Memorandum

MIAMI-DADE COUNTY

Date: March 21, 2023

To: Honorable Chairman Oliver G. Gilbert, III
and Members, Board of County Commissioners

Agenda Item No. 2(B)(5)
April 4, 2023

From: Daniella Levine Cava
Mayor

Subject: Evaluation of Potential Impacts of Sea Level Rise on Existing Underground and Lower-Level Garages – Directive No. 212094

On October 5, 2021, the Board of County Commissioners (Board) passed Resolution No. R-960-21 directing the County Mayor or Mayor's designee to accomplish the following: (1) study potential sea level rise impacts, such as increases in flooding, with respect to existing underground or lower-level garages, (2) make recommendations as to measures and practices that may mitigate flooding occurrences in such existing garages, and (3) urge municipalities within Miami-Dade County to take action to address and minimize potential impacts of sea level rise, such as increases in flooding, with respect to such parking garages within their jurisdictions.

This report addresses the directive by studying current and historic underground garage permitting and construction standards within Miami-Dade County and the various challenges presented by underground garages as they relate to flooding, such as water intrusion, corrosion, maintenance, and other variables, as well as potential impacts of sea level rise. The report also presents recommendations as to how the identified issues might be mitigated.

In summary, the report provides information on the many parameters that could affect underground and lower-level garages while addressing the resolution's three points. The recommendations herein include an analysis and checklist that can be standardized through the building recertification program which covers the unincorporated municipal service area (UMSA) and all municipalities. Revisions to the recertification process to effectuate these recommendations for next year's cycle will be presented to the Board of Rules and Appeals (BORA), which has authority to formulate recertification procedures under Chapter 8-11(f) of the Miami-Dade County Code. Recommendations for new construction include establishing a local technical amendment to the Florida Building Code which would create resiliency by requiring new underground garages to be designed to withstand the effects of sea level rise. This amendment will be proffered to the Board in the form of an ordinance, which will require sponsorship by a Board member to then be heard for first reading. If such an amendment were adopted, it would be in effect throughout UMSA and all municipalities within the county. Staff will be sharing these recommendations with BORA, the building industry and municipal building officials to seek their comments as we prepare the code changes and technical amendments for adoption.

Please contact Lourdes M. Gomez, Director, Department of Regulatory and Economic Resources, at (305) 375-2886.

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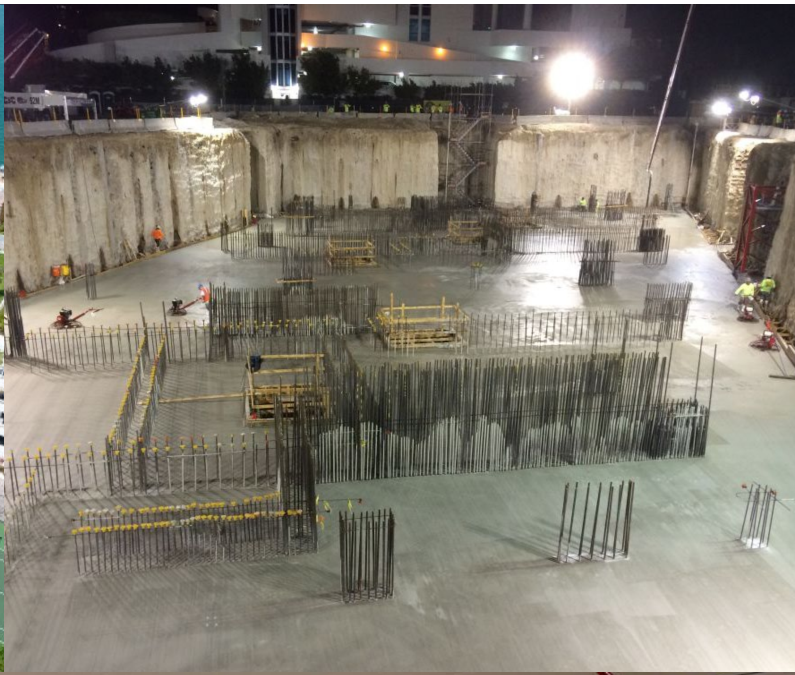
Evaluation of Potential Impacts of Sea Level Rise on Existing Underground and Lower-Level Garages

Prepared by

Department of Regulatory and Economic Resources

Resolution 960-21



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MIAMI-DADE COUNTY
REGULATORY AND ECONOMIC RESOURCES

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1.0 Introduction

The Miami-Dade Board of County Commissioners (BCC) on October 5, 2021, passed resolution R-960-21directing the Mayor or Mayor's designee to (1) study potential sea level rise impacts, such as increases in flooding, with respect to existing underground or lower-level garages, (2) make recommendations as to measures and practices that may mitigate flooding occurrences in such existing garages and (3) urge municipalities within Miami-Dade county to take action to address and minimize potential impacts of sea level rise, such as increases in flooding, with respect to such parking garages within their jurisdictions.

This report addresses this directive by studying current and historic underground garage permitting and construction standards within Miami-Dade County, the various challenges presented by underground garages as they relate to flooding, such as water intrusion, corrosion, maintenance, and other dynamics, as well as potential anticipated impacts of on-going sea level rise. The document also presents recommendations as to how the issues identified can possibly be mitigated.

In order to comprehensively study underground and lower-level parking garages, the context and various drivers for the creation of such structures should be understood. The history of parking garages is linked to the need for parking associated with development. Parking garages have been in existence in the United States for over 100 years and were a result of the automobile boom of the early 1900's. The earliest known parking garage in the United States was built in 1918 for the Hotel La Salle at 215 West Washington Street in the West Loop area of downtown Chicago, Illinois. As the number of vehicles has grown, the need for easy and accessible parking has increased, particularly in dense urban areas. The parking garage, of which the underground and lower-level parking garages are a subset, became a solution for addressing parking demands within the smallest amount of land footprint possible.

In Miami-Dade and other municipal jurisdictions, zoning regulations establish minimum parking requirements and limit the maximum height of structures within various areas. Additionally, land use polices are in place that incentivize infill development within high density areas to yield the highest return on infrastructure investments (transit, roads, utilities, etc.) as well as protect valuable environmental resources.

As demand and the value of land have increased in Miami-Dade County, meeting parking requirements for medium to high density development utilizing surface level parking has become highly impractical and economically challenging. For this reason, the number of parking garages have increased significantly in recent years.

With relation to underground garages specifically, these have been developed since the 1960's across the country. At the time, they were thought to be highly innovative saving space in highly constricted areas and providing other co-benefits. The Millenium Garages in Chicago, constructed approximately 20 years ago, is the largest system of underground garages in the country with 9,176 stalls and 3.8 million square feet of space. In Miami-Dade County underground garages are less common due to our local geology and flood risks; however, there are many examples across the county. One of the earliest examples is the David William Hotel in 1965. The largest and deepest garage in Miami-Dade County is that of the Jade Signature Condominium building in Sunny Isles Beach at over 50 feet deep and containing over 425 spaces.

Locally, building and maintaining an underground garage is typically more expensive than an above ground parking garage. In most places, the primary drivers for underground garages include physical constraints, land value, and height limitations. In high density parcels that are limited in size, especially those of significant value (waterfront, luxury, etc.), the incorporation of an underground garage allows the developer not to forgo several floors of livable space for parking. Therefore, in these instances, there is a cost to benefit analysis performed which may suggest that an underground parking garage is worthwhile from an economic perspective, despite the additional up-front and maintenance costs.

In South Florida, there are several unique challenges that impact the viability of underground parking structures. These include low ground elevation, short distance from ground surface to the groundwater table, a highly porous substrate, and a corrosive environment (particularly along the coast), among others. Additionally, due to the area's vulnerability to rainfall events and tidal fluctuations (coastal parcels), storms, and hurricanes, there is a greater risk for flooding of underground and lower-level garages. In particular, some underground garages may be located in areas where they are below the groundwater table or in locations where the groundwater fluctuates with the tides. With rising sea levels groundwater levels are also increasing in coastal areas. Therefore, groundwater levels in tidally influenced areas are expected to continue rising over the coming decades. Tidal flooding will also become increasingly frequent.

These factors increase the complexity associated with the design and construction of these structures, as well as long-term maintenance. Additionally, localized unique characteristics may increase the cost of underground garages. The cost of underground and low-level parking structures in Miami-Dade range between $25,000 to $50,000+ per parking space based on discussions with industry representatives. As a result, underground structures are one of the least commonly employed methods for the provision of parking in Miami-Dade County, however they are still being developed and related risks should be mitigated for the future.

Additionally, there are many existing garages which were built under previous building codes, requirements, and assumed water levels. As sea levels continue to rise these garages may need to be retrofitted. In some cases, rising water levels may only impact the usability of the spaces. In other instances, the increased frequency and duration of flooding may impact the structure itself and these are the cases that are the primary concern from a monitoring and inspection standpoint.

In the following sections of this report, information pertaining to building standards and considerations unique to underground and lower-level parking are presented in further detail along with discussions regarding impacts of historic and future sea level rise and related environmental conditions on these structures and associated policy determinations that could be helpful in mitigating risks and challenges.

2.0 Building Standards for Underground and Lower-Level Garages

Below is a summary of applicable Federal, State and local regulatory requirements that apply to the design and construction of underground and lower-level garages. The regulations below are all applicable to unincorporated Miami-Dade County. For each of the regulations below, there is an indication of applicability within municipal boundaries. It is important to note that the existing code requirements generally account for sea level rise through the application of freeboard, which is a factor of safety above the minimum required base flood elevation.

United States Department of Homeland Security - Federal Emergency Management Agency (FEMA)

The Department of Homeland Security's Federal Emergency Management Agency (FEMA) is responsible for all updates to the Flood Insurance Rate Maps (FIRM), the updates to the Flood Insurance Study (FIS), and for the administration of the National Flood Insurance Program (NFIP). The FEMA FIRMs and the FIS delineate the Special Flood Hazard Areas (SFHAs), the Base Flood Elevations (BFEs), flood zone designations, and regulatory floodways. Unincorporated Miami-Dade County and municipalities must each adopt the FEMA FIRMs and the FIS when updates become effective to continue participation in the National Flood Insurance Program (NFIP) and for their residents to be able to purchase flood insurance at discounted premiums. The FEMA FIRMs and FIS work with the Florida Building Code to establish minimum building construction requirements to mitigate flood risks and damage countywide. These requirements impact underground and lower-level garages by establishing the bottom of the lowest horizontal structural member of the lowest floor must be above base flood elevation, generally prohibiting underground garages within the FEMA "V" Zones (Coastal High Hazard Areas). FEMA V Zones are located along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves (storm surge). Outside of V zones, all below-grade non-residential parking garages must be dry-floodproofed; therefore, hydrostatic and hydrodynamic forces must be considered in the design. There are various best practices that can be employed to protect a below-grade garage from floodwaters including designing the garage entry to be above base flood elevation or making the garage entrance transition upwards via a ramp which terminates above the BFE plus any applicable freeboard. There are fewer options available to retrofit an existing structure where the waterproofing has begun to fail. In some areas it may also be more challenging and expensive to retrofit existing underground garages where there are physical constraints that limit the ability to raise the entrance ramps.

Furthermore, FEMA Technical Bulletin 6-93 titled Below-Grade Parking Requirements for Buildings Located in Special Flood Hazard Areas published in accordance with the National Flood Insurance Program (NFIP) should be followed. The purpose of the bulletin is to provide technical guidance for below grade parking garages for non-residential and mixed-use buildings in Special Flood Hazard Areas (SFHAs) shown on the Flood Insurance Rate Maps (FIRMS).

Florida Department of Environmental Protection (FDEP)

The Florida Department of Environmental Protection (FDEP) instituted the Florida Coastal Construction Control Line (CCCL) to define portions of beaches and dune systems subject to severe water level fluctuations based on a 100-year storm event. The CCCL is not a seaward limit for construction of upland structures (as in a setback line), rather delineates the inland limit of areas where special siting and design considerations are necessary to protect the beach-dune system and to protect proposed and existing structures, adjacent properties, and achieve the preservation of public beach access. The CCCL program regulates structures and activities which can cause beach erosion, destabilize dunes, damage upland properties, or interfere with public access.

FDEP has jurisdiction over structures seaward of the CCCL, which was created in Miami-Dade County in 1982 and runs south from the Broward County line on the barrier islands, east of Collins Avenue (through existing structures) along Fisher Island, and then to Virginia Key and Key Biscayne. The Florida Building Code includes the CCCL requirements within its Chapter 31 - Special Construction. The Florida Building Code is automatically effective for both unincorporated and municipal areas upon adoption by the State. Various provisions within FAC 62B-33 – Rules and Procedures for Coastal Construction and Excavation, would prevent the development of underground or at-grade garages. Limitations in the law such as 62B-33.005(4)(d) "construction will not result in the net excavation of the in situ sandy soils seaward of the control line or 50-foot setback", together with FEMA limitations in Coastal V Zones make underground parking garages infeasible.

Below is an illustration of the CCCL Map showing Fisher Island. Note that there are many structures seaward of the CCCL.

Figure 1 – Illustration of Coastal Construction Control Line in Fisher Island, FL

<u>The Florida Building Commission</u>

The South Florida Building Code (in effect from 1956 through March 2002), and the Florida Building Code which has been in effect ever since, establish the minimum standards for design and construction of structures within Miami-Dade County. The Florida Building Code becomes effective automatically for both unincorporated and municipal areas upon adoption by the State.

The code addresses requirements for any underground structures (which includes underground parking facilities), such as resistance to uplift and lateral forces on floors and walls, groundwater control, waterproofing, and concrete quality (by reference). The current code includes by reference the American Society of Civil Engineers Standard 24, Flood Resistant Design and Construction.

Florida Building Code (FBC) Chapter 19 covers the design of concrete which references the American Institute of Concrete (ACI) 318-14 standard, with the exceptions noted in Section 1905. FBC Chapter 35 lists all references to standards used in the application of the building code. Although not listed, the reference standard ACI-362.1-12 "Guide for the Design and Construction of Durable Concrete Parking Structures may serve the design professional as guidance in the design of underground parking structures.

While the National Electric Code (NEC) does not have a section specific to underground parking garages, its general requirements for circuits and their location apply in garages. Branch lines are permitted below base flood by FEMA's National Flood Insurance Program regulations. Receptacles and lighting circuits located below base flood must be on a Ground Fault Circuit Interrupter (GFCI) breaker. GFCI's are fast-acting circuit breakers designed to shut off electric power in the event of a ground-fault within as little as 1/40 of a second. The GFCI is rated to trip quickly enough to prevent an electrical incident. Electrical panels must be located above the base flood elevation. Sump pumps must be classified as the submersible type. Mechanical ventilation equipment located below base flood must also be on a GFCI circuit.

The Florida Fire Prevention Code (FFPC), the Florida version of the National Fire Protection Association (NFPA), together with the Florida Building Code include requirements for egressing and fire protection of underground parking garages. Chapters 9 and 10 of the FBC have provisions for fire protection in the form of fire sprinklers and maximum travels distances to the means of egress, primarily exit stair towers. Underground parking garages are considered enclosed for the purposes of complying with fire protection and mechanical ventilation requirements. Section 404.6 of the FBC outlines the requirement of an enclosed parking garage with references to Section 404 of the Florida Mechanical Code for required mechanical ventilation.

<u>Miami-Dade County Code</u>

Chapter 11C of the Miami-Dade Municipal Code addresses the requirements of development within flood hazard districts. The Chapter was established by ordinance in 1987 and is regulated by Miami-Dade County Department of Environmental Resources Management (DERM). Chapter 11C of the Code of Miami-Dade County is applicable within unincorporated Miami-Dade County and municipal codes may incorporate Chapter 11C by reference. There are several requirements of Chapter 11C that apply to underground and lower-level garages. The sections most relevant to these facilities are highlighted below:

- 11-C-3: Development in either Special Flood Hazard (SFH) Areas, Coastal High Hazard (CHH) Areas, or Outside Special Flood Hazard Areas.

  "(m) Review proposed development to assure that no use shall be made for other than crop, grove, nursery and grazing purposes, or similar uses, and no building of any type shall be constructed, erected upon or moved to any land below the elevation established by the County Flood Criteria Map as adopted by the Board of County Commissioners, or the back of sidewalk elevation of the road fronting the property, or if there is no sidewalk, the

elevation of the crown of road or street abutting such building site, whichever is higher…… The provisions of this subsection shall not apply to off-street parking facilities constructed underground and other similar types of below grade areas within a building which are not lowest floor and contain neither electrical nor mechanical equipment. <u>All such facilities constructed below grade shall be designed and constructed and contain essential equipment, if necessary, to prevent infiltration and accumulation of water or to provide for immediate and continuous elimination of water. A Florida registered engineer or architect shall submit data and a floodproofing certificate to assure that the design complies with all guidelines of Section 11C-5(b)</u>."

- 11-C-5: Development within Special Flood Hazard Areas

  "(a) *No new construction or substantial improvement of any residential structure or manufactured home shall be permitted in SFH Areas, and no building permit referred to in Section 11C-3 of this chapter shall be issued therefor, unless said new construction or substantial improvement has the lowest floor (including basement) elevated to or above the level of the regulatory flood (100-year flood). Electrical main panels servicing the building and other attendant utilities are prohibited below the base flood elevation.*

  (b) No new construction or substantial improvement of any nonresidential structure shall be permitted in SFH Areas, and no building permit referred to in Section 11C-3 of this chapter shall be issued therefor, unless said new construction or substantial improvement has the lowest floor (including basement) elevated to or above the level of the regulatory flood (one-hundred-year flood), or if the lowest permitted floor level of such nonresidential structure (including basement) is below the regulatory flood level then such nonresidential structure together with attendant utility and sanitary facilities shall be floodproofed up to one (1) foot above the level of the regulatory flood; provided that the lowest floor level of such nonresidential structure (including basement) shall be not more than ten (10) feet below the regulatory flood level."

In summary the codes currently ensure that underground parking shall be designed and constructed, as needed, to resist infiltration and accumulation of water and/or to provide for immediate and continuous elimination of water, meeting all applicable code requirements.

Residential construction, such as multi-family condominium and apartment buildings, does not allow for underground parking. Non-residential construction, such as retail and mixed-use buildings, must have lowest floor (including basement) flood-proofed to one foot above regulatory flood elevation.

3.0 Considerations Unique to Underground Garages

There are a number of technical considerations applicable to the design of underground and lower-level parking garages. Sea level rise is exacerbating flooding risks and there are some measures that may help mitigate those risks. These can be categorized into broad groupings as follows:

General Design Parameters:

Underground garages must contain waterproofing to protect the structure along exterior walls as per the building code. This is achieved via coating and/or water stops in the concrete structure. Additionally, electrical branch circuits below base flood elevation which power devices such as receptables, lighting, and ventilation equipment must be on a Ground Fault Circuit Interrupter breaker to prevent energizing flood waters.

Egress and fire protection become an integral part of the design for underground parking garages due to the nature of the confined space. During the design phase, the design professional must analyze the space to make sure sufficient egressing capabilities are installed within the appropriate travel distances. The Florida Fire Prevention Code together with the Florida Building Code Chapter 10 on means of egress provide the parameters that must be met. Furthermore, fire suppression systems are utilized to provide sufficient protection and time for occupants of an underground garage to reach an exit. Given the nature of fuel filled vehicles within an underground parking garage, smoke sensors and fire sprinklers must be installed in accordance with the Florida Building Code Chapter 9.

The Florida Building Code Section 406.6 requires the installation of mechanical ventilation within underground parking garages in compliance with Section 404 of the Florida Mechanical Code. Ventilation equipment may be installed remotely via ductwork above base flood to avoid damage due to flood waters. With relation to flood mitigation, sump pumps must be installed to remove flood waters from each parking level. Discharge becomes an issue when the ground area is inundated from rising water and therefore the disposal location needs to be considered for the sump pumps. Catch basins, retention areas, or discharge wells must be considered carefully, especially when ground saturation is expected. As noted in the electrical code, sump pump must be the submersible type to prevent damaging the pump. Additionally, consideration should be given to connecting sump pumps to a power backup system such as a generator.

Lastly, elevators are necessary in providing accessibility to the different levels of parking, much like an above grade parking structure. While the elevator cab is allowed to reach the lower levels below base flood, the elevator cabs must be programmed to return to a level at or above base flood by default if not equipped with sensors capable of detecting water within the hoistway. This will help prevent damage to the elevator cab in flooding conditions. Existing buildings, especially those commercial buildings built prior to local ordinance or building code that adopted a freeboard requirement, would have been built relative to the base flood elevation at the time of the building's design and may not have incorporated a freeboard.

<u>Flood Management</u>

National Flood Insurance Program requirements impact the design of underground parking garages located within Special Flood Hazard Areas. FEMA published Technical Bulletin #6 containing technical guidance for below grade parking garages for non-residential and mixed-use buildings. TB #6 must be used in conjunction with Technical Bulletin #3, "Non-Residential Floodproofing – Requirements for Certification." An underground parking garage is considered equivalent to a basement, having all sides below grade. Below grade parking is allowed exclusively under non-residential and mixed-use buildings in A, AE, and AH flood zones. An underground parking garage is not allowed in V-Zones (Coastal High Hazard Areas). Some of the flood management requirements specific to underground garages include:

- All below-grade parking garages must be dry-floodproofed; therefore, hydrostatic and hydrodynamic forces must be considered in the structural design. These forces are calculated during design and are based on best available information and practices at the time. FEMA's Technical Bulletin 3, "Non-Residential Floodproofing – Requirements and Certification," must be consulted for necessary guidance on floodproofing designs for below grade parking garages.

- A critical element in any floodproofing design for a below-grade parking garage is the point where the garage entrance ramp meets the street grade. The best method of protecting a dry-floodproofed garage from floodwaters is to design the garage entry to be above BFE plus any applicable freeboard.

- A warning and evacuation plan must be developed and tested so that it can be readily implemented when a flood threatens. Such a plan is necessary for all below-grade garages.

- The building's walls must be "substantially impermeable to the passage of water." FEMA has adopted the U.S. Army Corps of Engineers (USACE) definition of substantially impermeable from the USACE publication "Flood Proofing Regulations." This document states that a substantially impermeable wall "shall not permit the accumulation of more than 4 inches of water depth during a 24-hour period if there were no devices provided for its removal. However, sump pumps shall be required to control this seepage."

- The building's utilities and sanitary facilities, including heating, air conditioning, electrical, water supply, and sanitary sewage services, must be located above the BFE plus any applicable freeboard, completely enclosed within the building's watertight walls, or made watertight and capable of resisting damage during flood conditions.

- All of the building's structural components must be capable of resisting specific flood-related forces. These are the forces that would be exerted upon the building as a result of floodwaters reaching the BFE plus any applicable freeboard (at a minimum) or floodproofing design level, and include the following:

    a. Hydrostatic Flood Force—This is the force that water at rest exerts on any submerged object. For a floodproofed building design, the calculations of hydrostatic flood forces must include saturated soil pressure on any portion of the building that is below grade.

    b. Buoyancy-This is the vertical force associated with the building's tendency to float when inundated or surrounded by floodwaters.

c. Hydrodynamic Force—This is the force exerted on vertical surfaces exposed to moving floodwaters. The determination of hydrodynamic force is based on the expected velocity of the floodwaters with depths to the floodproofing design level (BFE plus any applicable freeboard or higher).

d. Debris Impact Force—This is the force associated with flood-borne debris striking the side of a building. This force presents the greatest unknown to the designer, but a value must be estimated to develop an effective floodproofing design.

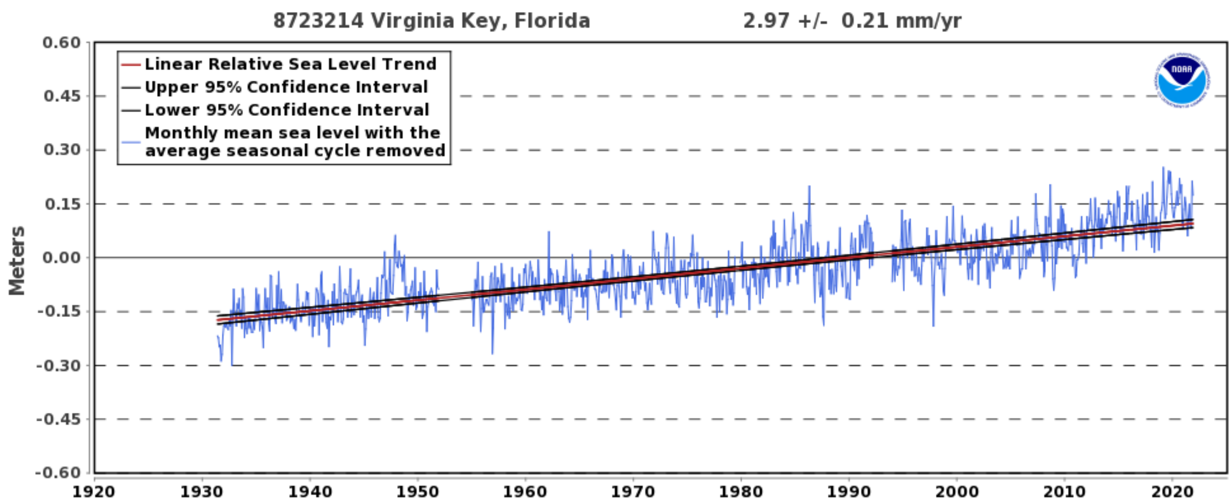
4.0 Potential Impacts of Sea Level Rise (SLR)

Sea level rise in Miami-Dade County

We have long records of changing water levels from the network of tide gauges along our coast that have been measuring the tides, in some locations, for more than a century in some cases. Additionally, the trend of global sea level rise has been confirmed by a suite of increasingly sophisticated instruments, deployed across the oceans, on polar ice and in orbit measuring water levels from space.[1] Local measurements of changing water levels including changes measured at the Virginia Key tide gauge (Figure 2) and the Key West and Vaca Key tide gauges (Figure 3) show increasing sea levels. In Miami, the tide gauge records begin in the early 1930s. Since that time sea levels have increased about 10 inches (Figure 2). The Key West tide gauge, shows a similar trend with an increase of 9.5 inches since records began in 1913 (Figure 3).

[1] NASA "Understanding Sea Level" <https://sealevel.nasa.gov/understanding-sea-level/overview>

Figure 2: Changes in Sea Level Measured at Tide Gauges in Miami



More recently sea levels have increased at a faster pace[2]. Since 1994, measurements at the tide gauge on Virginia Key have recorded an increase of more than four inches in average sea levels (Figure 2). Since 2000 sea levels have risen 3.9 inches at the Key West tide gauge (Figure 4).[3]

The U.S. Army Corps of Engineers (USACE) has published a tool that allows users to compare the measured changes in water levels to the USACE sea level change projections. Figure 3 shows how the average water levels (mean sea level) have changed over time at the Vaca Key and Key West tide gauges. The five-year average is shown as the light blue line and the longer (smoother) 19-year average water level is shown as the thick navy-blue line. Both averages at both tide gauges are tracking closer to the USACE's high sea level rise curve (shown as the red line). While it is important to continue monitoring changes, it is clear that changing sea levels and related flood risks need to be integrated into the designs of buildings and other critical infrastructure.

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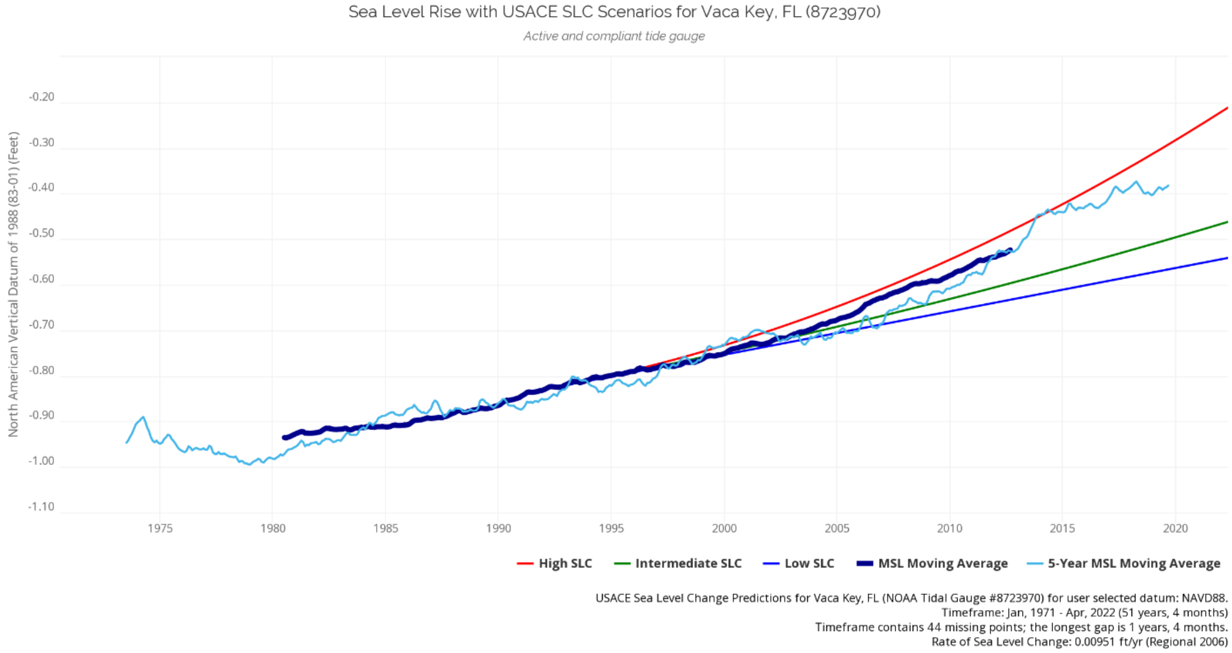
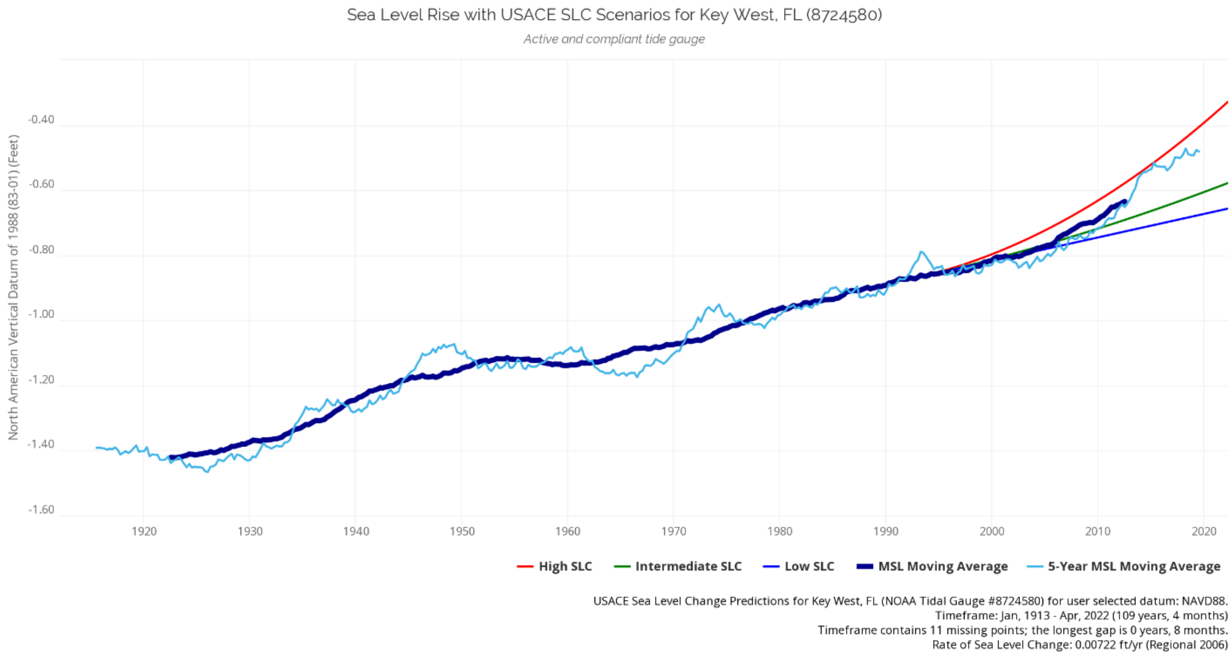
[2] Intergovernmental Panel On Climate Change, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–35. https://doi.org/10.1017/9781009157964.001 pg. 10: "Global mean sea level (GMSL) is rising, with acceleration in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets (*very high confidence*), as well as continued glacier mass loss and ocean thermal expansion."; "Global and European Sea Level Rise" European Environment Agency <https://www.eea.europa.eu/ims/global-and-european-sea-level-rise>; Sweet, W.V., B.D. Hamlington, R.E. Kopp, et al. 2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf

[3] Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group (Compact). February 2020. A document prepared for the Southeast Florida Regional Climate Change Compact Climate Leadership Committee. p.5

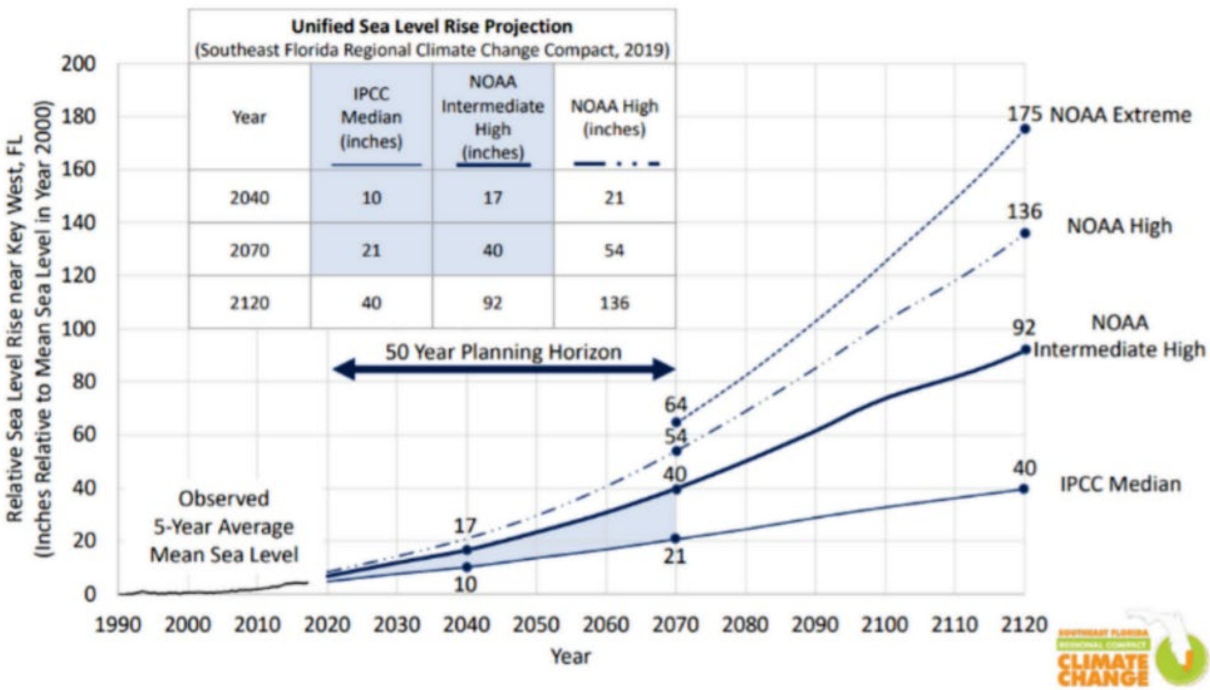
Figure 3: Measured Sea Levels at Vaca Key and Key West Tide Gauges compared to the US Army Corps of Engineers' SLR Projections





While local water levels fluctuate daily, yearly, and over the course of decades, it is important to note that the rise in average sea levels that has occurred so far will not recede over the next several decades. All formal projections for sea levels put forward by NOAA, NASA, the IPCC and others project a continue increase in average see levels in southeast Florida through the end of this century. To plan for future sea level changes Miami-Dade County stakeholders rely upon the Unified Sea Level Rise Projection for Southeast Florida developed by the South Florida Regional Climate Change Compact (Figure 4). The projection was updated in 2019 by a panel of scientists to reflect the best available data. This projection, based on 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.

Figure 4: Unified Sea Level Rise Projection for Southeast Florida



How Sea Level Rise is Affecting Groundwater Levels

In South Florida, groundwater levels are linked to ocean levels and therefore are altered by rising sea levels in tidally influenced areas (along the coast). Groundwater levels change seasonally and are at their highest at the end of the wet season (typically 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") 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. For areas east of the District's water control structures the groundwater levels are impacted by the tides. For areas immediately on the coast the height of the tide and the groundwater are very similar.

As tides rise, the groundwater in certain areas will increase. Inland areas may see more subtle changes because the tidal influence is lessened as you move inland and the District's water management system may be able to maintain groundwater levels to some extent through the management of the primary canal conveyance system. However, the regional system may not be able to provide the same level of flood protection under future scenarios without substantial investments in capital improvements. The four graphics in Figures 5 and 6 show a highly simplified illustration of the process of groundwater rise. Figure 5 shows a highly simplified illustration of average conditions. The groundwater is lower in the dry season when there is a deeper layer of unsaturated ground. In the wet season this unsaturated zone is reduced. Figures 6 shows how groundwater conditions are expected to change in tidally influenced coastal areas under future conditions. In these coastal areas average groundwater levels will be permanently higher when sea levels are permanently higher. In areas where the groundwater level is close to the surface it may affect existing below ground infrastructure unless that infrastructure was designed to account for future groundwater rise or was designed to be sited in saturated soils.

Figure 5: Average Ground Water Levels (Current Conditions) in Dry & Wet Season

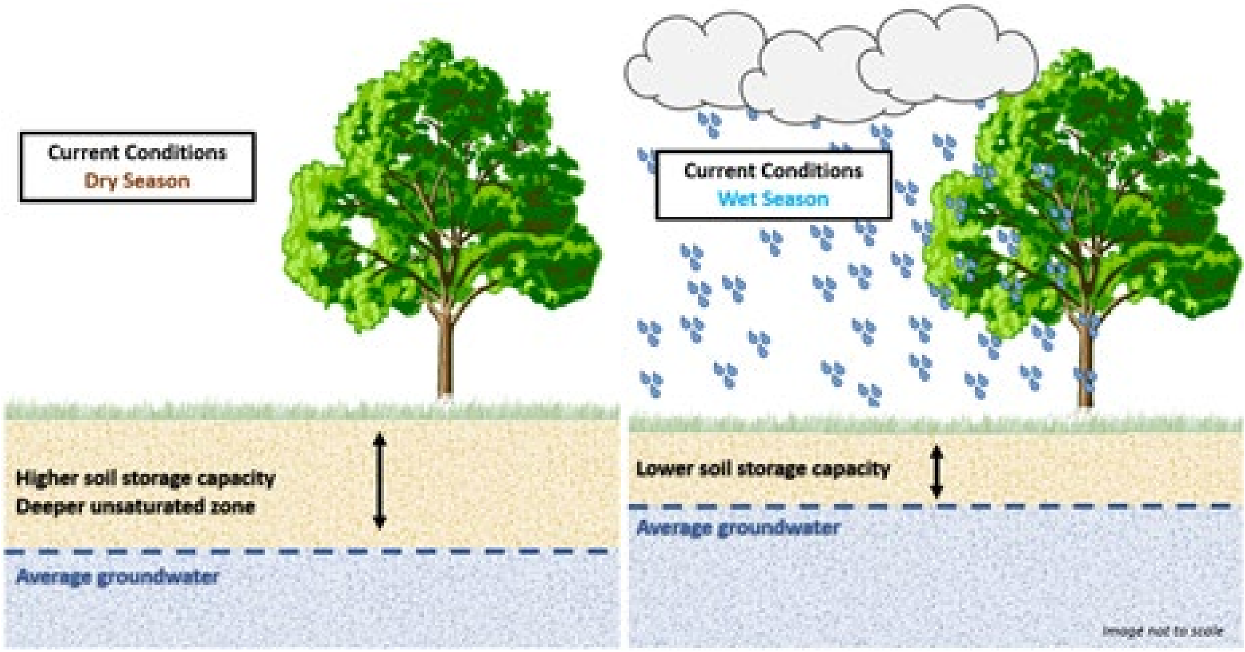
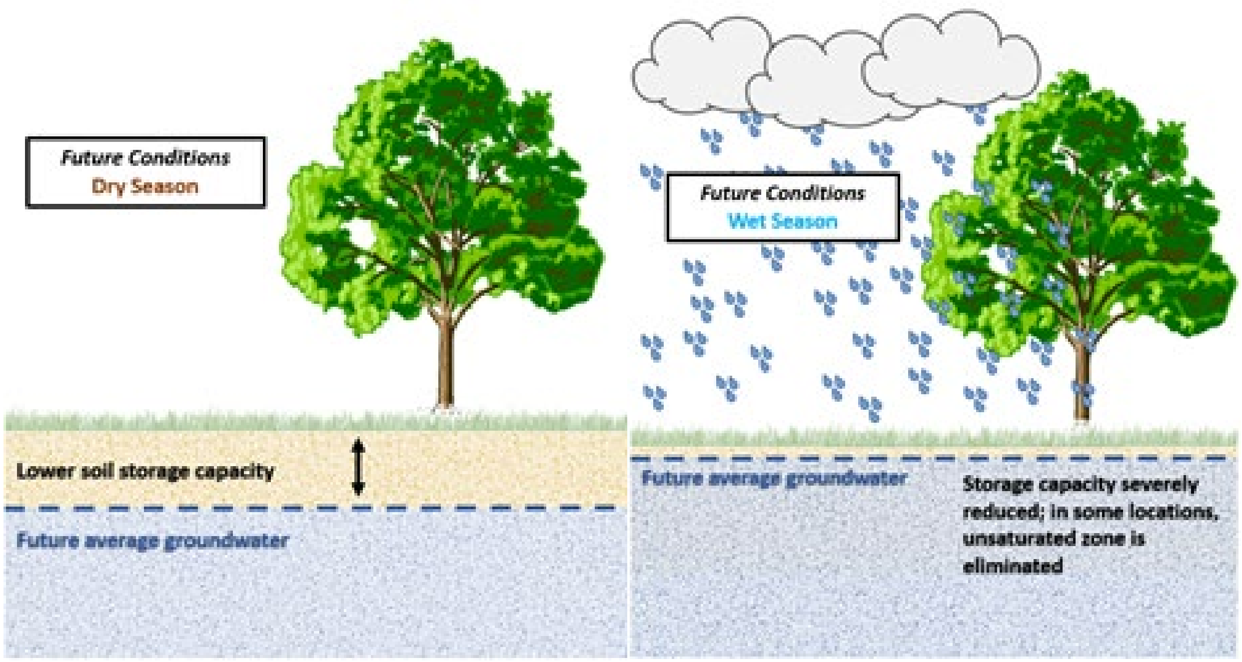


Figure 6: How Average Ground Water Levels Could Change Under Future Conditions in Tidally Influence Coastal Areas in Dry & Wet Season



Areas of the County Anticipated to be Impacted by Higher Groundwater Levels

Miami-Dade County, federal agencies, and local universities have invested in studies, staff scientists and technical experts to understand how these changes will affect our community. Previous reports have detailed the existing modeling and observations and the outputs of this work are publicly available.

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.

One of the most important and recently completed studies is the County's 2021 Stormwater Master Plan. The Miami-Dade County watershed numerical models represent more than 780 square miles of inland and coastal areas. The signed and sealed 2021 Stormwater Master Plan Report includes the results of the eleven watershed numerical models countywide that were revised to account for current and future County hydrologic and hydraulic conditions. This latest update of the watershed numerical models incorporates the changes in hydrology and hydraulics due to current and future projected population growth, ground elevation, SLR scenarios, land use, groundwater levels (current and forecasted), rainfall volumes and intensity, and surface water stages and flows related to specified precipitation events. This information was used to create inundation maps for the entire county.

For each watershed, the updated models were calibrated for rainfall events, upstream and groundwater boundary conditions, and for outfall tidal conditions including current and future scenarios. The Unified SLR Projections from the Southeast Florida Regional Climate Change Compact from 2015 and subsequent revision in 2019 were utilized for the future SLR scenarios (Figure 4). The tidal elevation current scenario used was the observed median sea level for the current NOAA epoch (ending in 2001), adjusted by adding the first harmonic constituent obtained from the Virginia Key NOAA tidal station. Using the increments from the Compact projections, the NOAA Intermediate High curve, was selected as a conservative approach for 2040, 2060, 2080, and 2100 SLR estimates. The outfall conditions to Biscayne Bay were developed reflecting potential SLR using NOAA's intermediate high rate, which is slightly greater than the U.S. Army Corps of Engineers (USACE) high rate of SLR. For each of the five scenarios (2020, 2040, 2060, 2080, 2100), ten simulations were used to develop flood maps for 24-HR storms with recurrence intervals of 5-, 10- and 25-years and for 72-hour storms with recurrence intervals of 5-, 10-, 25-, 50-, 100-, 500- and 1000-years.

In addition to the hydraulic and hydrologic analysis completed to determine runoff rates and drainage system performance, peak flood geospatial mapping was applied to determine the maximum flood depths. For each of the eleven watersheds, the flood depth was determined using the full hydrodynamic model which represents the relationships between rainfall, soil characteristics, topography, geometry of the sub-watersheds and canal network. The peak stages within each sub-watershed were used to develop flood maps depicting flood depths. Flood maps and depths of inundation are available for all watersheds in Miami-Dade County for all the storm events listed above, for all current and future scenarios modeled.

Specific facilities with underground and low-level parking can be best analyzed (on a case-by-case basis) using the inundation maps described above based on each facility location.

This detailed and rigorous modeling of current and future flood risks was also used to develop suggested revisions to the County Flood Criteria. This updated criteria provides excellent guidance on appropriate design standards to minimize flood risks into the future. Using this best available information would help to reduce flood risks to new and substantially improved structures.

<u>How Elevated Water Levels Affect Underground and Lower-Level Garages</u>

Rising sea and groundwater levels can impact existing infrastructure/buildings. Some infrastructure is designed to be submersible or to sit in saturated soils. However, increasing groundwater levels increase hydrostatic force on infrastructure. This can lead to increased infiltration through cracks or other defects. Overtime if this flooding is frequent or persistent it may stress certain materials. If the flood waters are salty or brackish it may accelerate the deterioration of materials through corrosion.

When infrastructure was designed in the past, there was often 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. For example, the calculated forces on a structure may have been made with assumptions about historic water levels. Similarly, the design team may not have assumed that the average groundwater levels would increase with the tide and may have underestimated frequency of saturated conditions. Therefore new, higher water levels may affect existing infrastructure, but the significance of that impact will be very specific to the asset and the design assumptions and construction details.

In addition to direct groundwater flooding impacts, changes in precipitation frequency and intensity, coupled with sea level, will likely lead to an increasing frequency and duration of stormwater flooding. This street level flooding may affect nearby below ground areas. 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. 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 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 many systems' original design capacity. 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.[1] The most at-risk stormwater systems are 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.

This increased frequency, duration, and depth of flooding can impact underground garages should the garage entrance be at or near grade, and if other mitigation measures (like trench drains) are not sufficient to keep up with flooding. Actions that can be taken to mitigate risks associated with increased flooding, ground water intrusion, and corresponding impacts to underground and lower-level parking garages are discussed in the following section.

5.0 Recommendations

Sea levels have been rising for several decades and due to local geology and historical development patterns, the Southeast Florida region is one of the most exposed areas in the world. Miami-Dade County has been working for years to proactively address these risks and has published a Sea Level Rise Strategy. The challenge of adapting to rising waters can be addressed at the site scale and at the community level.

There are several policy enhancements that can be considered to address concerns associated with the impacts of sea level rise upon underground and lower-level parking structures. Although current Miami-Dade County Code and other regulations seek to mitigate the risk of flooding within these structures, and prohibits underground garages along most of the coast, there are many buildings within Miami-Dade that were built prior to the creation of these standards and even current standards do not explicitly account for increased sea and ground water levels.

At the building or site level, some impacts from sea level rise can be addressed relatively easily over time by incrementally modifying infrastructure. For other assets the costs to "retrofit" or address issues with existing structures could be more challenging or costly. For existing underground garages rising water levels may be causing increased buoyancy and hydrostatic forces on the structure, increased corrosion due to more frequent flooding with brackish water, increased infiltration, or overtopping of the entrance ramp by floodwaters. Some of these issues may be challenging to fully address. Certain changes can be made relatively easily such as installing additional sump pumps in the garage, additional trench drains or barriers at the entrances, or increasing drainage capacity. Other issues may be difficult to address such as failure of the exterior waterproofing, corrosion, modifying the height of entrance ramps or the floor. For these reasons, this report recommends proactive monitoring and maintenance to ensure that these issues are addressed in a timely manner before contributing to any larger structural issue.

An analysis of each lower-level or underground garage would be necessary on a case by case basis to determine the conditions and potential site-specific remedial actions. However, the following general recommendations will work towards increasing safety and resilience of these existing structures and are being further developed by RER staff for incorporation into the recertification process:

1. Engineering Analysis of Underground and Lower-Level Garages - It is recommended that as part of the building recertification process articulated within Chapter 8 of the Miami-Dade County Code, that is applicable throughout the county, a site-specific analysis upon the next recertification cycle of the building be required for all underground and lower-level garages where the wet season ground water levels exceed the lowest floor elevation and/or the garage entrance is lower than the base flood elevation on current County Flood Insurance Rate Maps (FIRM).

This analysis can apply to all Private and Public facilities. The County can conduct such an assessment for its own facilities; likewise, the municipalities would do their own facilities; and private facilities can be required to conduct and report their own assessments. Necessary repairs to lower-level or underground garage would be identified and undertaken to meet minimum standards to prevent high risk impacts due to flooding and sea level rise through the application of a permit.

2. Additional considerations and mitigative measures for existing Underground and Lower-Level Garages could include the following, which could be incorporated into the building recertification program as checklist items:

   - Analyzing the structure for impacts of additional hydrostatic pressure on lowest level floor slab and enclosing walls due to current and projected sea level rise (based on remaining building life expectancy).
   - Maintain waterproofing where possible to an acceptable seepage rate.
   - Elevating the entrance drive to the parking garage to Base Flood Elevation (BFE) plus applicable freeboard (a safety factor above BFE).
   - Providing signage alerting to possible flooding.
   - Dry-floodproofing the garage openings to base flood level plus freeboard for non-residential buildings.
   - Ensure sump pumps are fully operational.
   - Make sure all elevators are either programmed to return the cab to a floor at or above the BFE or be equipped with sensor that would prevent the cab from lowering into a flooded hoistway.
   - All electrical branch lines are protected by GFCI circuits.
   - Ensure building materials used in the underground garage are resistant to damage from flooding.

Current building codes include designing new buildings to current base flood elevations plus one foot of freeboard. To enhance the future resiliency of new buildings the following design parameters are recommended:

1. Groundwater and Uplift Design Forces - As parking structures are lighter than other building structures, specific consideration must be given to the method of controlling and managing water ingress and the potential development of uplift pressures, known as buoyancy forces. Loads arising

from even modest depths of water will give rise to significant effects and may give rise to instability if not properly addressed.

2. A local technical amendment to the Florida Building Code, applicable throughout the county, will be proffered to the BCC which would require designers of new underground garage structures to consider future sea level rise and ground water conditions when designing the elevation of openings into the underground garage, as well as buoyancy and hydrostatic forces on the below grade structure. Once a BCC member sponsors this amendment, the ordinance will be presented to the BCC for first reading.

At the community level, Miami-Dade County is working to proactively address the risks of sea level rise and the risks of storm. To a certain extent, the risks of flooding and hurricanes are inherent to our location; however, there are many measures in place to minimize the consequence of these events. These measures, like our building code and floodplain ordinance, help reduce the risks of loss of life in a hurricane. They also help our entire community bounce back more quickly from a storm because fewer of our buildings are at risk of serious damage. Similarly, with the risks of sea level rise, there is a community-level benefit from ensuring that the majority of our buildings are protected from flooding and can bounce back quickly after an event. RER has formulated an update to the County's Flood Criteria that will require the elevation of sites throughout Miami-Dade County to address future conditions including anticipated sea levels and flood elevations. These measures will help our entire region by making our economy and society more resilient to the storms and sea level rise we can expect in our region.