Memorandum

MIAMI-DADE COUNTY

Date: March 11, 2021

Agenda Item No. 2(B)(7)
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 Water and Sewer Infrastructure and Road Infrastructure to Sea Level Rise- Directive No. 180464

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. The following report is submitted in response to Resolution No. R-361-18 adopted by the Board of County Commissioners (Board) on April 10, 2018. The resolution directed the administration to study how sea level rise will affect water and sewer infrastructure and road infrastructure and to provide recommendations to reduce those 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 in the next available Board meeting agenda.

If you have questions concerning the above, please contact James F. Murley, Chief Resilience Officer, Department of Regulatory and Economic Resources, at 305-375-5593 or at James.Murley@miamidade.gov.

Attachment

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RECOMMENDATIONS TO PROTECT WATER, SEWER, AND ROAD INFRASTRUCTURE FROM SEA LEVEL RISE IMPACTS

February 2019

Final Report for Resolution R-361-18

Contents

Introduction

Flooding amplified by sea level rise is already affecting Miami-Dade County's water, sewer, and transportation infrastructure in certain areas. Sea levels are approximately four inches higher than they were in the early 1990s and are expected to rise an additional two to six inches in little more than a decade. Rising sea levels directly increase the risks of failing or underperforming infrastructure. For example, the sanitary sewer system is affected in two primary ways: by flooding at facilities and by impacting the overall operation and capacity of the collection and treatment system. Higher water levels impact the transportation network by reducing access to properties, flooding evacuation networks, deteriorating roadway surfaces and substructures, and damaging vehicles (including County transit and emergency response vehicles) that drive through saltwater.

Figure 1: King Tide flooding can affect the roadways and other infrastructure along the utility corridor

County departments are actively planning for these impacts and have already invested in reducing these risks; however, more work is needed. This report provides several recommendations to reduce the vulnerability of these infrastructure systems. By coordinating efforts across departmental lines, the County can more efficiently and cost-effectively address these risks. Additional work is needed to develop design standards that account for changing conditions and sufficiently protect County infrastructure over the lifetime of assets. These changes will continue to be balanced with addressing other needs, such as maintaining reasonable costs and reducing environmental impacts.

Supporting resolution

On February 10, 2018, the Board of County Commissioners (Board) passed Resolution No. R-361-18, which directs the Mayor or Mayor's designee,

> "to prepare a report containing recommendations on how to best protect the County's water and sewer infrastructure and road infrastructure from the impacts of sea level rise, including how best to maintain the County's ability to respond to changing road and water and sewer needs due to sea level rise impacts, as discussed herein. This report shall also include, but is not limited to, recommendations as to any changes to the Miami-Dade County Code which may be advisable."

In response to Resolution No. R-361-18, this report provides an overview of past studies; discusses on-going efforts to reduce vulnerabilities; and provides recommendations for addressing flood risks.

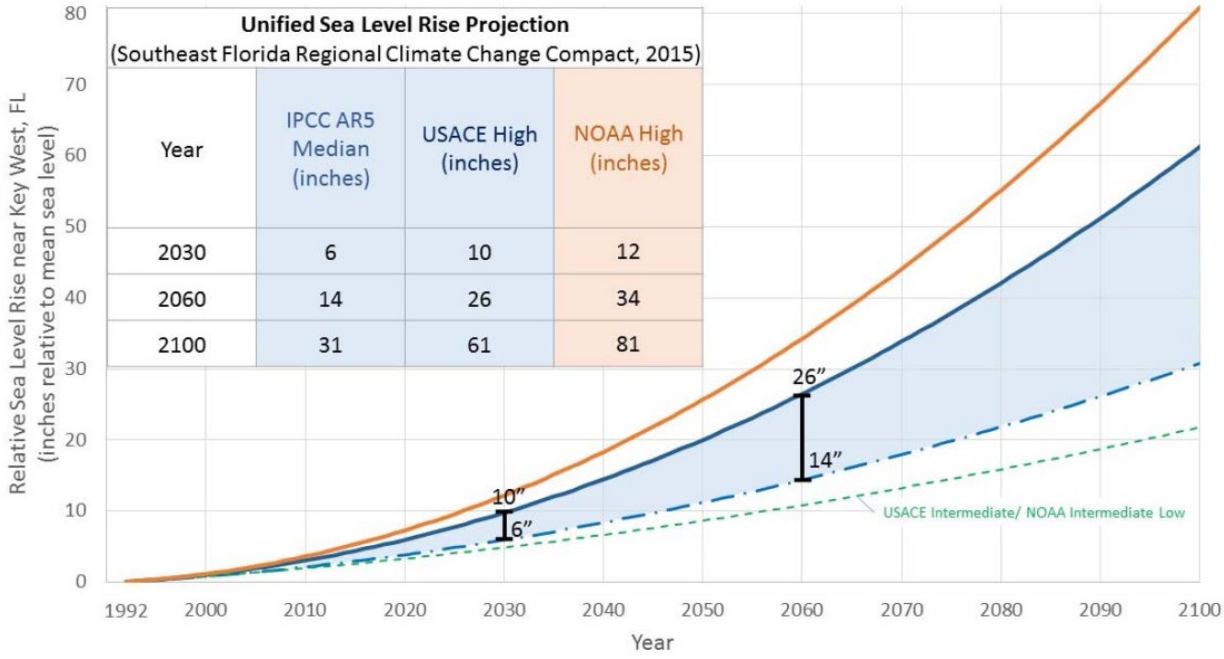
Sea level rise

Measurements at the Virginia Key tide gauge have indicated an increase of more than four inches in average sea levels since 1994.[1] As a consequence, the seasonal high tides, or "King Tides," have become deeper and more frequent. In coastal areas east of the South Florida Water Management District (SFWMD) water control structures, groundwater levels are affected by the tides and have risen as sea levels have increased.[2]

In order to accurately forecast how sea levels are expected to change over the coming decades, 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) as directed in Resolution No. R-451-14.[3] The projection was updated in 2015 by a panel of scientists to reflect the best available data and indicates that 12 years from now, mean sea levels are expected to be six to ten inches higher than 1992 levels. By 2060, sea levels are expected to be 14 to 26 inches higher.[4]

To understand how groundwater levels will change in the coming decades, the Water and Sewer Department (WASD) worked with the U.S. Geological Survey to develop and calibrate a coupled surface-water/groundwater model. This model has shown that groundwater levels are expected to rise, most notably east of the water control structures.[5]

Figure 2: Unified sea level rise projection for Southeast Florida



[1] This increase is based on the calculated increase in monthly mean sea levels measured at the Virginia Key tide gauge from 1994 through September 2017. Raw data are available from the National Ocean and Atmospheric Administration at https://tidesandcurrents.noaa.gov/stationhome.html?id=8723214

[2] Sukop, Michael C. et al. (2018). "High temporal resolution modeling of the imact of rain, tides, and sea level rise on water table flooding in the Arch Creek basin, Miami-Dade County Florida USA." Science of the Total Environment. March 2018. https://www.sciencedirect.com/science/article/pii/S0048969717328814

[3] 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

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

[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

How could sea level rise affect these systems?

Much of the County is vulnerable to flooding, and there are many areas where today's sea levels during the King Tide season are compromising the effectiveness of existing infrastructure. Rising sea levels will exacerbate these risks unless steps are taken to protect infrastructure. A brief description of how these changes are affecting water and sewer infrastructure and roadways is below, and several previous reports have described these impacts in more detail (Appendix 1).

Water and sewer infrastructure

Rising sea levels affect the sanitary sewer system in two primary ways: through flooding at facilities and by impacting the overall operation of the collection and treatment system due to increased groundwater levels and precipitation patterns. Changes in sea levels are increasing the risk of higher storm surges. This risk is particularly significant given that the three wastewater treatment plants are located along the coast (Figure 3). WASD has invested in studies quantifying these risks and is designing new facilities above these future storm surge elevations. WASD is also retrofitting existing infrastructure, including pump stations, to be less exposed to risk. More information on these studies and infrastructure hardening efforts is available in other reports.[6] Additionally, sea level rise will affect salt water intrusion rates; however, these impacts are described in a previous report and are not addressed here.[7]

Figure 3: Three coastal wastewater treatment plants

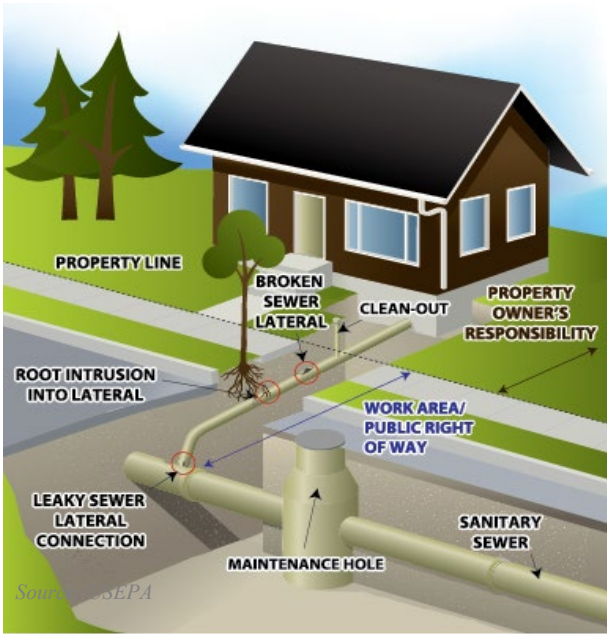
In addition to direct flooding impacts, sea level rise (coupled with changes in precipitation frequency and intensity) also increases the volume of wastewater being conveyed and treated. The flow added to the system from tidal inundation of land, rain events, and groundwater is referred to as inflow and infiltration (I&I) (Figure 4). Inflow and infiltration can cause increased operations costs associated with conveyance and treatment of the extraneous water, reduced treatment capacity, increased risk of sanitary overflows, and the overdesign of pump stations and infrastructure. 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. In areas that are experiencing King Tide flooding, an increase in I&I has been observed by WASD. Chronic flooding can also lead to an increase in I&I when residents illegally remove manhole covers of the sewer system to alleviate the street flooding in their neighborhood. More information on these impacts is available in previous reports.[8]

[6] For more information on WASD's efforts to adapt to sea level rise efforts see: https://www.miamidade.gov/water/capital-improvements-programs.asp

[7] The relationship between sea level rise and saltwater intrusion is described in a previous report in response to Resolution R-48-15, which is available at https://www.miamidade.gov/green/library/sea-level-rise-flooding-saltwater-intrusion.pdf.

[8] For a comprehensive review of issues associated sanitary sewers and stormwater infrastructure, refer to the upcoming final report for Resolution R-906-16, "Vulnerability of sanitary sewers and stormwater infrastructure to sea level rise." The link was not available at the time of this report as it was in the process of approval by the Board.

Figure 4: Sources of inflow and infiltration



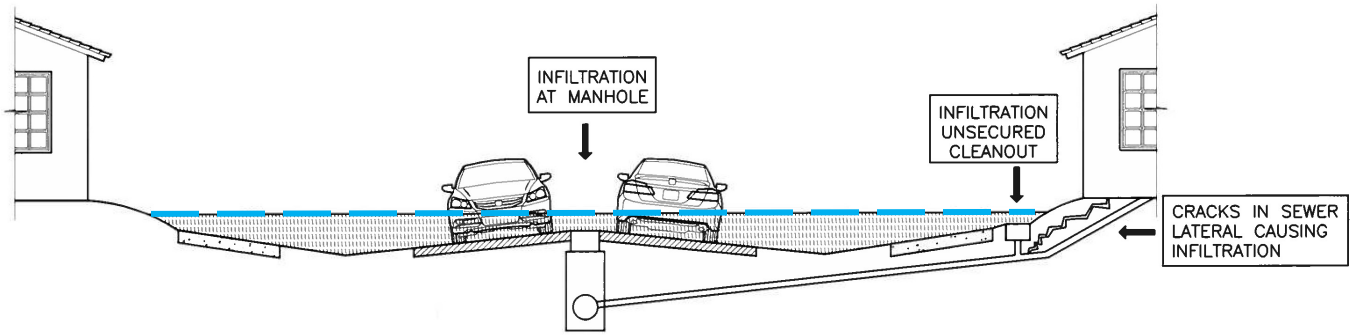
Infiltration – groundwater entering sanitary sewers through defective pipe joints and broken pipes

Inflow – water entering sanitary sewers from inappropriate connections

The WASD Planning Section has started to research how pump stations are affected by King Tides to determine a methodology to project the impact of sea level rise. WASD explored how the flow rate at several nearshore pump stations changed on dry days during King Tides. An initial study, which will be followed up with subsequent analysis, found a correlation between higher tides and the flow rate at selected pump stations. Results indicated that flow can vary greatly with tidal fluctuations. The flow rate at the pump station was lower when the tide was lower and as the tide rose, the flow increased. When tide levels peaked, the flow doubled, despite the dry weather. More investigation is planned to determine whether the change was definitively related to the tidal flooding and to develop a methodology to forecast how sea level rise will affect inflow and infiltration.

Inflow and infiltration is also directly related to increased flooding in the roadways (Figure 5). Typically, street flooding can increase inflow as floodwaters enter the sanitary sewer system through manhole covers in the Right-of-Way or through "cleanouts" which are connected to the sewer system along "laterals" between private properties and the sewer system. Cleanouts are typically located near the back of the sidewalk. While they are designed to have a tight fitting cap that will prevent water from entering, cracks or other issues can arise over time which lead to inflow through these areas. Infiltration happens when there are cracks in the pipes or other infrastructure that allow groundwater to seep into the sanitary sewer system. As flooding increases with sea level rise and as groundwater levels increase, inflow and infiltration is expected to increase unless proactive, protective measures are scaled up. Measures to reduce inflow and infiltration are typically very cost-effective because they reduce the volume of water that needs to be conveyed and treated.

Figure 5: Roadway flooding can increase inflow into the sanitary sewer system



OVER–TOPPED STREETS CAUSE WATER TO INFLOW INTO MANHOLE COVERS. OVER–TOPPED SEWER CLEAN–OUTS CAN CAUSE WATER TO IN–FLOW INTO SEWER LATERALS. CRACKED SEWER COLLECTION PIPES AND SEWER LATERALS CAUSE WATER TO INFILTRATE INTO THE SEWAGE COLLECTION SYSTEM.

Wastewater is also treated by onsite (or decentralized) wastewater treatment systems that are not part of the sanitary sewer system. These include septic systems, which are used to treat wastewater from individual properties such as homes or businesses and return treated wastewater back into the environment (Figure 6). A separate report completed pursuant to Resolution R-911-17 assesses how septic systems may be impacted by current and future water levels and provides recommendations on expanding the sanitary sewer system to facilitate conversion of septic systems. Compromised systems can lead to public and environmental health impacts and secondary impacts from excess nutrients and chemical contaminants from bathrooms, kitchen drains, and laundry units. Septic systems can be a source of fecal bacteria contamination in orders of magnitude above recreational water quality criteria or expected background levels in floodwaters, including flooded roadways that occur during King Tide events.

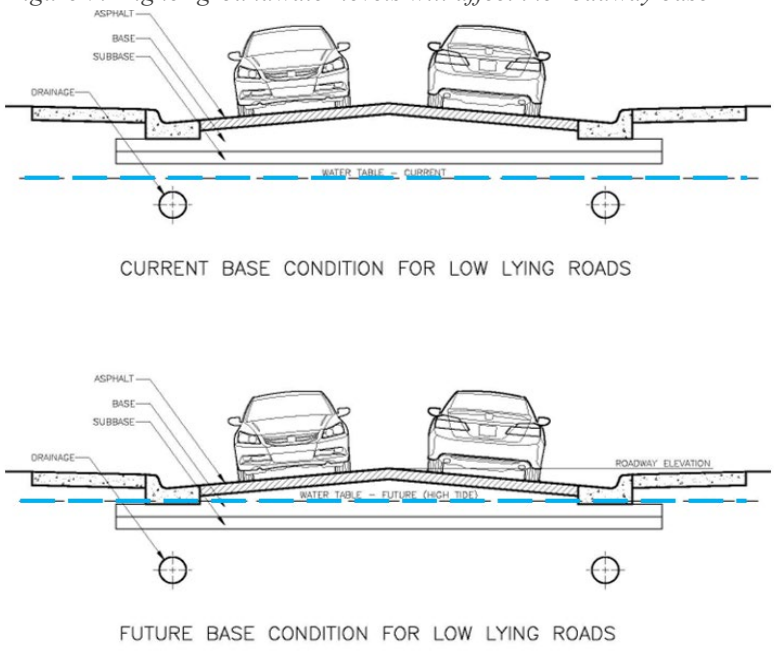
Figure 6: King tide flooding in a neighborhood served by septic systems

Roadways

Higher water levels, which are often typically observed during King Tides or storms, have multiple impacts on the transportation network. Roadways are typically designed to follow the lowest profile within a given area. While this helps alleviate flooding risks to adjacent properties, it also means roadways may be some of the first assets affected by higher water levels. High water levels can reduce access to properties, impact evacuation networks, deteriorate roadway surfaces and substructures, and damage vehicles (including transit and emergency response vehicles) that pass through or sit in saltwater. High water levels may also block access to a flooded area or force emergency vehicles to find alternative routes. Higher average groundwater levels can reduce drainage capacity and increase inundation, which will increase wear and tear on the roadways and can lead to additional pot holes.[9] This is particularly true if the road base becomes saturated for an extended period of time (Figure 7). Even areas that are not directly affected by flooding can be impacted as travel patterns shift in response to the disruption in low-lying areas.

Sea level rise will lead to indirect impacts such as increased erosion and higher storm surge. These changes are likely to increase erosion along coastal causeways and streets and could affect embankments. Previous reports have indicated that coastal causeways are some of the most vulnerable and critical assets.[10] Higher water levels may also affect bridge clearances and increase corrosion. Low-lying assets spanning waterways can be particularly vulnerable.

Figure 7: Higher groundwater levels will affect the roadway base



Several studies have analyzed the vulnerability of the transportation system, including studies from the Federal Highway Administration (FHA) and the University of Florida under contract to the Florida Department of Transportation.[11] The FHA includes sea level rise considerations in their planning and design guidelines.[12]

The County's Stormwater Master Plan includes an assessment of the vulnerability of County-owned roadways. When the next iteration of the Master Plan is completed in the next few years, additional information will be available on vulnerable road segments. In contrast to earlier versions, the next iteration of the Stormwater Master Plan will include sea level rise in the flood risk modeling. For a comprehensive review of issues associated with transportation infrastructure, as well as an analysis of available tools related to resilience in the transportation sector, see previous reports.[13]

[9] Berry, L., "Development of a Methodology for the Assessment of Sea Level Rise Impacts on Florida's Transportation Modes and Infrastructure", 2012. P. 8

[10] For more information see the report in response to Resolution No. R-235-16 available at http://www.miamidade.gov/mayor/library/memos-and-reports//2016/11/11.30.16-Final-Report-for-Assessment-of-Available-Tools-to-Create-a-More-Resilient-Transportation-System-Directive-160220.pdf

[11] See Appendix 1 for a summary of various studies.

[12] The Federal Highway Administration has been working on multiple resources available including a Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance available at https://ops.fhwa.dot.gov/publications/fhwahop15026/index.htm.

[13] More information is available in the final report for Resolution R-235-16, "Assessment of available tools to create a more resilient transportation system". http://www.miamidade.gov/mayor/library/memos-and-reports//2016/11/11.30.16-Final-Report-for-Assessment-of-Available-Tools-to-Create-a-More-Resilient-Transportation-System-Directive-160220.pdf

On-going initiatives to reduce vulnerability

A number of existing policies require infrastructure planning and design to consider sea level rise, including Resolution No. R-451-14 and the Comprehensive Development Master Plan Policy CM-9H (Appendix 3) which mandate that all capital projects consider sea level rise.[14] In addition, Resolution No. R-617-17 requires that County civil infrastructure projects use the Envision Rating System, which includes climate risk criteria.[15] The Envision Rating system is a framework that includes 64 sustainability and resilience indicators, called 'credits,' organized around five categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience. These collectively address the sustainability of infrastructure projects. Several County departments have assessed the vulnerability of their own infrastructure systems and changes in flooding risks are part of these assessments. The efforts of individual departments are described below.

The Water and Sewer Department

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 hydrological conditions. This work, done in partnership with the Office of Resilience (OOR), 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.[16]

WASD has been methodically developing an approach to harden projects in preparation for increased flooding and higher storm surges. As part of the larger capital improvement plans required by the Environmental Protection Agency's Consent Decree with the County and ocean outfall legislation adopted by the State, new design standards 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 8). Hazard mitigation grant funds have also been sought 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

Figure 8: Electrical panels are elevated on a four foot pad to protect them from flooding

[14] This resolution requires that all County capital projects consider sea level rise as part of the planning, design and construction.
[15] More information on the Envision Rating System is available at: https://sustainableinfrastructure.org/how-it-works/
[16] The relationship between sea level rise and saltwater intrusion is described in a previous report in response to Resolution R-48-15, which is available at https://www.miamidade.gov/green/library/sea-level-rise-flooding-saltwater-intrusion.pdf.

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 entire enterprise. The department is also actively collaborating with peers through the Resilient Utilities Coalition, and with other organizations 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 vital components first.

Figure 9: Tidal flooding before the roadway improvements

WASD continues to address inflow and infiltration through several programs including the Pump Station Improvement Program (PSIP), which is managing a number of upgrades to the pump station and force main systems to ensure compliance with regulatory programs. The program is determining the impact of excessive inflow and infiltration on the overall operating condition of the pump station system. 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, work is being performed by both WASD forces and external contractors and includes activities such as replacing main lines and laterals, grouting, point repairs, manhole repairs, and pipe lining. In summary, WASD invested more than $100 million into reducing inflow and infiltration between fiscal years 2014 and 2018 and the department intends to devote another $111 million by 2022.

Roadways

New roads are designed for specified levels of service for drainage, which are detailed in Section D-4 of the Public Works Manual and the Florida "Greenbook."[17] This section establishes the design criteria for each roadway. Transportation infrastructure must also comply with the Florida Department of Environmental Protection (FDEP) standards and the Florida Department of Transportation (FDOT) standards.[18] The Comprehensive Development Master Plan (CDMP) also includes policies that touch upon the flood level of service including Policy CON-5A and CON-5E (Appendix 3).[19]

Over time, the level of service can suffer as additional development increases run-off, as groundwater levels rise, as sea levels rise, or as the drainage network capacity diminishes. Therefore, the County regularly inspects existing drainage infrastructure to determine which areas may have capacity issues. These areas are rated using a Maintenance Rating Program scale to prioritize improvements. There is a simultaneous process to systematically evaluate the vulnerability of the transportation network as part of the Stormwater Master Planning process. Through the assessment of flooding risk by stormwater basin, staff identify roadway segments that are no longer meeting their "designed level of service" or, in other words, are more flood-prone than they were originally

[17] The Florida Department of Transportation's "Manual of Uniform Minimum Standards for Design, Construction and Maintenance for Streets and Highways" is available at http://www.dot.state.fl.us/rddesign/FloridaGreenbook/FGB.shtm
[18] The Florida Department of Transportation design manuals are available at *http://www.dot.state.fl.us/rddesign/Drainage/files/DrainageManual.pdf*
[19] The County's Comprehensive Development Masterplan is available at http://www.miamidade.gov/planning/cdmp.asp

designed to be. The Stormwater Master Plan evaluation process is currently incorporating sea level rise into this iteration and will have updated results within the next two years. This analysis will help categorize critical capital improvements. Once the vulnerable segments are identified, this information is passed on to the Miami-Dade Department of Transportation and Public Works. The department, in turn, goes through a prioritization process to identify opportunities to retrofit the roadway and improve the level of service. Needed improvements are typically funded by the Stormwater Utility Fee and other drainage-specific funding sources. Major roadway improvements are also funded by Roadway Impact Fees (RIF); however, projects paid for by that funding source are not based on flooding risks but are specifically tied to capacity improvements. Road Impact fees cannot be used to pay for existing deficiencies or maintenance of roadways. However, improvement projects are designed to be brought up to the elevation required by the County Flood Criteria whenever possible.

Figure 10: Flood-prone Bayshore Drive is being elevated

Some roadways affected by sea level rise have already been improved. For example, in cooperation with the City of Miami Beach, a section of Dade Boulevard was raised over two feet to reduce King Tide flooding. This elevation was based on an additional safety factor (freeboard) above observed King Tide elevations. On the mainland in the Arch Creek watershed, the County raised a segment of NE 16th street more than a foot to reduce the vulnerability of flooding from that tributary and to meet the standards of the County Flood Criteria maps. The County Flood Criteria map is based on historic conditions and does not currently account for future sea level rise.

In another coastal neighborhood that has experienced recurrent King Tide flooding (Figure 9), WASD is piloting a new approach to mitigate flooding. Because of the low elevations of the adjacent properties, it was not possible to raise the roadway without causing adverse impacts to neighboring structures. This project, therefore, has explored other options including installing a small berm to reduce direct tidal flooding and changing the cross section to raise one side of the roadway.

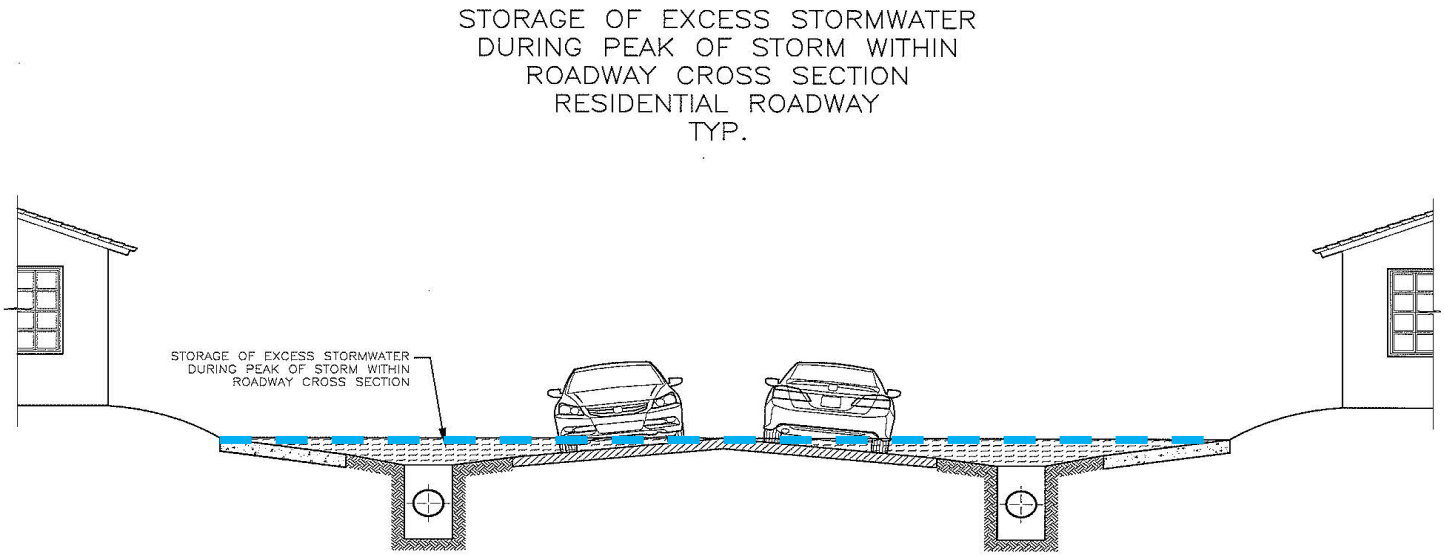
The department is currently working with the City of Miami to elevate flood-prone Bayshore Drive in Coconut Grove (Figure 10). The design of this project explicitly incorporates the change in sea level expected over the 30-year design life of the roadway. This improvement project will significantly reduce the risk of further disruptions due to tidal flooding; however, it also underscores the challenges of raising roadways in a developed area. This project requires careful coordination with the adjacent properties to minimize the impact to abutting homes, businesses, vegetation, historic walls, and driveways.

In the existing urban environment it is not always feasible to retrofit the roads and bridges to adapt to changing water levels and ensure the required level of service. In some cases, raising a roadway may be extraordinarily challenging because it would increase the risk of flooding to adjacent areas. By design, most roadways are lower than the adjacent homes and businesses. This allows the roadway cross sections to collect and hold rainwater during a storm and therefore minimize the risk of flooding to the surrounding properties (Figure 11). If a roadway was raised above the neighboring properties, the ability to store water would diminish and flood risks would increase. Therefore, a roadway's elevation is often constrained by the elevation of the adjacent properties.

Similarly, it can be challenging to raise bridge heights in developed areas where it may be constrained by the adjacent properties, availability of space, or the elevation of adjacent roadways.

In coastal areas where the groundwater is affected by the tides, and where flooding is caused directly by high tides, it is difficult to reduce flooding using drainage technologies currently in place. When the elevation of the land is no longer higher than the elevation of the water it becomes difficult, if not impossible, to use gravity to drain standing water except during low tides. Pumps can be used to move water out of these areas; however, in coastal environments, the pumps may be pumping against the tide. There are also many trade-offs with using pumps to overcome these challenges. Pumps require energy and therefore require an uninterrupted power supply to avoid failing. A failure in the power supply or some other component could lead to flooding. There is also an increased cost and environmental impact associated with pumping. Currently, it costs approximately $3 million to construct each pump station. It costs approximately $50,000 per year for operations and maintenance for each pump station, and these costs would be higher if they were pumping saltwater. Operating the County's 18 existing stormwater pump stations and eight control structures is costing almost $1 million per year and moving to a stormwater system reliant on pumping would result in a significant increase in this cost.[20] Most importantly, pumps may not be effective in many low-lying coastal areas over the long-term.[21] Pumps in certain locations may end up circulating saltwater and may be minimally effective at drawing down groundwater levels. Additionally, pumps used to move saltwater can have a significantly shorter lifespan and therefore be more expensive in terms of capital and maintenance costs than pumps used in a freshwater environment. A recent study by the South Florida Water Management District found that elevating buildings and roadways was more effective in addressing sea level rise and more cost-effective than a series of pumps. [22] This same study found even very large forward pumps were not effective in the long-term in the face of sea level rise.[23] Elevating structures also provides additional protection from storm surges, which pumps cannot provide.

Figure 11: Roadways are designed to reduce the risk of flooding to adjacent properties by storing stormwater



[20] The Department of Transportation estimates that operating the existing pump stations costs approximately $912,000 a year to operate.
[21] It is important to note that a drainage system which relies soley on pumping without considering the boundary conditions, or the discharge points, and the overall hydrology of the area, may not be technically effective.
[22] Bouwer, Laurens et al. 2017. "Assessment of alternative flood mitigation strategies for the C-7 Basin in Miami, Florida." Deltares & the South Florida Water Management District. Link: ftp://ftp.sfwmd.gov/pub/kkonya/C7_FPLOS_Reports/Risk%20Assessment_of_3_Alternative_Flood_Mitigation_Strategies_for_the_C-7_Basin_in_Miami_Florida%20-%20DELTARES.pdf
[23] ibid

Bridges

For bridge design, the Florida Department of Transportation requires some amount of sea level rise to be considered as part of the design process for any new bridge. This is an important design component as sea level rise was shown to be partially responsible for a bridge failure that occurred along the I-10 in Pensacola, Florida (Figure 12). The bridge was damaged by Hurricane Ivan in 2004. Between the time the bridge was designed and the time of the storm, engineers found that sea levels rose three to four inches. According to Dr. Scott Douglass, a coastal engineer from the University of Alabama, damage to the I-10 bridge during Hurricane Ivan was worse as a result of the additional load of approximately 44,000 pounds on the bridge attributed to the three to four inches of sea level rise.[24] While Florida Department of Transportation requires sea level rise be considered as part of the design process, the agency's recommended methodology does not account for the same amount of sea level rise as the Southeast Florida Climate Compact's Unified Projections. Designing for too little sea level rise over the life of an asset, such as the I-10 bridge, can increase the risk of damage in the wake of a hurricane.

Figure 12: Damage to I-10 bridge in Pensacola following Hurricane Ivan

Source: Florida Highway Patrol, 2004

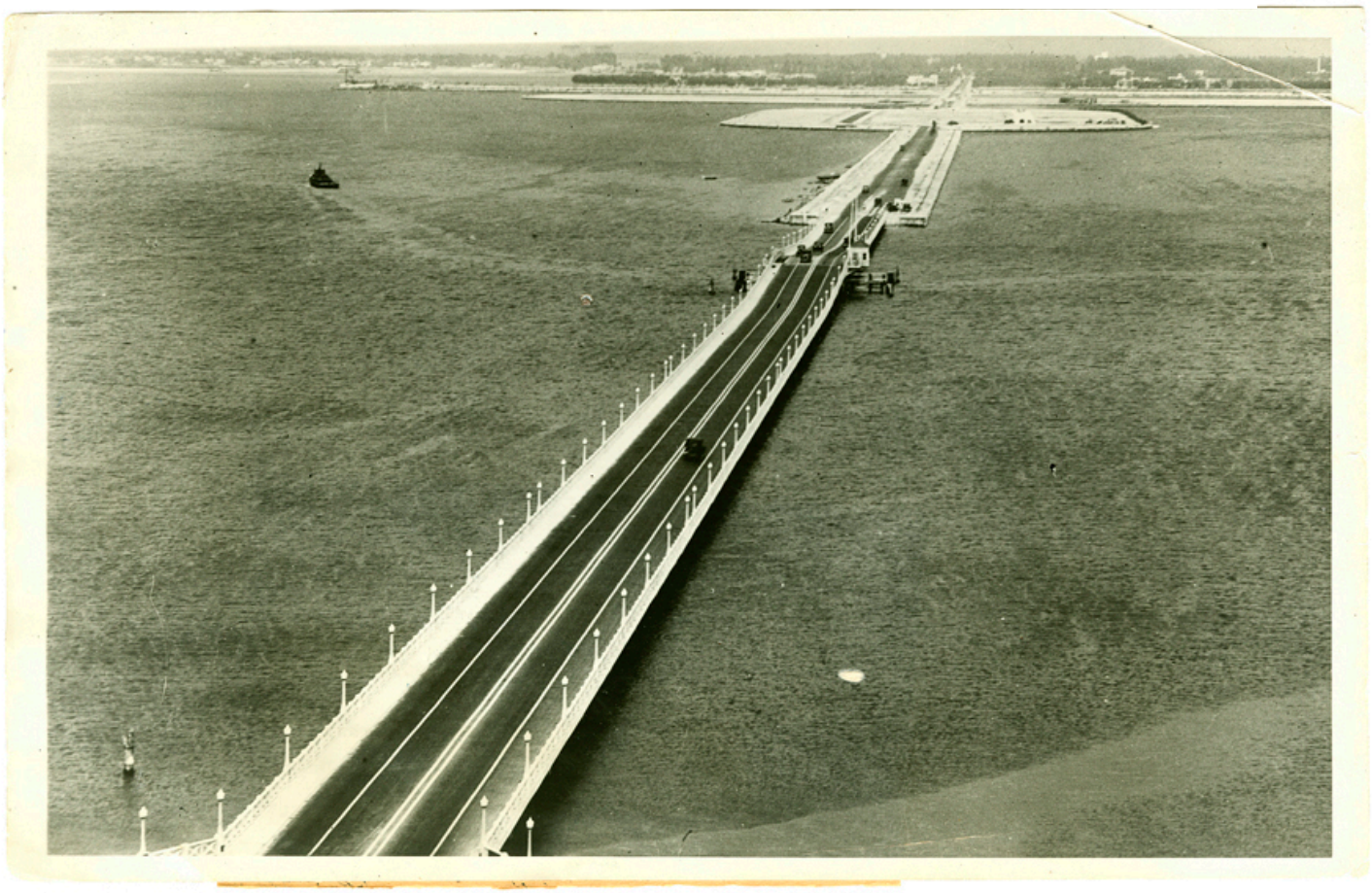
As the County designs new bridges, rising water levels and surge levels will be part of the design process. The most recent sea-level rise trends will be considered when scoping new or replacement bridge projects. However, there are many existing bridges that were designed before these policies were enacted. For example, sea levels have risen approximately nine inches since the Venetian Causeway was constructed in 1927 (Figure 13).[25] While many other things have changed since then, including civil engineering practices and safety standards, the subtle changes in water levels can change the loads and stresses on existing structures. To ensure the safety of these structures, the Department of Transportation currently inspects all of the County-owned bridges every two years on a rotating schedule to ensure they are structurally sound.

[24] More information from FDOT's findings can be viewed in their webinar, with comments by Dr. Douglass concerning sea level rise and the I-10 bridge starting around minute 37:00: https://connectdot.connectsolutions.com/p4so2ik63yt/?launcher=false&fcsContent=true&pbMode=normal

[25] While direct measurements of sea levels in the 1920s are not available, records are available from 1931 through the present. In the decade from June 1, 1931 until June 1, 1941 the average sea level was -1.41896 feet NAVD 88. In the decade from June 1, 2008 to June 1, 2018 the average sea level was -0.63673 feet. This represents a change of slightly more than 9 inches. The measurements of water levels from the 1930s were measured by at the NOAA tide gauge at the Miami Beach (https://tidesandcurrents.noaa.gov/waterlevels.html?id=8723170&units=standard&bdate=19310601&edate=19410602&timezone=GMT&datum=NAVD&interval=m&action=) and the measurements from the most current decade are from the NOAA tide gauge at Virgina Key (https://tidesandcurrents.noaa.gov/stationhome.html?id=8723214)

Sea level rise has been one of many issues considered during the current Venetian Causeway Project Development and Environment (PD&E) study. Preliminary alternative analyses have shown that increasing the vertical clearance of bridges along the Venetian Causeway will reduce potential impacts from storm-surge events, and sea level rise. The most recent sea-level rise data will be considered once the final design of the selected alternative is underway. Moving forward the County will need to review current criteria for building bridges, clearance, scour velocities and increased rain intensity to ensure they account for the expected changes in these variables.

Figure 13: When the Venetian Causeway was constructed sea levels were approximately 9 inches lower



Recommendations on how best to reduce the vulnerability of these systems

While efforts are on-going to reduce the vulnerabilities of County-owned infrastructure systems, the following recommendations offer additional steps and opportunities to more proactively address the challenge of sea level rise. All departments will continue to review how adaptation measures affect other goals such as maintaining reasonable costs and environmental quality. The County will need to change the way new systems are designed and will need to retrofit existing infrastructure. These challenges will be most urgent in areas east of the South Florida Water Management District's water control structures and areas where the groundwater is tidally influenced. County design standards should move away from using fixed criteria and historic data and move toward standards that will protect the infrastructure over its entire functional life.

Overall recommendations

- There are opportunities to more closely 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 right-of-way. 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 criterions are still based on historic water levels and do not account for the dynamic changes observed over the past few decades. Some design guidelines 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, high tides are increasing groundwater levels. The County has invested in integrated surface and groundwater modeling to understand how sea levels will affect groundwater levels between 2018 and 2040. 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.[26]

- In the interim, the County Flood Criteria (§ 11C) 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.

- 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

[26] Updated maps and standards from Broward Conty can be found here: http://www.broward.org/Environment/Engineering/Pages/GroundwaterMaps.aspx.

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 roads 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 including 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 the need for updating standards and prioritizing improvement projects.

- In order to retrofit existing infrastructure, many adaptation measures will require the use of additional space outside of the roadway (utility corridor). Therefore, it is recommended that the County explore funding sources, such as Federal Emergency Management Agency (FEMA) grant programs, to procure land for infrastructure and natural water storage.

- 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 should be updated to reflect the mandate in R-451-15. By including the policy in the Code, the Board can increase consistency of enforcement across departments. 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.[27]

- Additional flooding of roadways due to higher sea and groundwater levels is expected to lead to increased infiltration and inflow into the sanitary sewer system. 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; however, in the long-term, it will likely be most effective to adapt the roadway, water, sewer, and stormwater infrastructure simultaneously to limit the impact of tidal inundation to all of these systems.

[27] 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.

Roadways

- The Comprehensive Development Master Plan and Public Works Manual currently specify the established flood protection levels of service for roadways based on design storm events; however, this assessment does not include an evaluation against sea level rise. It is recommended that the County reassess the performance of the current standards and reassess which storm events are most appropriate. It is also recommended that the County work with university partners to evaluate how standards need to be changed to account for the potential for more frequent or severe storm events expected as a result of climate change. It is also recommended that the County move to a system of incorporating projected levels of service into designs, including evaluating sea level rise and groundwater conditions, to ensure infrastructure will be protected over the lifespan of the asset.

- Currently, there is no dedicated funding source to reconstruct coastal roadways impacted by sea level rise. It is recommended that additional sources be identified to allow for improvements to these vulnerable roadways. As one potential source, It would be prudent to seek funding from FEMA to mitigate roadway flooding issues.

- In some instances, it may be more cost-effective and environmentally sustainable to buy out flood-prone properties than it is to provide extensive, energy-intensive drainage infrastructure and coastal protections to chronically or permanently inundated areas. Buy-outs of willing sellers may be especially prudent in areas where the groundwater is tidally influenced and is at or near the ground level. These areas can then be used as public spaces for recreation and for passive water storage. Currently, the only funding available for purchasing property from willing sellers is from the federal government; however, these funds are intermittent, scarce, and difficult to secure. It is therefore recommended that the County identify a mechanism for buy-outs from willing sellers to address the most severely repeatedly flooded areas.

Bridges

- It is recommended that the Miami-Dade County Department of Transportation and Public Works (DTPW) finalize the scour study of County bridges and implement a scour-critical substructure rehabilitation program. This is especially important for bridges with unknown foundations within tidal waters, such as those along the Rickenbacker Causeway. Funds should be dedicated to strengthen or replace existing bridge foundations to prevent catastrophic damage during storm surge events as well as damage from wave action and tidal flooding.

- In order to allow replacement bridges to be designed to be resilient to climate change, additional space may be needed to allow for further elevation. A dedicated funding source should be found for buying out properties or easements adjacent to existing bridge approach slabs, or touch-down points. It can be difficult to increase the vertical clearance of coastal bridges as private property may be affected when slabs, wing walls, and retaining walls encroach into private easements.

- The Office of Resilience will work with the DTPW to convene the scientific and engineering expertise necessary to advise and assist the department as they adjust their design criteria to account for sea level rise.

- It is recommended that the County implement a real-time hydrologic monitoring network which will measure water levels, discharges, current velocity, and sediment levels.

- The County will work with the Florida Department of Transportation's (FDOT) district office to coordinate efforts and work toward a consistent approach to account for sea level rise in roadway and bridge designs based on locally-appropriate sea level rise projections.

- It is recommended that the County consider conducting a study of the vulnerability and adaptation measures needed for all coastal causeways.

- It is recommended that the FDOT should develop a series of studies of bridge scour which should also account for potential sea level rise. The studies should implement numerical hydrodynamic models, and include detailed bathymetry and other characterization studies related to bridge scour.

Water and sewer infrastructure

- WASD will continue to implement the Inflow and Infiltration and Flow Reduction Programs, and other efficiency initiatives focused on the challenges presented by aging infrastructure.

- It is recommended that the County implement Code changes to require reduced inflow and infiltration from definicencies 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 seek to reduce future vulnerability under defined conditions. This includes elevating critical facility structures and including ring dikes and dewatering pump systems to protect against flooding.

- WASD will develop engineering design standards (i.e. pump station resilience design guidelines) including updating the design guide for wastewater treatment plants to include a decision matrix related to which facility hardening measures should be evaluated for implementation.

- 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 Water Utility Accelerator Programs
    - The Utility of the Future Today
    - 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 expansion 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 masterplan could reduce the cost of expanding and improving the infrastructure required for development.

Appendix 1: Previous studies

Many reports have identified specific areas in need of sea level rise and flood mitigation, with some projects identified in the reports currently underway. The following list of reports is not meant to be comprehensive; it serves to underscore the wealth of information available. Some reports address multiple issues, such as vulnerability assessments that combine analyses of stormwater and sewer infrastructure.

MIAMI-DADE GREEN TECHNOLOGY CORRIDOR WATER AND SEWER STUDY

This study, completed in April 2012, examined the water and sewer infrastructure needs of the commercial and industrial areas inside the "Miami-Dade Green Technology Corridor." The Corridor was established in March 2011 via the Board of County Commissioner's Resolution No. R-197-11 to help focus economic development and marketing efforts around companies and entrepreneurs that deal with renewable energy, energy efficiency, and other environmentally beneficial technologies. The Corridor is located in the unincorporated area bounded by Northwest 127th Street to the North, Northwest 27th Avenue to the East, Northwest 37th Avenue to the West, and the Miami River to the South. The report identified water and sewer infrastructure deficiencies in that area and recommended a phasing plan for capital improvements that will bring services to that zone. The evaluation indicated that improvements were required including extending gravity sewers and increasing the capacity of existing pump stations. New infrastructure was proposed for a significant portion of the area, currently without sewer services. The project cost for the sewer infrastructure to serve all commercial and industrial properties inside the Corridor was estimated to be $31 million. Several projects have transitioned to design and construction and all corridor projects are expected to be completed prior to 2022. These projects are funded by the Building Better Communities General Obligation Bond program, Project 17, established to fund sewer expansions for commercial properties in via Resolution No. R-537-14.

GENERAL OBLIGATION BOND COMMERCIAL CORRIDOR SEWER PROGRAM

Resolution No. R-537-14 approved the allocation of $126 million from the Building Better Communities General Obligation Bond Program Project No. 17 - "Countywide Water and Sewer System Enhancements" to fund extension of the sewer system to developed commercial and industrial corridors. The Research Section of RER Planning Division then developed a methodology to evaluate and rank the 29 projects proposed in the Sewer Service to Commercial Properties study developed pursuant to Resolution No. R-597-13. Each of these projects were ranked based on a variety of considerations including planning, environmental, special economic areas, land use, current business environment, and existing socio-economic conditions. Ten projects were identified for completion with the available funding.

VULNERABILITY OF SANITARY SEWERS AND STORMWATER INFRASTRCUTURE TO SEA LEVEL RISE

This report provides an overview of how sanitary sewer systems and stormwater systems may be impacted by current and future water levels. This report outlines how rising sea levels are already affecting these systems in certain areas and describes which areas will be impacted in the future. Finally, the report provides recommended steps to reduce these vulnerabilities. This report builds on several previous studies that have identified areas that are currently vulnerable to flooding and will increasingly be flood prone due to sea level rise if additional measures are not taken. The Miami-Dade Water and Sewer Department has conducted several studies to establish future conditions as part of planning and designing capital investment projects.

ASSESSMENT OF AVAILABLE TOOLS TO CREATE A MORE RESILIENT TRANSPORTATION SYSTEM

On March 8, 2016, the Board passed Resolution R-235-16, which directed the administration, "to analyze and implement under certain circumstances the methods and tools from the Federal Highway Administration and the Florida Department of Transportation that may be used to assess the vulnerability to sea level rise and extreme

weather for future County transportation projects as well as other possible applications." The final report describes how sea level rise has and could affect transportation. The second portion describes specific studies that have analyzed the transportation network's vulnerability to sea level rise and storm events. The report also reviews the existing tools from the federal and State governments that can help assess the vulnerability of the transportation system moving forward and discusses their potential utility for planning and other uses.

FEDERAL HIGHWAY ADMINISTRATION CLIMATE RESILIENCE PILOT PROJECT FOR SOUTHEAST FLORIDA

In 2013, the FHA launched a Climate Resilience Pilot Program, to assist state and local partners to improve the resilience of their transportation systems to extreme weather events and climate change. One of the 19 pilots projects was focused on Southeast Florida and included Palm Beach, Broward, Miami-Dade, and Monroe Counties.[28] The Miami-Dade Metropolitan Planning Organization (MPO – now the Transportaiton Planning Organization TPO), Broward MPO, Palm Beach MPO, and the Monroe County Planning and Environmental Resources Department worked together with the FHA to conduct a detailed vulnerability assessment of the region's transportation infrastructure. The study revealed that several road and rail segments within the County are currently vulnerable to flooding and will become more so as sea levels rise if no measures are taken. Causeways to the barrier islands such as Key Biscayne and Miami Beach were found to be highly exposed, in part due to their low elevations and also due to the long detour lengths that would result if a roadway was impacted. The study also found that regional roadways that pass through wetlands, such as Tamiami Trail and Card Sound Road, are also highly vulnerable. This is again due to their low elevation, high flood exposure, and the long detour lengths due to limited alternative routes.

STORM SURGE, SEA LEVEL RISE, AND TRANSPORTATION NETWORK DISRUPTION IMPACTS PROJECTS

This study, which was funded by the FDOT, attempted to quantify the general economic impacts of the resulting disruptions. In doing so, a potential expanded application of the recently-adopted regional travel demand model was tested in order to help understand the impact on potential emergency responses. Results from this regional study show the potential impacts of storm surge amplified by sea level rise during three different historical storm events including a storm like Hurricane Andrew (striking Miami-Dade County), Hurricane George (striking Broward County), and a hurricane hitting Palm Beach County. While the disruption to Miami-Dade County's transportation network is most extensive during a simulated Hurricane Andrew, there are still impacts from storms hitting farther north in Broward County and Palm Beach County. As with the previous study, these results indicate that causeways to the barrier islands are particularly vulnerable. It is also important to note that while Hurricane Andrew was a Category 5 storm it was not the worst case scenario in terms of storm surge for the County. If Miami-Dade were to be hit by a larger or slower-moving storm in the future, the flooding impacts from storm surge could be much more severe.

RAPID ACTION PLAN: VULNERABILITY OF COUNTY ASSETS TO SEA LEVEL RISE AND FUTURE STORM SURGE

The Rapid Action Plan is part one of a two-phase project to identify County assets and capital improvement projects vulnerable to sea level rise and future storm surge, including assets within the Department of Transportation and Public Works. Results from this phase show that roughly 46% of County-owned properties, or 590 of the 1,090 that were assessed, are vulnerable to some degree of sea level rise and storm surge inundation impacts. Additionally, this study evaluated 28 priority capital improvement projects and found that an additional up-front investment of resiliency measures of approximately $6.3 million could avoid estimated losses of $24 million. Based on these preliminary cost estimates, it is estimated that potential damages to capital projects could be mitigated with a 4% increase to project budgets. This is an aggregate estimate and some projects will be more (or less) cost effective to protect.

[28] For information on the other pilot projects see http://www.fhwa.dot.gov/environment/climate_change/adaptation/.

Appendix 2: Relevant Comprehensive Development Master Plan Policies

There are many Comprehensive Development Master Plan (CDMP) policies that are supportive of proactively addressing the challenges sea level rise poses to the County's infrastructure. Below is a list of some of the most relevant policies from the current CDMP.

LU-3G. Miami-Dade County shall, by 2017, analyze and identify public infrastructure vulnerable to sea level rise and other climate change-related impacts. This analysis shall include public buildings, water and waste water treatment plants, transmission lines and pump stations, stormwater systems, roads, rail, bridges, transit facilities and infrastructure, airport and seaport infrastructure, libraries, fire and police stations and facilities.

LU-3I. Miami-Dade County shall make the practice of adapting the built environment to the impacts of climate change an integral component of all planning processes, including but not limited to comprehensive planning, infrastructure planning, building and life safety codes, emergency management and development regulations, stormwater management, and water resources management.

Objective TE-1. Miami-Dade County will provide an integrated multimodal transportation system for the circulation of motorized and non-motorized traffic by enhancing the Comprehensive Development Master Plan and its transportation plans and implementing programs to provide competitive surface transportation mode choice, local surface mode connections at strategic locations, and modal linkages between the airport, seaport, rail and other inter-city and local and intrastate transportation facilities. These plans and programs shall seek to ensure that, among other objectives, all transportation agencies shall consider climate change adaptation into their public investment processes and decisions.

TE-1G. Miami-Dade County shall develop and adopt climate change adaptation and mitigation strategies for incorporation into all public investment processes and decisions, including those concerning transportation improvements.

TE-1H. Transportation agencies developing their transportation plans for Miami-Dade County shall take into consideration climate change adaptation and mitigation strategies through project review, design, and funding for all transportation projects. Transportation agencies should consider extending their planning horizons appropriately to address climate change impacts.

Objective TC-6. Plan and develop a transportation system that preserves environmentally sensitive areas, conserves energy and natural resources, addresses climate change impacts, and promotes community aesthetic values.

TC-6D. New roadways shall be designed to prevent and control soil erosion, minimize clearing and grubbing operations, minimize storm runoff, minimize exposure and risk of climate change impacts such as increased flood conditions, and avoid unnecessary changes in drainage patterns.

WS-3F. The Miami-Dade County Water, Wastewater, and Reuse Integrated Master Facilities Plan, the primary vehicle for planning for water, sewer, and reuse facilities, shall continue to be updated on a regular basis. The integrated Master Plan shall include initiatives to address climate change and sea level rise that would impact the water and sewer infrastructure and drinking water supplies.

CM-9H. Rise in sea level projected by the federal government, and refined by the Southeast Florida Regional Climate Change Compact, shall be taken into consideration in all future decisions regarding the design, location, and development of infrastructure and public facilities in the County.

CON-5A. The Stormwater Management (Drainage) Level of Service (LOS) Standards for Miami-Dade County contain both a Flood Protection (FPLOS) and Water Quality (WQLOS) component. The minimum acceptable Flood Protection Level of Service (FPLOS) standards for Miami-Dade County shall be protection from the degree of flooding that would result for a duration of one day from a ten-year storm, with exceptions in previously developed canal basins as provided below, where additional development to this base standard would pose a risk to existing development. All structures shall be constructed at, or above, the minimum floor elevation specified in the federal Flood Insurance Rate Maps for Miami-Dade County, or as specified in Chapter 11-C of the Miami-Dade County Code, whichever is higher.

- Basin-specific FPLOS standards shall be established through the adoption of a Stormwater Master Plan to be approved by the Miami-Dade Board of County Commissioners and the South Florida Water Management District. Until the approval of basin-specific FPLOS standards through this coordinated process, the following additional exceptions shall apply:
  a) Wherever Miami-Dade County has adopted cut and fill criteria pursuant to Chapter 24-48.3(6) of the County Code (November 30, 2004) including fill encroachment limitations necessary to prevent unsafe flood stages in special drainage basins, the minimum applicable FPLOS standard shall be the degree of protection provided by the applicable cut and fill criteria;

  b) Where cut and fill criteria have not been established north of S.W. 152 Street inside the Urban Development Boundary (UDB), the minimum acceptable FPLOS standard shall be protection from the degree of flooding that would result for a duration of one day from a ten-year storm;

  c) West of Levee-31 N, there shall be no off-site drainage, all septic tank drainfields shall be elevated above the hundred-year flood elevation, and the extent of land filling shall be minimized as provided in applicable provisions of the Miami-Dade County East Everglades Zoning Overlay Ordinance. The County shall review these criteria when the water management facilities programmed in the N.E. Shark River Slough General Design Memorandum and the C-111 General Reconnaissance Review are fully operational.

CON-5E. Miami-Dade County shall establish a priority listing of stormwater drainage and aquifer recharge improvements needed to correct existing system deficiencies and problems, and to provide for future drinking water needs. This shall include:

- Drainage/stormwater sewer system improvements in developed urban areas with persistent drainage problems;
- Canal and/or stormwater drainage improvements in developed urban areas that have less than one in ten year storm protection and where no roadway drainage improvements are planned or proposed, which would remedy the problems;
- Hydrologic modifications that are needed to deliver water to public waterwells or to protect those waterwells from prospective contamination.

This shall be based on such factors as:

- Miles of canals with out-of-bank flow;
- Miles of collector and local streets impassable during a 5 year storm;
- Miles of minor arterial streets impassable during a 10 year storm;

- Miles of principal arterials, including major evacuation routes, that are impassable during a 100 year storm; and
- Number or structures flooded by a 100-year storm.

ICE-5G. All County departmental master plans and strategic business plans shall include and prioritize climate change mitigation and adaptation strategies. Climate change related amendments shall be recommended through the next feasible, regularly scheduled amendment process or departmental master plan update for each respective planning document.

a) Each County department shall consider extending planning horizons (i.e. 30, 50, 75-year plans) as appropriate to adequately address the projected long-term climate change impacts into resource allocation recommendations.
b) All new departmental climate change policies and programs shall be monitored for effectiveness.