# Memorandum

MIAMI-DADE COUNTY

**Date:** March 11, 2021

Agenda Item No. 2(B)(5)
April 20, 2021

**To:** Honorable Chairman Jose "Pepe" Diaz
and Members, Board of County Commissioners

**From:** Daniella Levine Cava
Mayor

Daniella Levine Cava

**Subject:** Report Regarding Vulnerability of Sanitary Sewer and Stormwater Infrastructure to Sea Level Rise - Directive No. 161835

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As part of my operation to catch up on the backlog of items, we are bringing you reports that were pending from the previous administration. This report is submitted in response to Resolution No. R-908-16 adopted by the Board of County Commissioners (Board) on October 5, 2016. The resolution directed the administration to study how sea level rise affects sanitary sewer and stormwater infrastructure and to identify:

1) how sanitary sewer and stormwater systems may be affected by sea level rise;
2) the potential risks involved;
3) areas of the County that could be most impacted;
4) recommendations on how best to eliminate the vulnerability of sanitary sewer and stormwater systems to sea level rise; and
5) recommendations as to any further technical and financial evaluations and legislative or administrative actions that may be necessary to address the vulnerabilities and problems identified.

Specifically, the report provides an overview of how sanitary sewer and stormwater systems work; how both systems are impacted by current and future water levels; describes which areas will be impacted; and recommends steps to reduce these vulnerabilities.

This report was developed as a collaborative effort between the departments of Regulatory and Economic Resources and Miami-Dade Water and Sewer as well as the Department of Transportation and Public Works.

In accordance with Ordinance No. 14-65, this report will be placed on the next available Board meeting agenda. If you have any questions or concerns, please do not hesitate to contact James Murley, Chief Resilience Officer, Department of Regulatory and Economic Resources, at 305-375-4811.

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# VULNERABILITY OF SANITARY SEWERS AND STORMWATER INFRASTRUCTURE TO SEA LEVEL RISE

January 2021

Final Report for Resolution No. R-908-16

# Introduction

On October 5, 2016, the Board of County Commissioners passed Resolution No. R-908-16, which directs the Mayor or Mayor's designee to:

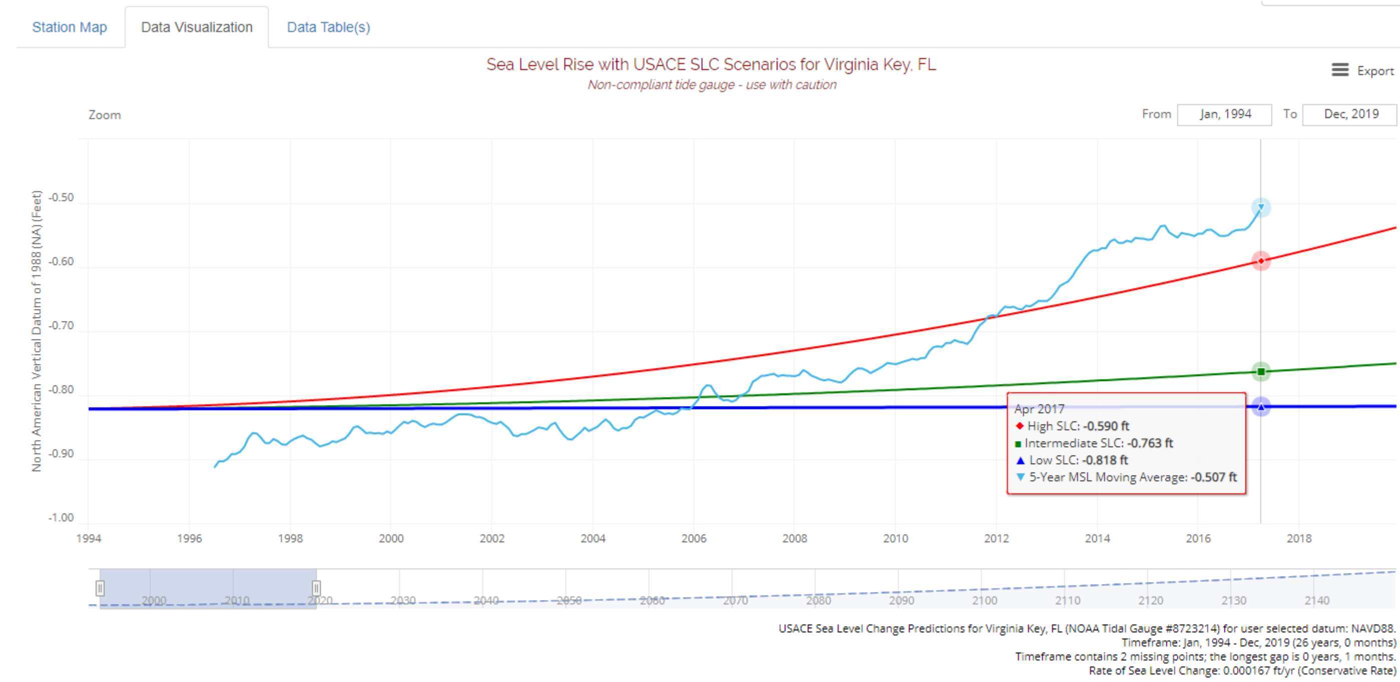
> "Study and assess how sea level rise may affect sanitary sewer and stormwater systems in Miami-Dade County, and to prepare a report. The report shall, at a minimum, identify: (1) how sanitary sewer and stormwater systems may be affected by sea level rise; (2) the potential risks involved; (3) areas of the County that could be most impacted; (4) recommendations on how best to eliminate the vulnerability of sanitary sewer and stormwater systems to sea level rise; and (5) recommendations as to any further technical and financial evaluations and legislative or administrative actions that may be necessary to address the vulnerabilities and problems identified."

In response to this resolution, this report provides an overview of how sanitary sewer and stormwater systems work; how both systems are impacted by current and future water levels; describes which areas will be impacted; and recommends steps to reduce these vulnerabilities. This report builds on several previous studies that have identified vulnerabilities to the County's infrastructure due to flooding risks amplified by sea level rise (see Appendix 1). This report and many others are also being used to inform the development of the County's Sea Level Rise Strategy which will be released in Summer of 2020. The development and use of the Sea Level Rise Strategy fulfills a key action (#7) in the County's broader Resilient305 Strategy. Reiterated by each initiative, it is important to remember that many areas are already vulnerable to flooding today and it is often cost-effective to protect key infrastructure ahead of a storm.

# Sea level rise impacts in Miami-Dade County

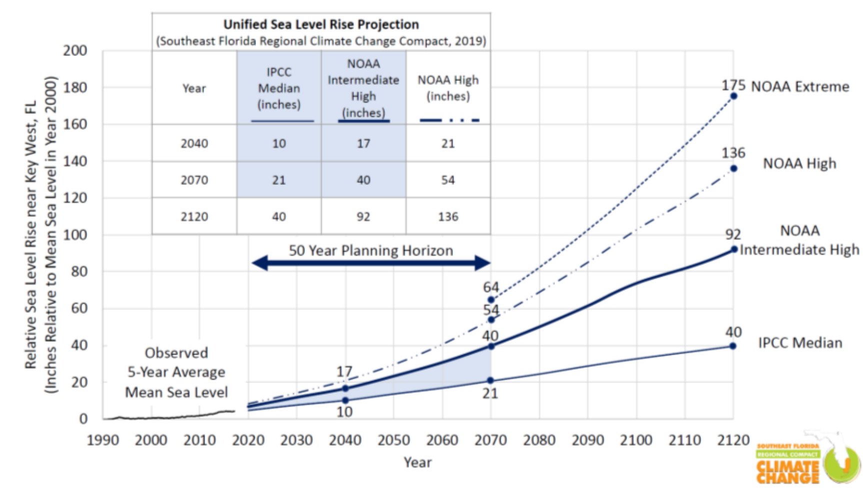
Since 1994, measurements at the tide gauge on Virginia Key have recorded an increase of more than four inches in average sea levels (Figure 1).[1] Over this period the observed increase in water levels (shown as the teal line) has surpassed the Army Corps of Engineers' high sea level rise projection curve (shown as the red line). While it is important to continuing monitoring changes and refining the projections, it is important the County integrate sea level rise into the design of critical infrastructure.

*Figure 1: Sea Level Rise observations at Virginia Key compared to the US Army Corps of Engineers Projections*




For all planning purposes Miami-Dade County relies upon the *Unified Sea Level Rise Projection for Southeast Florida* developed by the South Florida Regional Climate Change Compact (Figure 2).[2] The projection was updated in 2019 by a panel of scientists to reflect the best available data. The latest science indicates that mean sea levels could be between 10 to 17 inches higher than 2000 levels by 2030. By 2070, average levels are expected to be 21 to 40 inches higher.[3]

*Figure 2: Unified sea level rise projection for Southeast Florida*

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[1] This increased is based on the calculated in sea levels at the Virginia Key tide gauge from 1994 through September 2018. Data available at https://climate.sec.usace.army.mil/slr_app/

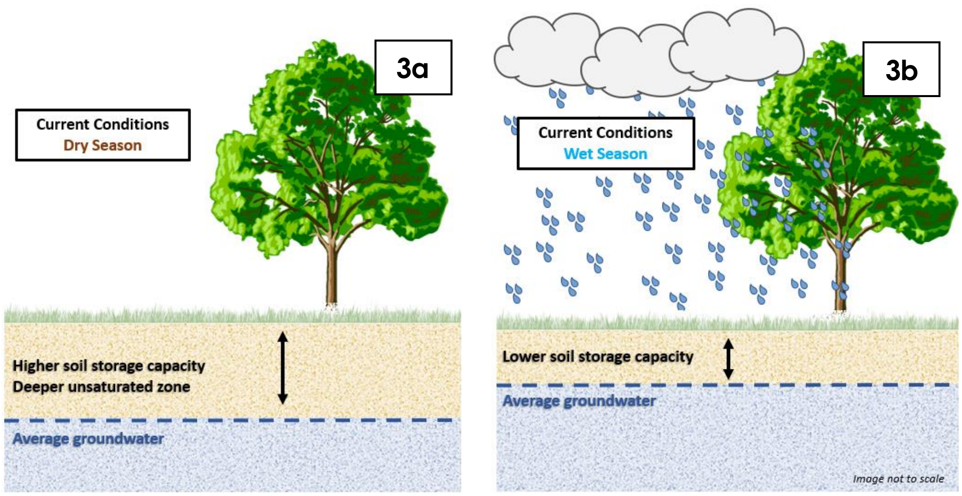
[2] Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group (Compact) October 2015. *Unified Sea Level Rise Projection For Southeast Florida*. A document prepared for the Southeast Florida Regional Climate Change Compact Steering Committee

[3] These changes are all relative to the baseline year 1992.

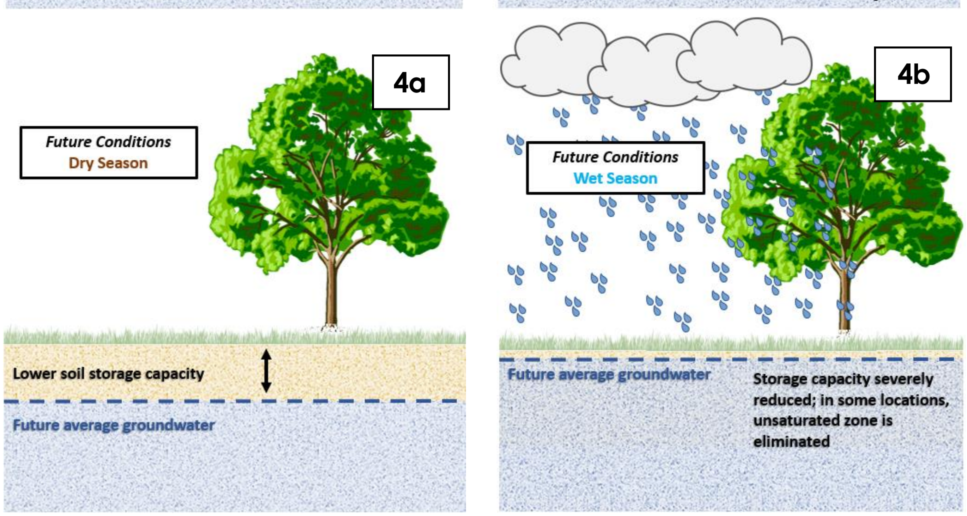
# How sea level rise affects groundwater levels

In South Florida, groundwater levels are linked to ocean levels and therefore are altered by rising sea levels. Groundwater levels change seasonally and are at their highest at the end of the wet season (typically around October). During the dry season or periods of drought the water table naturally falls due to the lack of rain. The South Florida Water Management District ("The District") also actively manages the groundwater levels for inland areas. The District works to adjust the water level in the canals so that groundwater levels do not get so high they lead to flooding, but also not so low that salt water intrudes inland.[4] For areas east of the District's water control structures the groundwater levels are impacted by the tides.

As tides rise, the groundwater in these areas will increase. Inland areas will also see more subtle changes because the District's water management system. The regional system may not be able to provide the same level of flood protection without substantial changes. The four graphics in Figures 3 and 4 show a simplified process of groundwater rise. Figures 3a and 3b shows a simplified picture of the current average conditions. The groundwater is lower in the dry season and there is a deeper layer of unsaturated ground. In the wet season this unsaturated zone is reduced so there is less "soil storage" or ability to absorb rain after a storm. Figures 4a and 4b shows future conditions where average groundwater levels are permanently higher leading to a decrease in "soil storage." Where groundwater levels are close to the surface, existing drainage infrastructure and sewer infrastructure can be affected if they were not designed to be located in saturated soils.




*Figures 3a and 3b: Average groundwater levels under current conditions in the dry and wet seasons*




*Figures 4a and 4b: Average groundwater levels under future conditions in the dry and wet seasons*

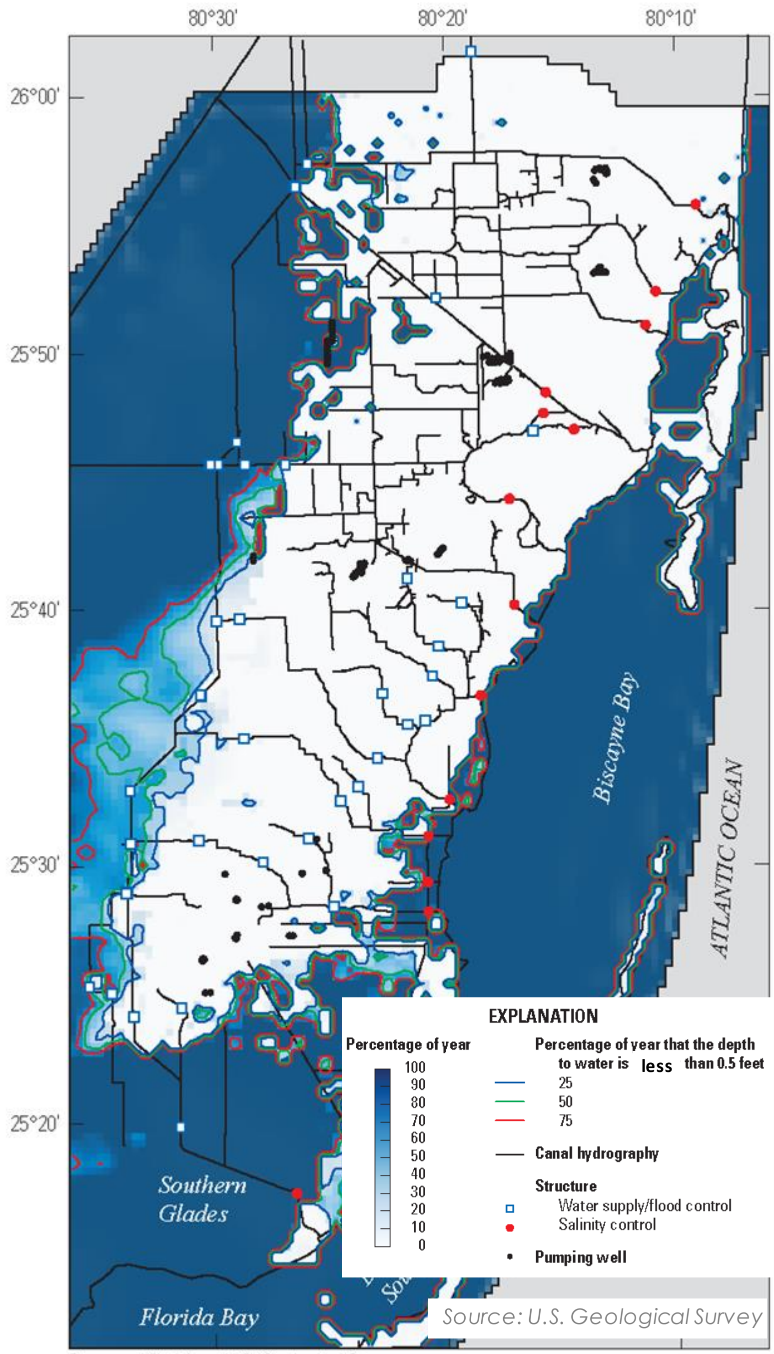
[4] For more information on water management in South Florida, see the presentation here: http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2018/01/2-Kivett-Strowd-presentation.pdf

The following studies illustrate how different precipitation patterns and rising groundwater levels caused by rising sea levels will likely decrease the amount of soil storage and put more stormwater and sewer infrastructure at risk.

To understand how sea level rise will impact groundwater resources, the County is collaborating with the U.S. Geological Survey (USGS). Their research has indicated that rising sea levels will increase groundwater levels in certain areas (Figure 5).[5] The effects will be more pronounced in certain locations, such as in South Dade and along the coast, but the entire water management system will be affected. By 2040, many areas (shown in blue in Figure 5) will experience groundwater levels within half a foot of the surface more than 25% of the year. For other areas, shown in a darker blue color, groundwater levels are expected to be within half a foot of the surface more than 75% of the year. When groundwater levels are close to the surface it can affect both stormwater and wastewater infrastructure such as piping, manholes, pump station wet wells, septic systems, gravity injection wells and french drains if they were not designed to be in saturated soils.

Subsequently, the RAND Corporation conducted a study to understand how sea level rise and various precipitation forecasts would affect groundwater. [6] Through this project, they created an online mapping tool, which allows users to see how groundwater levels are expected to change (Figure 6). Users can go online and see when groundwater levels will rise above a certain threshold under future scenarios.[7] As shown in Figure 5, the areas where groundwater levels

*Figure 4: Percentage of time water-table elevations are less than 0.5 ft. below land surface in the 30th year of the scenario simulation period for increased sea-level and groundwater pumpage conditions*




Base modified from U.S. Geological Survey 1:2,000,000-scale digital data

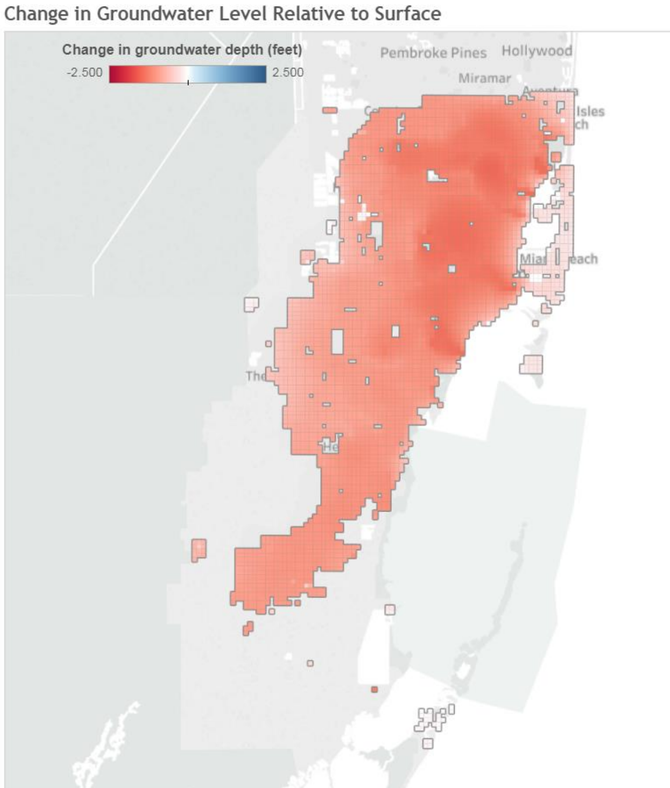
[5] Hughes, Joseph D., and White, Jeremy T., 2014, Hydrologic conditions in urban Miami-Dade County, Florida, and the effect of groundwater pumpage and increased sea level on canal leakage and regional groundwater flow: Scientific Investigations Report. http://pubs.usgs.gov/sir/2014/5162

[6] The full report can be found online at: http://www.miamidade.gov/green/library/2018-10-19-adapting-land-use-and-water-management-plans.pdf

[7] The online decision support tool can be found online at: https://public.tableau.com/profile/rand4185#!/vizhome/RR-1932-MCF_review/Introduction

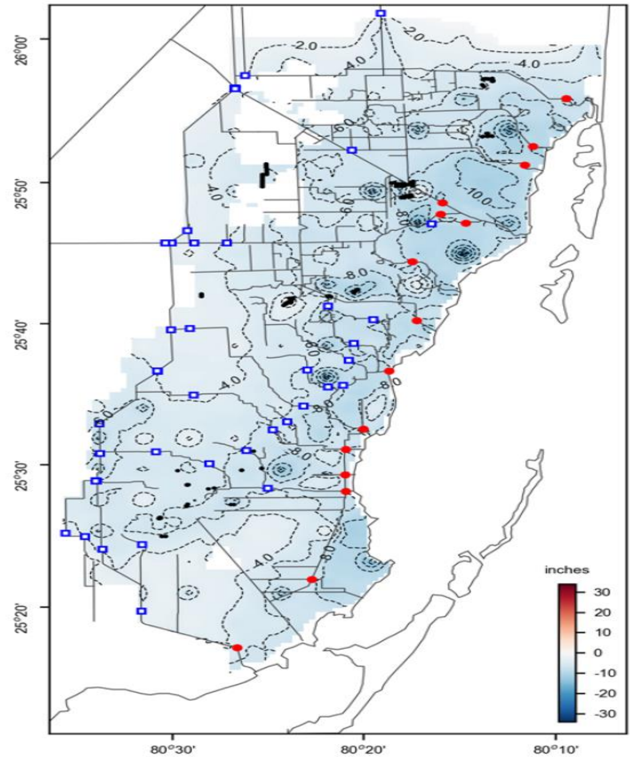
are expected to rise are shown in red. This change occurs across the entire County, but are most pronounced changes are along the coasts and canals. This figure shows the effects of an increase in sea level rise of 18 inches.

*Figure 5: Online mapping tool showing how groundwater levels will change under different sea level rise and precipitation scenarios*




*Source: RAND Corporation*

*Figure 7: Difference in wet season soil storage with a high sea level scenario*




*Source: Florida International University*

Recently, Florida International University's Sea Level Solutions Center completed research on how groundwater levels will change in the next fifty years (2060-2069). Their study looked at how groundwater changes under high and low sea level rise conditions. They found groundwater levels will be higher across the County with the potential to impact both coastal and inland infrastructure (Figure 7).

Broward County was also concerned about this issue and worked with the USGS to study in-depth how this loss of soil storage would affect their county. The scientists recently published their report, "Potential of Increased Inundation in Flood-Prone Regions of Southeast Florida in Response to Climate and Sea-Level Changes in Broward County, Florida (2060-2069)".[8] As with similar studies in Miami-Dade, they found the greatest increases along the coast. In those areas they found the increases in groundwater level were nearly equivalent to sea level rise. Where the average wet-season depth to groundwater is less than one foot the USGS indicated that there is a "much higher likelihood of becoming inundated during moderate precipitation events."[9] They also evaluated how effective pumping could be at protecting areas with elevated groundwater levels and found large pumps would be required to provide flood protection for coastal areas. Their study also notes that "sea-level rise can

[8] Decker, J.D., Hughes, J.D., and Swain, E.D., 2019, Potential for increased inundation in flood-prone regions of southeast Florida in response to climate and sea-level changes in Broward County, Florida, 2060–69: U.S. Geological Survey Scientific Investigations Report 2018–5125, 106 p., https://doi.org/10.3133/sir20185125.
[9] Ibid. p. 30

increase regional groundwater levels… increasing the likelihood and duration of inundation events within inland neighborhoods."[10]

Altogether, because the expected higher groundwater levels will lead to a decrease in soil storage and groundwater levels that are very close to the surface, sea level rise will challenge existing drainage and wastewater treatment infrastructure that was not designed to be located in saturated soils.

## Areas of the County that will be impacted by higher groundwater

Previous studies have indicated that rising sea levels will increase groundwater levels and impact low-lying areas - some of which are far from the coast. There are many inland areas near water bodies, particularly in the southern and western parts of the County that will be affected because the water table could be within inches of the surface. While this section focuses on areas that are vulnerable to higher groundwater levels there are other impacts of sea level rise, such as changing the canal levels, which will also affect sewer and stormwater infrastructure.

### Methodology

For this study, staff scientists from the Water and Sewer Department modeled and mapped how groundwater levels will change. These areas are concerning because high groundwater levels can pose a number of challenges to both the sanitary sewer and stormwater systems. To identify areas with high groundwater levels, the study began with an analysis of places that are currently at-risk and areas expected to be impacted by 2040 due to sea level rise. Areas that are currently vulnerable to flooding due to the influence of higher groundwater levels are shown in the "base-case scenario." Areas vulnerable in 2040 are shown in the "sea-level scenario." Appendix 3 contains a full description of the methodology used to identify vulnerable areas and the technical assumptions.

This study has identified areas which are *likely* to be vulnerable due to very high groundwater levels using land surface elevation, groundwater levels, sea level rise projections, and historical climate conditions. Currently, Miami-Dade County groundwater models have a relatively low spatial resolution therefore these results are intended to identify broad areas where more detailed study is needed. This model is not detailed enough to provide clear design or infrastructure planning guidance for areas along the coast and islands. More detailed site-specific analysis to include considerations of land use, imperviousness, soil type, water table cycle, and existing and planned stormwater infrastructure will be completed before any infrastructure investments are made. As modeling improves over time staff will continue to refine this analysis. A much more detailed analysis is completed to model stormwater flooding and this is described in subsequent sections.

### Findings

This study modeled and mapped areas where groundwater levels are close to the surface under current and future conditions. Maps were developed to show where the groundwater is currently close to the ground surface under ***average wet conditions*** and during ***99th percentile level conditions*** which would typically follow a storm (Table 1).[11][12] Under current conditions, there are many areas where the groundwater levels are high; however, most of this land is outside the Urban Development Boundary. Figure 10 depicts future conditions and shows areas

[10] Ibid p. 2

[11] Percentile for groundwater levels – A percentile is a groundwater value below which a certain percentage of groundwater observations lie. Groundwater values were computed with the U.S. Geological Survey's Surface Groundwater Model.

[12] As described in Appendix 3, the model does not simulate a single storm scenario (e.g. 10-year or 100-yr), but instead simulates long-term climate conditions based on historical climate conditions from the 1996-2010 period of record.

where groundwater levels will be close to or above the surface under average *and* maximum water levels in the peak of the wet season. On each of these maps the vulnerability is classified and shown in different colors. This classification system is explained in Table 1 and Figure 8.

Classification 1, shown in tan in Figures 9 and 10, are the least vulnerable areas. In these areas, the groundwater during average wet conditions is at least half a foot below the ground surface under all conditions (even after a storm). Classification 2, shown in light green, are slightly more vulnerable. In these areas the $99^{th}$ percentile water level may get within half a foot of the surface following a storm event. Classification 3, shown in dark green, are more vulnerable as the $99^{th}$ percentile water level could be higher than the ground elevation in the storm leading to temporary groundwater flooding. Classification 4, show in teal, is more vulnerable and shows areas where the groundwater during average wet conditions is less than half a foot below the surface and where the $99^{th}$ percentile water level is below the surface. Classification 5, shown in light blue, are the most vulnerable. In these areas both the groundwater during average and the maximum levels are above the ground elevation. In undeveloped areas, these areas would be wetlands, lakes or under mean sea level.

*Table 1: Vulnerability classifications*

| | Average groundwater level | 99th percentile groundwater level (post-storm) |
|---|---|---|
| Classification 1: | More than half a food below ground | More than half a foot below ground |
| Classification 2: | More than half a foot below ground | Within half a foot below ground |
| Classification 3: | More than half a foot below ground | Above ground surface elevation |
| Classification 4: | Within half a foot of ground elevation | Above ground surface elevation |
| Classification 5 | Above ground surface elevation | Above ground surface elevation |

*Figure 8: Vulnerability classifications*

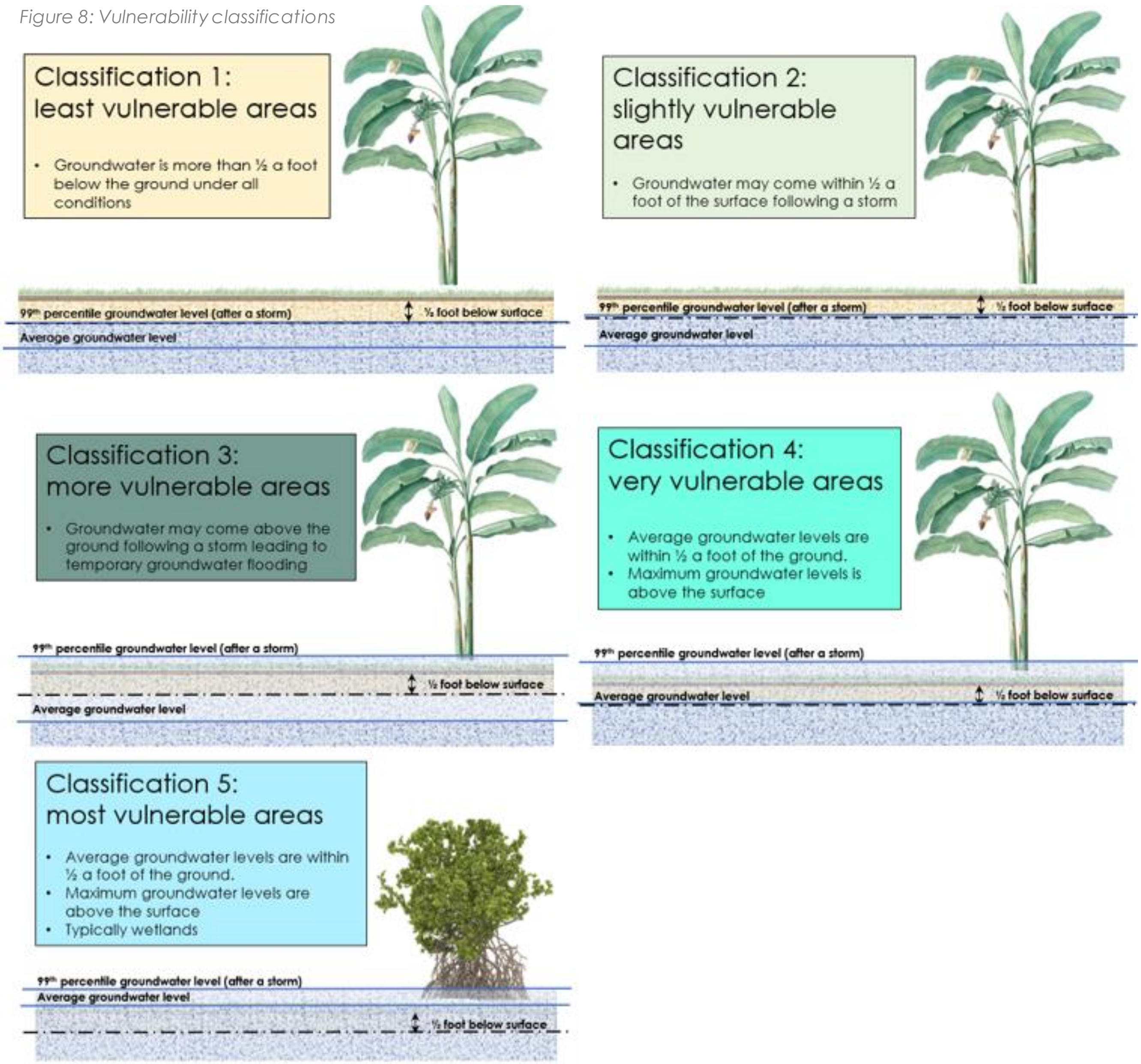



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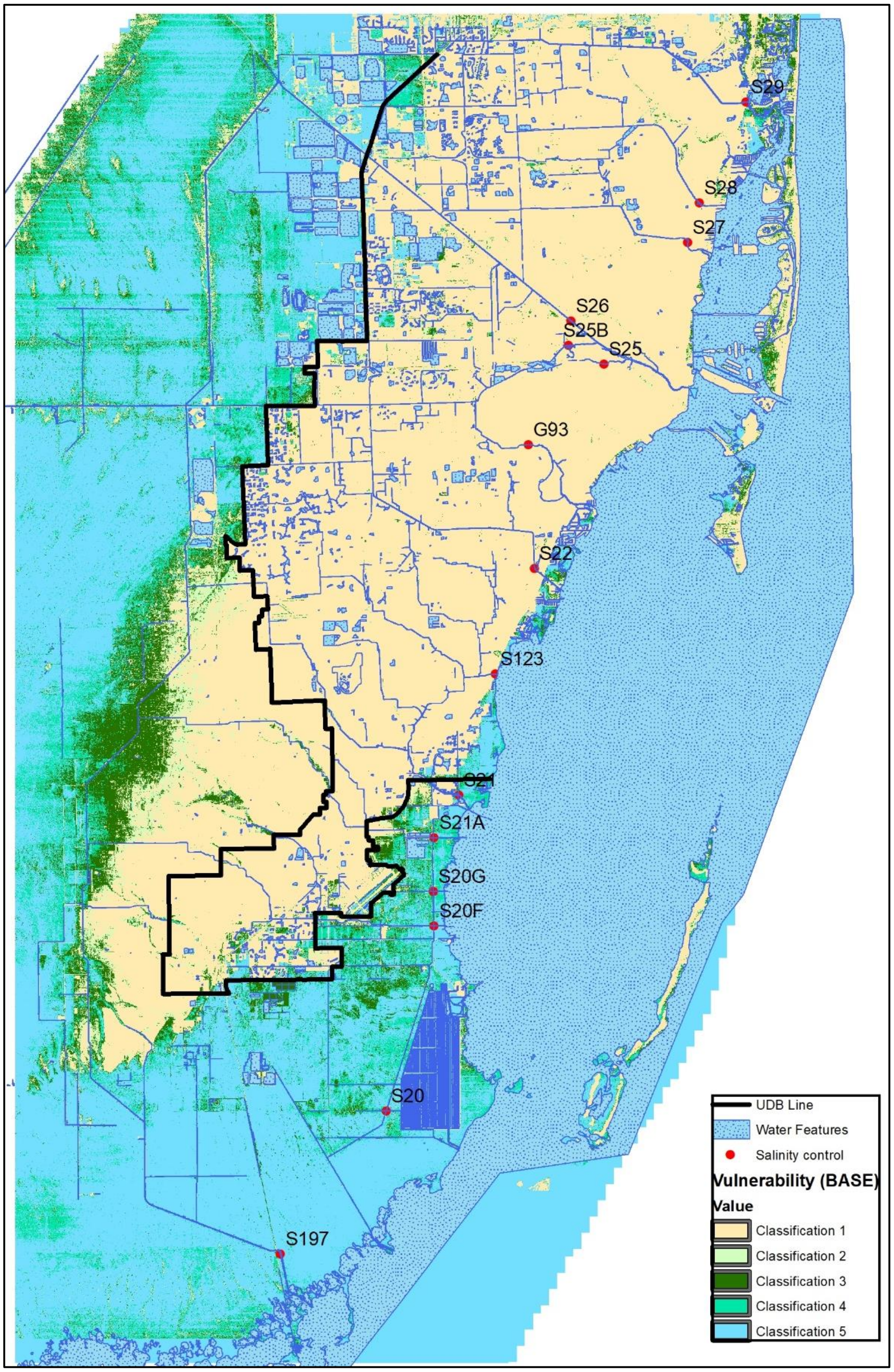
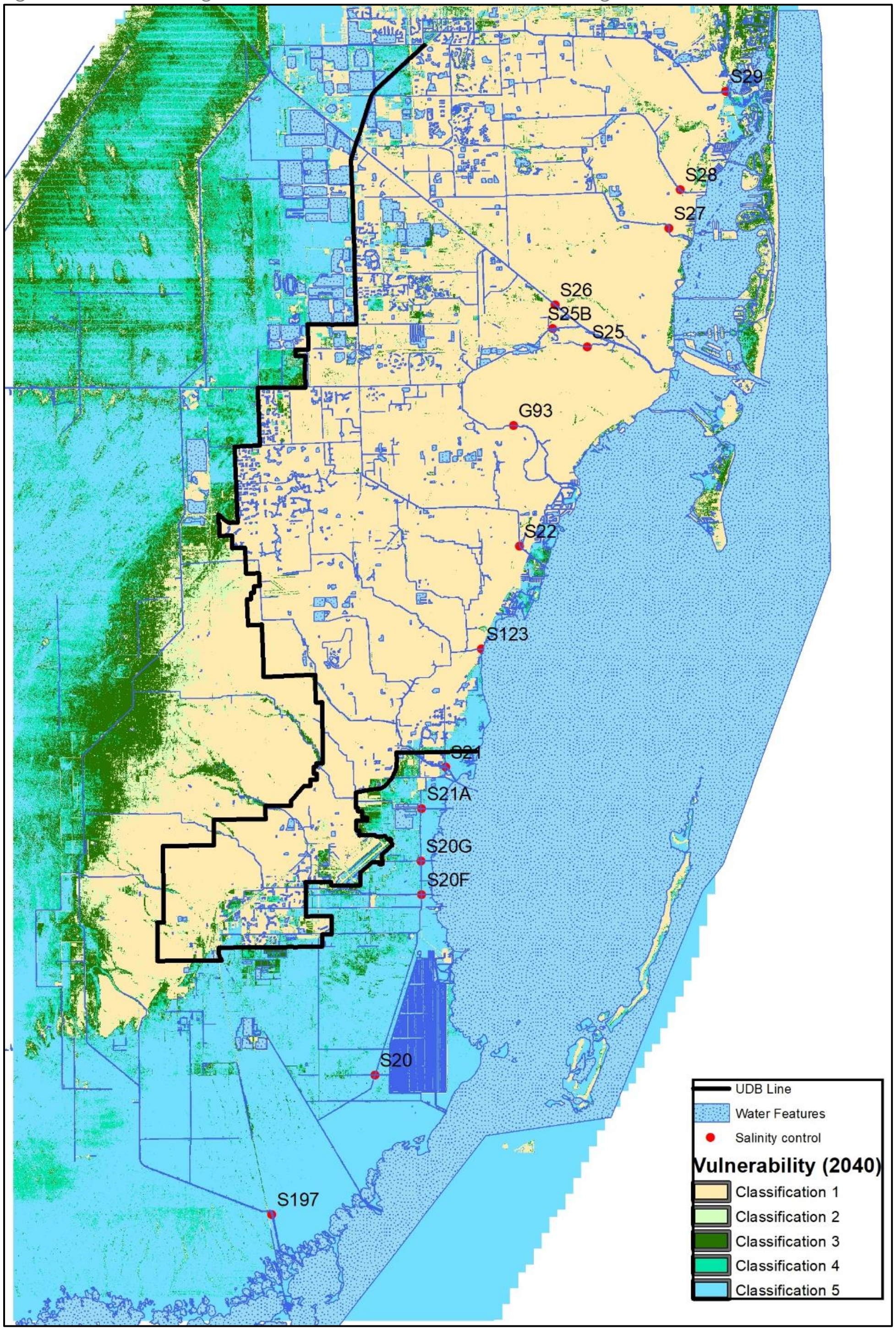
*Figure 9: Areas with groundwater levels close to or above the ground under current conditions (or the "base-case scenario")*



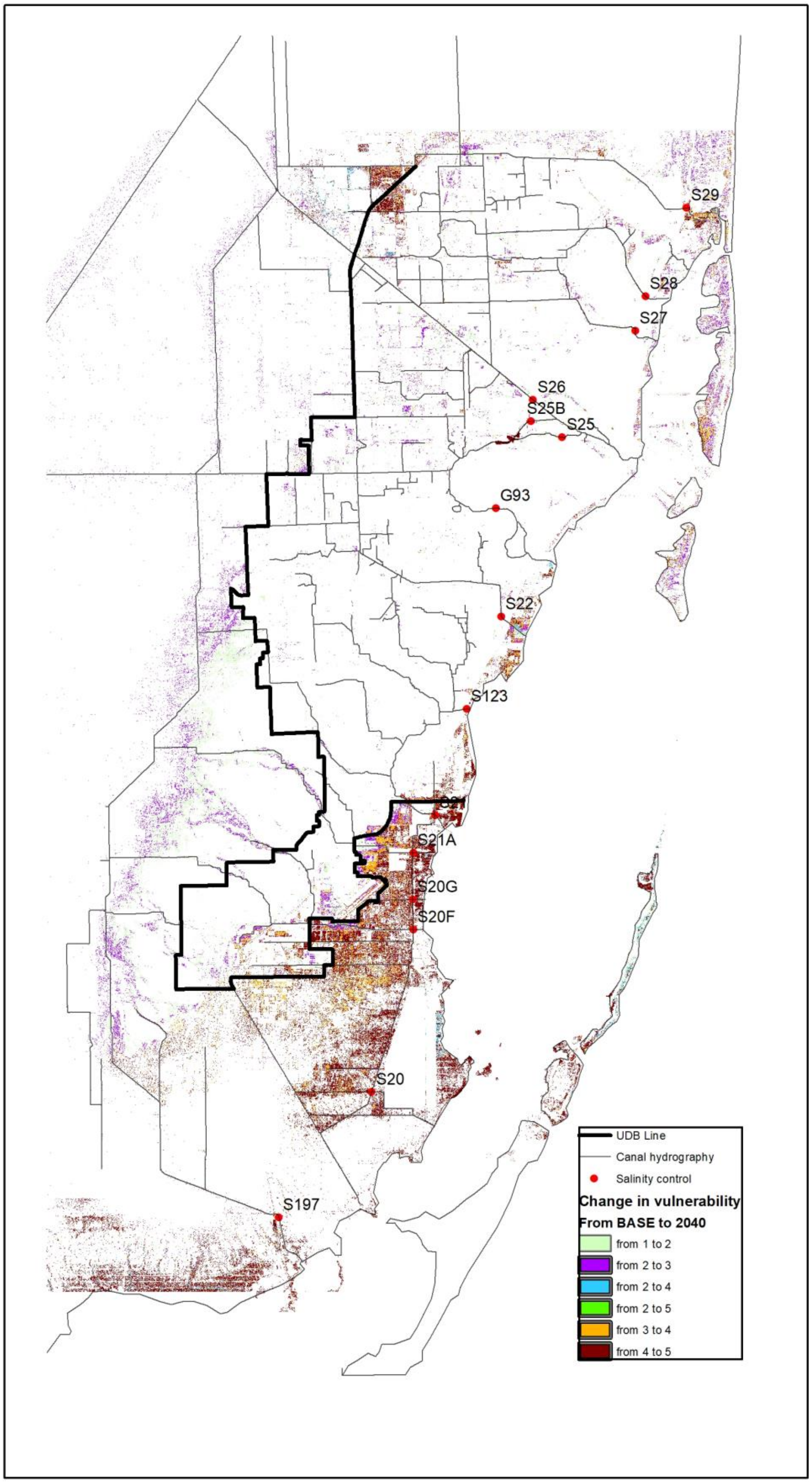

*Source: Miami-Dade County*

*Figure 10: Areas with groundwater levels close to or above the ground under future conditions (2040) (or the "sea-level" scenario)*




*Source: Miami-Dade County*

*Figure 11: Areas where sea level rise leads to a change in the vulnerability classification*




*Source: Miami-Dade County*

Increasing groundwater levels due to sea level rise in the future increases the vulnerability of certain areas. Figure 11 highlights areas where the change with future conditions leads to a change in the vulnerability classification. Classification 1 is the least vulnerable case while Classification 5 is the most vulnerable. Many of the most vulnerable areas are outside of the Urban Development Boundary.

# How elevated water levels affect infrastructure

Rising sea and groundwater levels can impact existing infrastructure. Some infrastructure, such as sanitary sewer pipes, are designed to be submersible. However, increasing groundwater levels increases hydrostatic force on piping and therefore increases infiltration at joints and defects which can compromise their function. Moreover, increasing groundwater levels potentially exposes defects otherwise not contributing to infiltration. Where the groundwater rises above ground, it may result in additional inflow and infiltration. In addition, soil and groundwater characteristics can also increase corrosivity of pipes. Other infrastructure, such as "wet" and "dry" exfiltration trenches, or French drains, were not designed to be permanently inundated. For those infrastructure assets, higher groundwater levels can compromise their effectiveness, leading to water pollution and increased flood risks. Elevated groundwater levels can also intrude upon, weaken, and cause premature failure of the pavement sections found above some drainage infrastructure features.

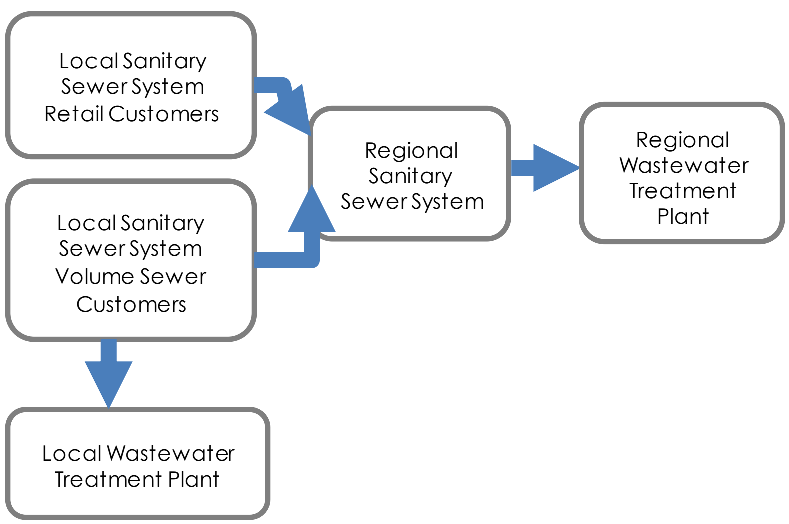
When infrastructure such as the regional water management system was designed in the past, there was an assumption that water levels would stay the same over the life of the asset. The codes and common practice did not necessarily require engineers to include provisions for rising water tables over time. Therefore new, higher water levels may compromise existing infrastructure. The following sections will describe how elevated water levels are specifically affecting existing sanitary sewer and stormwater infrastructure managed by Miami-Dade County and how those impacts are expected to change with time and rising waters.

# How sea level rise affects the sanitary sewer system

## Sanitary system overview

In Miami-Dade County, wastewater is handled under two broad categories: (1) onsite systems and (2) centralized systems. Onsite systems include septic systems and are used where centralized systems are not available. The impacts to septic systems are described in a separate report. [13] The centralized system relies upon a network of pipes, manholes and pumps which convey wastewater from buildings to locations where treatment and disposal occurs. The centralized system includes the collection system, transmission systems, and treatment plants. The collection and transmission system includes both a Local Sanitary Sewer System and the Regional Sanitary Sewer System. [14] The local systems feed into the regional system (Figure 12). The regional system includes interceptor lines (pipes), manholes, pump stations and force mains needed to serve all customers, including retail and wholesale customers (also known as volume sewer customers). These volume sewer customers include fifteen Municipal Utilities which convey wastewater from their local systems to the County's regional system.

*Figure 12: Schematic of the Wastewater Treatment System*




Miami-Dade County has sixteen public utilities that own and operate sanitary sewer systems. This includes the

[13] For more information on how septic systems in Miami-Dade County are impacted by sea level rise, see report: http://www.miamidade.gov/green/library/vulnerability-septic-systems-sea-level-rise.pdf

[14] The local systems include pipes, manholes, pump stations and force mains serve retail customers.

Miami-Dade Water and Sewer Department (WASD) and fifteen municipal utilities. Two of the sixteen (WASD and the City of Homestead) also own and operate wastewater treatment plants. A list of public utilities and their services, as well as a list of municipalities and their utilities, is provided in Appendix 2.

## The impact of sea level rise on the sanitary sewer system

Rising sea levels affect the sanitary sewer system in two primary ways: through flooding at facility sites, such as plants and pump stations, and by impacting the overall operation of the collection and treatment system. For example, the three wastewater treatment plants located along the coast are subject to increasing inundation from changes in sea levels (Figure 13). In the near term, sea level rise in combination with changes in precipitation intensity and frequency compound the damaging impacts of storm surge on facilities during extreme weather events.

In addition to flooding impacts, changes in precipitation frequency and intensity, coupled with sea level rise, could cause increases in the volume of wastewater being conveyed and treated. The flow that enters the system from stormwater and groundwater is referred to as inflow and infiltration. Inflow and infiltration (or "I & I") can cause increased operation costs associated with conveyance and treatment of the extraneous water, reduce sewer and treatment capacity, increased risk of sanitary overflows, and the overdesign of pump stations and infrastructure. The increased flow caused by I & I can also lead to surcharge conditions, Fats, Oils, and Grease (FOG) blockages, sanitary sewer overflows, and building plumbing backups (e.g., overflowing toilets). I & I is an infrastructure integrity issue that every system must manage and one that is exacerbated by sea level rise, due to a rise in groundwater levels.

Additionally, sea level rise will continue to cause an increase in the frequency of tidal events that compromise the capacity of the drainage system when limited to a gravity-based operation, which may increase the volume of inflow and infiltration. The gravity-based water management system in South Florida will be described in more detail in another section.

Increasing groundwater exposes more sewer system joints and defects to groundwater hydrostatic pressures increasing infiltration. Street level flooding increases and encourages both direct and indirect illicit connections to the sanitary sewer system

*Figure 13: Current wastewater treatment plants in coastal Miami-Dade County*

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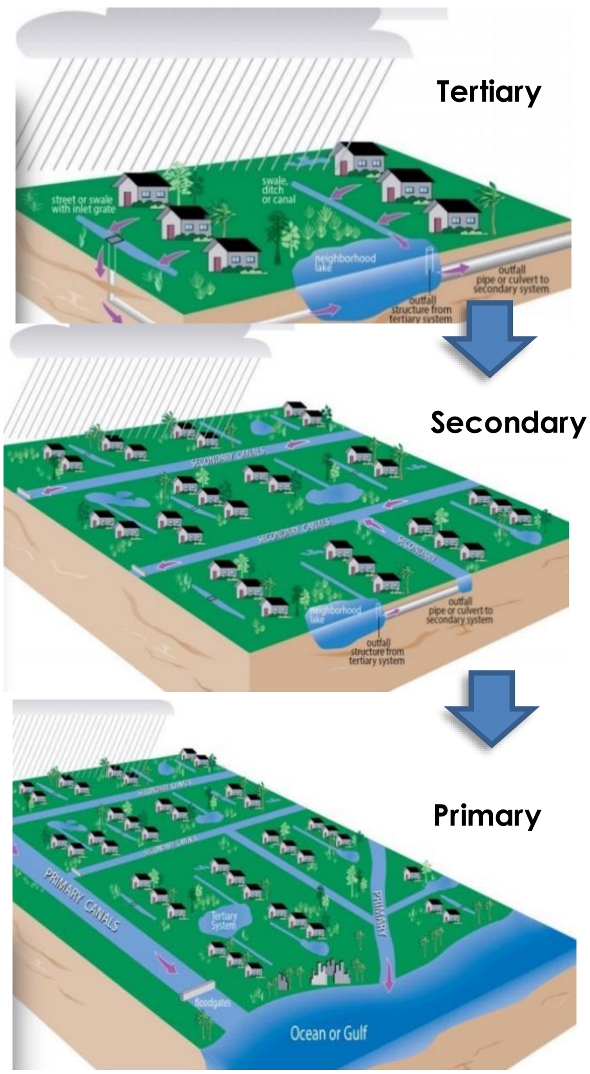
# How sea level rise affects the stormwater system

## Stormwater system overview

Stormwater is the accumulation of rainwater that either gets absorbed into porous (or pervious) surfaces like grass swales, forests, farm fields, and other areas of "open ground," detained or retained in dry or wet ponds and lakes, or runs off on non-porous (or impervious) surfaces like streets, parking lots, and rooftops, causing ponding and flooding.

*Figure 14: Three-tiered stormwater management system (South Florida Water Management District)*




The stormwater infrastructure system serving Miami-Dade County is divided into three parts which are shown in Figures 14 and 15.[15] This three-tiered interconnected system manages stormwater as it moves through the tertiary, secondary, and primary drainage systems:

Tertiary (neighborhood) drainage systems benefit localized areas in unincorporated Miami-Dade County, municipalities and Florida Department of Transportation right-of-ways by providing immediate and ongoing flood protection. Components include exfiltration trenches (French drains), catch basins, manholes, outfalls, pollution control structures, drainage wells, swales, ponds, and wet and dry detention retention areas. These tertiary elements may be owned, maintained, and operated by Miami-Dade County, municipal jurisdictions, Florida Department of Transportation, or private owners.

Secondary drainage systems benefit a larger area including municipal and unincorporated areas by working in conjunction with and thereby increasing the effectiveness of the tertiary systems. Secondary drainage systems include the secondary canal conveyance system which is tributary to the primary conveyance system and made up of canals, lakes, culverts, control structures and stormwater pump stations. These secondary elements are owned, maintained, and operated by Miami-Dade County and municipalities.

Primary drainage systems are the main hydrological control system which the aforementioned systems depend on. The primary system connects the flow of water from the Everglades to the bay and provides protection from flooding to saltwater intrusion to unincorporated and municipal areas. Components include the primary canal conveyance system, salinity control structures, other inland control structures, pump stations, stormwater impoundment areas, and protective levees. These primary elements are owned, maintained, and operated by the South Florida Water Management District (SFWMD).

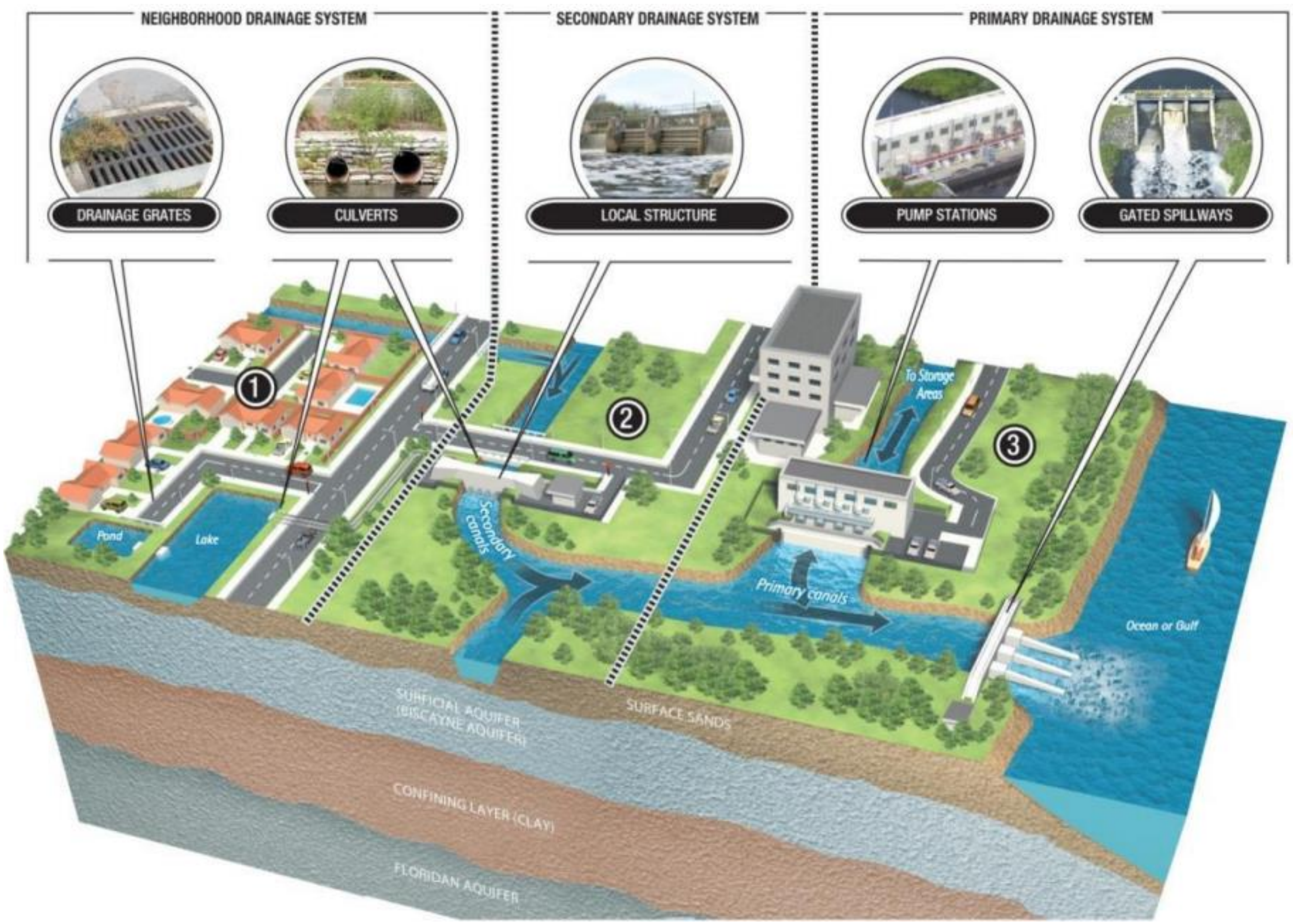
[15] For a presentation with more information on the stormwater system, refer to this poster: https://www.sfwmd.gov/sites/default/files/documents/presentatiion_before_after_storm.pdf

At all scales, the drainage system involves different types of grey (pipes, pumps, etc.) and green infrastructure[16] (e.g., permeable pavement, bioswales, rainwater harvesting, green streets, conservation areas, etc.). These stormwater control measures primarily rely on gravity to move water from higher elevations at the surface to the ground by infiltration and seepage and through the canals to the ocean. The water control structures on the canals also rely on gravity, allowing water to naturally flow from higher stages to lower stages (the ocean through outfalls).[17] Additionally, the South Florida Water Management District operates two forward pumping stations on the C-4 canal and Miami River to drain flood waters into the bay.

**The key stormwater infrastructure owned, maintained, and operated by Miami-Dade County includes:**

- Over 200 miles of secondary canals;
- 18 stormwater pump stations;
- 15 control structures;
- Over 85 lakes and wet detention areas;
- Over 1.7 million linear feet of exfiltration trenches or French drains;
- Over 1.6 million linear feet of culverts, equalizers, outfalls, other solid piping;
- Almost 400 pollution control structures, and
- Over 52,000 catch basins

*Figure 15: Interconnected components of the stormwater system (South Florida Water Management District)*




[16] Low-Impact Development and Green Infrastructure: Pollution Reduction Guidelines for Coastal Water Quality in Southeast Florida. Florida Department of Environmental Protection. 2019. Pg 69.

[17] Becauese of gradual sea level rise and extensive development, gravity alone was no longer sufficient to drain the "C-4" watershed. As a consequence, the South Florida Water Management District installed two 'forward' pumps stations around the Miami Airport to move water mechanically.

## The impact of sea level rise on the stormwater system

**Flooding impacts**

Stormwater management systems were created to capture one to seven inches of rainfall (5-year design storm) into the ground and drain it from the surface to prevent or reduce flooding. However, water levels observed during high tides (or "King-tides") in the past, have become more frequent with sea level rise. Recent water levels have exceeded the systems' original design capacity. Table 2 summarizes the impacts of future sea level rise on all three tiers of the stormwater system. Sea levels are projected to increase 14 to 26 inches by 2060. [18] As sea levels continue to rise, reduced gravitational effect will slow down the flow of water through the coastal control structures which ultimately increases the frequency and duration of flooding during heavy rains events.[19] As sea level rise causes groundwater to rise to one foot below ground surface, the efficiency of the exfiltration systems are reduced by 75%. When the groundwater gets to within half a foot of the surface the efficiency is reduced by up to 90%. Even with the current conditions, some gravity-based water control structures are not performing as designed.[20] Drainage wells will also become less effective as the groundwater levels rise.

*Table 2: Impacts of Sea Level Rise on Stormwater Systems*

| | **Impact on Stormwater System** | | |
|---|---|---|---|
| **Sea Level Rise Consequence** | **Tertiary** | **Secondary** | **Primary** |
| **Higher water levels at outfalls** | Stormwater can back up through pipes, drains, manholes, neighborhood canals, etc. | Secondary canal water levels can increase. The water level increase can slow or block the flow of water from gravity stormwater drainage systems causing back flow and flooding upstream | Pumps and salinity control structures are stressed with higher water levels; large canals can see water back up due to higher water levels at the outfalls |

[18] Unified Sea Level Rise Projection for Southeast Florida. 2014. Pg. 5.
[19] Potential for Increased Inundation in Flood-Prone Regions of Southeast Florida in Response to Climate and Sea-Level Changes in Broward County, Florida, 2060-69. U.S. Geological Survey. 2018. Pg. 2.
[20] RCAP Implementation Guidance Series: Regional Impacts of Climate Change and Issues for Stormwater Management. 2012. Pg. 11.

| | | | |
|---|---|---|---|
| **Elevated groundwater levels** | Less storage and less infiltration into soil increases runoff and puts stress on drainage components, prolonging localized flooding | Increased runoff can overwhelm culverts, drainage basins, and carry more pollutants into secondary canals | Higher volume of runoff can stress pump and canal systems, creating flooding along primary canals |

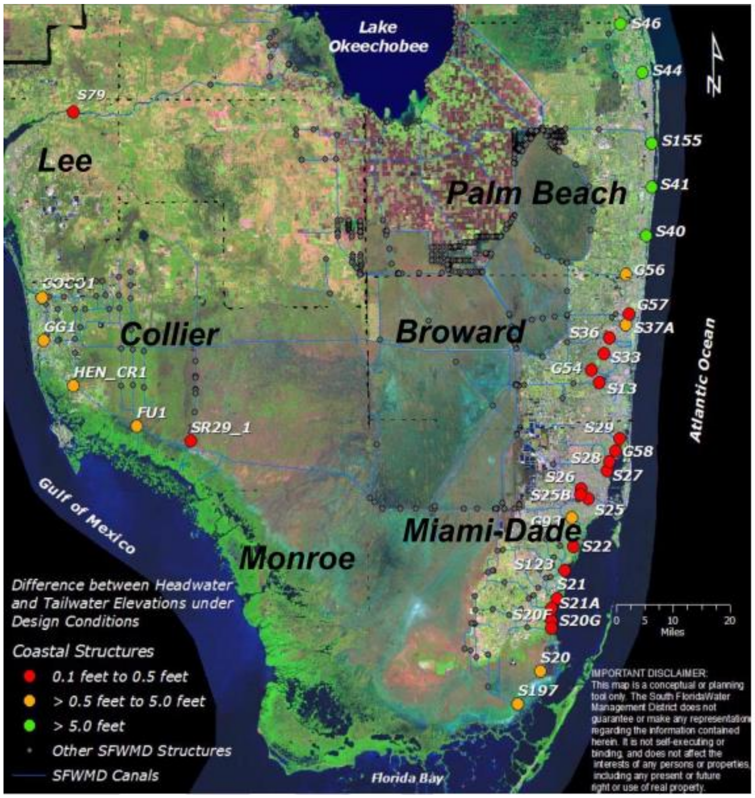
The most at-risk stormwater systems are located in coastal areas, specifically where ground elevations are low. With sea level rise, the stormwater system endpoints or "outfalls" are experiencing higher tides. This can sometimes cause backflow through the system into communities. Therefore, the upstream gravity conveyance system will have to rely on larger storage capacity to avoid flooding developed areas. Increased storage can be achieved through improvements to primary and secondary canals, lakes, and additional infiltration and exfiltration system capacity.

Where the gravity-based system is not adequate, several municipalities such as the City of Miami Beach[21] and the City of Miami as well as the County have invested hundreds of millions of dollars in the last decade to install large pumping systems in low-lying trouble spots to help reduce flooding impacts. These pumping systems are expected to alleviate flooding to an extent depending on the future rate of sea level rise. However, it is currently challenging due to physical constraints and costs to fully address the water quality issues associated with pumps in very urban environments. They can also be energy-intensive, which contributes additional greenhouse gases. Moving forward, stormwater infrastructure design will need to better consider predicted groundwater levels which will rise with sea levels (as described above) as well as any projected increases in the frequency of extreme rainfall events.

[21] City of Miami Beach Rising Above – Stormwater Program. http://www.mbrisingabove.com/your-city-at-work/stormwater-program/

Likewise, regional water management practices by the South Florida Water Management District and the U.S. Army Corps of Engineers are critical to avoid over-stressing the stormwater system during higher tidal elevation events. The South Florida Water Management District has conducted several studies about the impact of climate change and sea level rise on the regional stormwater system. These studies have shown that high water levels have already reduced drainage capacity.[22][23] One other study assessed the vulnerability of major coastal structures operated by the South Florida Water Management District and found 13 of 16 structures in Miami-Dade county were highly vulnerable with just 0.1 to 0.5 feet between headwater (upstream) and tailwater (downstream) elevations under design conditions (Figure 16).[24] One study of the C-7 watershed found that retrofitting the existing primary canal system will likely require substantial investment in new infrastructure and may require changes in land use that will take years to implement.[25] Another study focused on the C-4 watershed found that portions of the watershed presently have a 1-in-10 level of service for flood protection (for a storm event that has a 10% chance of occurring in a given year) and are at risk for nuisance flooding at less than design storm conditions.[26] The same study states that conditions are expected to worsen further because of sea level rise by 2025-2030. Rising sea levels may cause failure of the primary system and significant flooding in 6 of the 26 developed sub-watersheds by 2050-2060.[27]

*Figure 16: Sea Level Rise Vulnerability of Coastal Structures (South Florida Water Management District)*




The effects of higher tides can range from localized to widespread ponding and flooding of roads, emergency routes, buildings, and water damage to both public and private properties (Figure 17). With extensive flooding, there is the potential to affect property values, businesses, and public health. There are areas of Unincorporated Miami-Dade County with low ground elevations that currently experience frequent tidal inundation.

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[22] Assessment of alternative flood mitigation strategies for the C-7 Basin in Miami, Florida. South Florida Water Management District. 2017. Pg. 3.

[23] More importantly, as sea levels increae, these studies indicated that drainage will be further impacted.

[24] Sea Level Rise and Climate Trends: Potential Impacts and Adaptation. South Florida Water Management District. 2016. Pg. 17.

[25] Assessment of alternative flood mitigation strategies for the C-7 Basin in Miami, Florida. South Florida Water Management District.2017. Pg. 40.

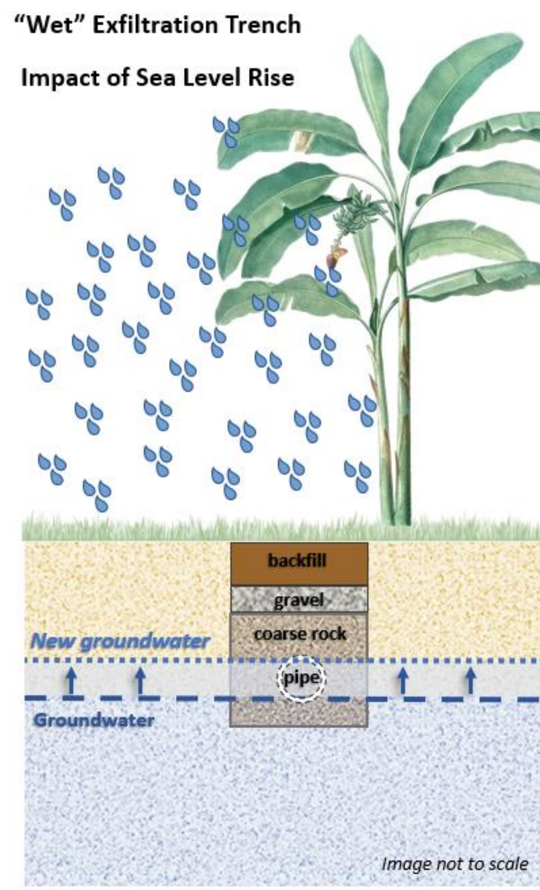
[26] Flood Protection Level of Service Analysis for the C-4 Watershed. South Florida Water Management District. 2015. Pg. viii.

[27] Flood Protection Level of Service Analysis for the C-4 Watershed. South Florida Water Management District. 2015. Pg. viii.

*Figure 17: King-tide flooding coming up through storm drains near the Shorecrest neighborhood in 2019 (Miami-Dade County)*

Higher tides have a direct negative impact on capacity and operations of underground stormwater infrastructure. As sea level rises above ground, the exfiltration systems become conduits or channels for flooding of low-lying communities. Higher ground water levels may reduce the protection that stormwater infiltration and exfiltration systems provide. These systems are designed to work partially above ground water levels. As groundwater rises with rising sea level, the ability to use infiltration and exfiltration infrastructure in areas with higher groundwater tables may be compromised. Therefore, when the land elevation or the built infrastructure is not sufficient to retain and store enough stormwater, there is the potential to reduce the level of flood protection and ability to treat run-off leading to water pollution. There may be a need to retrofit or transition to a closed pipe system in low-lying areas of Miami-Dade County where groundwater is high. However, there are cost and environmental implications to retrofitting any infrastructure.

*Figure 18: Potential impact of rising groundwater levels on function of wet exfiltration trenches.*



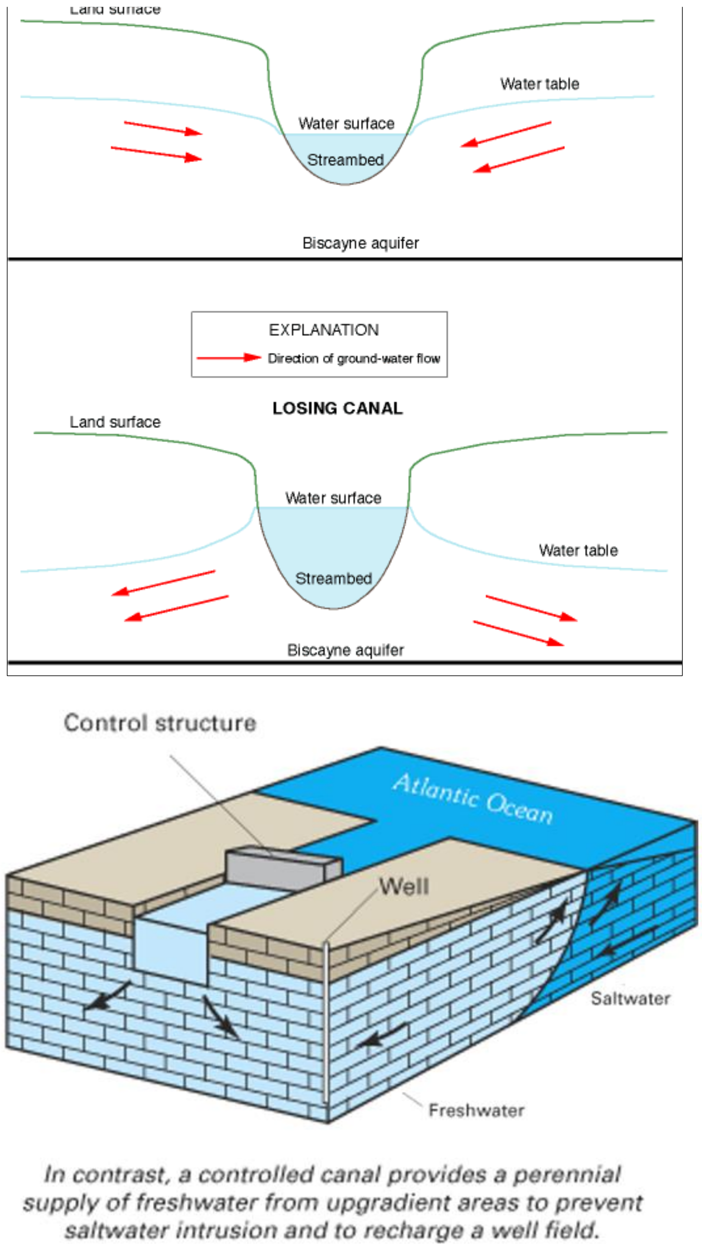

As sea level and groundwater rise, infrastructure that is not designed to withstand frequent or permanent inundation will be negatively impacted, leading to reduced efficiency and, in some cases, system failure (see Figure 18 for renderings of a "wet" exfiltration trenches and the possible impact of sea level rise on unsaturated trench depth).[28] It can be costly, and there are areas where it may be technically, economically, or socially challenging to address persistent flooding without substantial redevelopment because the land is no longer high enough above the bay or groundwater. Additionally, low-lying areas may need to have multiple infrastructure systems retrofitted at the same time.

Additionally, the stormwater system helps recharge groundwater for the region. Historically, the water levels in the canal system could be raised during dry periods which assists with groundwater recharge and holds back saltwater intrusion into freshwater

[28] FDOT Draft Stormwater Quality Handbook, 2010: http://www.fdot.gov/roadway/drainage/files/StormwaterQualityAppHB-DRAFT.pdf

aquifers. This is called a "losing canal" (Figure 19). As sea levels rise and the gravity-based system becomes less effective, salt water may intrude further into the canal system threatening the freshwater aquifers.[29]

*Figure 19: The role of canals in influencing groundwater levels (left) and preventing saltwater intrusion (right) (U.S. Geological Survey)*




[29] Miami-Dade County Report on Flooding and Salt Water Intrusion. 2016. Pg. 49.

**Water quality impacts**

As water moves through the urban environment, it picks up and transports pollutants throughout all three tiers of the stormwater system. Miami-Dade County's Department of Regulatory and Economic Resources - Division of Environmental Resources Management (DERM) conducts surface water quality samples and monitoring at 87 locations along Biscayne Bay and in several major canals and tributaries that lead to the Bay. The County[30] monitors various pollutants that can come from stormwater runoff including nutrients (like phosphorus and nitrogen), sediments, coliform (potential pathogenic) bacteria, and metals (e.g., lead, zinc, cadmium, copper, and nickel) that most often come from degradation of automobiles. These pollutants can have direct impacts to public health and natural habitats.[31]

To regulate stormwater discharge into surface waters, the County issues Class II permits for development projects. At a minimum, the first inch of rainfall that is not absorbed by the ground is required to be retained on site because studies have shown that 90% of the pollution is picked up in this first inch of rainfall runoff. [32] While the stormwater system is designed to treat the first inch of rainfall, rising water levels saturate parts of the system and reduce the system's ability to function as intended. This leads to increased runoff and downstream conveyance of pollutants throughout the system. Additionally, the use of pumps designed to alleviate flooding can pick up sediment, increase turbidity at discharge locations and contribute to decreased water quality if it does not have the appropriate water quality treatment (e.g. drainage wells). When too much of a certain pollutant is found in a water body, it may be classified as 'impaired' by the Florida Department of Environmental Protection. Miami-Dade County already has several impaired water bodies including Upper Arch Creek, Little River, the Miami River, Wagner Creek, Coral Gables Canal, and portions of Biscayne Bay[33][34].

"Traditional development practices have significant adverse impacts on hydrology and water quality. Impervious cover, piping, and soil compaction increase the runoff volumes and rates, while reducing infiltration and groundwater recharge. This approach efficiently conveys pollutants, such as nutrients, metals, pathogens, and sediments, off site and into receiving waters. Conventional stormwater management and treatment has focused on "end of pipe" solutions that provide less effective treatment. The changes in water quality and hydrologic functions caused by traditional development are significant and have been shown to be insufficient at sustaining healthy ecosystems downstream. Nutrient levels in surface waters have remained stubbornly high after several decades of standard networks of stormwater sewer collection and treatment pond systems." - Florida Department of Environmental Quality EP Low Impact and Green Infrastructure. pg. 6

These existing water quality issues will likely be exacerbated by rising sea levels for the following reasons:

a. Higher water levels during high tides and storm events that block or back up into outfalls will increase flooding extent and duration which could lead to more polluted stormwater as debris (leaves, trash, pet

[30] Miami Dade County Department of Regulatory and Economic Resources – Surface Water Quality. https://www.miamidade.gov/environment/surface-water-quality.asp

[31] Low-Impact Development and Green Infrastructure: Pollution Reduction Guidelines for Coastal Water Quality in Southeast Florida. Florida Department of Environmental Protection. 2019. Pgs. 5-11.

[32] Miami-Dade County Department of Regulatory and Economic Resources – Class II Permit. https://www.miamidade.gov/permits/class-2.asp

[33] Final Total Maximum Daily Load Report. Florida Department of Environmental Protection. 2012. https://floridadep.gov/sites/default/files/fecaltmdl_miami-dadeco.pdf

[34] Comprehensive Verified List. Florida Department of Envrionmental Protection. 2018. https://floridadep.gov/dear/watershed-assessment-section/documents/comprehensive-verified-list

waste, etc.) and contaminants (oils, metals, and fertilizers) mix with stormwater.[35] Excess nutrients and debris can cause algal blooms and lower oxygen levels in the water.[36]

b. Rising groundwater levels will allow less infiltration of stormwater onsite and in natural areas/greenspace, adding to runoff volume and related pollutant load.
c. Increasing amounts of saltwater can be conveyed to inland surface and groundwater through the stormwater system subjecting it to contamination.
d. Contaminant plumes may be affected by the shifting of ground water levels and flow. Contaminated sites, including Superfund sites, for which a contamination remedy is in place, are required to evaluate the groundwater quality through a monitoring schedule, which also assesses the effectiveness to the remedy on achieving the cleanup goals. Monitoring wells installed for compliance and assessment purposes (e.g., gas stations, etc.) facilitate the Department's monitoring of the groundwater quality and its potential impacts to receptors.
e. The additional use and number of pumps installed to reduce future flooding impacts will increase system complexity and require more comprehensive monitoring of water quality.

The inability to effectively manage current and future flooding of the stormwater system can also presents serious risks to the health of the regional marine habitats, fisheries, and coral reef system.[37] The pollution (e.g., nutrients like phosphorus) from excess stormwater runoff is considered to be a key contributor to degradation of the water quality in Biscayne Bay damaging or killing significant portions of sea grasses in Biscayne Bay which support the larger ecosystem and tourism economy.[38] A study conducted by the Department of Regulatory and Economic Resources showed there was between 63-93% decrease in sea grass extent for 79th Street Basin, Julia Tuttle Basin, Venetian Basin, and others (Figure 20)[39]. The Biscayne Bay Task Force is currently reviewing relevant data, prior studies, and assessments from experts in order to make recommendations to the Board of County Commissioners with regards to identifying problem areas, prioritizing projects and identifying legislative activities related to the management and vitality of Biscayne Bay.

To address these impacts moving forward with expected sea level rise, the County will need to work closely with local, regional, state, and federal water management partners to reduce stormwater runoff volume, reduce pollution, and improve water quality through traditionally grey infrastructure solutions and a greater emphasis on green infrastructure or nature-based solutions.

*Figure 20: Decrease in seagrass between 2005-2018 by basin (Miami-Dade County)*

[35] U.S. Environmental Protection Agency. Nonpoint Source: Roads, Highways and Bridges. https://www.epa.gov/nps/nonpoint-source-roads-highways-and-bridges

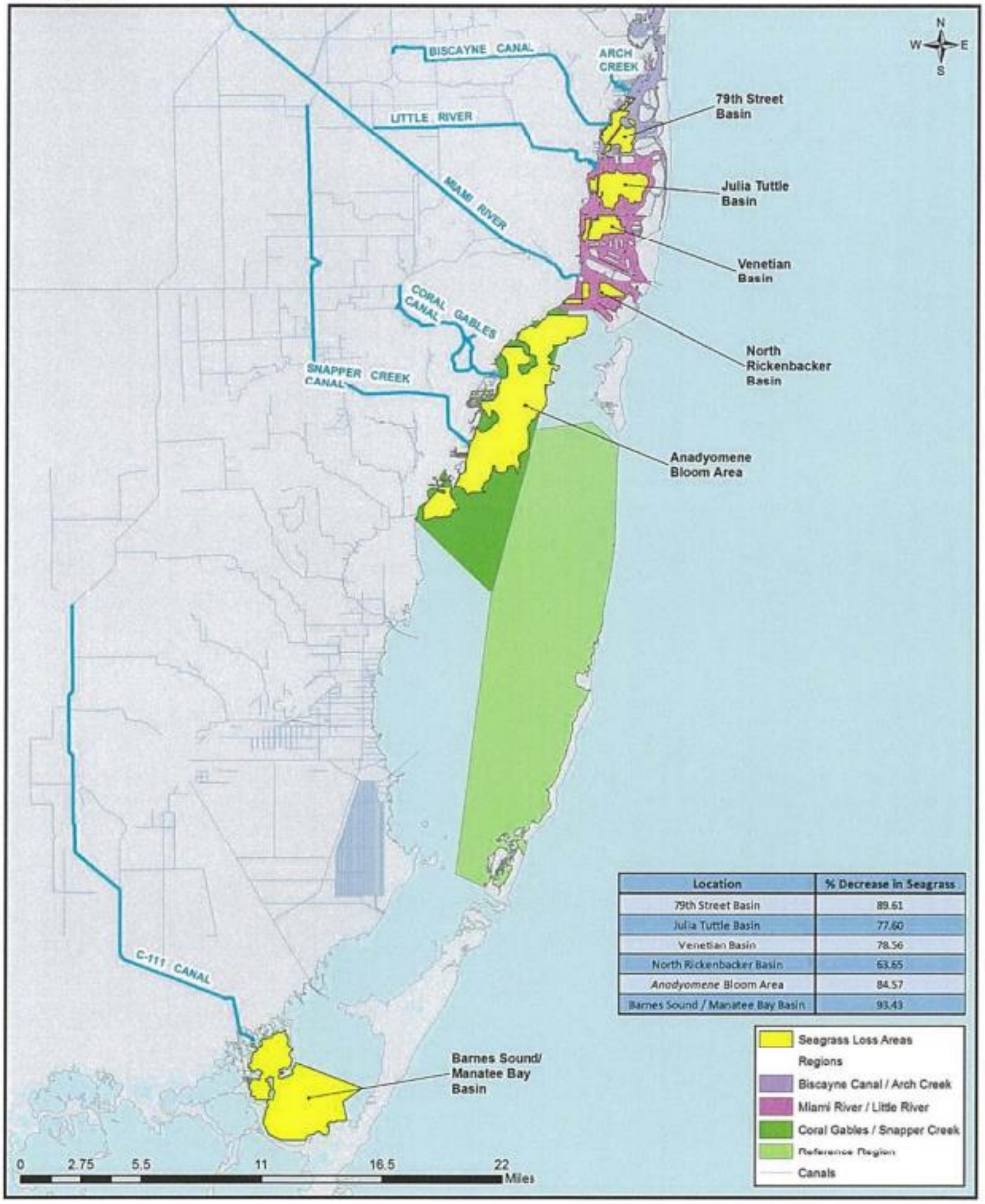
[36] South Florida Water Management District – Your Impact on the Environment. https://www.sfwmd.gov/community-residents/what-can-you-do

[37] Low-Impact Development and Green Infrastructure: Pollution Reduction Guidelines for Coastal Water Quality in Southeast Florida. Florida Department of Environmental Protection. 2019. Pg. 24.

[38] Report on the Findings of the County's Study on the Decline of Seagrass and Hardbottom Habitat in Biscayne Bay- Directive No. 171537. Miami-Dade County. 2019. Pg. 2.

[39] Data analysis between 2005 and 2018. Report on the Findings of the County's Study on the Decline of Seagrass and Hardbottom Habitat in Biscayne Bay- Directive No. 171537. Miami-Dade County. 2019. Pg. 18

## Decrease in Seagrass by Basin




| Location | % Decrease in Seagrass |
|---|---|
| 79th Street Basin | 89.61 |
| Julia Tuttle Basin | 77.60 |
| Venetian Basin | 78.56 |
| North Rickenbacker Basin | 63.65 |
| *Anodyomene* Bloom Area | 84.57 |
| Barnes Sound / Manatee Bay Basin | 93.43 |

**Intergovernmental Coordination and Financing**

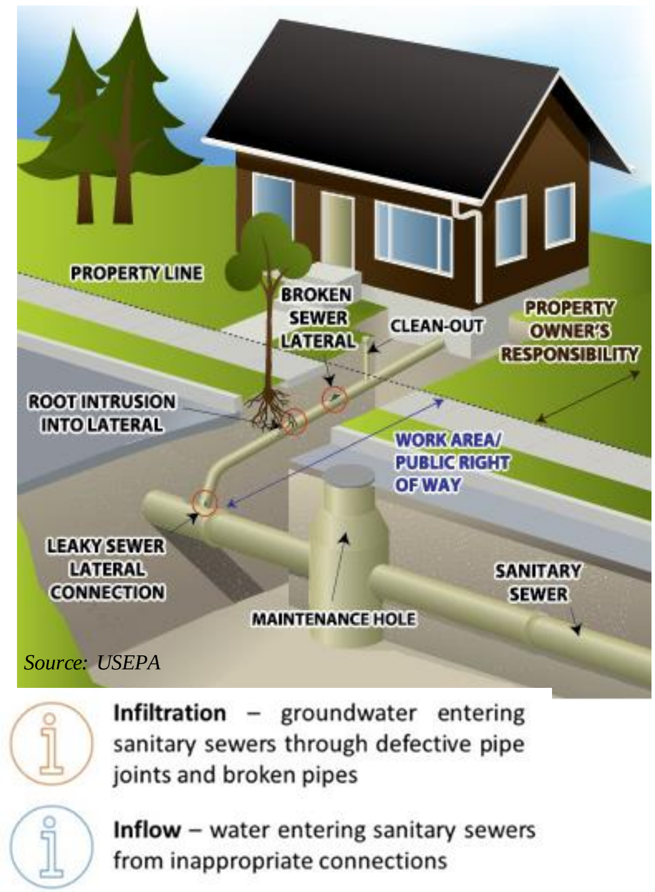
The County's stormwater engineering analysis used for planning and management is conducted by modeling thirteen hydraulic and hydrologic watersheds or basins. These watersheds include areas within municipal political boundaries. Fees collected by the County's Stormwater Utility are used to provide stormwater management services to the Unincorporated Municipal Service Area residents. However, at the regional level, the Secondary Canal System under County jurisdiction also provides stormwater protection and flood control benefits to municipal residents. For these regional benefits, municipalities share the costs to repair and maintain the Secondary Canal System.

Additionally, municipal stormwater utilities collect their own revenue and plan their own stormwater capital master plans. Major state roadway system expansions and improvements have separate state revenue and their own separate capital drainage master plans. The County's Stormwater Master Plan will continue to update trends and forecasts to establish new adaptive remediation actions as needed to continue to provide the most cost-effective best management practices to control flood risk and vulnerability in our community. Likewise, it is important to continue technical partnerships with Federal Emergency Management Agency, U.S. Army Corps of Engineers, U.S. Geological Survey, National Oceanic and Atmospheric Administration, Florida Department of Transportation, South Florida Water Management District, neighboring Counties, County and non-County critical facilities, other Federal/State agencies and private industry to promote future exchange of technical information critical for stormwater planning and operations at the local and regional levels.

## The issue of inflow and infiltration on both systems

Inflow and infiltration occurs when stormwater or groundwater enters the sanitary sewer system. Inflow refers to stormwater entering a system at points that are directly connected to the system, such as through manhole covers (Figure 21). Infiltration refers to groundwater entering a system through indirect means, such as through cracks in sanitary sewer pipes or faulty connections, defects, and joints. Inflow and infiltration is an infrastructure integrity issue that every system must manage; however, it is exacerbated by the rise in sea level and groundwater levels and increased stormwater flooding.

*Figure 21: Key sources of inflow and infiltration (Source: EPA)*




Both inflow and infiltration can cause issues, particularly with regard to 1) increasing the volume of water conveyed to the central sanitary sewer system; 2) increasing pollutants into the sanitary sewer system and 3) increasing pollution from the sanitary sewer system into the stormwater system, thus potentially polluting groundwater and impacting the environment. Inflow and infiltration can increase operational costs associated with conveyance and treatment of the extraneous water, reduced sewer and treatment capacity, the overdesign of pump stations and infrastructure, and an increased risk of building plumbing backups (e.g. overflowing toilets) and sanitary overflows particularly in areas where flow is reduced by blockages of Fats Oils Greases (FOGs). In areas that are experiencing king tide flooding, an increase in inflow and infiltration has already been observed by the Miami-Dade County Water and Sewer Department. The reduction of inflow and infiltration will improve overall service delivery including enhanced operational performance of the sanitary sewer system, reduced treatment and pumping costs, and help create a more sustainable built form throughout the County. More information about the impacts of inflow and infiltration is available in previous reports.[40]

With increased stormwater flooding, the sewer system can be directly impacted through increased inflow and infiltration. Prolonged flooding can allow excess water to seep into the sanitary sewer system through cracks or breaks. As flooding increases, inflow and infiltration is expected to increase unless proactive, protective measures are scaled up. Measures to reduce inflow and infiltration can be very cost-effective because they reduce the volume of water that needs to be conveyed and treated. For this reason, all 16 utilities are actively investing in reducing inflow and infiltration; however, to effectively address this issue it must be addressed in concert with the improving the stormwater system.

[40] "Recommendations to protect water, sewer, and road infrastructure from sea level rise impacts." 2018. Miami-Dade County. *At this time, the report is being reviewed by the County Mayor's Office. Once approved, the report will be found here:* http://www.miamidade.gov/green/climate-change.asp

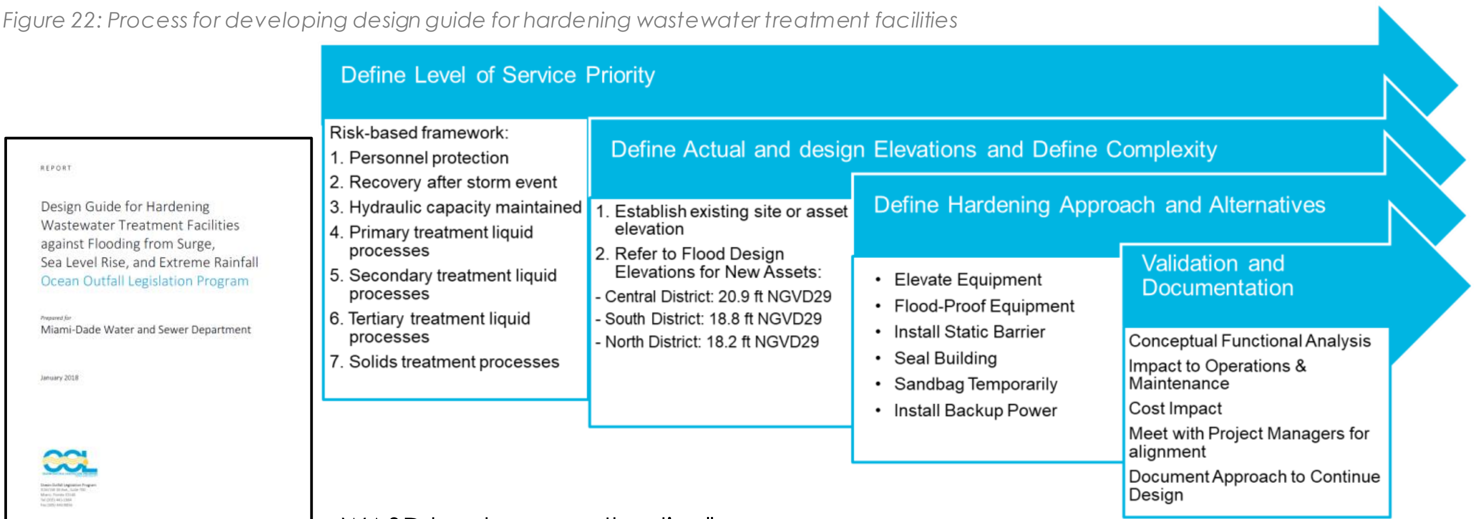
# Steps that have been taken to protect against rising groundwater and sea levels

Many departments have invested in vulnerability studies, modeling future conditions, and water management research in close collaboration with academic experts.

## Steps taken to protect the sanitary sewer system

For the past several years, WASD has been working to systematically identify the vulnerabilities of the system to climate change. WASD continues to monitor and analyze hydrologic conditions. This work, done in partnership with the Office of Resilience, the Division of Environmental Resources Management (DERM), the United States Geological Survey (USGS), and the South Florida Water Management District (SFWMD), involves regular measurement of ground and surface water elevations, measurements of salinity, and the use of digital models to forecast changes over time associated with sea level rise. This analytical work tracks saltwater intrusion into the water supply aquifers, provides the basis for storm surge modeling as sea level rises, and provides insight into the functionality of the drainage system. More detailed information about efforts to monitor and minimize saltwater intrusion are available in previous reports.

*Figure 22: Process for developing design guide for hardening wastewater treatment facilities*




WASD has been methodically developing an approach to harden projects in preparation for increased flooding and higher storm surges (Figure 22). As part of the larger capital improvement plans required by the Environmental Protection Agency's Consent Decree and ocean outfall legislation adopted by the state, new design standards (See Appendix 6) are being applied to ensure new projects will be designed to provide continuity of service under future conditions projected throughout the lifetime of the assets (Figure 23). Hazard mitigation grant funds have also been sought and awarded to help protect the largest and most critical pump stations from flooding and wind damage and to improve electrical reliability. As these efforts are still underway, the department is continuing to invest in improving the understanding of the vulnerabilities of the system, refining the design standards used, and improving the implementation of these standards across the enterprise.

*Figure 23: Electrical panels are elevated on a four-foot pad to protect them from flooding*

The department is also actively collaborating with peers through the Resilient Utilities Coalition, and with other departments and local academic experts, to integrate the latest data and best practices into its planning. It is important to note that given the scale of the water and sewer systems, it will take decades to fully implement these improvements and new standards. Therefore the department has prioritized the improvements based on criticality and is focusing its work on the most essential components first.

WASD continues to address inflow and infiltration through several programs including the Pump Station Improvement Program, which is managing a number of upgrades to the pump station and force main systems to ensure compliance with regulatory programs. WASD invested more than $100 million into reducing inflow and infiltration between fiscal years 2014 and 2018 and the department intends to spend another $111 million dollars by 2022. The program is determining the impact of excessive inflow and infiltration on the overall operating condition of the pump stations. WASD aims to significantly and cost-effectively reduce average and peak flows in the sewer system through reducing excess flow and optimizing pump station operation. This reduction of flows into the conveyance system provides additional savings in capital infrastructure. Currently, all work is performed by WASD forces and external contractors and includes activities such as replacing main lines and laterals, grouting, point repairs, manhole repairs, and pipe lining.

The program objective is to pursue cost-effective solutions that reduce infiltration and inflow and quantifying savings. By developing these tools, the County will minimize the risk of oversizing infrastructure improvements and can delay the need for the capital costs of wastewater treatment plant capacity expansion. The key reasons for addressing inflow and infiltration are:

- Decreased wastewater sewer capacity
- Increased treatment and pumping costs
- Potential health risks (sewer overflows)
- Limited resources
- Regulatory mandates
- Conflicting drivers
- Changing conditions

WASD can reduce costs for transporting and treating wastewater by implementing all cost-effective inflow and infiltration reduction projects and minimize liability from water pollution and public health risks posed by sanitary sewer overflows that may occur during storm events.

## Steps taken to protect the stormwater system

**Modeling work**

The Miami-Dade County Stormwater Utility was established on June 18, 1991 by Ordinance No. 91-66. Section 24-51 implements the provisions of Sections 403.0893 and 403.0891 of the Florida Statutes by creating a countywide Stormwater Utility (SWU) to plan, construct, operate and maintain stormwater management systems.

The Water Management Division of the Department of Regulatory and Economic Resources, Division of Environmental Resources Management, administers Miami-Dade County's Stormwater Management Program (SWMP), and is responsible for identifying and addressing the current and future stormwater drainage, flooding, and water quality needs in our service territory.

Fees collected by the County's Stormwater Utility are used to provide stormwater management services to Unincorporated Miami-Dade County residents. At the regional level, the Secondary Canal System under County jurisdiction also provides stormwater protection and flood control benefits to municipal residents. For these regional benefits, municipalities share the costs to repair and maintain the Secondary Canal System.

In 2019, Resolution R-83-19 directed allocation of revenues for an increased stormwater fee for the Miami-Dade County Stormwater Utility towards stormwater projects that relate to future sea level rise and future storm events.[41]

Miami-Dade County is highly advanced in stormwater adaptability planning and mitigation implementation, as recognized by the County's participation in the Federal Emergency Management Agency Community Rating System Program. Miami-Dade County entered the Community Rating System program in 1994 and since 2003, has received an excellent Community Rating System rating due to its efforts to plan, improve, maintain and operate the local stormwater and flood control systems. As an incentive for participating communities, flood insurance premium rates are discounted. Residents in special flood hazard areas of the Unincorporated Municipal Service Area of the County are eligible to receive a premium discount of up to 25%. The excellent Community Rating System rating for unincorporated areas resulted in a total annual reduction in flood insurance premiums for its residents of over $14 million in 2018. These savings represent an average of over $129 in flood insurance premium reduction per the County's Unincorporated Municipal Service Area flood insurance policy in the special flood hazard areas. Only a handful communities nationwide are currently rated at a better class.

The County's Stormwater Management Program supports the Miami-Dade County's Comprehensive Development Master Plan process, emergency preparedness and management activities, the stormwater infrastructure maintenance activities, the engineering evaluations and improvements to the County's Flood Protection Level of Service and Water Quality Level of Service, and the County's local and regional efforts in climate change, sea level rise and adaptation planning. The process and recommendations resulting from the Stormwater Management Program are funded by the stormwater utility (flood prevention, infrastructure improvements, and operations and maintenance activities).

Because the Stormwater Management Program is integral to the Comprehensive Development Master Plan, its progress and effectiveness is monitored during periodic Evaluation Assessment Reviews. Stormwater Management Programs are evaluated annually as a part of the National Pollutant Discharge Elimination System permits issued to unincorporated Miami-Dade County and other municipal permittees by the U.S. Environmental Protection Agency and administered by the Florida Department of Environmental Protection.

[41] Miami-Dade Board of County Commissioners – R-83-19. January 23, 2019. http://www.miamidade.gov/govaction/matter.asp?matter=182879&file=true&fileAnalysis=false&yearFolder=Y2018

The County Stormwater Management Program maintains a Stormwater Master Plan which includes current as well as forecasted engineering data analyzed and updated using industry-recognized methods and tools. More information on the County's Storm Water Master Plan can be found in Appendix 5.

**Construction projects**

The Department of Transportation and Public Works oversees the construction of roadway drainage improvement projects. In addition to projects that have been completed in the past the department currently has two planned improvements. The first project is focused on retrofitting and hardening two existing coastal stormwater pump station. The existing pump stations are susceptible to damage by storm surge, sea level rise and other hazards. The pump stations are located along NE Bayshore Drive at the intersection of NE 109 Street and NE 110 Street in unincorporated Miami-Dade County.

The second planned improvement is along NE 89 St from NE 10 Ct to North Bayshore Drive consist of the construction of a storm drainage system which will include the installation of exfiltration trenches (French drain) along with drainage inlets in the public right-of-way. In addition, improvements will include roadway reconstruction to raise the elevation of the road's southern edge and construction of a berm between the roadway and the seawall to help mitigate local tidal flooding produced by king tides along NE 89th Street.

Stormwater Short- and Long-Term Capital Plan

The Stormwater Master Plan (SWMP) process has identified a Short-Term Capital Program for Flood Protection and Control (2018 – 2025) of which $61 million in projects is currently in a bidding phase or under construction. The capital program includes over $300 million in additional projects that are in the planning, design, right-of-way acquisition, and/or under discussion for implementation with other state agencies and municipal partners. In addition, the SWMP has also identified an Enhanced Long-Term Capital Plan Addressing Vulnerabilities of Stormwater Critical Infrastructure (2025 – 2075) with over $200 million for a 50+-year horizon identifying unfunded improvements in the service territory under County jurisdiction. Both the short- and long-term capital plans address level of service concerns in flood protection and water quality, and include adaptability and mitigation of vulnerabilities due to future sea level change.

# Recommendations to reduce vulnerabilities

Existing policies require sea level rise impacts on infrastructure be considered during the planning, design, and construction phase. Resolution No. R-451-14 requires all capital projects to consider the impacts of sea level rise as County policy. In addition, Resolution No. R-617-17 requires the Envision Rating System be used for County civil infrastructure projects. This policy reduces vulnerability through the application of the Climate Risk criteria.

The Board of County Commissioners requested recommendations on how best to eliminate the vulnerability of sanitary sewer and stormwater systems to sea level rise; and recommendations as to any further technical and financial evaluations and legislative or administrative actions that may be necessary to address the vulnerabilities and problems identified. The following are recommendations for additional steps to reduce vulnerability of the sanitary sewer and stormwater systems.

## Recommendations for both systems

- As the largest and most influential component of the water management system in the region, the Central and South Florida (C&SF) Flood Control Project created by the U.S. Army Corps of Engineers has not been restudied since 1999.[42] To address rising water levels and other regional changes, the County should continue to advocate for a **reassessment and redesign of the C&SF project by the USACE** in coordination with the South Florida Water Management District. Changing climate conditions, especially sea level rise have diminished the flood protection provided by the system. This reassessment should consider creating a regular cycle for reviewing the control elevations for systems that drain directly into the bay as levels become more affected by sea level rise. This recommendation further supports the request found in the Southeast Florida Regional Climate Change Compact Counties 2019 Legislative Priorities.

- There are opportunities to better **coordinate infrastructure improvement projects** across departments. Coordinated planning in low-lying, vulnerable areas will create opportunities to address multiple problems simultaneously. For example, some vulnerable areas are affected by flooded roadways and saturated septic and drainage systems. **Coordinating the improvements** in the roadways, drainage systems, and water and sewer infrastructure will reduce the overall project costs, improve planning, and reduce construction disruption. Most importantly, it will avoid the potential pitfalls of addressing these issues in a piecemeal fashion including using different design standards and requiring frequent disruptions to the roads. It is recommended that the scope of the on-going utility coordination meetings be expanded to focus on utility improvements in flood-prone areas specifically. The County will also work to coordinate construction projects with the municipalities to leverage each other's efforts whenever possible.

- Currently, there are different approaches being used across departments to incorporate sea level rise into design standards. While significant efforts have been made in updating design standards, several codes are still based on historic water levels and do not account for the dynamic changes observed over the past few decades. Several codes also do not account for the changes anticipated over the coming decades. It is recommended that all future capital projects fully account for **sea level changes expected over the lifetime** of a given asset. In some instances, this will require being more stringent than existing codes.

- Due to porous local geology and rising sea levels, higher tides are increasingly impacting groundwater levels. Due to decreases in drainage efficiency of the stormwater system and higher sea levels,

[42] US Army Corps of Engineers – Central and Southern Florida Project Comprehensive Review Study. 1999. https://usace.contentdm.oclc.org/digital/collection/p16021coll7/id/11271

groundwater stages will increase, and stormwater infrastructure will need to be updated and upgraded to prepare for this. The County has already invested in integrated surface and groundwater modeling to understand how sea levels will affect groundwater levels between 2018 and 2035. It is recommended that infrastructure affected by groundwater levels be designed for the **groundwater levels expected over the lifetime** of a given asset so that the asset can function properly over its entire design life. This will require updating existing standards to reflect anticipated groundwater levels, as has been done in Broward County.[43] If adopted, changes proposed as part of the County's Evaluation and Appraisal Report of the Comprehensive Development Master Plan (May 2019 CDMP Amendment Cycle, Application No. 6) would address this issue. The proposed policy directs the creation of future groundwater maps that can be used in the design of structures and stormwater management systems, at a minimum. Recent research from Florida International University provides an updated analysis of future groundwater maps.[44]

- In the interim, the **County Flood Criteria (§ 24) should be updated** to reflect current groundwater conditions or revised to include an additional safety factor above the existing requirements to account for the water levels expected over the lifetime of the asset.

- The **County salt barrier control line**, included in the Water Control Plan PB 126 Pg 39 (Appendix 4) should also be reviewed and updated as necessary and this should include a review of all stormwater canals and outfall structures that are located on this established line or eastward of it to determine their continued efficacy to prevent salt intrusion into the stormwater system behind the structures as well as to prevent salt intrusion landward of the County's salt barrier control line. Any uncontrolled outfalls to tidal waters shall be evaluated and updated with backflow preventers or weirs as appropriate to prevent uncontrolled "backwards" flow of saltwater into the canals or any other portion of the stormwater system at the location of the salt barrier line.

- While the County has control of design standards for its own infrastructure, there are numerous constraints to retrofitting infrastructure in developed areas. As mentioned, it is often not possible to elevate a roadway to the desired elevation because the adjacent structures are too low. Therefore, it is advisable to consider mandating additional elevation of new or substantially improved structures above roadways to provide additional **freeboard** for buildings and provide flexibility in the future to raise infrastructure to match future conditions. This should be explored for all buildings, not only those within the Special Flood Hazard Area.

- To understand how sea level rise will affect existing infrastructure and to systematically identify **areas in need of improvements**, it is recommended that the County continue cutting edge modeling and engineering analyses in coordination with other agencies, such as the South Florida Water Management District. These projects should also be included in the Local Mitigation Strategy in order to take advantage of outside funding opportunities as they become available. Additionally, work is needed to consolidate the findings of various studies. This includes synthesizing information on stormwater planning, groundwater modeling and other studies within the region, to improve understanding of the impacts of sea level rise and climate on local hydrology and how best to update standards and prioritize improvement projects.

- In order to retrofit existing infrastructure, many adaptation measures will require the use of additional space outside of the right of way (utility corridor). Therefore, it is recommended that the County explore funding sources, such as Federal Emergency Management Agency and Community Development Block

[43] Updated maps and standards from Broward County can be found here: http://www.broward.org/Environment/Engineering/Pages/GroundwaterMaps.aspx.
[44] Potential Implications of Sea-Level Rise and Changing Rainfall for Communities in Florida using Miami-Dade County as A Case Study. Sea Level Solutions Center, Florida International University. June 2019. https://slsc.fiu.edu/_assets/pdfs/fbc_fiu_finalreport_22aug2019.pdf

Grant – Disaster Recovery grant programs, to **procure land for infrastructure and natural water storage**. The need to develop mechanisms and policies for acquisition of additional right of way as part of the platting or developmental permitting process should also be pursued.

- In accordance with Resolution No. R-617-17, departments should employ the **Envision Infrastructure Rating System**, specifically the risk reduction criteria for capital improvement projects, as early in the planning process as possible to maximize the effectiveness of the alternatives analysis.

- It is necessary to build organizational capacity to address these vulnerabilities; therefore, it is recommended that the County continue to invest in **specialized employee training**.

- In accordance with **Resolution No. R-451-15, all County infrastructure projects must consider sea level rise** projections during all project phases. The Miami-Dade County Code of Ordinances should be updated to reflect the mandate in R-451-15. By including the policy in the Code, the Board can increase internal exposure to the policy. Additionally, the Board and County departments can point to a specific, County-wide policy on sea level rise (in addition to the Comprehensive Development Master Plan) when external audiences ask how the County is incorporating sea level rise considerations into County planning. Through the process of updating the County code, the sea level rise policy could be inserted into Chapter 9 as Article IV, directly following "Article III. The Sustainable Buildings Program," which describes a program that is also overseen by the Office of Resilience.[45]

- Additional flooding due to higher sea and groundwater levels is expected to lead to increased **inflow and infiltration of groundwater into the sanitary sewer system and increased saltwater intrusion into the stormwater system including into the canals and through tidal outfalls**. It is recommended that staff continue to analyze these impacts to evaluate different approaches to mitigate these issues. Short-term measures could include the use of watertight manhole covers or other measures to limit inflow to sewers and increased use of back flow preventers at stormwater outfalls; however, in the long-term, it will likely be most effective to adapt the roadway, water, sewer, and stormwater infrastructure simultaneously or integrated manner in order to reduce the impact of tidal inundation to all of these systems. Secondary or other canals that are not needed for drainage such as the Card Sound Road canal or canals in the Model Lands that are pathways for saltwater intrusion may need to be filled to buffer or slow the inland migration of saltwater. Additionally, the County should continue to assist in the evaluation of the potential to fill all or a portion of the lower C-111 canal in the salt intruded area adjacent to Everglades National Park through the CERP planning process for the C-111 Spreader Canal Eastern project.

## Recommendations for the sanitary sewer system

- DERM will continue to require that all 16 utilities implement the Inflow and Infiltration and Flow Reduction Programs, and other efficiency initiatives.

- DERM will continue to develop protection standards for sanitary sewer systems that acknowledge current vulnerability and reduce future vulnerability under defined conditions

[45] The County Code of Ordinances, Article III. Sustainable Buildings Program, can be found at this link: https://library.municode.com/fl/miami_-_dade_county/codes/code_of_ordinances?nodeId=PTIIICOOR_CH9STCOCOBUROBRCA_ARTIIISUBUPR. The Code could be updated to include the County sea level rise policy immediately following this article.

- It is recommended that the County continue to require private systems to reduce inflow and infiltration and implement code changes to further reduce inflow and infiltration from deficiencies in the privately-owned portion of the sewer system on private property through inspection and testing programs for large parcels.

- WASD will continue to develop designs that acknowledge current vulnerability and reduce future vulnerability under defined conditions. This includes measures such as elevating critical facility structures, hardening infrastructure to impacts from flooding, and implementing gray and green infrastructure projects.

- WASD will continue to develop guidelines and other tools to facilitate the resilient design and operation of the wastewater treatment system.

- WASD will continue to leverage partnerships to enhance technical resources and legislative support, including:
    - Resilient Utility Coalition - Becoming a Resilient Utility
    - Southeast Florida Regional Climate Change Compact
    - Department of Energy Wastewater Utility Accelerator Programs
    - Department of Energy Better Plants Program
    - The Utility of the Future Today
    - U.S. Environmental Protection Agency
    - Federal Emergency Management Agency
    - Florida Department of Economic Opportunity
    - U.S. Department of Housing and Urban Development
    - U.S. Department of Agriculture
    - U.S. Army Corps of Engineers

- WASD will seek to enhance understanding of population forecast scenarios with respect to migration away from vulnerable areas to consider in utility planning.

- It is recommended that the County develop a masterplan for service expansion where it is desired (for example, in urban centers and low-lying areas with vulnerable septic systems) to identify what infrastructure and investment would be needed to address these challenges. Developing a master plan could reduce the cost of expanding and improving the infrastructure required for development. Areas experiencing other impacts of rising sea level and groundwater that might require a comprehensive adaptation approach, one that addresses more than wastewater disposal issues, should be considered as part of this process. This approach will be essential in ensuring the most effective social, environmental, and economic results, which may include alternative wastewater disposal technologies, redevelopment, establishment of adaptation action areas, voluntary buyouts, etc.

## Recommendations for the stormwater system

- Work with the Army Corps of Engineers and the South Florida Water Management District to systematically reassess the Central and Southern Florida Flood Control Project and how the regional network is being affected by sea level rise. Identify options to ensure the regional system can provide sufficient flood protection into the future as well as to implement operational and/or structural upgrades at the coastal structures to maintain their effectiveness for the prevention of saltwater intrusion.

- Work with the Army Corps of Engineers and the SFWDM to review and update as appropriate the operational triggers for the coastal structures and implement any changes at the earliest possible opportunity as was recently accomplished at the S-20 control structure.

  Strengthen on-site stormwater retention and flood protection requirements to reduce the reliance of future development on the regional and secondary canal system and reduce the of flooding on to adjacent properties caused by new development or redevelopment.

- Upgrade the FPLOS and WQLOS of County Collector and UMSA Local Residential Streets whenever feasible by providing improvements to the drainage system. As part of the County's Stormwater Master Planning effort, DERM may reassess the level of service requirements for various drainage basins and adjust standards, planning and management to account for future climate conditions, including sea level rise.

- Ensure that the drainage infrastructure for all County projects is designed to account for continuing groundwater and sea level rise for the foreseeable future, drawing from Broward County's precedent. This will require going beyond existing County code requirements for stormwater management and may also require revisions to the CDMP.

- Revise the County Flood Criteria as well as the County-established Salt Barrier Line provisions to reflect changes needed due to sea level rise.

- Evaluate stormwater outfall systems that discharge to tidal waters and make improvements as necessary to prevent uncontrolled "backwards" flow of saltwater into the stormwater system in order to protect water quality from saltwater contamination via the stormwater system.

- Revise the basins where the cut and fill criteria apply.

# Appendix 1: Relevant prior studies

| **Sea level rise/climate change impact studies (including climate variables considered in conjunction with sea level rise)** | |
|---|---|
| Storm Tide and Effects of Sea Level Rise: Impacts at Miami-Dade Water and Sewer Wastewater Treatment Facilities *(Hazen and Sawyer, 2013)* | This study was conducted as a preliminary analysis of the effects of sea level rise on coastal wastewater treatment plants. Components included developing future conditions based on sea level rise, storm surge, wind speeds, mangrove attenuation, risk assessment, and adaptation strategies and cost estimates. |
| Hydrologic Conditions in Urban Miami-Dade County, Florida, and the Effect of Groundwater Pumpage and Increased Sea Level on Canal Leakage and Regional Groundwater Flow (USGS in cooperation with Miami-Dade County Water & Sewer Department, 2014) | The purpose of this report is to (1) quantify hydrologic conditions in urban areas of Miami-Dade County between 1996 and 2010;(2) quantify the effect of groundwater pumpage from the Biscayne aquifer on canal leakage throughout the urban areas of the county for all of the well fields operated by the Miami-Dade County Water and Sewer Department (MDWASD); (3) determine how canal leakage may change in response to increased groundwater pumpage and increases in sea level; and (4) determine how increased groundwater pumpage may change groundwater seepage from the Everglades. The model was used to estimate changes in surface-water stage and discharge, groundwater levels, canal leakage, and the position of the freshwater-seawater interface resulting from projections of future groundwater pumpage rates and (or) sea level. |
| Sea Level Rise Projections for Miami-Dade County *(CH2M, 2015)* | Sea level rise projections to be used in developing facility hardening plans for infrastructure components of the Ocean Outfall Legislative program. |
| Rainfall Intensity, Duration, and Frequency Projections Based on Climate Change for Miami-Dade County *(CH2M, 2015)* | This report assesses Miami - Dade Water and Sewer Department (WASD) wastewater facility vulnerability and risk to projected changes in precipitation intensity, duration, and frequency (IDF). |
| Extreme Wind Speed and Sea Level Pressure Change Analysis for Miami-Dade County *(CH2M, 2015)* | This technical memorandum documents the literature reviewed and data analysis results from extreme wind speed and sea level pressure changes under climate change providing change factors data for storm surge modelling work to be conducted for the Ocean Outfall Legislative Program. |
| Surge and Flood Modeling Update for Miami-Dade County *(CH2M, 2017)* | Provides updated and additional modeling scenarios and establishes pump station prioritizations based on flooding and criticality to inform updates to the pump station facility hardening design guidelines as part of the Ocean Outfall Legislative Program. |
| South Miami Coastal Resilience: The Value of Mangrove Restoration *(CH2M, 2017)* | A wide swath of publicly owned wetlands lies between the SDWWTP and the open waters of Biscayne Bay, |

| | |
|---|---|
| | providing the plant with some degree of flood protection. From the water's edge to the west, tall, dense mangrove gives way to a tidal marshland dominated by dwarf red mangrove, and finally, freshwater marsh dominated by white mangrove and buttonwood. The purpose of this project was to explore how these wetlands will fare as sea level rises and to assess how much risk reduction would be provided by a combination of potential natural and hybrid features. |
| **Studies incorporating sea level rise projections to analyze impacts on wastewater operations and inform design** | |
| Validation Report alternative strategies proposed in the Ocean Outfall Legislation (OOL) Compliance Plan | The purpose of this report was to vet the costs, strategies, and schedules identified in the MDWASD OOL Compliance Plan. The Envision Rating System was selected to perform this comparative evaluation due to its ability to consider the full range of environmental, social, and economic impacts of the multibillion dollar OOL investment program. The Envision Rating System was used at the planning stage to determine the "right" project and will be used to enhance the sustainable design of projects as the OOL Program moves forward. |
| Pump Station Prioritization based on Criticality and Risk of Flooding *(The Nature Conservancy and CH2M, 2017)* | This report evaluates the risk reduction services provided by the existing natural and potential constructed features seaward of the Miami-Dade County Water and Sewer Department's (WASD's) South Dade Wastewater Treatment Plant (SDWWTP). The purpose of this project was to explore how these wetlands will fare as sea level rises and to assess how much risk reduction would be provided by a combination of potential natural and hybrid features. |
| Pump Station Peak and Average Flow Composition *(CH2M, April 2017)* | This study provides updated flows to account for changes due to climate change for incorporation in the 2013 OOL Compliance Plan (OOLCP) as part of the validation effort for this plan. |
| **Design Standards/Guidelines based on sea level rise projections & impacts** | |
| Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall *(CH2M, 2018)* | This document summarizes elevations below which wastewater treatment facility assets should be protected or hardened to withstand or recover from flooding from projected future combinations of storm surge from tropical storms and hurricanes, coupled with extreme rainfall and sea level rise (SLR) at each of Miami-Dade Water and Sewer Department's (WASD's) three wastewater treatment plants, specifically the North District Wastewater Treatment Plant (NDWWTP), Central District Wastewater Treatment Plant (CDWWTP), and South District Wastewater Treatment Plant (SDWWTP). In addition, |

| | |
|---|---|
| | future hydraulic conditions are specified for tailwater on outfalls from the NDWWTP and CDWWTP. |
| Design Guide for Hardening Wastewater Pump Station Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall *(CH2M, 2015)* | This document summarizes elevations below which wastewater pump station facility assets should be protected or hardened to withstand or recover from flooding from projected future combinations of storm surge from tropical storms and hurricanes, coupled with extreme rainfall and sea level rise (SLR) at each of the Miami-Dade Water and Sewer Department's wastewater pump stations (PS). |

# Appendix 2: Public Utilities in Miami-Dade County

A list of public utilities and their services, as well as a list of municipalities and their utilities, is provided below:

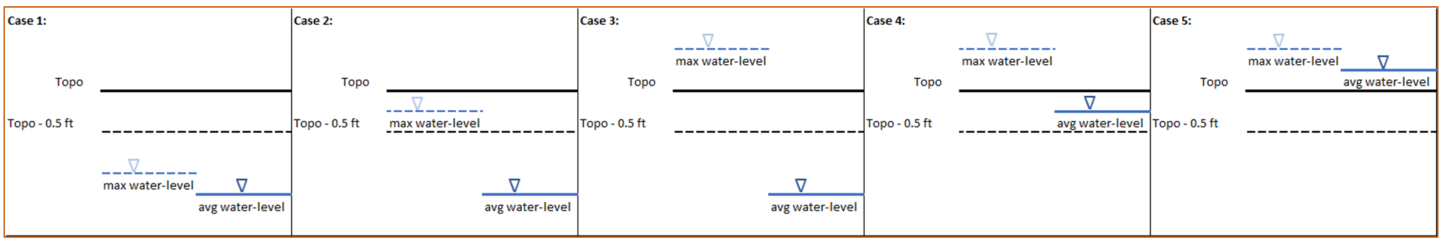
| Miami-Dade County Public Utilities | | | | |
|---|---|---|---|---|
| Utilities | Wastewater | | Water | |
| | Collection & Transmission | Treatment | Supply & Treatment | Distribution |
| 02 - Miami Beach | Yes | No | No | Yes |
| 03 - Coral Gables | Yes | No | No | No |
| 04 – Hialeah | Yes | No | Partial | Yes |
| 06 - North Miami | Yes | No | Yes | Yes |
| 07 - North Miami Beach | Yes | No | Yes | Yes |
| 08 - Opa Locka | Yes | No | No | Yes |
| 10 – Homestead | Yes | Partial | Yes | Yes |
| 12 - Bal Harbour Village | Yes | No | No | Yes |
| 13 - Bay Harbor Islands | Yes | No | No | Yes |
| 14 – Surfside | Yes | No | No | Yes |
| 15 - West Miami | Yes | No | No | Yes |
| 16 - Florida City | Yes | No | Yes | Yes |
| 22 – Medley | Yes | No | No | Yes |
| 23 - North Bay Village | Yes | No | No | Yes |
| 27 - Hialeah Gardens | Yes | No | No | Yes |
| 30 - Miami-Dade WASD | Yes | Yes | Yes | Yes |

# Appendix 3: Methodology Used to Identify Vulnerable Areas

This study began with an analysis of areas that are currently at most risk due to existing groundwater levels and then explored areas that are expected to be impacted by 2035 with higher sea and groundwater levels. The analysis showing currently vulnerable areas is shown below as the "base case scenario." Future vulnerability is shown as the "sea-level scenario." The tables below provide more details on the technical assumptions used in the vulnerability assessment. Table 1 described the vulnerability categories used and the threshold values that were used to determine whether an area was vulnerable. Table 2 provides more detail about the modeled scenarios.

*Table 1: Description of the various vulnerability conditions*

| | Maximum Groundwater Level (max water-level) | Average Groundwater Level (avg water-level) |
|---|---|---|
| Case 1. | More than half a foot below ground surface elevation | More than half a foot below ground surface elevation |
| Case 2. | Within half a foot below ground surface elevation | More than half a foot below ground surface elevation |
| Case 3. | Above ground surface elevation | More than half a foot below ground surface elevation |
| Case 4. | Above ground surface elevation | Within half a foot of ground surface elevation |
| Case 5. | Above ground surface elevation | Above ground surface elevation |




Topo=ground surface elevation

*Table 2: Description of modeled scenarios*

| | Base-Case Scenario | Sea-Level Scenario |
|---|---|---|
| Description | Represents areas that may already be impacted by current (2017) water levels | Represents areas vulnerable due to anticipated sea level rise and groundwater rise in 2040. |
| Water Level Data | Historical data from Virginia Key tide gauge | Representative of a National Research Council curve III increase (National Research Council, 1987) (Figure X). This represents an increase of approximately 12 inches from 2011 through 2035. |

To identify areas where infrastructure may already be impacted by current water levels and areas that could be impacted by future water levels this study relied on the following data sources and assumptions (Table 3).

*Table 3: Description of data sources*

| Data Source | Description |
|---|---|
| Land surface elevation | 5-foot Digital Elevation Model derived from 2015 LiDAR (source: Miami-Dade County) |
| Groundwater levels | Derived from the U.S. Geological Survey's Surface Groundwater Model. Based on USGS model "Increased Sea Level" scenario (Hughes and White, v.1.2, 2016). This assessment used a 30-year simulation period from 2011-2040 and used daily time steps. Precipitation was based on repeating climate conditions from 1996-2010 and assumed that groundwater pumpage was conducted with the allocation projected to year 2033 (Miami-Dade Consolidated PWS Water Use Permit; currently active and issued on 2015). |

| | |
|---|---|
| Sea level rise | Consistent with the "Unified Sea Level Rise Projection for South Florida"[46] this study assumed mean sea level increased 15.26 inches from an annual average stage of –9.43 in 2011 to 5.82 inches NAVD 88 at the end of the 30-year scenario simulation period (Figure 8). A sea-level change was applied to average daily predictive tides, which were calculated as a function of predicted and observed average daily tide, for the 15-year period from 1996-2010 and used twice in a repeating pattern to define the entire 30-year scenario simulation period. This assumes that historic interannual variability will repeat over the next several decades.<br><br>Note that the annual average stage as documented in Hughes and White (2016) was corrected (4.37 inches upward) to match the sea levels observed during 2011-2016. Throughout the subsequent time period (2017-2035) sea levels were increased according to the NRC curve starting with a corrected initial value for 2017. |
| Precipitation | Precipitation was based on repeating observed climate conditions from 1996-2010 in both scenarios. These conditions were repeated twice to cover the full-time period being studied (2011-2040). The observed conditions included a significant flood event which was replicated in the simulation in 2015 and 2030. |

[46] Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group (Compact) October 2015. Unified Sea Level Rise Projection For Southeast Florida. A document prepared for the Southeast Florida Regional Climate Change Compact Steering Committee

# Appendix 4: Dade County Water Control Plan – Salt Barrier Line

PB 126 pg 39

AMENDED PLAT OF

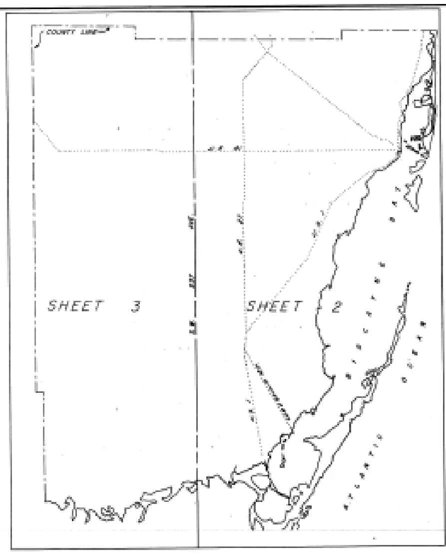
## DADE COUNTY WATER CONTROL PLAN

*SHEETS 1, 2, AND 3 HEREOF BEING AN AMENDED PLAT OF THE DADE COUNTY WATER CONTROL PLAN (P.B. 94 P. 4)*

*DEPARTMENT OF ENVIRONMENTAL RESOURCES MGMT., WATER MANAGEMENT DIVISION.*

*DADE COUNTY, FLORIDA*

— NOVEMBER 1984 —




WATER CONTROL PLAN

INDEX MAP

*KNOW ALL MEN BY THESE PRESENTS:*

That the board of County Commissioners of Dade County, Florida has caused to be made the attached plat entitled, "Amended Plat of Dade County Water Control Plan", the same being in three (3) sheets, said plat to supersede those Dade County Water Control Plan previously recorded in P.B. 64 P. 114, P.B. 70 P. 26, P.B. 73 P. 14, P.B. 77 P. 42, and P.B. 94 P. 4.

That Resolution No. R-41-85 of the Board of County Commissioners, filed in the Public Records of Dade County, Florida establishing this new Water Control, is hereby made to apply expressly to this revised map.

That the purpose of this map is to establish guidelines for designing water-control facilities for land development to indicate locations of existing works and to show general locations of proposed canals, levees, dams, control structures, pumping stations, drainage divides, (all subject to changes dictated by new developments and Dade County Environmental policies), and other drainage features of the water control systems of Dade County and the South Florida Water Management District.

In Witness Whereof the Board of County Commissioners of Dade County, Florida, has caused these presents to be executed by the Mayor and its clerk and its Corporate Seal to be affixed hereto this 8 day of January A.D. 1985.

BOARD OF COUNTY COMMISSIONERS, DADE COUNTY, FLORIDA

Signed by [signature] Mayor

Attest [signature] Deputy Clerk

This plat was prepared by the Dade County Environmental Resources Management Department, Water Management Division, under instructions from the Director of said Department and is subject to revision whenever determined by said Department to be warranted.

[signature] Water Control Engineer
Registered Engineer No. 13269 State of Florida

This plat was approved by the Dade County Planning Department this 27 day of November 1984.

By: [signature]
Director

This plat was approved by the Dade County Public Works Department this 28 day of Nov 1984.

By: [signature]
Director

This plat was approved by Resolution R-41-85 passed and adopted by the Board of County Commissioners of Dade County, Florida this 8 day of JAN. 1985.

[signature] Chairman
Attest: R. Brinker, Clerk of Circuit Court
By: [signature] Deputy Clerk

This plat is hereby approved for record.

[signature]
Director: Dept. of Environmental Resources Mgmt.

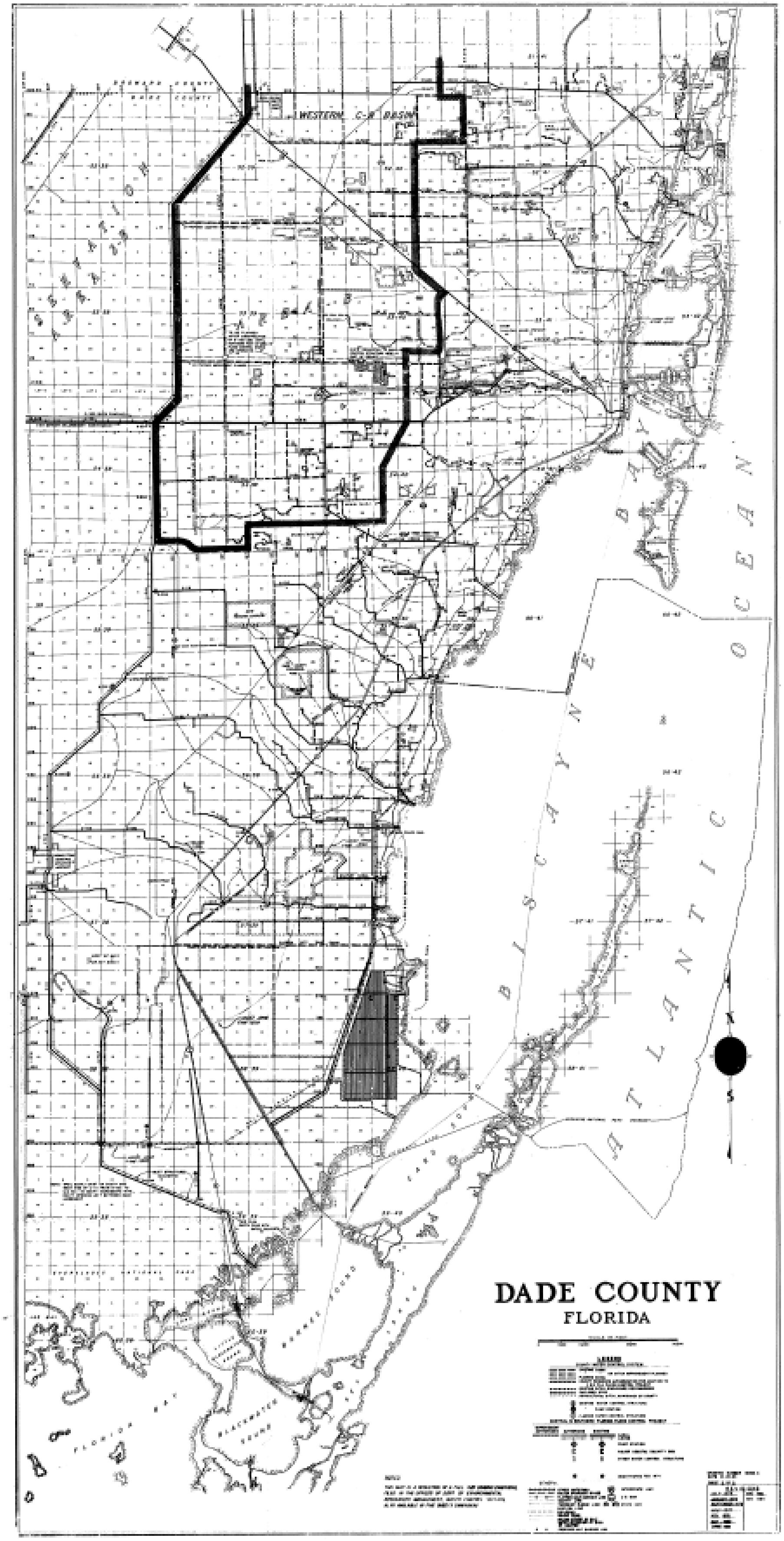
This plat was filed for record this 14 day of February 1985 at 4:35 PM in book 126 of plats at page 39 1-3 public records of Dade County, Florida.
This complies with the provisions of the laws of Florida.

R. Brinker
Clerk of the Circuit Court
by [signature] Deputy Clerk

SHEET 1 OF 3

DEPARTMENT OF ENVIRONMENTAL RESOURCES MANAGEMENT WATER MGMT. DIV. W.G. 18002-5

PB126 pc 397



# Appendix 5: Miami-Dade County Stormwater Master Plan

The County SWMP maintains a Stormwater Master Plan which includes current as well as forecasted engineering data analyzed and updated using industry-recognized methods and tools, such as:

- The U.S. Army Corps of Engineers (USACE) – National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise Curves and USACE Regulation ER 1100-2-8162 (Incorporating Seal Level Change in Civil Works Programs);
- USACE Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects (ECB No. 2014-10);
- SE FL Regional Climate Change Compact and updates;
- Latest MDC Sea Level Rise Task Force Report & Recommendations;
- FEMA risk assessment tools and Risk Map methodology for flood plain mapping;
- FEMA Flood Insurance Rate Maps (FIRM);
- The latest U.S. Geological Survey (USGS) Mapping of Water Levels and Trends in Miami-Dade County;
- Miami-Dade County Water and Sewer Department (WASD) and USGS surface groundwater interface model to forecast ground water levels under sea level rise scenarios;
- South Florida Water Management District (SFWMD)/USGS surface water stages;
- NOAA storm surge forecasts;
- NOAA tidal elevations and anomalies, historical sea level change;
- USACE/South Florida Water Management District (SFWMD) water management operations;
- Most up-to-date County land use and other planning information;
- Most up-to-date stormwater infrastructure mapping information; Florida Building Code and related requirements for new construction and substantial improvements to existing structures and infrastructure, both public and private;
- Chapter 24 of the Code of Miami-Dade County and other County and SFWMD drainage and flood control regulations;
- County Flood Criteria;
- Most up-to-date County topographic information (LIDAR); and
- Most current version of hydrologic/hydraulic simulation modeling software (XP-SWMM) and ArcGIS.

More specifically, the Miami-Dade County Stormwater Modeling includes:

- Direct coupling of inland and coastal hydrology within the domain of Miami Dade County, including rainfall, operation of primary and secondary canals, and changes in Sea Level (diurnal tidal, extreme events storm surge, long-term Sea Level Rise)
- Primary Conveyance System managed by SFWMD, includes primary canals and structures
- Secondary Conveyance System managed by Miami-Dade County, includes canals, structures, pumps
- Outfalls in Biscayne Bay – water levels in the Bay directly affect the operation of the structures and water levels upstream
- Complexity of the stormwater management requires use of hydrologic and hydraulic models to provide predictive analysis of various scenarios

The general criteria to answer flood quantity and water quality questions includes:

- Hydrologic and hydraulic analysis

- GIS integration
- Simulation of free-surface flow, pressure flow, and surcharged flow
- Simulation of floodplains, canal systems, stormwater systems, BMPs (including green infrastructure), watersheds, sanitary sewers, and combined sewers
- Modeling of quantity and quality problems associated with urban runoff
- Single-event and continuous simulation on catchments having storm sewers and natural drainage, for prediction of flows, stages and pollutant concentrations
- Capability to simulate structure operation
- Simulation of urban hydrologic and quality cycles, including rainfall, surface and subsurface runoff, flow routing through drainage network, storage and treatment
- Statistical analysis on long-term precipitation data and output from continuous simulation, assessment challenges and countermeasures
- Tidal/groundwater/storm surge/overland flow boundary conditions

# Appendix 6: Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Storm Surge, Sea Level Rise, and Extreme Rainfall

REPORT

# Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall

## Ocean Outfall Legislation Program

*Prepared for*

Miami-Dade Water and Sewer Department

January 2018

OCEAN OUTFALL LEGISLATION PROGRAM
MIAMI-DADE COUNTY

Ocean Outfall Legislation Program
3150 SW 38 Ave., Suite 700
Miami, Florida 33146
Tel (305) 441-1864
Fax (305) 443-8856

# Contents

# Acronyms and Abbreviations

| | |
|---|---|
| BFE | base flood elevation |
| CDWWTP | Central District Wastewater Treatment Plant |
| FB | freeboard |
| NDWWTP | North District Wastewater Treatment Plant |
| NYCDEP | New York City Department of Environmental Protection |
| SDWWPT | South District Wastewater Treatment Plant |
| SF | safety factor |
| SLR | sea level rise |
| WASD | Miami-Dade Water and Sewer Department |
| WWTP | wastewater treatment plant |

# 1 Purpose and Background

This document summarizes elevations below which wastewater treatment facility assets should be protected or hardened to withstand or recover from flooding from projected future combinations of storm surge from tropical storms and hurricanes, coupled with extreme rainfall and sea level rise (SLR) at each of Miami-Dade Water and Sewer Department's (WASD's) three wastewater treatment plants, specifically the North District Wastewater Treatment Plant (NDWWTP), Central District Wastewater Treatment Plant (CDWWTP), and South District Wastewater Treatment Plant (SDWWTP). In addition, future hydraulic conditions are specified for tailwater on outfalls from the NDWWTP and CDWWTP.

The design elevations selected by WASD are different for existing and for new facilities, as summarized below. The basis of these recommendations is detailed in separate documents. In short, the design criteria for existing facilities are based on the FEMA Base Flood Elevation (BFE) at the CDWWTP and SDWWTP (10.0 ft NGVD29), with an allowance for 3.0 ft of SLR, 2.0 ft of freeboard, and 1.0 ft of safety factor, and no rainfall, which totals 16.0 ft. The design criteria for existing facilities at NDWWTP selected by WASD will also be 16.0 ft, though the FEMA BFE there is 2 ft lower at 8.0 ft. For new facilities, more recent estimates of surge coupled with SLR and extreme rainfall are used at each of the wastewater treatment plants, with 4.0 ft of SLR and 2.0 ft of freeboard. The SLR and precipitation estimates for hardening assets to withstand flooding are based on high projections for 50-year planning horizon. The SLR and precipitation estimates for setting tailwater hydraulic boundary conditions on outfalls are based on high projections for 25-year planning horizon.

These estimates may be revised periodically as information on storm surge, sea level rise, and extreme precipitation projections is revised. The estimates provided in this document were revised in 2017.

# 2 WASD Level of Service Priorities for Facility Resilience during Extreme Events

WASD has adopted a risk-based framework to guide the design of wastewater facilities for these extreme events, which recognizes that they are low probability, but potentially high consequence if systems fail. To guide the elevation and type of facility hardening measures that engineers should consider when designing flood protection or recovery measures, WASD has set the following ranking of processes to be protected, in declining order:

1. Personnel protection and hydraulic capacity maintained
2. Primary treatment liquid processes
3. Secondary treatment liquid processes
4. Solids treatment processes

# 3 Design Elevations for Existing and New Facilities

## 3.1 Flood Hardening Design Elevations

Table 1 summarizes the design flood elevations for existing and new facilities at the three wastewater treatment plants. Figures 1, 2, and 3 summarize the flood elevations graphically for the NDWWTP, CDWWTP, and SDWWTP, respectively, along with critical existing assets.

Table 1. WWTP Summary of Design Criteria for Hardening against Flooding from Storm Surge, Sea Level Rise (SLR) and Extreme Storm Events.
*Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall*

| | For Retrofitting of Existing WWTP Facility Assets | | For New WWTP Facility Assets | |
|---|---|---|---|---|
| **Facility** | **ft NGVD29** | **Basis** | **ft NGVD29** | **Basis (50-year planning horizon)** |
| CDWWTP | 16.0 | FEMA BFE + 3ft SLR from SEFLCC(2011) +FB +SF | 20.9 | Surge + 48" SLR + FB + 21" (100-yr, 72-hr) rainfall |
| SDWWTP | 16.0 | FEMA BFE + 3ft SLR from SEFLCC(2011) +FB +SF | 18.8 | Surge + 48" SLR + FB + 21" (100-yr, 72-hr) rainfall |
| NDWWTP | 16.0 | Same as CDWWTP and SDWWTP | 18.2 | Surge + 48" SLR + FB + 21" (100-yr, 72-hr) rainfall |

Notes:

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 50-year planning horizon

WWTP = wastewater treatment plant

## 3.2 Outfall Tailwater Hydraulic Design Elevations

Table 2 summarizes the design hydraulic tailwater elevations for outfalls served by new facilities at the NDWWTP and CDWWTP. The table also shows the elevations with 100-year storm surge and rainfall, and the SLR of 1.5 ft (approximately 25-year planning horizon). The values in Table 2 are presented without freeboard and safety factor.

Table 2. Peak Tailwater Elevations at each WWTP, for 100-Year Storm Surge and Rainfall, with Sea Level Rise of 1.5 ft (without Freeboard or Safety Factor)
*Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall*

| **Station** | **ft NGVD29** | **Basis (25-year planning horizon)** |
|---|---|---|
| CDWWTP | 14.0 | Surge + 18" SLR + 19" (100-yr, 72-hr) rainfall |
| NDWWTP | 12.2 | Surge + 18" SLR + 19" (100-yr, 72-hr) rainfall |

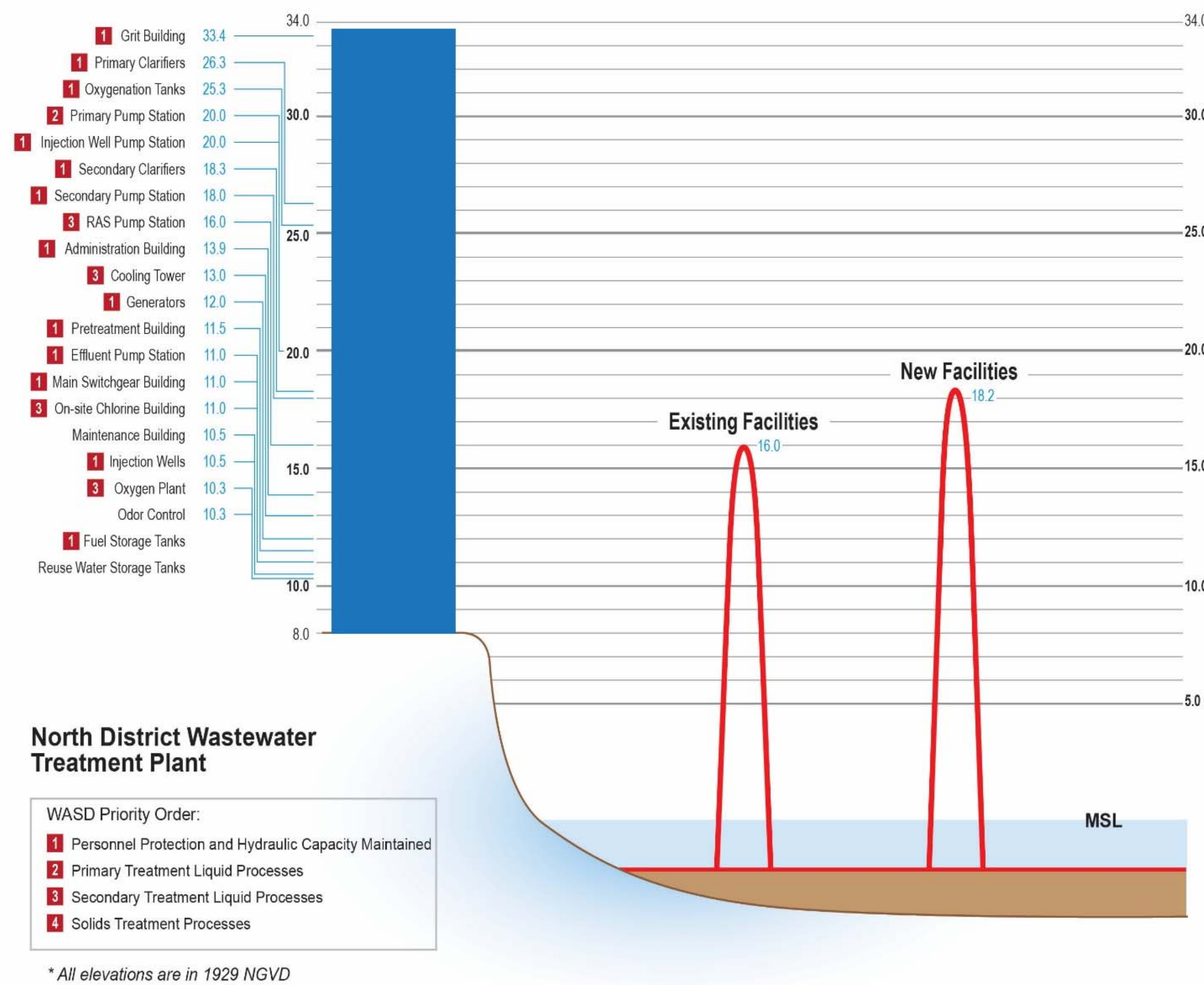



Figure 1. Facility Hardening Design Elevations and Prioritization of Critical Facilities for the North District Wastewater Treatment Plant

*Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall*

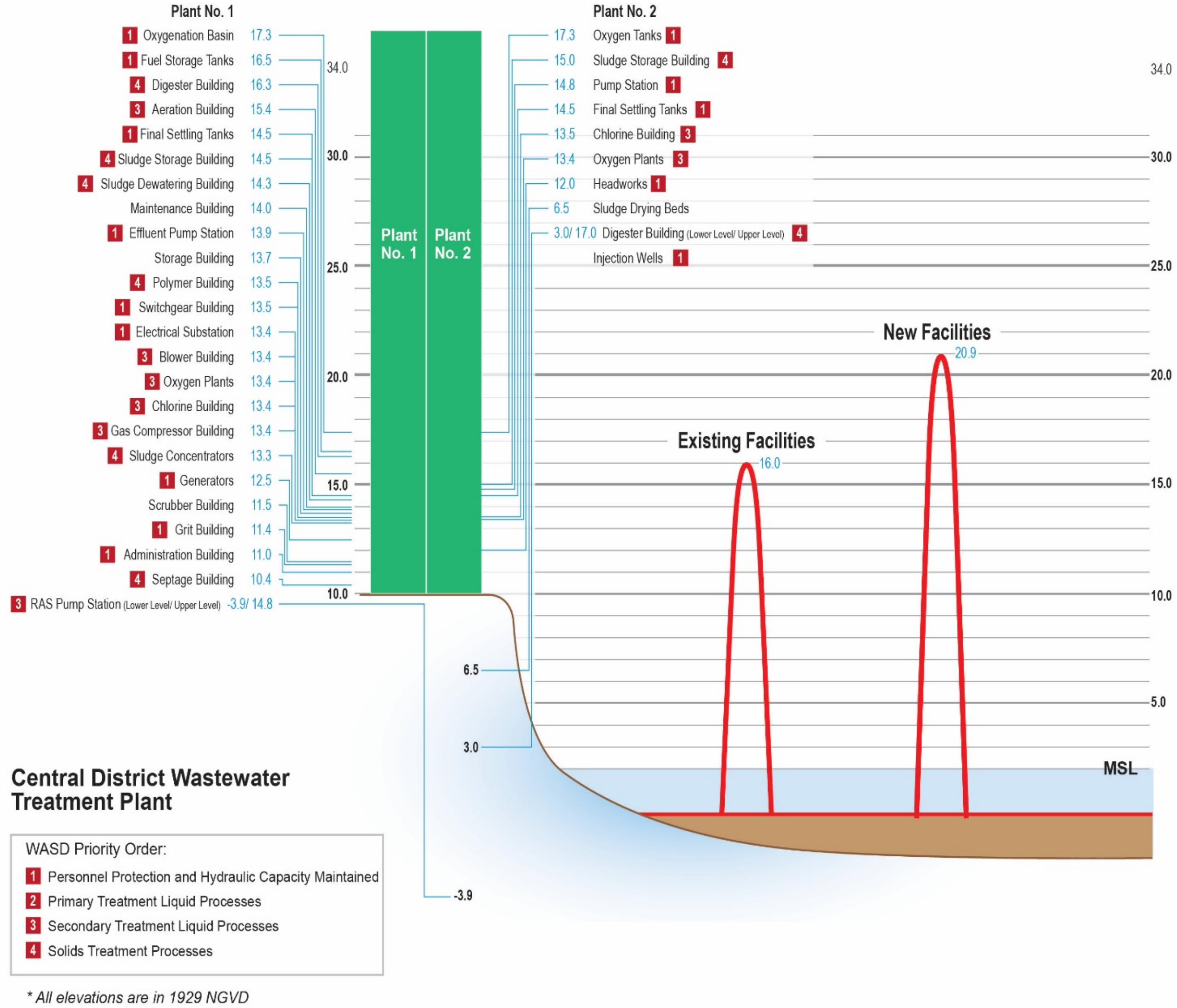



Figure 2. Facility Hardening Design Elevations and Prioritization of Critical Facilities for the Central District Wastewater Treatment Plant
*Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall*

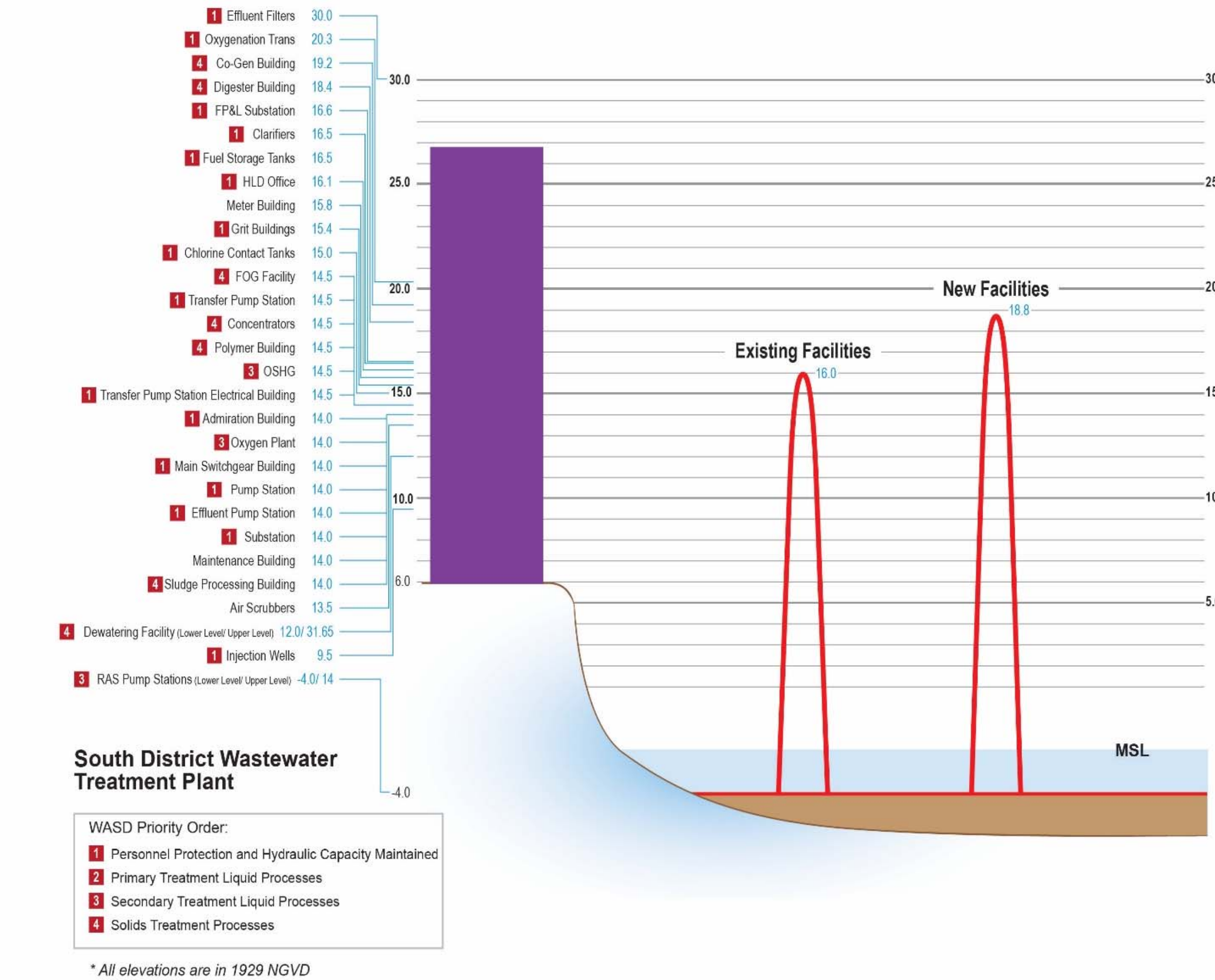



Figure 3. Facility Hardening Design Elevations and Prioritization of Critical Facilities for the South District Wastewater Treatment Plant
*Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall*

# 4 Facility Hardening Approaches

To protect assets against flooding from extreme events, design engineers should evaluate facilities and structures to understand flood pathways that can lead to critical systems, such as power sources, electrical and mechanical systems, motors, and pumps. Flood pathways include but are not limited to doors, windows, areaways, tunnels, grates, conduits, manholes or other wall penetrations. Those locations should be identified as at-risk if threshold elevations are below the assigned flood elevation in Table 1. Figure 4 lists facility hardening measures that can be considered by design engineers, based on criticality of the facilities relative to WASD level of service goals stated above.

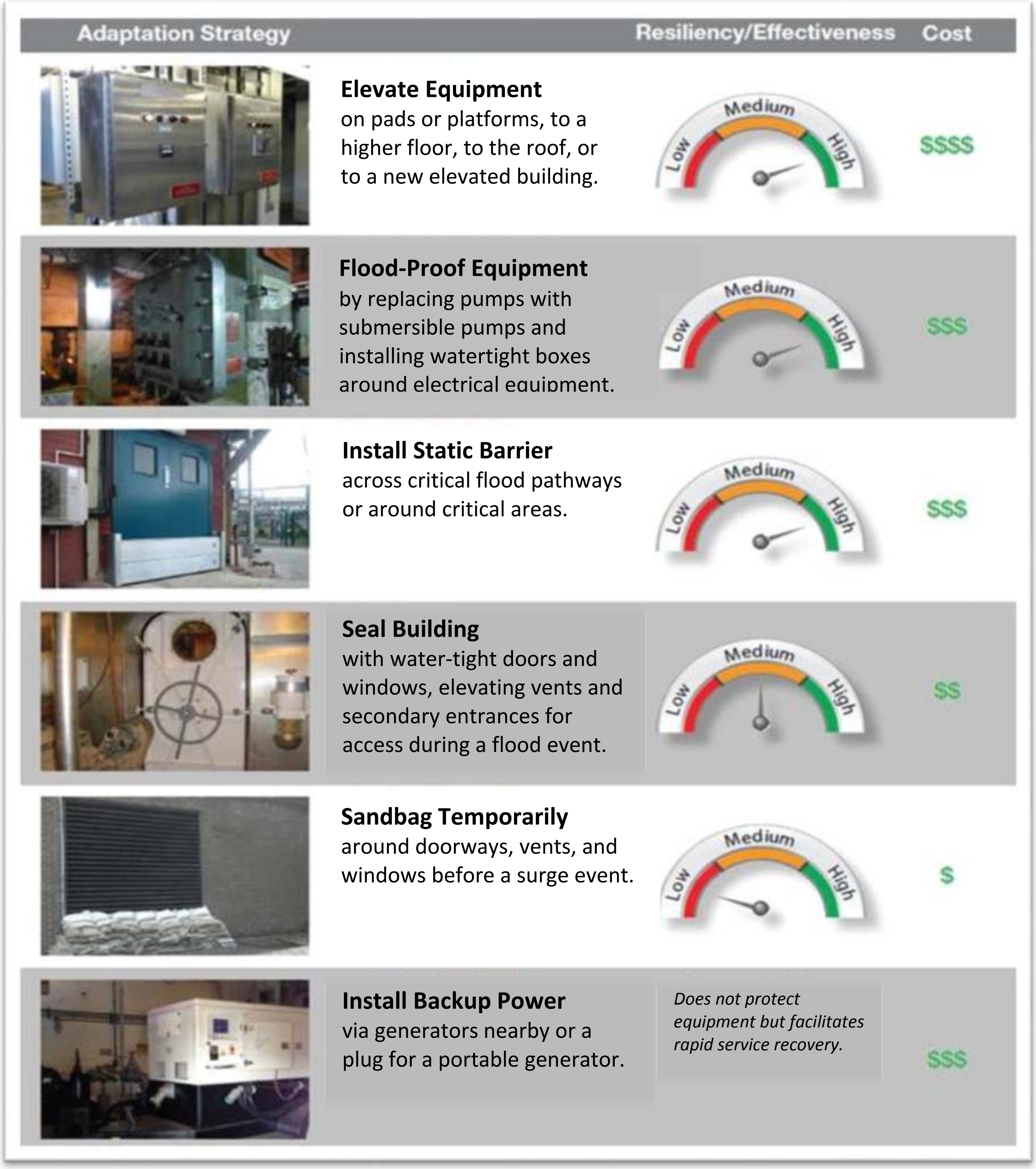



Figure 4. Facility Hardening Approaches. (Source: NYCDEP, 2013)
*Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall*

# 5 References

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