yard piping.

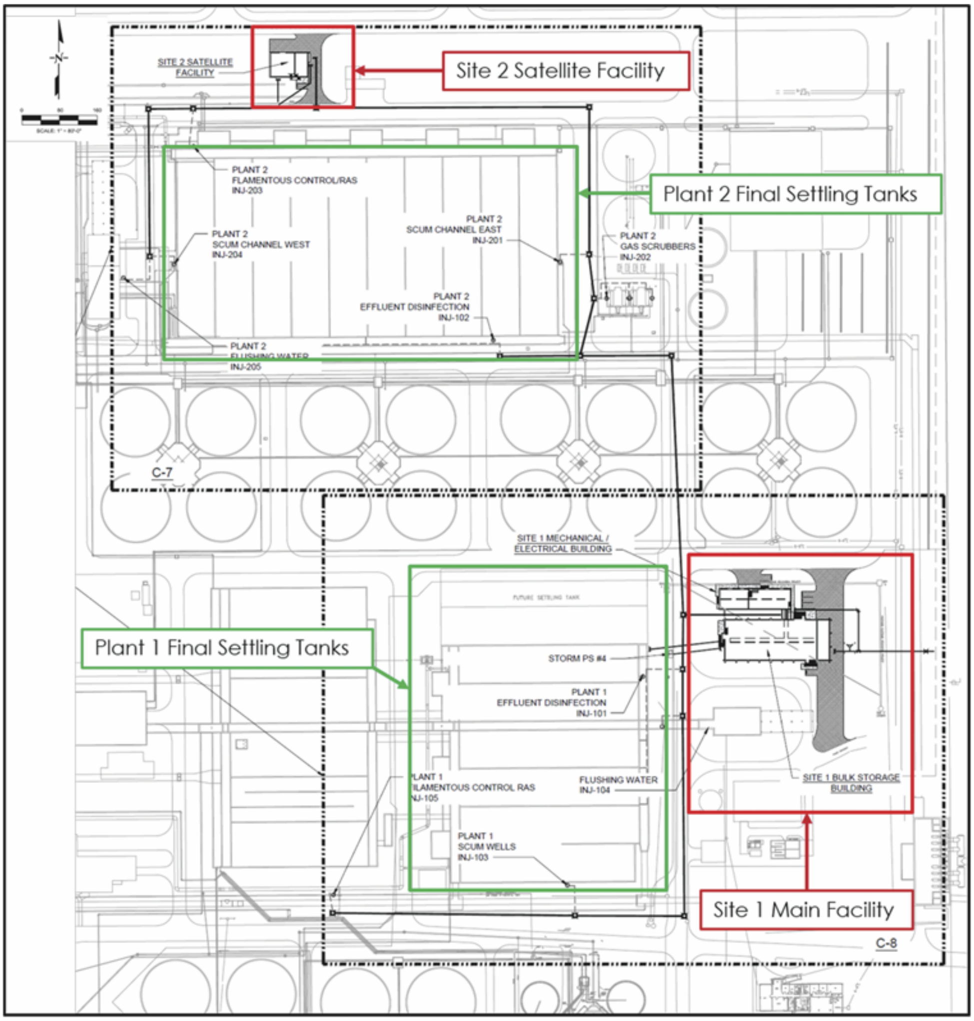

Figure 2. Overall System Site Plan

Design Approach and Challenges

Due to the need to implement this project quickly and meet EPA milestone dates, detailed design was structured between progressive design phases, including a 60 percent design charrette and a final 100 percent design submittal. Workshops were held with the client and the project management team at each phase of the design to ensure that the client was aware of any design changes and approved the overall design. The design process was essentially an integrated approach among the design team, the client's project management team, and the client. During design, various changes occurred to the layout of the new chlorination system to accommodate logistics of system maintenance and process control. During detailed design it was decided that the chlorination facilities would consist of only two sites: one main storage facility (site 1) and one satellite facility (site 2), as shown in Figure 2.

One significant design challenge was to accommodate structural loads of the NaOCl storage tanks at the main storage facility. In order to accommodate the structural needs of the tanks, the main facility (site 1) was split into two buildings: the bulk storage building and the mechanical/electrical building. Based on the plant's average daily demand, 16 fiberglass reinforced plastic (FRP) NaOCl storage tanks (20,000 gal each) were required to be stored at the main facility. The tanks are arranged in a back-to-back configuration along two rows, with a common center spill containment trench and an elevated walkway between the tanks, providing common access to the top of all tanks. One of the additional FRP tanks, also referred to as a scavenger tank, serves to contain possible chemical spills, and any retained chemical in the scavenger tank can be placed into service to the metering pumps serving the NaOCl feed system. Space has also been reserved for two additional tanks to be installed in the future to allow expansion of feed capabilities.

The bulk storage building is divided into the tank area and the truck bay. Truck deliver-

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ies are received on the east side of the bulk storage building. The main mechanical/electrical building consists of 11 diaphragm metering pumps and two NaOCl transfer pumps, which replenish the satellite facility. There are also spill pumps at the main facility: two spill pumps for the containment trench, and one spill pump to transfer spills or accumulated liquids from the truck bay sump to the containment trench.

The satellite facility (site 2) has two 2,500-gal storage tanks and 10 diaphragm metering pumps. During detailed design it was decided that the storage tanks would be made of high-density polyethylene (HDPE) material. The facility has provisions to fill the tanks via truck deliveries, which may be used at the discretion of the chief plant operator. The site 2 satellite facility serves ancillary plant processes, where the injection points are closer to site 2.

Other challenges included additional hardening design considerations for storm surge protection. The 2015 BODR required flood protection walls for the chlorination facilities. During detailed design the flood protection walls were raised to 20.3 ft in accordance with WASD design criteria requirements for sea level rise. The main chlorination storage facility represents a critical asset within the central plant and disruption of services due to flooding would impact the plant from meeting permit requirements for disinfection. Illustrated in Figure 3 is a 3D depiction of the NaOCl site 1 facility.

The 2015 BODR also specified provisions for yard piping. Reliability of the liquid chemical feed system was essential, and a combination containment piping/chemical line system design was used for most of the chemical conveyance yard piping during detailed design. The yard piping plan incorporated single-walled HDPE piping for the chemical lines, which is pulled through polyvinyl chloride (PVC) containment piping. In order to accommodate this configuration, the yard piping plan incorporated straight lines as much as possible, with terminations at junction boxes, also referred to as chemical vaults.

Leak detection was also incorporated into these vaults. Liquid-level detection in the vault is used to signal to the operator when a leak is registered in the yard piping. The chemical vaults have a completely sealed floor and a traffic-rated leakproof lid, which minimizes the amount of rainwater entering the vaults. When a leak is detected at a vault, maintenance personnel can identify the leak origin and deal with the affected chemical line independently of the rest. Each injection point also has two lines, allowing one line to be placed out of service during a pipe replacement, but not interrupting service.

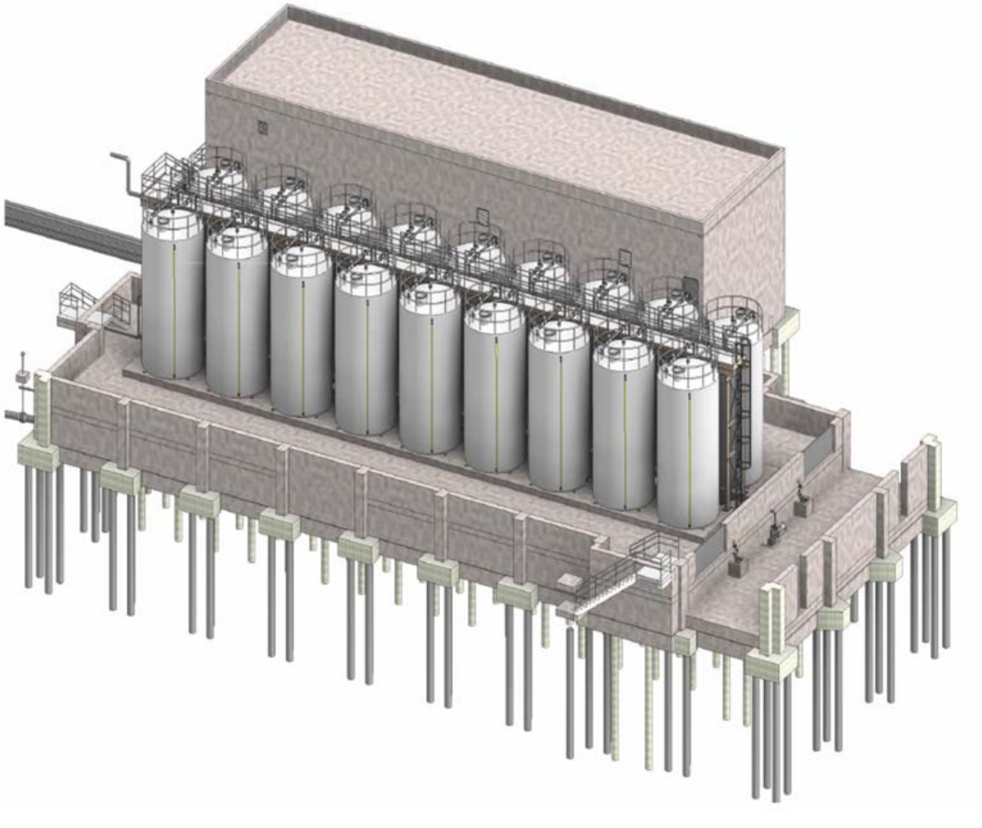

Figure 3. Site 1 Main Facility (3D Model)

Engineering Services During Construction

The CDWWTP chlorination project also presented many challenges during construction. As part of the implementation plan and schedule, WASD invested in the prepurchase of equipment, including a remote telemetry unit (RTU). The CDWWTP has a network of RTUs within a process monitoring and control system (PMC). The RTUs are connected to WASD's overall supervisory control and data acquisition (SCADA) system. Control of the automated processes for the new chlorination facilities are provided by the RTUs and the auxiliary panels are located between the RTU panels and all field devices and instrumentation. In the event of metering pump failure, the standby pump will automatically turn on and adjust its speed to the set points. Any automatic control functionality is provided through the RTUs.

A programmable logic controller (PLC)-based panel with human machine interface (HMI) display contains the programming logic for the system. During construction Stantec provided engineering services that included assistance with start-up of new equipment and testing of the SCADA equipment. The design specifications include control strategies for all main areas of the chlorination facilities, including but not limited to the tank-filling operations, metering pumps, storage tanks, and yard piping leak detection. This testing process during construction includes final integration and point-to-point tests to ensure functionality of all inputs and outputs with the process control equipment and instrumentation. Coordination meetings were held during construction to review start-up logistics and identify adjustments to the control strategies based on maintenance personnel input.

Another challenge during the construction phase was the development of an operation and maintenance (O&M) manual. The chlorine facilities introduced a brand-new process within the plant's existing O&M, and coordination with WASD staff was critical to ensure that the O&M was tailored to operational needs. Workshops were held to discuss O&M content, including dosage requirements for the various injection points. Disinfection efficiency at the plant effluent varies as a function of chlorine dosage, contact time, and effluent turbidity.

Regulatory requirements for the CDWWTP

mandate a minimum total residual chlorine (TRC) limit of 0.5 mg/L after a 15-minute chlorine contact time. To comply with this regulatory requirement, a target chlorine residual of 1 mg/L is recommended. In the case of the new metering pumps for the new chlorination system, feed adjustments are manually controlled. The new pumps require speed adjustment to maintain the target chlorine residual level, increasing the speed to attain a higher residual and reducing the speed to attain a lower residual. The O&M identified both storage and dosage requirements.

The site 1 (main facility) was placed into operation in December 2017 and site 2 (satellite facility) was placed into operation in July 2018.

Conclusion

The CDWWTP chlorination project is an example of the design and construction challenges encountered from transforming an existing chlorine gas disinfection system to a NaOCl dosing system. The design layout of the NaOCl storage and feeding system was a critical component of the detailed design. It was important to understand the structural needs of the NaOCl tanks and determine an efficient layout that was functional for plant personnel. Equipment testing and integration of instrumentation were some of the greatest challenges during construction. Coordination with WASD staff was also critical during development of the O&M manual. Overall design workshops and construction meetings were the most essential tools throughout the entire project, focusing on understanding the project goals and client needs.

Acknowledgments

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