Climate Adaption and Resilience for Miami-Dade County Wastewater Treatment Plants

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Miami-Dade County is one of the largest metropolitan areas in the United States. Over time, increased episodes of flooding and storm surge have posed a threat to the Miami-Dade community and its infrastructure. Sea level rise (SLR) has become a regional concern for southeast Florida and government agencies that provide essential public services. The Miami-Dade Water and Sewer Department (WASD) represents one of these agencies, and SLR has become an integral part of its planning and adaption strategies that focus on protecting local water and wastewater utilities from catastrophic flooding events.

The effluent pump station (EPS) at the Central District Wastewater Treatment Plant (central plant) is an example of an asset that requires additional hardening efforts. The EPS, located on the southeast side of the central plant, receives treated effluent that is discharged through an ocean outfall. Pumps at the station operate to discharge water during periods when it can't travel by gravity flow to the ocean outfall. These pumping efforts are normally required during periods of peak flows at the plant or high tide. The WASD has elected to build a new electrical building for EPS in an effort to protect critical electrical equipment from storm surge. The new electrical building is designed to meet an SLR design elevation of 20.3 ft, which was calculated based on research and design standards.

Design engineers working on this project had to incorporate this design elevation across all disciplines. These challenges offered opportunity for creative and ingenious solutions toward meeting the 20.3-ft design criteria. The design process was a collaborative effort among different engineering disciplines and the WASD staff. The EPS design project, among other wastewater treatment plant projects in Miami-Dade, provides a unique model for engineering design teams that must incorporate SLR elevation as an element within their design. Public agencies in various coastal communities have implemented local guidelines and policies that require SLR as an integral design factor for any new building or retrofit. This article will provide other design teams with a holistic model on how to design utilities that must adapt to SLR.

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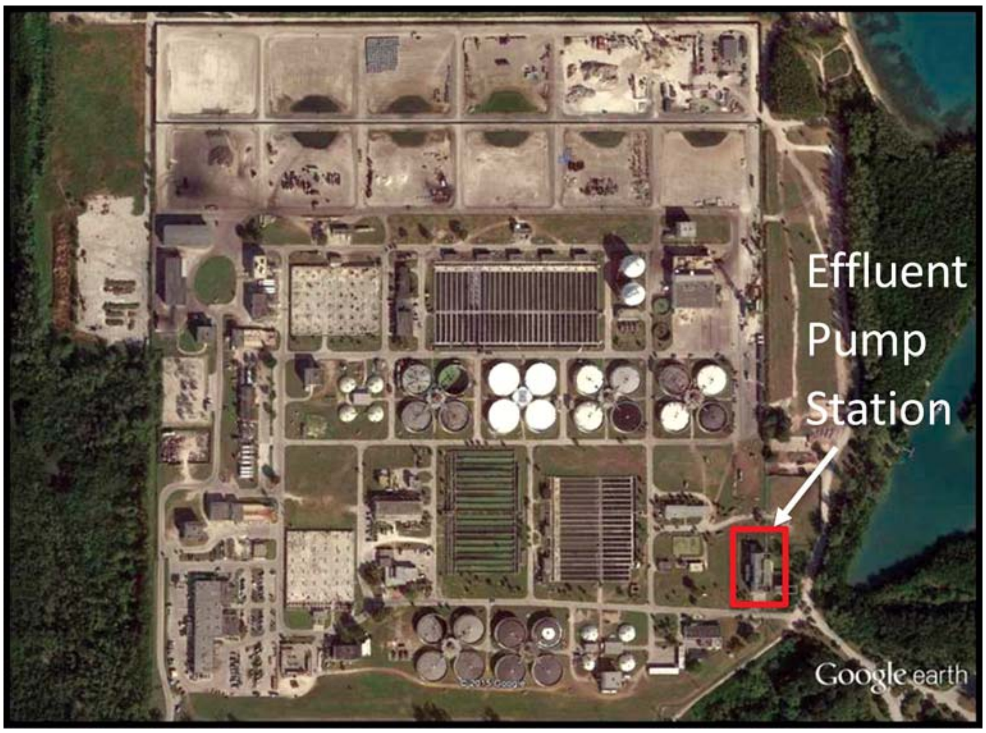

Figure 1. Site Location of Effluent Pump Station *(2016 Basis of Design Report)*

Background

On any given day, WASD provides water and wastewater service to over 2 million residents and thousands of visitors throughout Miami-Dade County. The WASD currently operates three wastewater treatment plants (North District, Central District, and South District) that serve Miami-Dade County, providing service to approximately 354,000 retail customers and 13 wholesale customers. The oldest and largest wastewater treatment facility is the central plant, which was constructed in 1956. The raw wastewater that is pumped to the central plant is hydraulically split to two treatment plants: Plant 1 and Plant 2. 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, secondary clarification, and basic disinfection. The treated effluent from the secondary clarifiers at Plants 1 and 2 are combined at the EPS and discharged to an ocean outfall. The entire plant handles approximately 143 mil gal per day (mgd) on an average annual daily flow (AADF) basis, and more importantly, this facility is located on an island: Virginia Key. Unlike other major utilities in the state, WASD faces the challenges of expanding, replacing aged equipment, and protecting its existing infrastructure at the central plant on the barrier island as the population increases; however, complicating these challenges and the impacts associated with SLR is the fact that the plant is located in an area that is designated as a flood hazard area and vulnerable to storm surge. The Federal Emergency Management Agency (FEMA) has established flood hazard maps that identify separate zones based on flooding risk, and a base flood elevation (BFE) is determined for each zone based on this information. As a result, WASD has incorporated SLR as important design criteria in hardening efforts for the central plant and its other two treatment plants. Mitigation efforts include replacing electrical equipment that has deficiencies and elevating the equipment for critical assets within the treatment plants.

The EPS is located on the southeast side of the plant (Figure 1) and represents a critical asset within the central plant. The pump station is not air conditioned and currently houses eight 500-horsepower (HP) vertical turbine pumps that operate during peak flows. Failure of these pumps will hinder the plant's ability to dispose of treated effluent. In order to address the issue associated with the failure of the EPS during flooding conditions, the proposed design for the EPS was to remove all electrical equipment within the building.

According to existing condition reports, published in 2008 and updated in 2012 by MWH, existing electrical equipment at the pump station, including the motor control centers (MCC), switchgears, and transformers, were determined to have reached their useful life and required replacement. Additional recommendations included replacing the existing inefficient magnetic clutch drives for the pumps with variable frequency drives (VFDs), as well as replacing the existing 500-HP pump motors. To protect the facility, it was determined to relocate all of the critical electrical equipment to a new single-story annex building located west of the existing EPS building. A one-story building was more favorable towards internal maintenance activities, equipment loading, and personnel access.

The new annex building layout has three main areas:

- Transformer area
- Electrical room
- Control room that also includes a rest room

The transformer area will be divided into two smaller rooms (Room 1 and Room 2), which will provide space for two 5,000-kilovolt-ampere (kVA) transformers and two 300-kVA transformers. In the electrical room will be two arc-resistant 5 kV metal-clad switchgears, two MCCs with a main-tie-tie-main arrangement that will replace the existing automatic transfer switch (ATS) configuration, and eight new VFDs associated with the effluent pumps; the motors and pumps, however, will remain in the existing EPS building. The control room will include the new remote terminal unit (RTU) panel that will communicate with new equipment, as well as existing equipment in the existing EPS building. The new annex building will also be designed to accommodate SLR requirements.

Table 1. Wastewater Treatment Plant Sea Level Rise Elevation Design Criteria *(CH2M, 2015)*

	Existing WWTP Facility Assets		New WWTP Facility Assets	
	ft. NGVD29	Basis	ft. NGVD29	Basis
CDWWTP	16.0	FEMA BFE + 3ft SLR from SEFLCC(2011) +FB +SF	20.3	2075 Surge+1.23m(48")SLR + FB +SF+21"(100-yr, 72-hr rainfall)
SDWWTP	16.0	FEMA BFE + 3ft SLR from SEFLCC(2011) +FB +SF	19.0	2075 Surge+1.23m(48")SLR + FB +SF+21"(100-yr, 72-hr rainfall)
NDWWTP	16.0	Same as CDWWTP and SDWWTP	17.1	2075 Surge+1.23m(48")SLR + FB +SF+21"(100-yr, 72-hr rainfall)
FB= Freeboard = 2.0 ft. per ASCE Standard 24-05/2010 FBC Category IV				
SF= Safety Factor = 1.0 ft. per 2014 MWH study at CDWWTP				
SLR = 1.23m = 48" per NOAA High projection for 2075 (USACE High projection is 0.93m)				

Action Plan Development

Southeast Florida is an excellent example of a coastal region with an infrastructure and unique habitat that are extremely vulnerable to the impacts of climate change. These concerns were recognized in 2009 when four counties, which included Miami-Dade, Monroe, Broward, and Palm Beach, created the Southeast Florida Regional Climate Change Compact (SFRCCC), with the main objective of implementing mitigation strategies and sharing information in an annual forum (SFRCCC, 2011).

In 2012, a regional climate action plan (RCAP) was developed that included seven areas of focus and 110 recommendations for policy implementation (RCAP, 2012). The RCAP was created as a guide for participating counties within the regional compact. The objective of the plan was to create synergy among all of the participating counties and encourage collaboration on mitigation strategies that focus on specific climate change issues. The action plan includes goals within, but not limited to, the areas of sustainable communities, water supply management, and agriculture. The regional compact has also created a database to track which counties and municipalities have successfully implemented these strategies. The Miami-Dade GreenPrint, the county's sustainability plan, is an extension of the 2012 RCAP, incorporating initiatives within the seven areas of focus. Although the GreenPrint includes additional initiatives to the existing 110 policy recommendations within the RCAP, the objective is consistent.

In September 2014, the Miami-Dade Board of County Commissioners adopted an ordinance relating to the rules of procedures of the commissioners amending Section 2-1 of the code of Miami-Dade County to require that all agenda items related to planning, design, and construction of county infrastructure include a statement that the impact of SLR has been considered. The county ordinance was adopted based on recommendations provided by the Miami-Dade Sea Level Rise Task Force in the June 2014 final report. The task force was created by Resolution R-599-13 on July 2, 2013, to review the relevant data, prior studies, assessments, reports, and evaluations of the potential impact of SLR on vital public services and facilities, real estate, water and other ecological resources, waterfront property, and infrastructure (Miami-Dade County, 2017).

As a result of the county ordinance, an SLR assessment was incorporated into all design and construction activities for WASD facilities, including wastewater treatment plants and pump stations. The SLR design criteria for existing assets within wastewater treatment plants were adopted by WASD based on recommendations in the report, "Technical Memorandum: Central District Wastewater Treatment Plant Engineering Approach for Climate Adaptation and Resiliency," prepared by MWH in 2014. A design elevation of 16 ft was highlighted for all three regional wastewater treatment plants, including North, Central, and South, referred to in Table 1. The design elevation was established based on recommendations provided by the American Society of Civil Engineers (ASCE) standards and SFRCCC.

Continued on page 24

Continued from page 23

The ASCE provides technical standards for the construction of new buildings and structures in particular buildings that are located within a flood hazard area. The ASCE 24-05 is a standard for flood-resistant design and construction, which recommends a design elevation of 2 ft above the existing BFE. In 2015, a document was developed by SFRCCC titled, "Unified Sea Level Rise Projection," that was created as a planning tool for risk assessment of flood-vulnerable areas. The SFRCCC concluded that Miami-Dade County would experience a 3-ft SLR by 2075, and engineering design should incorporate this estimate into all projects. The 16-ft design elevation for existing wastewater treatment plant assets was calculated based on the plant's BFE, adding an additional freeboard (FB) of 2 ft (as recommended by ASCE), incorporating the SFRCCC guidance of 3 ft and adding 1 ft as a safety factor. According to the FEMA flood hazard map (Figure 2), the central plant is located in Zone AE (determined by FEMA as an area inundated by a 1 percent annual chance of flooding), with a BFE of approximately 10 ft.

In 2015 CH2M developed a report titled, "Design Guide for Hardening Wastewater Treatment Facilities Against Flooding From Surge, Sea Level Rise, and Extreme Rainfall." Based on the 16-ft SLR design criteria developed by MWH for existing facilities, CH2M developed separate SLR design criteria for new assets constructed within all three wastewater treatment plants. An SLR design elevation of 20.3 ft was determined for the central plant. The design elevation, similar to the MWH design elevation, incorporated a BFE of 10 ft, a FB of 2 ft, and a safety factor of 1 ft, while also incorporating a higher SLR guidance factor of 4 ft, a 21-in. precipitation estimate, and an estimated storm surge factor for 2075. Overall, based on this estimate, a 20.3-ft SLR design elevation was incorporated into the EPS project.

Design Approach and Challenges

The SLR was a major consideration with regards to the electrical improvements project for EPS and associated substations No. 11 and No. 12 to elevate and protect critical electrical equipment during storm surge conditions. The existing high-voltage transformers, MCCs, switchgears, pump motors, and drives are currently installed at an elevation of 14 ft above the City of Miami datum, which clearly does not meet the required SLR elevation of 20.3 ft. In order to meet the design elevation requirement, a new annex building will be constructed west of the existing building with a finished floor elevation of 20.3 ft to house the new electrical equipment. The design team for this project was split into seven main disciplines including civil; instrumentation and control; architectural; structural; heating, ventilation, and air conditioning (HVAC); plumbing; and electrical.

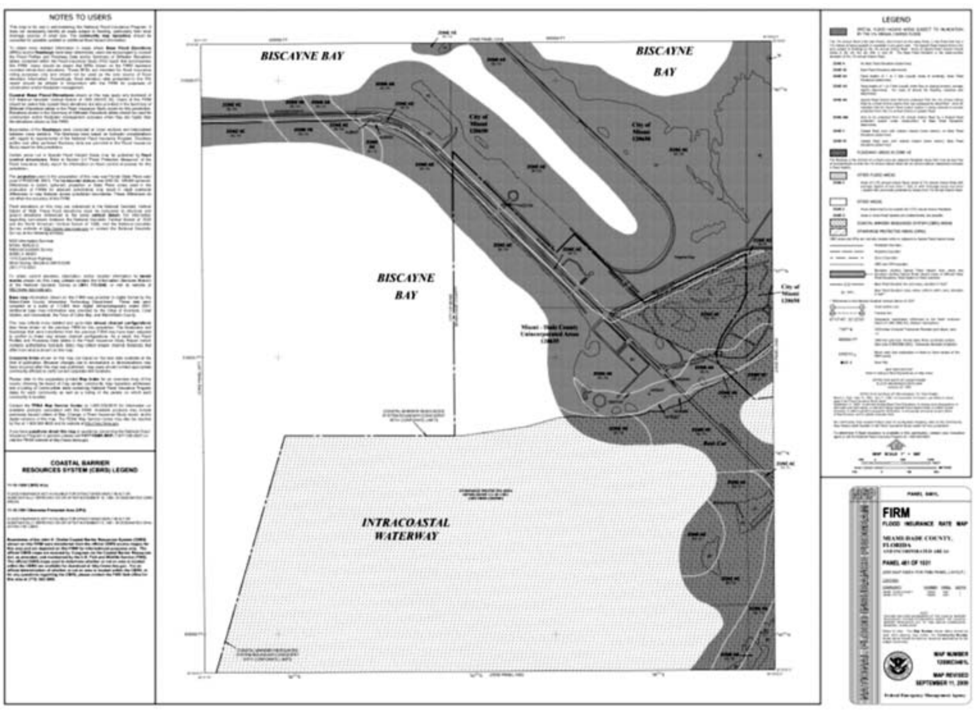

Figure 2. Federal Emergency Management Agency Flood Map *(www.fema.gov)*

A technical memorandum was initially developed detailing existing condition reports, recent site investigations, and proposed infrastructure improvement. After the technical memorandum was submitted, a basis of design report followed detailing alternative evaluations considered for the new electrical building, such as considerations for a single story or two stories and a description of the discipline design criteria. The project design was structured between progressive design phases, including an initial 30 percent design submittal, followed by a 60 percent design submittal and then a final 100 percent design submittal. Workshops were held with the client and project management team at each phase of the design to ensure the client is aware of any design changes and approves the overall design. The design process was essentially an integrated approach among the design team, the client's project management team, and the client.

Design challenges for the project varied for each of the design disciplines that were required for this project. The flood load for the new building was determined based on flood Zone AE, a BFE of 10 ft, and an SLR design requirement of 20.3 ft, which resulted in many challenges with regards to the structural design of the new building. Some of the structural challenges were as follows:

- In order to suspend the building to a finished floor of 20.3 ft, a concrete beam and column system was designed to support the reinforced floor slab. The concrete frame created by the floor concrete beam and column becomes a moment-resistance frame, and a cast-in-place concrete column was positioned to support the concrete beam and floor slab. The building foundation was also supported by auger cast-in-place piles, and for this design, each column was supported by five concrete piles.
- The size of the building also posed a difficult challenge. The new electrical building is approximately 163 ft long by 66 ft wide, which creates a long span of framing and a heavier load for the roof beams. These roof beams were designed to approximately 5 ft and 6 in. in depth. A 32-in. deep precast double tee with 2-in. concrete topping was used, along with the roof concrete beam for roof support.
- Another structural design item included in the project was a covered walkway between the new electrical building and existing pump station building. The purpose of the walkway was to provide a covered accessibility point between both buildings for onsite personnel. The covered walkway is also elevated and supported by a concrete beam and

column system; however, each floor beam is supported by two smaller concrete columns and less piles. An expansion joint between the existing building and walkway was also created to balance any slight potential differences in height between the floor elevation within the existing building and the floor elevation of the walkway.

Architecturally, an elevated building also posed various design challenges. For example, in order to access separate areas within the building, multiple stairs were needed to provide access points. Per code, two means of egress were required for each room within the building; therefore, platforms and staircases were provided along all sides of the building. Platforms near the transformer and electrical rooms were also designed to support load and clearance for arc-resistant technology, such as the metal clad switchgears and the three cooling towers located on the north side of the building. Guardrails were provided along the side of the platforms and staircases and the elevated floor slab also created a crawl space underneath the building. To minimize unauthorized access to the crawl space, the openings along the sides of the building were covered by a black vinyl-coated chain link fence with privacy slats. In addition, the covered walkway between both buildings also required a staircase between the new building and walkway due to their differences in floor height.

Building mechanical design also resulted in many challenges, which were associated with locating the three cooling towers on the same plinth as the 20.3-ft design elevation and the cooling requirements associated with the elevated building. The weight of the cooling towers was more of a challenge on an elevated platform in comparison to towers directly located on a slab on-grade. Cooling towers are filled with water, which increases their weight; therefore, the platforms slab must account for the increased weight of the cooling towers. Additionally, in order to meet clearance requirements, a larger platform area was required for the cooling towers. Another challenge was the piping required for the condensate lines of the HVAC system, as well as the restroom within the building.

Generally, pipes for a single-story building would normally run within an underground trench beneath the slab; however, for this building the indoor piping required suspension and additional reinforcement. A final design challenge associated with the mechanical design included accounting for cooling losses, which are triggered by an elevated slab. These cooling

Continued on page 26

Continued from page 25
losses must be accounted for during selection of the size of the AC equipment. In comparison, on-grade installation of HVAC equipment would not require additional clearance space or cause cooling losses.

The civil design challenges included providing access points along the side of the building, including sidewalks, driveways, and onsite parking. Multiple staircases for the elevated platforms required additional coordination between discipline leads to ensure that the egress paths are clear, safe, and easy to access to the grade and parking lot. The proposed grading was designed to minimize any ponding water within the crawl space and allowed for stormwater to travel by sheet flow to existing sodded/swale areas and collect within existing structures. As a result of the SLR requirements, WASD and MWH are developing a stormwater master plan and drainage system for the plant under a separate project.

The instrumentation and electrical design challenges included the location of the duct banks required for wiring needs between the new building and existing building, and new power cables will be installed between the two buildings. The existing remote terminal unit (RTU) will be removed and a new RTU will be installed within the new electrical building. The existing fiber optic network will be expanded to the new electrical building and connected to the new RTU. The equipment that will remain in the existing EPS building, such as the pumps and pump motors, will communicate with the new RTU. In addition, the existing feeder cables for the existing building will be replaced with new feeder cables between the plant's main switchgear building and the new electrical building. The new feeder cables will use a combination of both existing and new duct banks. Due to the new building's floor slab elevation and foundation concrete column system, routes for the underground duct banks had to be coordinated with the location of concrete columns underneath the building.

Probably the best lesson learned by those involved was coordination. During the design phase of this project, a significant amount of coordination among the discipline leads and the WASD maintenance and operation staff was essential to ensure that all needs for each discipline were met. Weekly progress meetings with the leads were held to discuss all design issues and coordination actions required. These weekly meetings proved to be an essential communication tool throughout the design process. A project schedule was also developed to ensure that all responsibility roles were highlighted and design deadlines were met. In addition, scheduled review meetings were held with WASD's maintenance and operational staff to ensure that their specific requirements, such as maintenance and removal of equipment, access to equipment, and so forth, were met.

Software Modeling

The EPS project also incorporated Autodesk Revit modeling throughout the design process. Revit is building information modeling (BIM) software that allows engineers to design with three-dimensional capability. The software allows for designers from multiple disciplines to work on different elements of the building design at the same time, allowing for improved clash detection. In addition, designers can share information, such as specific design details from another discipline, which can be incorporated as a background and built upon during various phases of the design. For the EPS project, Revit modeling was an essential design tool that allowed discipline leads to coordinate their designs and reduce potential conflicts. For example, the architectural model for the electrical building was used as a background for other disciplines, such as electrical, in order to accurately locate equipment within the space. The three-dimensional design model also improved the quality of the project design by providing a visual tool that effectively demonstrated the design concept to the client. This visual tool allowed for greater collaboration between the design team and WASD during the workshops.

Conclusion

The EPS project is an example of the design challenges facing wastewater treatment plants that must adapt to SLR. The design challenges encountered during this project offered an opportunity for all design leads to work together and be interconnected throughout different phases of the project. The structural design was perhaps the most important design element of the project. Designing the electrical building for an SLR elevation of 20.3 ft began with an understanding of the structural needs of the building, including dead loads, live loads, rain loads, wind loads, soil loads, and most importantly, flood loads. Knowledge of flood hazard mapping services, such as the FEMA flood map, was important to understand the impact of flood loads on the new electrical building.

The structural needs for all other disciplines required an understanding of the live loads for different areas of the building. The SLR elevation of the building made the structural design process a bit more challenging toward meeting these load needs. The design process was a collaborative effort among all discipline leads and the use of three-dimensional software, such as Autodesk Revit, allowed for efficient and creative design solutions. Success of the project was also dependent on understanding the project goals and client needs. Communication mediums, such as the design workshops with WASD staff and progress meetings with the discipline leads, were essential tools throughout the design process. Overall, incorporating SLR as design criteria for wastewater treatment plants involved a strong effort from both WASD and Miami Dade County. It was important to have a holistic approach throughout the design process in order to effectively adapt SLR within the design.

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