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Miami Beach Integrated Water Management

Road Elevation Strategy and Recommended Sea Level Rise/ Tidal Flood Adaptation Projects

Final

February 28, 2020

City of Miami Beach

RFQ 2018-312-KB

JACOBS

Memorandum

3150 SW 38th Avenue, Suite 700
Miami, FL 33146
T 305.441.1846
F 305. 443.8856
www.jacobs.com

Subject	**Road Elevation Strategy and Recommended Sea Level Rise/Tidal Flood Adaptation Projects**
Project Name	Integrated Water Management – Work Order 01 – Task 2 Deliverable
Attention	City of Miami Beach, Public Works Department
From	Jacobs
Date	February 28, 2020

Executive Summary

In 2013, the City of Miami Beach (hereafter, the "City") established a 3.7-foot NAVD88 minimum crown of road elevation policy as the level of service (LOS) for all City roads to maintain dry roadways during 'sunny day' flooding events caused by king tides. During the last 6 years, the City experienced multiple flood events that exceeded certain assumptions that led to the 2013 policy. Additionally, national (National Oceanographic and Atmospheric Administration) and regional (Southeast Florida Regional Climate Change Compact) sea level rise (SLR) projections have been updated. Also, during the last six years, the application of the policy at the neighborhood level has created some issues. Lessons learned about public/private property harmonization of projects to date, as well as the findings and recommendations of the 2018 Urban Land Institute review of the Miami Beach Stormwater Management and Climate Adaptation, motivated the City to review and update the 2013 approach.

On January 21, 2020, Jacobs and the City conducted a public meeting to obtain public input on the proposed road elevation strategies and project prioritization methodology prior to Jacobs finalizing the recommendations presented in this memorandum. A summary of the proceedings and public comments received, along with a copy of the presentation slides, is included as Appendix D.

Strategy and Goals

In 2019, Jacobs Engineering Group Inc. (hereafter, "Jacobs") was engaged to review and update the road elevation policy to reflect new observations and projections and provide flexibility to accommodate private property harmonization. The Jacobs strategy in this memorandum is based on the following goals for the updated policy:

- Avoid sunny day flooding on road surfaces.
- Establish updated minimum elevations for 2020.
- Address groundwater elevation, and therefore, poor pavement performance.
- Address harmonization upfront.
- Based on sound and objective engineering, yet flexible and adaptable in a low-lying, dense coastal community.
- Potential order-of-magnitude project costs were considered in project identification and grouping; however, a cost quantification and benefit-cost analysis for each project was not performed as part of this task.

Furthermore, the strategy identifies road segments currently at highest risk based on 2018 Lidar. These are identified as tidal flood action projects (TFAP) for Prioritization Task 3, a companion item to this task. Section 5 of this memorandum details the methodology and lists these high-priority road segments. There are 65 road elevation projects, with a total length of 41.3 miles, representing 22.5 percent of the approximately 184 total miles of city, county, and state roads in Miami Beach.

Policy

The proposed road elevation policy considers sea level rise over time, surface water elevation, groundwater elevation, road clearance, harmonization, and the general urban fabric. Not all roads are equal, and every roadway project should be reviewed through the five elements of this policy as neighborhood design criteria packages are crafted.

1. Minimum Road Elevation Criteria

Three formulas have been created, and all three must be evaluated per project. The three methods for minimum road elevation are:

- Method 1, minimum road surface elevation
- Method 2, minimum road base elevation
- Method 3, private property harmonization

Given the conditions in the City, with surface water and ground water, coupled with projected SLR, the goal of every project is to elevate high-priority road segments as much as possible to receive the best results from the investment. However, if the minimum road elevation from methods 1 and 2 results in a road raising project that creates constraints with private property harmonization, then method 3 (harmonization) determines road elevation.

2. An **Evaluation of Limiting Factor and Selection of Minimum Road Elevation** are calculations performed early in the design phase. These take into consideration the type of road, SLR, and freeboard clearance and are used to determine final elevations for emergency, major, and local roads.

3. Policy Application and Project Timing

While infrastructure projects are typically directed and managed by Public Works and Capital Improvement Program (CIP) departments, given the complexity of the policy and its implications to private property and the urban fabric of the City, the City Commission may want to empanel a combination of engineers, planners, and financial analysts (or a subset of the City Manager's Ready Team) to run through the steps in this policy and the necessary calculations to make early design determinations and project funding and sequencing decisions. Engineers and project managers can then ensure a successful project delivery.

4. Road Section Hardening and Referenced Standards

A variety of options are included in this memorandum to inform the decision-making process on a project-by-project basis. These include asphalt enhancement, base material options, geotextiles, sub-base conditioning, ground water/surface water management, and Florida Department of Transportation's black base.

5. The **Alternative Road Sections** of the policy include road design considerations that should be evaluated to maximize the value of the corridor and provide co-benefits to the City. These include complete streets, road diets, green infrastructure, urban canopy, alternative pavement materials, and inverted crown.

Conclusion and Next Steps

It is recommended that the City Commission accept this report and deliberate its findings. Upon final public discussion, the policy should be updated into the City's Stormwater Master Plan, Public Works Manual, CIP Standard Operating Procedures, language in future design packages, and guidance documents for staff, project managers, and consultants to ensure consideration and implementation. It is further recommended the City continue to update and review its policy as national and regional SLR scenarios are updated periodically.

1. Background

According to the Urban Land Institute's Advisory Services Panel Report for the City of Miami Beach (hereafter, the "City"), Miami Beach's low elevation "is one of its key vulnerabilities" and "over 20 percent of the properties in Miami Beach lie below 3.7 feet [ft] NAVD [North American Vertical Datum of 1988], with 93 percent within the FEMA-designated Special Flood Hazard Area".[1] Miami Beach's elevation is an important driver for protecting the City's road infrastructure and maintaining access for continuity of municipal operations, emergency services, residents, business owners, and visitors in the City.

As a result, the City has been proactive in mitigating flood threats as part of the City-wide flood mitigation program and numerous City policies including the development of a road elevation policy. In 2013, the City established a 3.7 ft NAVD88 minimum crown of road elevation as the level of service (LOS) for all City roads (refer to Figure 1) to maintain dry roadways during 'sunny day' flooding events, caused by king tides. This elevation is based on the equation shown below and is composed of a 1.7-ft maximum high-water level (based on historical tidal records), 1.0 ft of anticipated sea level rise (SLR) for a 30-year service life, plus 1.0 ft of freeboard. The 1.0 ft of freeboard is intended to keep the lowest portions of any roadway (that is, edge of pavement [EOP], shoulders, gutters, and swales) above this anticipated high-water level. Unless noted otherwise, all elevations in this memorandum are expressed in feet and are based on NAVD88.

Min. EOP Elev. = 1.7 ft max high water + 1.0 ft SLR + 1.0 ft freeboard = 3.7 ft. NAVD88

Since 2013, the City has experienced multiple flood events that exceeded the maximum high-water elevation of 1.7 ft, with high-water elevations of more than 2.2 ft. In addition, updated SLR projections have been published by the National Oceanographic and Atmospheric Administration (NOAA) in 2017,[2] resulting in an increase to the 1.0 ft of SLR included in the current policy. Lastly, during implementation of current policy in key areas of the City, the importance of harmonization with the adjacent private property has proven to be a critical success factor, indicating that additional flexibility is needed in the policy to accommodate properties that would experience a hardship through the implementation of a fixed road elevation policy for reasons including vehicular access restrictions and drainage.

For these reasons, the City has asked Jacobs Engineering Group Inc. (hereafter, "Jacobs") to review and update the road elevation policy to reflect these new observations, projections and flexibility to accommodate private property harmonization.

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[1] Urban Land Institute (ULI). 2018. *Stormwater Management and Climate Adaptation Review.* A ULI Advisory Services Panel Report for Miami Beach, Florida. April.

[2] National Oceanic and Atmospheric Administration (NOAA). 2017. *GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES.* NOAA Technical Report NOS CO-OPS 083. Silver Spring, MD. 2017.

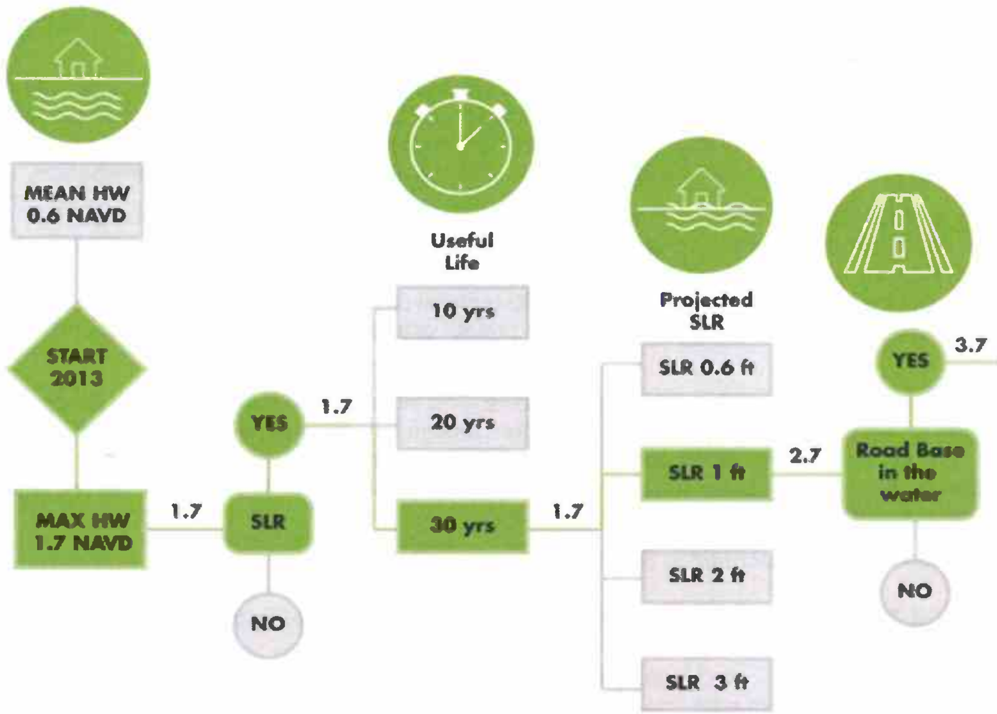

Figure 1. City of Miami Beach 2013 Road Elevation Policy Decision Tree

2. Goals of the Road Elevation Strategy

Based on the above background and guidance from the City received during several meetings with the City's Ready Team and City Commissioners, Jacobs has developed a road elevation strategy that includes both an updated policy for elevating roads and a recommended list of road elevation projects, which are hereafter referred to as sea level rise and tidal flood adaptation projects (TFAPs). The goals of each strategy element are summarized below, followed by a summary of the analysis and specific recommendations for each.

2.1 Updated Road Elevation Policy Objectives

Based on the above background, Jacobs established the following goals for the new road elevation policy:

- ***The policy should support keeping road surfaces above the king tide elevation to avoid sunny day flooding.*** The accepted public metric for a successful City flood mitigation program and related policy is perceived as mitigating sunny day flood events; therefore, this should be a minimum standard for this policy. However, additional public education is required to improve understanding of the multiple flood mechanisms and the composition of king tide flooding, as this event often incudes some level of wind-driven surge, which may not be fully mitigated through this policy alone.
- ***The policy should establish new minimum elevations for City roads based on updated tidal records and SLR projections.*** The new road elevations include elevated high-water elevations in terms of LOS for flood recurrence frequency and updated SLR projections along with the selection of sea level curves based on road criticality.
- ***The policy should address increasing groundwater elevations and concern for poor pavement performance and premature pavement failure related to saturated road base.*** With the karst limestone surface geology in Miami Beach, the groundwater levels mimic tidal conditions. Coupled with the City's low elevation, these conditions result in the potential for saturated road base, especially for the City's lowest roads, which can adversely affect the performance of their pavement

sections. Use of alternate materials and road section hardening can mitigate this concern by helping to improve pavement performance and lengthening the road life span.

- ***The policy should address concern for private property harmonization.*** In compliance with the *City's Do No Harm Policy*, the policy should incorporate flexibility to adapt to the conditions of each project site to avoid creating any adverse conditions for private property owners, including Americans with Disabilities Act (ADA) access, vehicular access, stormwater management, and aesthetics.
- ***The policy application should be standardized, unbiased, objective, and transparent.*** The application of the current road elevation policy has resulted in the lack of public support in some areas of the City. As a result, this new policy will need to be robust, flexible, and adaptable, and its application must be transparent and inclusive of the general public, based on sound engineering judgement that addresses the uniqueness of each project site and that benefits the neighborhood and the City.
- ***The policy should also consider cost implications.*** The initial capital cost of building roads using a higher minimum elevation and more robust pavement design criteria is expected to be higher than using the current City road elevation policy and design standards. However, experience has shown that the life-cycle cost of a resilient asset is often less than that of a non-resilient asset when factoring in higher maintenance costs and shorter service life.

The Road Elevation Policy is described in Section 4 and accompanying appendices.

2.2 Goals of Tidal Flood Adaptation Projects (Including Road Raising)

The second part of the strategy was to identify road segments that are currently at risk of tidal flooding based on site-specific elevation of each road so that those discrete road elevation projects can be factored into the citywide prioritization of capital projects. That prioritization of project groups and neighborhoods is discussed in a separate memorandum.

The road elevation projects are referred to hereafter as sea level rise/TFAPs because their primary purpose is to address "sunny day" flooding resulting from high tides. The TFAPs would be raised based on the recommended road policy to minimize the risk of flooding now and from future sea level rise.

The different flooding mechanisms that are addressed by the policy and the TFAPs are summarized in Section 3; TFAP identification and prioritization is presented in Section 5.

3. Flooding Mechanisms

Flooding can occur anywhere it rains and at any time of the year with little to no warning as a result of extreme tides or weather events. Flooding can occur as a result of extreme rainfall, extreme tides, and storm surge. These phenomena may occur independently or in combination with others, resulting in varying frequency, severity, and duration of flooding during the year. As sea levels increase gradually over time, the frequency, severity, and duration of flooding is anticipated to increase.

King tides, a common term used to describe the tides that have caused sunny day flooding, are the highest predicted tides of the year and usually occur in the fall in Florida. However, this tidal event often occurs in combination with wind, current, and/or barometric pressure influences, which results in a high-water elevation that exceeds the tidal influence alone.

For the purposes of this study, the following definitions/descriptions related to flood mechanisms and water levels are used:

- **King Tide**: The maximum astronomical tide (Perigean Spring Tide), extreme high tide that occurs when the moon is aligned with the sun and closest to the earth, or in its perigee. This event usually occurs in the fall in Florida and is also sometimes referred to as "sunny day flooding" because it may occur in the absence of rain events.
- **Mean High Water**: The average of all the high-water tidal observations over the tidal datum epoch. This tide level approximates the daily high tides, which varies.

- **Mean Higher High Water**: The average of the daily high-water tidal observations over the tidal datum epoch. This tide level approximates the monthly high tides, which varies.
- **Sea Level Rise**: The future SLR projections are taken from the latest available reputable scientific sources (in this case, NOAA 2017 SLR projections are used). *Note: The SE FL Regional Climate Compact published the last Unified SLR Projections in October 2015,*[3] *and is expected to release an update in December 2019, suggesting a review and possible update to this policy, may be necessary to reflect the latest information.*

4. Road Elevation Policy

The proposed road elevation policy has been organized to accommodate the above objectives and contains the following elements, as further described below:

- Minimum Road Elevation Criteria
- Evaluation of Limiting Factor and Selection of Minimum Road Elevation
- Policy Application & Project Timing
- Road Section Hardening and Referenced Standards
- Alternative Road Sections and Other Considerations

4.1 Minimum Road Elevation Criteria

The development of updated minimum road elevations for City road projects involves many factors, most of which are related to the effects of climate change and result in continually increasing flood elevations. These factors include the baseline water surface elevations (or maximum water elevations that correlate to a probability of flooding), sea level rise, groundwater elevations, road base clearance above groundwater, and the harmonization of new roads with the existing private property (specifically related to vehicular access and drainage).

These factors have been summarized into three distinct methods to determine the minimum road elevation for a given project in the City. Each project must be reviewed using all three methods to determine the limiting factor, which will drive the minimum elevation for the road. The three methods are described in the following sections along with the application methodology.

4.1.1 Minimum Road Surface Elevation (Flood LOS - Method 1)

The LOS for roads in Miami Beach is a choice the City makes, based on a balance of risk versus cost, considering available budgets and the health and safety of City residents and visitors. A higher LOS equates to a higher road elevation and a lower probability of flooding on the road surface. The higher the road elevation, the higher the cost for road construction and private property harmonization, but the lower the cost of ownership for the road asset over the course of its service life.

The Flood LOS Method (refer to Appendix A) is comprised of several components that combine to form the recommended minimum road elevations, as depicted in Table 1. These components include:

- High Water Surface Elevations used to determine Baseline Water Elevation (BWE)
  - The water surface elevations in terms of maximum water levels are a common reference point used in road design and are primarily based on historical events and probability of future occurrence; this elevation varies based on road criticality given the expected high road performance for critical access roads.
- Sea Level Rise Projections
  - This analysis uses the 2017 NOAA SLR projections because they are the latest available projections available and tailored to the southeast Florida coastline. The updated projections for southeast Florida will be available in December 2019.

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[3] Southeast Florida Regional Climate Change Compact. 2015. Sea Level Rise Work Group. *Unified Sea Level Rise Projection for Southeast Florida*. August 12.

- The SLR value selection was based on a 30-year road life span, with the SLR curves selected based on road criticality, as recommended by the Southeast Florida Compact.
  - The Intermediate High curve was selected for local roads.
  - The High curve was selected for critical access roads.
- Point of Measurement (reference point)
  - The 2013 City road elevation policy had selected the crown of road (typically located along the roadway centerline) as the reference point for applying the policy, likely because of the focus on ensuring ingress/egress along the road crown or highpoint for emergency vehicles.
  - This new policy recommends using the road EOP as the reference point for the following reasons:
    - It is a higher LOS than using the crown of road;
    - It ensures a more consistent LOS for all roadway lanes by keeping the entire paved surface of the roadway above the high water level (for normal crown roads), regardless of the roadway's cross-sectional geometry (width, cross-slope, etc.).

The Method 1 equation is represented as:

BWE + 30-year SLR = Minimum Road Elevation (at EOP)

4.1.2 Minimum Road Base Elevations (Groundwater - Method 2)

Similar to LOS Method 1, the Groundwater Method of determining the minimum road elevation is equally important to consider, as high groundwater conditions can cause saturation of the road base, which can lead to failure of the road's pavement system under traffic loading.

The Groundwater LOS Method is comprised of several components that combine to form the recommended minimum road elevations, depicted in Table 1 for Method 2. These components include:

- High Water Surface Elevations used to determine BWE
  - The Baseline Water Elevation for Method 2 is either the estimated SHGWT elevation beneath the road or the current MHHW elevation of 0.6 ft for the City, whichever is higher.
- Sea Level Rise Projections
  - This analysis uses the 2017 NOAA SLR projections because they are the latest available projections available and applied to the southeast Florida coastline. Updated projections for southeast Florida are expected in December 2019.
  - The SLR value selection was based on a 30-year road life span, with the SLR curves selected based on road criticality, as recommended by the Southeast Florida Compact.
    - The Intermediate High curve was selected for local roads.
    - The High curve was selected for critical access roads.

Table 1. Summary of Design Road Elevation Methods for Roads Built in 2020

Method	Method 1 Limited Flooding at Edge of Road[a]			Method 2 Limited Tidal Wetting of Road Base[a]
Applicability	Residential Roads	Commercial Roads	Emergency Roads	All Roads
Level of Service	Minimum Standard to Avoid Flooding from 50% Chance Tide + 2-yr Surge Event with SLR for 30 yrs	Minimum Standard to Avoid Flooding from 20% Chance Tide + 2-yr Surge Event with SLR for 30 yrs	Minimum Standard to Avoid Flooding from 10% Chance Tide + 10-yr Surge Event with SLR for 30 yrs	Limited Tidal Wetting of Road Base
Current Probability of Flooding	50%	20%	10%	N/A
Baseline Water Elevation	1.7 ft	2.3 ft	3.0 ft	MHHW of 0.6 ft[b] or SHGWT beneath roadway (whichever is higher)
Sea Level Rise	1.3 ft	1.3 ft	1.8 ft	1.3 ft
SLR Rationale	30 years, NOAA 2017 Intermediate-High Curve	30 years, NOAA 2017 Intermediate-High Curve	30 years, NOAA 2017 High Curve	30 years, NOAA 2017 Intermediate-High Curve
Road Section Thickness	N/A	N/A	N/A	1.0 ft[c]
Min. Road Base Clearance Above MHHW or SHGWT	N/A	N/A	N/A	1.0 ft
Min. Road Elev. (at EOP)	**3.0 ft[d]**	**3.6 ft[d]**	**4.8 ft**	**3.9 ft[c]**

[a] The higher design road elevation calculated by the two methods should be selected.

[b] The MHHW of 0.6 ft NAVD was calculated based on the NOAA tides and currents data for the Virginia Key Tide gauge for the tidal epoch of 1994 to 2018. The calculated MHHW elevation will continue to increase over time as sea levels rise. NOAA revises these values on a periodic basis, as published on their website, which may or may not reflect the most current tidal observations. The MHHW should be updated on a regular basis to reflect increasing tide levels.

[c] The road section thickness of 1.0 ft, is intended to represent a typical pavement system thickness for either an asphalt or concrete paved road, which includes the sum of the pavement and base layer thicknesses. Depending on the traffic and soil conditions used to design the pavement system as well as the type of pavement system selected, the total road section thickness for a specific project may be greater or less than 1.0 ft and the minimum road elevation will need to be adjusted accordingly.

[d] Final minimum road elevation may be controlled by Method 2, depending on the final design thickness of the roadway pavement system and the Baseline Water Elevation selected for Method 2.

Notes:

Regardless of the type of base material used to support the roadway pavement, a minimum base clearance of 1.0-ft above the MHHW or SHGWT elevation (whichever is greater) is highly recommended for all roads, to prevent the road's stabilized subgrade and base course from becoming overly saturated and thereby weakened, leading to pavement failure.

The SLR projection factored into the minimum road elevation will provide some freeboard for the early years of the pavement system, which will diminish over time as the water levels increase.

MHHW = Mean Higher High Water

NOAA = National Oceanic and Atmospheric Administration

SHGWT = seasonal high groundwater table

All elevations are in NAVD88

- Road Section Thickness
  - The thickness of the road section will vary with each road project as required to achieve the desired structural value given the soil and traffic conditions and other project characteristics.
  - For the purposes of this policy, the following road section was assumed:
    - 1.5-inch-thick asphalt pavement wear course
    - 2.5-inch-thick asphalt pavement base course
    - 8.0-inch-thick aggregate base material
    - In total, a 12-inch-thick road section (not including compacted sub-grade)
  - Where the road section design exceeds this 12-inch (1.0-ft) thickness, inclusive of base material and pavement (base and wear course), the difference in additional thickness should be added to the minimum road elevation to ensure the bottom of the road base is elevated above the future SHGWT.
- Road Base Clearance Above SHGWT
  - The most common material used for road base in South Florida is limestone. When compacted and kept dry, this material will maintain the structural stability of the road for many years, even beyond 30 years, when designed to accommodate the anticipated loading.
  - When this material becomes saturated, it softens and loses its ability to provide structural support for the pavement, often causing pavement cracking, potholes, and general pavement failure over time.
  - To avoid this, vertical clearance is provided between the bottom of the base layer and the SHGWT (referred to as base clearance) to minimize or prevent saturation of the base material from groundwater. A minimum of 1 ft of base clearance is recommended, with 3 ft being preferred for added protection over the life span of the road system. *Note: water can migrate above the groundwater table, potentially into a roadway's base layer through capillary action.*
  - Alternate base materials are also recommended, but a minimum of 1 ft of base clearance is still recommended, where practicable.

The Groundwater LOS Method is derived from the Florida Department of Transportation's (FDOT's) statewide and local District 6 base clearance requirements for FDOT roadways, which are specified in Section 210.10.3 of the FDOT Design Manual[4] and Sections 2.3.1, 2.3.1.1, and 2.3.1.2 of the FDOT District 6 ICPR Applications Manual.[5]

The Method 2 equation is represented as:

BWE + 30-year SLR + Road Section Thickness + Base Clearance = Min. Road Elev. (at EOP)

4.1.3 Private Property Harmonization (Method 3)

If the minimum road elevation selected from methods 1 and 2 result in a road raising project that creates constraints with private property harmonization, then method 3 (harmonization) will dictate the road elevation. The modification of the minimum road elevation should be applied only to the portions of the road elevation project driving the constraints and shall use the highest road elevation possible, up to the minimum design standard, that mitigates the constraints and provides the intended road performance. The identification of constraints is further described below.

Constraint Determination for Private Property Harmonization

The above minimum road elevations may not be feasible for application in some areas of the City because of physical constraints associated with the existing elevations of a given City roadway corridor, access impediments to adjacent private property, and/or because of limited width of road right-of-way

4 Florida Department of Transportation. 2019. *FDOT Design Manual*. January 1. https://www.fdot.gov/roadway/fdm/Default.shtm

5 Florida Department of Transportation District 6. 2015. *ICPR Applications Manual*. September.

(ROW) or easements to construct improvements. These hardships could potentially result in adverse access or drainage conditions for private property owners and should be avoided by using road hardening with reduced road raising elevations below the prescribed minimum elevation, set by the limiting factor. A combination of road hardening and road elevating are anticipated to be used for many low-lying areas of the City, as a result of these potential constraints.

The determination of a constraint should be based on objective criteria and not based on subjective input. Criteria to determine hardship are included below.

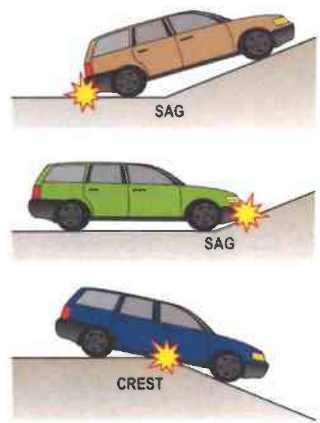
Note: TCE is a temporary construction easement established along one or both sides of a road ROW to allow for harmonization work outside of the road ROW during road construction. A permanent maintenance easement (PME) refers to a permanent maintenance easement established to allow the City to access, inspect, maintain, and if necessary, replace a drainage structure/feature outside of the road ROW after the drainage structure/feature is constructed. A traversable driveway is defined as a driveway that does not have any grade breaks along its vertical profile with an algebraic difference greater than 14 percent, without a straight or rounded profile transition, as required in the FDOT Design Manual. In addition, no portion of a traversable driveway connection's vertical profile shall have a slope that exceeds 10% for a commercial/critical facility and 28% for a residence.

Constraint Criteria:

1) Insufficient Space to Construct Necessary Harmonization Features

   If there is insufficient horizontal space within a road ROW and/or the lack of a construction easement necessary to construct any of the following harmonization features, where required along a roadway, it shall be deemed a constraint:

   - Traversable driveway connections not exceeding the following:
     - Maximum slopes:
       - 12.5 percent (1V:8H) slope for residential properties
       - 10.0 percent (1V:10H) for commercial properties
     - Maximum grade break: (algebraic difference between slopes at driveway connection with roadway, and existing driveway point of connection)
       - 14% grade break
   - ADA-compliant steps and ramps (per the latest approved ADA requirements).
   - Drainage features (for example, inlets, pipes, gutters, and swales) required for the removal of stormwater from property that previously drained freely by overland flow to the roadway drainage system; based on the City's latest approved stormwater LOS.
   - Transitional grading of unpaved ground surfaces with slopes not steeper than 1V:3H.
   - Retaining walls, including required foundation, tie backs, and safety railing.



Example Grade Break Constraints

2) Lack of Sufficient Easements
   - Absence of a TCE that is wide enough to allow for the construction of any necessary harmonization features outside the road ROW (listed above).
   - Absence of a PME that is wide enough to allow for the construction and permanent maintenance of a drainage structure/feature or other required improvements outside the road ROW after construction.
3) Adversely Low Finish Floor Elevation (FFE)

- If the FFE of an existing commercial building or residence adjacent to the road is more than 3 ft below the prescribed minimum EOP or back of sidewalk elevation along the roadway.

4.2 Evaluation of Limiting Factor and Selection of Minimum Road Elevation

The following process is intended to be performed either during Design Criteria Package (DCP) development or during the preliminary design phase of a neighborhood or roadway design project. To determine the minimum road elevation for any subject project, a determination of the limiting factor is needed, from the above. The process to select this limiting factor is as follows:

- **Step 1:** Determine the minimum road elevation from the **higher elevation** from the two methods 1) flooding LOS method and 2) groundwater method as outlined above.
- **Step 2**: Review harmonization criteria to determine if a hardship exists related to vehicular access or stormwater management.
- **Step 3:** Based on a site survey of the proposed road corridor, and the above hardship criteria, identify non-compliant portions of the road project relative to adjacent properties.
- **Step 4:** Determine if those hardships can be mitigated without lowering road elevation. If so, then incorporate mitigation measures into the project design.
- **Step 5:** If the hardships cannot be mitigated without lowering road elevation, then a determination of the road elevation at those points must be calculated with the intent of maintaining ADA pedestrian and vehicular access and facilitating stormwater management within the public ROW.

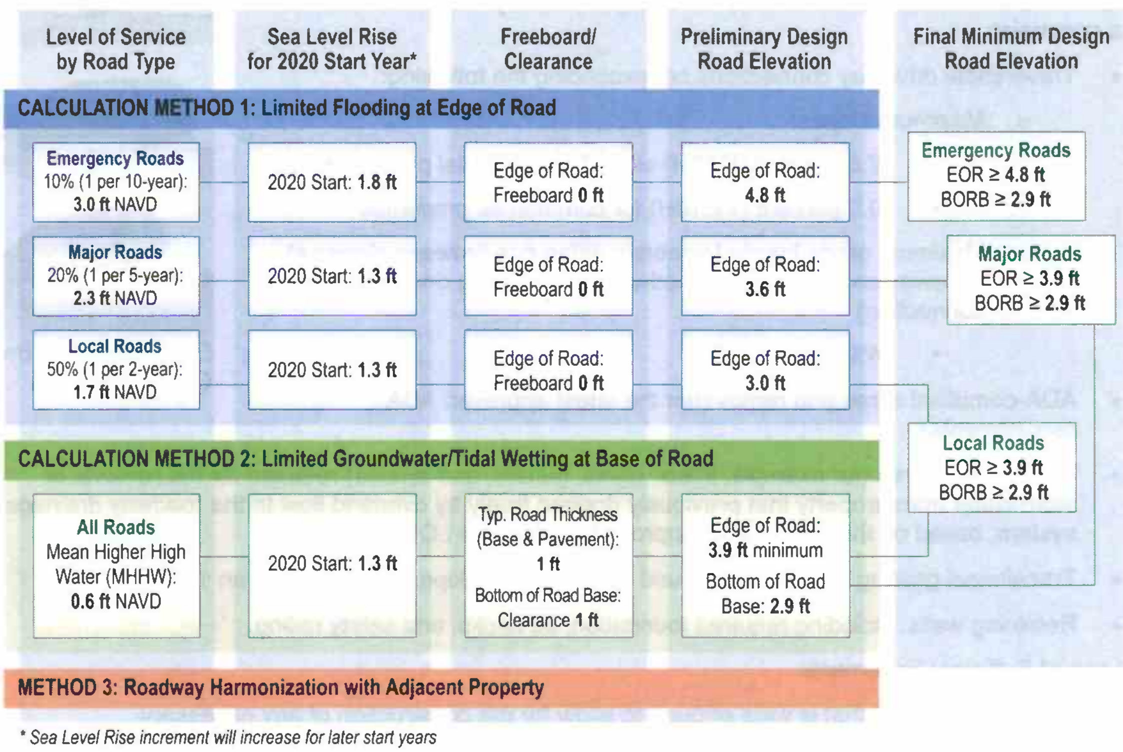


Figure 2. Road Elevation Policy Summary Chart

4.3 Policy Application and Project Timing

All City road projects are anticipated to follow this policy once adopted. The policy is expected to be administered by the Public Works department who will issue final approval for road elevation(s), prior to issuance of the final construction permits. Any project constraints that require a variance to the minimum road elevation must be submitted in writing to Public Works for review and consideration.

The proposed minimum road elevations are based on existing conditions and future projections as of the date of this memorandum, as summarized in Table 1, Figure 3 for the bottom of road base, and in Figures 4 and 5 for the edge of road surface.

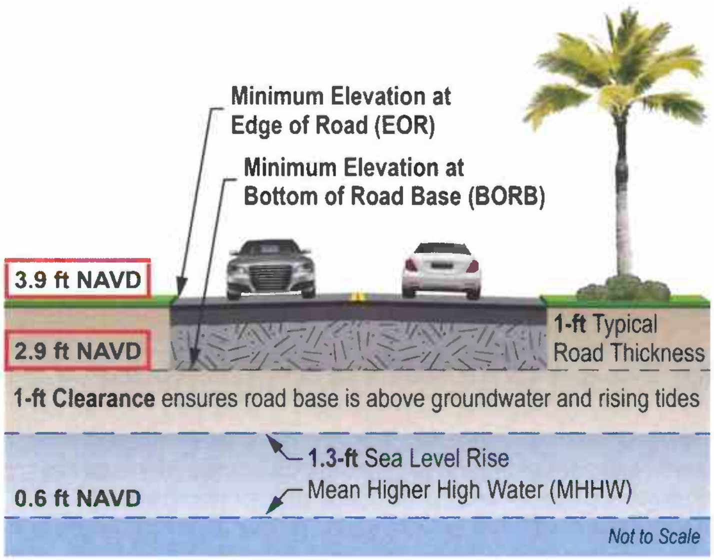


Figure 3. Minimum Elevation for the Bottom of Road Base is 2.9 ft NAVD for all Roads

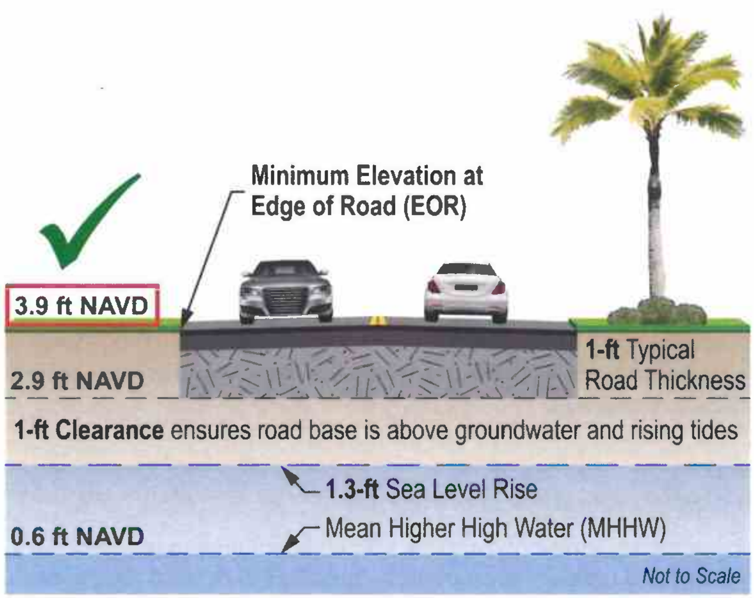


Figure 4. Minimum Elevation for the Edge of Road is 3.9 ft NAVD for all Major and Local Roads

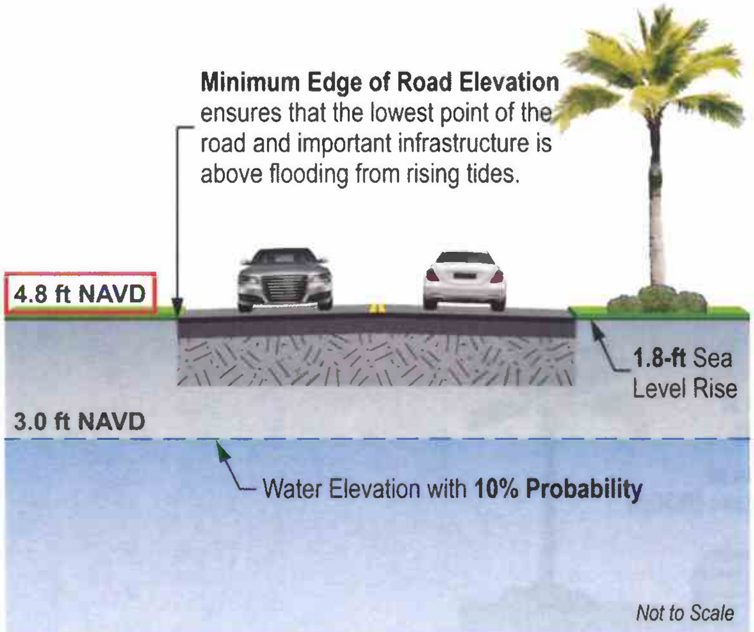


Figure 5. Minimum Elevation for the Edge of Road is 4.8 ft NAVD for all Emergency Roads

Future road elevation projects may require a revised set of criteria to meet the objectives of this policy. Therefore, any new road project should consider the anticipated construction date of the roadway and select the appropriate minimum elevations associated with that time horizon. This will promote improved road performance over its service life with the awareness that future flood and groundwater conditions are expected to be higher. Table 2 provides guidance for future road projects in 5-year increments.

Table 2. Minimum Road Elevations for Future Road Projects

All elevations shown are proposed edge of pavement minimum road surface elevations in ft NAVD88.

		2020	2025	2030	2035	2040
1	Emergency Roads	4.8	5.2	5.7	6.2	6.7
2	Commercial Roads	3.6[a]	3.9	4.2	4.6	5.0
3	Residential Roads	3.0[a]	3.3[a]	3.7[a]	4.0	4.4
4	Method 2 – Road Base protection from SHGWT	3.9	4.2	4.6	4.9	5.3

[a] Final minimum road elevation may be controlled by Method 2, depending on the final design thickness of the roadway pavement system and the BWE selected for Method 2.

Notes:

SLR projections are based on NOAA 2017 Intermediate High for application on commercial and residential roads and Method 2.

Emergency roads are based on NOAA 2017 High SLR projections.

4.4 Examples of Road Harmonization with Adjacent Properties

The application strategies to harmonize roadway elevation projects with adjacent private property vary with each project and between commercial and residential properties. Specific site context, public works DCP criteria, and recommendations from the project design team including geotechnical engineer will ultimately dictate the strategies at each project site to ensure project goals are met with no adverse effects on adjacent properties. Figures 6 and 7 provide some general examples of road harmonization for commercial and residential properties.

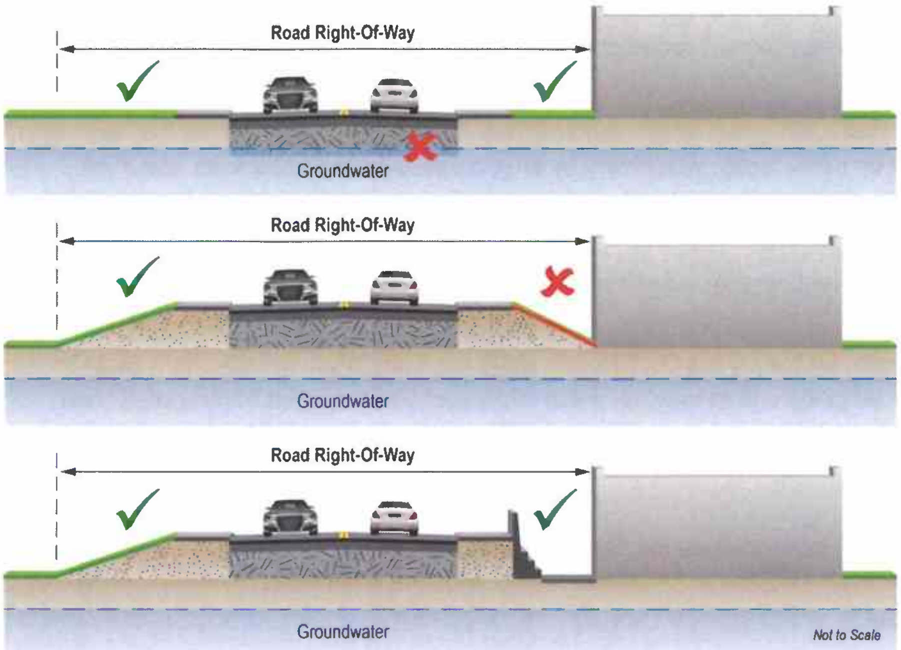


Figure 6. Example of Commercial Property Harmonization

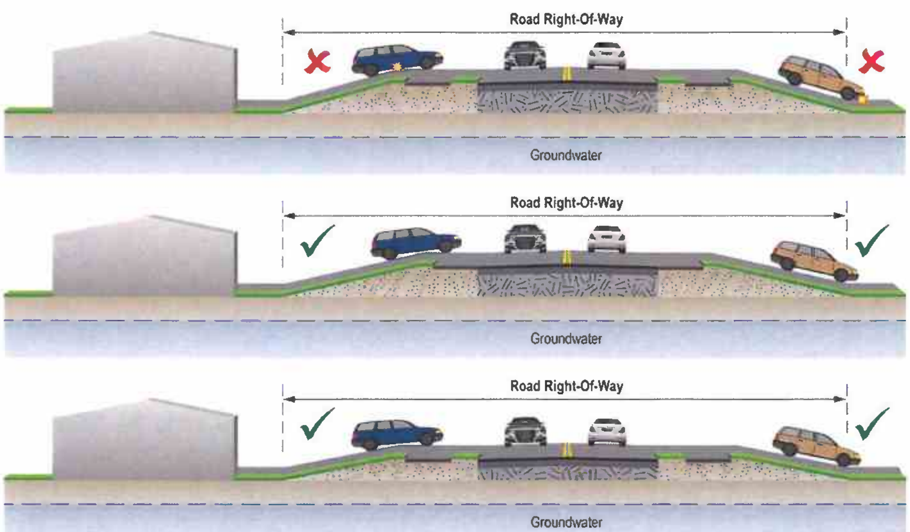


Figure 7. Example of Residential Property Harmonization

4.5 Road Section Hardening and Referenced Standards

There are numerous situations where road hardening may be warranted to strengthen the road system and improve performance. These situations may include:

- Inability to achieve the City's minimum road elevation because of harmonization issues
- For use on roads expected to have a longer service life
- For use on roads with higher criticality, such as access to hospitals or evacuation routes

For these situations, hardening of the road section is a viable strategy to promote enhanced performance and to achieve the desired service life with reduced maintenance costs.

4.5.1 Road Section Hardening Options

Road hardening can take on many forms, which vary by project based on soil conditions, elevation, proximity to surface waters, depth to groundwater, and other factors that all must be considered during the design phase of a project with guidance from a geotechnical engineer. Road hardening is not a substitute for elevating the road system above the saturation zone (seasonal high groundwater) or flood elevation, and the amount of freeboard provided cannot be replaced by specific road hardening strategies (refer to Appendix B).

While there is not a 'one-size-fits-all' application of these strategies for hardening roads, or a direct correlation between road elevation and hardening, these strategies, when applied appropriately, can improve the long-term performance of the road system. Strategies for consideration in hardening road pavement systems in the City include:

- Asphalt enhancement
  - Thicker asphalt structural course and/or thicker wear/friction course
  - Mix amendments, such as fiber reinforcement (FDOT Structures Manual, Vol. 4, Jan. 2019)
- Base material selection
  - Granular rock base
  - Asphalt base (a.k.a. black base) per FDOT standards
- Use of geotextiles
  - Materials vary - to strengthen pavement structural value and system performance
- Sub-base/subgrade conditioning
  - Portland cement mix-ins (soil cement)
- Groundwater and surface water management
  - Sub-surface cut off walls (impermeable vertical barriers)
  - Underdrains with pumps
  - Filter strips along back of pavement
  - Impermeable liners under base material

4.5.2 City vs. FDOT Road Design Standards

The FDOT *Flexible Pavement Design Manual*,[6] FDOT *Rigid Pavement Design Manual*,[7] and the FDOT *District 6 Pavement Design Guidelines*[8] provide pavement design standards and guidelines for state roadways in Florida. These pavement standards can be applied to the design of roads within the City to increase the resilience of the City's roads against the threat of rising groundwater and frequent flooding. Section 5.2.2 of the FDOT *Flexible Pavement Design Manual* includes a discussion about the effect that base clearance above groundwater levels has on the long-term durability and performance of pavements. Section 5.6.2 of the same manual includes a discussion regarding the use of asphalt base (full-lift asphalt) to overcome the challenge of meeting minimum base clearance requirements under a high groundwater condition with harmonization/back-of-sidewalk grade restrictions.

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[6] Florida Department of Transportation. 2018. *Flexible Pavement Design Manual*. January. https://www.fdot.gov/roadway/pm/publications.shtm

[7] Florida Department of Transportation. 2019. *Rigid Pavement Design Manual*. January. https://www.fdot.gov/roadway/pm/publications.shtm

[8] Florida Department of Transportation District 6. 2012. *Pavement Design Guidelines*. March.

Black base is a term used by FDOT to describe the replacement of typical base materials, such as limestone, with additional layers (lifts) of asphalt pavement or full lift asphalt pavement. The use of black base is recommended by FDOT for all state roads in Miami Beach because of the high groundwater conditions and low-lying elevation of the roads in the City. The use of black base, when used to replace conventional road base materials, may reduce the overall road system thickness as a result of the higher structural values of asphalt base compared to other granular base materials, which will be determined by a geotechnical engineer during roadway design. This reduced thickness may assist the City in achieving harmonization with adjacent properties; however, this must be determined by the project design team on a case-by-case basis.

The use of black base is recommended for City roads that cannot provide the minimum road elevations proposed within the new road elevation policy, which may occur as a result of harmonization with adjacent properties. In these instances, the use of black base is recommended for those roads, or portions of roads, that may experience flooding or base saturation from high groundwater conditions.

There are instances where the more recent FDOT standards are applicable for use in the City vs. the current City road design standards. In addition, an update to the City road design standards may also be warranted to factor in the new FDOT pavement design standards for consistent application and enhancement of the City's road network. This policy does not address these standards in a comprehensive way or state when the City standards should be used vs. FDOT standards. A full road design standard review should be performed to provide this level of analysis and guidance.

4.6 Alternative Road Sections and Other Considerations

In addition to providing a route for vehicular mobility, roadway corridors can provide other valuable services for a community, including supporting multi-modal transport, conveyance and treatment of stormwater, and space for landscaping and urban forestry. To enhance some of these co-benefits, the roadway improvements and their placement within the ROW can be modified from conventional approaches to directly support or position for the incorporation of these future benefits. The following sections outline road design considerations that could be incorporated into some roads to maximize the value the road corridors provide.

4.6.1 Complete Streets

According to the U.S. Department of Transportation, a complete street is a street that is designed and operated to enable safe and efficient mobility for all users, including pedestrians, bicyclists, vehicles, and public transportation riders.[9] A complete street is typically designated by the governing local authority and defined as part of the roadway design guidelines with respect to geometry, design aspects, and performance. A complete street approach is recommended specifically for the urban core of the City and areas with larger concentrations of pedestrians, with emphasis on areas where vehicular and bicycle/pedestrian conflicts often occur to improve the safety for all users. This approach often encompasses other design elements, such as green infrastructure and alternative pavement materials as further described below.

4.6.2 Road Diet

According to the Federal Highway Administration, a "Road Diet" is a road configuration that offers several high-value improvements at a low cost.[10] In addition to low cost, the primary benefits of a Road Diet include enhanced safety, mobility, and access for all road users and a "complete streets" environment to accommodate a variety of transportation modes. A classic Road Diet typically involves converting an existing four-lane, undivided roadway segment to a three-lane segment consisting of two through lanes and a center, two-way left-turn lane.

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[9] U.S. Department of Transportation. 2019. Complete Streets. Accessed October 15. https://www.transportation.gov/mission/health/complete-streets

[10] Federal Highway Administration. 2019. Accessed October 15. https://safety.fhwa.dot.gov/road_diets

This approach provides additional benefits including reducing the heat island effect by having less pavement, increasing pervious area for stormwater infiltration, and providing horizontal space for alternate uses, including multi-modal corridors, green infrastructure, and private property harmonization.

4.6.3 Green Infrastructure and Urban Tree Canopy

Green infrastructure (GI) and blue-green stormwater infrastructure (BGSI) provide an approach to stormwater management that manages the rainwater where it falls through a distributed system in place of a centralized system, offering the benefit of enhanced stormwater quality and reduced runoff volumes by capturing and retaining the 90^{th} to 95^{th} percentile average annual rain event. This approach captures the rainfall from most rainfall events and the first flush from larger events, where pollutants are often transported to sensitive receiving waters. The benefits of GI, when incorporated along roadways, include:

- Groundwater recharge
- Stormwater treatment for frequent rainfall events including nutrient uptake and capture of heavy metals, hydrocarbons, and other constituents
- Management of runoff at the source, helping to reduce stormwater conveyance infrastructure

Consistent incorporation of GI in road projects and other City capital projects would require a City policy and adoption of the guide that defines the objectives, application of applicable devices, the benefits of this approach, and the City regulation associated with the use of GI, related to quality and quantity of storm-water managed. The BGSI plan currently being developed will be an important first step in community education and awareness of the City's stance on use of GI and communication regarding the intent to develop a policy to implement GI across all public and private capital projects.

4.6.4 Alternative Pavement Materials

In addition to asphalt pavement, there are other pavement types that may be considered for limited application in appropriate locations of the City. These pavement types offer various benefits beyond mobility corridors that help to meet other City environmental and social objectives. These pavement types include:

- Porous pavement
  - Includes permeable pavers, porous asphalt, pervious (porous) concrete, concrete grid pavers, and plastic reinforcing grids (geocells)
  - Allows stormwater to infiltrate reducing runoff volumes and preventing the transportation of pollutants to receiving waters
- Concrete pavement
  - Has been shown to provide improved performance over flexible pavements, such as asphalt because of its additional strength
  - Considered to be more sustainable than conventional asphalt because of the lack of petroleum products used.
  - Has a higher reflective albedo because of its color over darker pavement types, helping to reduce heat island effects

4.6.5 Inverted Crown

An inverted crown road section is one where the mid-point or centerline of the road is the lower than the edge of pavement elevation. This road section is mostly commonly found in low volume and low speed roads, such as local roads and alleys or in roadways with vegetated medians. By inverting the crown, this road section promotes capture, conveyance and retention of stormwater within the road itself or center of ROW reducing the need for vertical curbing, curb inlets, and additional gray infrastructure typically found on a normal crowned urban road section. In turn, this can reduce the cost to construct and maintain the road and stormwater infrastructure. While not applicable on all City roads, an inverted crown section could address concerns of shedding stormwater from roadways onto private property.

5. Identification and Prioritization of Tidal Flood Adaptation Projects

The list of capital projects resulting from various planning processes and master plans, including the Stormwater Master Plan, utility R&R study, Transportation Master Plan, Blueways Master Plan, GO Bond project list, and the broader City Capital Improvement Program (CIP)project list, did not include a comprehensive list of roadraising projects based on flood risk. In order to incorporate these road raising projects into the capital project prioritization analysis performed in Task 3, a full list of road raising projects was required to be prepared. This section discusses the process used to develop and rank this project list for inclusion into Task 3, Project Grouping and Prioritization.

5.1 Delineation of Tidal Flood Adaptation Projects by Flood Risk

Roads that have a current risk of flooding were identified based on the latest available topographic data, from the Miami Dade County 2018 LiDAR ground surface digital elevation model. Roads were categorized based on the same groupings of frequency of flood risk and road type that were used for the road elevation strategy. Road types were sorted into local, major, and emergency road categories. Levels of flood risk were defined as shown in Table 3, which follows the same breakdown presented previously in Table 1 for the road elevation strategy. Figure 8 shows the distribution of roads by flood risk category throughout Miami Beach.

Table 3. Road Flood Risk Categories Used to Delineate Tidal Flood Adaptation Projects

Flood Risk Categories (Annual Percent Chance of Tidal Flooding)	Road Elevation Ranges for Each Corresponding Level of Tidal Flood Risk
50% or greater	Less than 1.7 ft
20% to 50%	1.7 to 2.3 ft
10% to 20%	2.3 to 3.0 ft
Less than 10%	Above 3.0 ft

Note: All elevations are in feet NAVD88.

The tidal flood risk mapping information shown on Figure 8 was used to delineate possible road elevation projects that could mitigate risk of tidal flooding, referred to as TFAPs. Recognizing that resources for capital projects are limited and work will have to be phased, the focus for delineation of TFAPs was on areas currently at highest risk. Therefore, the delineations focused primarily on pulling contiguous areas of greater than 20 percent chance of flooding shown in red and orange on Figure 8, but streets with slightly lower risk (yellow and green) that connected nearby higher risk streets were sometimes included to form discrete TFAP project areas. TFAPs were generally split at neighborhood boundaries even if roads at risk continued into adjoining neighborhoods.

Figure 9 shows the results of TFAP delineation. After discussion of the initial results, the City decided to exclude TFAP projects that were already in progress or in the initial phases of planning and design. The road raising project areas excluded from analysis included:

- Sunset Islands 3 and 4
- Sunset Harbor
- Palm and Hibiscus Islands
- Indian Creek (lower)
- Venetian Isles
- West Ave.
- Lower North Bay Road
- 1st Street

The TFAPs that Jacobs had identified for these areas were either deleted or were split to only include new areas that were not included in the existing City projects, most notably areas east of Alton Road that were not included in the West Ave. project, and Collins Ave. parallel to the Indian Creek Drive.

Lengths of Road by Elevation**

Elevation Range	Miles
0-1.7	8.2
1.7-2.3	32.1
2.3-3	48.8
>3	94.5

Figure 8. Distribution and Length of Roads in the City of Miami Beach Based on Four Tidal Flood Risk Categories (Based on 2018 LIDAR, may not reflect recent City road elevation projects)

Figure 9. Tidal Flood Adaptation Projects

5.2 Summary of TFAP Distribution of Flood Risk by Road Type

The result of the delineation of TFAPs was 65 different road elevation project areas, with a total length of 41.3 miles representing 22.5 percent of the approximately 184 total miles of City, County, and State roads in Miami Beach. The length of the TFAPs varies significantly, from 110 linear feet to 14,500 linear feet. Figure 10 summarizes the distribution of total length of all road types in the TFAPs, broken down by project type and tidal flood risk.

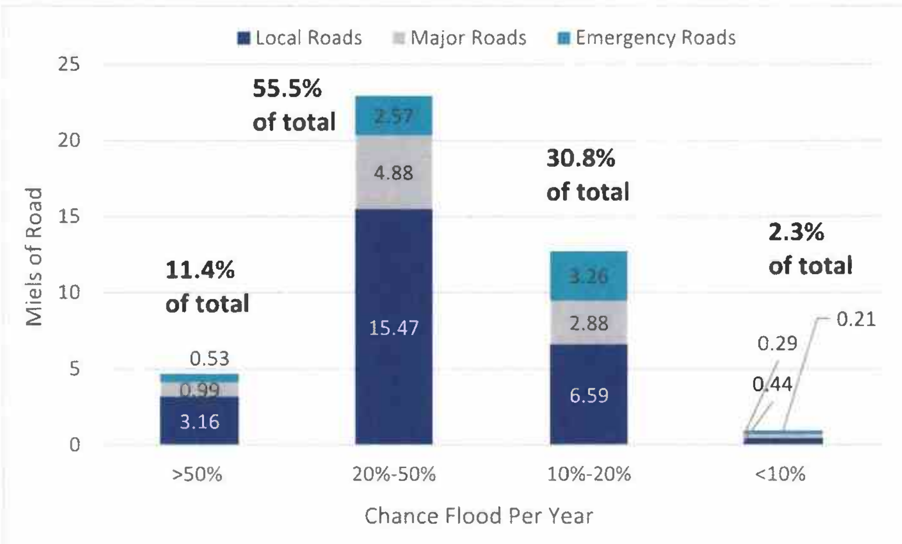


Figure 10. Distribution of Length of Roads by Type and Risk Category Combined for All Tidal Flood Adaptation Projects

The TFAPs project areas were then analyzed with geographic information system tools to develop a project-by-project summary of the length of roads by type and by risk category. Figure 11 shows the results of that analysis.

5.3 Development of a Risk Score and Ranking of TFAPs

The results in Figure 11 were then used to assign a risk score to each TFAP. The process involved three steps:

1) Assigning a weight to each combination of road type and flood risk, which reflects the relative importance of mitigating risk for a given road type. Jacobs staff developed weights to assign to each type of road and risk combination, as shown in the matrix in Table 4.
2) The risk level/road type weight is then multiplied by the percentage of road length in each risk/type combination to develop a raw weighted risk score for each TFAP, which does not reflect the overall length of roads in a given TFAP (only its aggregate level of risk).
3) The raw score is then normalized by multiplying the TFAP road length by the overall total road lengths in all TFAP, and then normalized to a maximum score of 10.

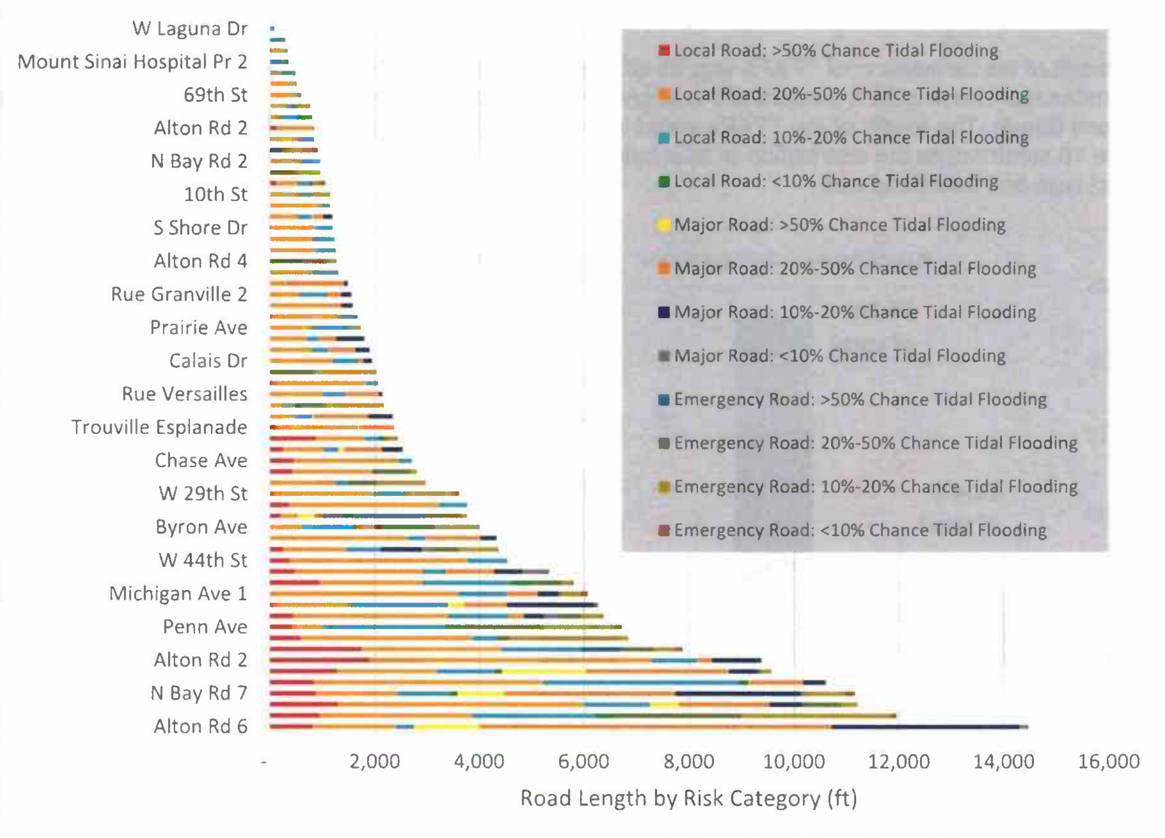


Figure 11. Length of Roads by Type and Flood Risk by Tidal Flood Risk Adaptation Project

Table 4. Matrix of Weights Assigned to Road Type and Flood Risk Level Combinations

	Risk Level			
Road Type	**>50%**	**20% to 50%**	**10% to 20%**	**<10%**
Emergency	100	95	70	20
Major	90	85	50	10
Local	80	70	30	5

Figure 12 shows the normalized risk scores for all TFAPs in rank order. These scores were used in the neighborhood prioritization process. Appendix C contains a map of the TFAPs across the City.

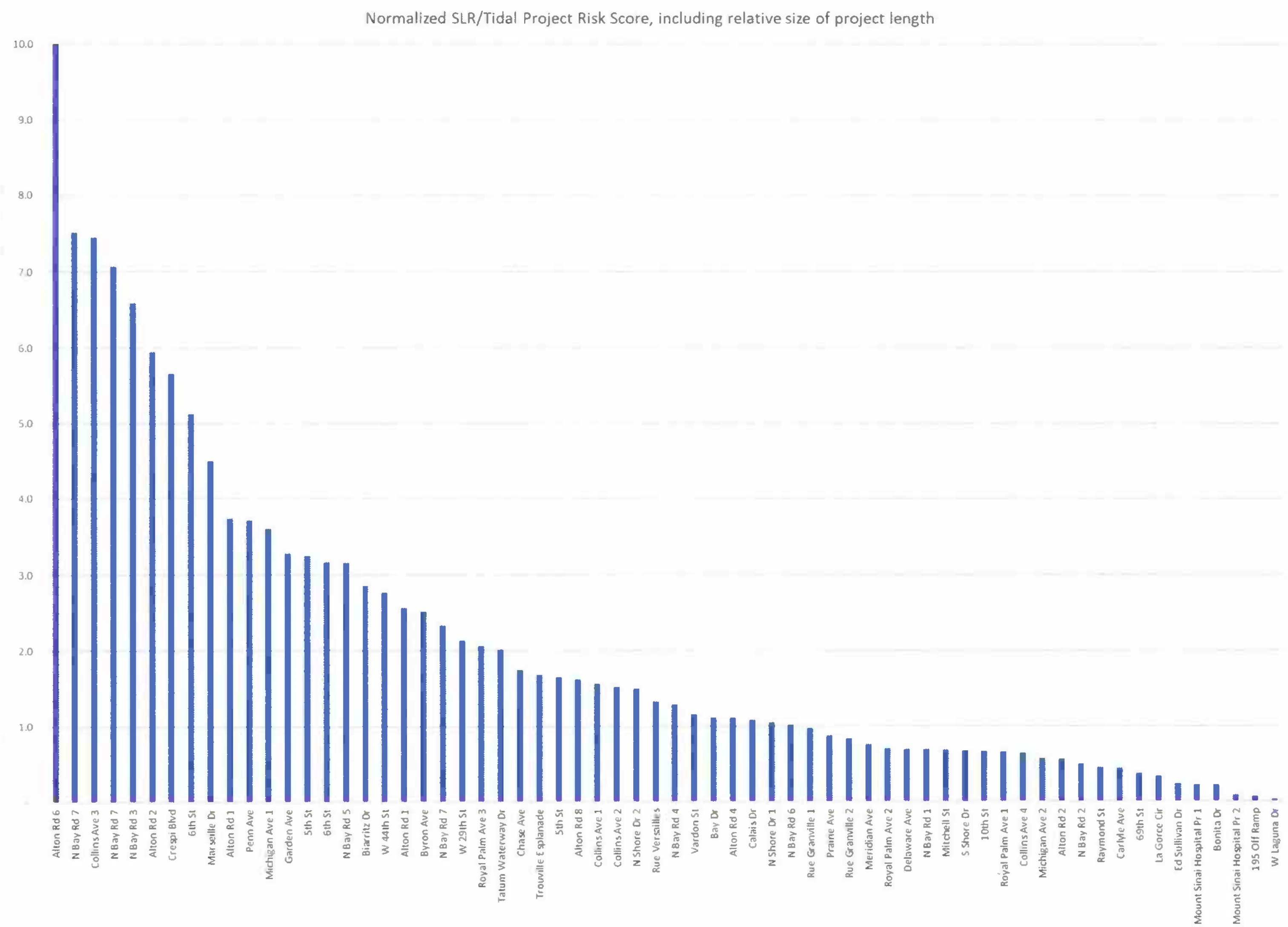


Figure 12. Weighted Risk Score for All Tidal Flood Adaptation Projects, Normalized by Project Total Length

6. Next Steps

The successful deployment of this updated Road Elevation Policy is based on a number of factors, including using the latest SLR projections, consistent application across all City road projects, well-defined and easy-to-follow guidance, particularly related to the hardship situations (variance), multi-departmental collaboration for complete street application, pilot testing of policy, and public engagement related to the participation and transparency of the policy development and use. These aspects should be incorporated into this process to position for the best possible success in launching the new road elevation policy for all City road projects.

The process undertaken to develop this new policy involved collaboration with the City's Ready Team to incorporate ongoing efforts and to capture the broader City needs and a public outreach campaign to build public trust and consensus for the City's new road elevation policy, which is intended to address the frequent road flooding (sunny day flooding, in particular), poor pavement performance, and the related increased operation and maintenance costs.

The process for completion and adoption of this policy includes the following anticipated steps:

1) City final review and acceptance of policy recommendations and TFAP projects
2) Present final policy recommendations and TFAP projects to City Commission for approval and referral to City staff to incorporate into City policy

Appendix A
Flood Exposure - Level of Service Analysis

JACOBS

Memorandum

3150 SW 38th Avenue, Suite 700
Miami, FL 33146
T 305.441.1846
F 305. 443.8856
www.jacobs.com

Subject	**Road Elevation Strategy: Updates to Design Road Elevations and Typical Road Sections, with Harmonization Considerations**
Project Name	Integrated Water Management – Work Order 1 – Task 2
Attention	City of Miami Beach
From	Jacobs
Date	October 18, 2019

Executive Summary

This memo outlines recommendations for updated design road elevations (DREs) based on updated analysis and/or data for the following:

- Frequency of high-water surface elevations (WSEs), irrespective of whether high WSEs are driven by astronomical tide or wind-driven water level increases
- Sea level rise (SLR) projections
- Clearance requirements are based on protecting road strength vs. minimizing road flooding at either the edge of road/edge of pavement (EOP) or crown of road

The updated recommendations herein are not based on a single target DRE. Instead, DRE recommendations vary based on the following road type:

- Emergency access roads
- Commercial
- Residential[1]

Rather than specifying a one-size-fits-all DRE guidance, this approach balances road raising with the criticality of the roads in question and/or number of residents/businesses served.

The recommended approach for establishing minimum road elevations involves the evaluation of two different road elevation constraints for any given road to determine the final design road elevation:

- The road elevation at the EOP that allows for limited flooding, based on level of service and sea level rise specified by road type
- The road elevation at the bottom of the road base that prevents saturation of the road base due to high groundwater (from high tide with sea level rise)

[1] These three categories are meant to be generic for ease of communication. They are assumed to apply to the following road classifications used by the City: emergency roads include "Principal Arterial" and "Major Collector" roads; commercial roads include "Minor Arterial" and "Minor Collector" roads; and residential roads include "Local" roads.

Of these two methods, the one resulting in the highest elevation should be used as the limiting factor. Table ES-1 summarizes the two methods of calculating DREs for all categories of roads. Based on the assumptions given in Table ES-1, Method 2 should be used for all roads, except for emergency roads. Therefore, the DRE for roads built in 2020 should be 3.9 feet (ft) NAVD for residential or commercial roads and 4.8 ft NAVD for emergency roads, unless harmonization constraints prevent using those targets. All roads should have a minimum bottom of road base elevation of 2.9 ft NAVD.

As presented in Attachment A, DREs should increase for roads built in later years to reflect the increasing sea levels anticipated to be present at that time.

Figure ES-1 illustrates the calculation of the minimum elevation for the bottom of road base (Method 2), which applies to all road types. Figure ES-2 illustrates the calculation for minimum elevation of the EOPs with Method 1, which applies to emergency roads because Method 1 produces a higher elevation than Method 2. Figures ES- 3 and 4 illustrate the calculation for commercial and residential roads, respectively, of minimum elevation of the EOP with both Methods 1 and 2. These figures show that Method 2 should be selected as it results in a higher elevation at the EOP of 3.9 ft, at least in the case of 2020 project start and a minimum pavement section depth of 1 ft.

Table ES-1. Summary of Design Road Elevation Methods for Roads Built in 2020

All elevations are in NAVD88.

	Method 1 – Limited Flooding at Edge of Roada			Method 2 – Limited Tidal Wetting of Road Basea
Applicability	Residential Roads	Commercial Roads	Critical Access Roads	
Level of Service	Minimum Standard to Avoid Flooding from 50% Chance Tide + Surge Event (2-yr), with SLR for 30 Years	Minimum Standard to Avoid Flooding from 20% Chance Tide + Surge Event (5-yr), with SLR for 30 Years	Minimum Standard to Avoid Flooding from 10% Chance Tide + Surge Event (10-yr), with SLR for 30 Years	All Roads, Road Base + Road Thickness
Current Probability of Flooding	50%	20%	10%	MHHW
Baseline Water Surface Elevation	1.7 ft	2.3 ft	3.0 ft	0.6 ft
Sea Level Rise	1.3 ft	1.3 ft	1.8 ft	1.3 ft
SLR Rationale	30 years, NOAA 2017 Intermediate-High Curve	30 years, NOAA 2017 Intermediate-High Curve	30 years, NOAA 2017 High Curve	30 years, NOAA 2017 Intermediate-High Curve
Road and Base Thickness (varies)	N/A	N/A	N/A	1.0 ft[b]
Road Base Clearance Above SHGWT (freeboard)	N/A	N/A	N/A	1.0 ft
Min. Road Elev. (edge of pavement)	**3.0 ft[c]**	**3.6 ft**	**4.7 ft**	**3.9 ft[b]**

[a] The higher design road elevation calculated by the two methods should be selected.

[b] Where road design thickness is greater than 12 inches (1.0 ft) inclusive of base material and pavement (base and wear course), the difference in additional thickness should be added to the minimum road elevation.

[c] Road elevations less than 3.5 ft using Method 1 will be influenced by Method 2 as the limiting factor.

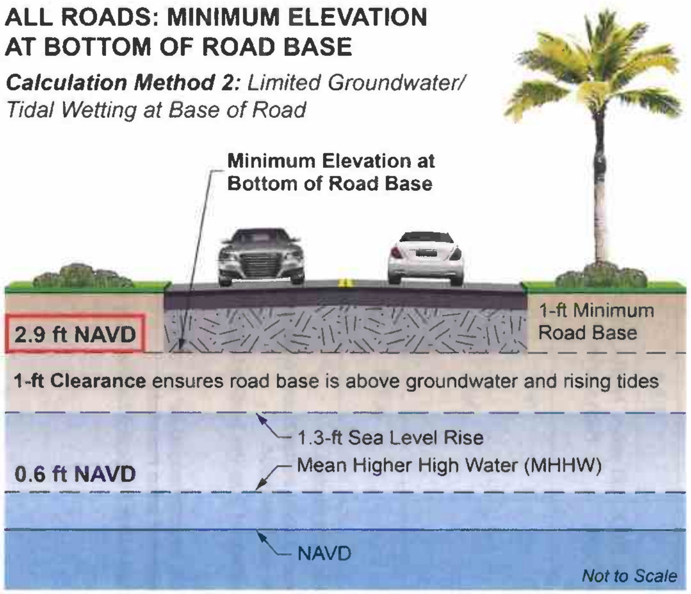
Note:

A 1-ft freeboard above the seasonal high groundwater elevation is highly recommended for all road base materials, although the effects on hardened base materials will be minimal compared to conventional base materials.

The SLR projection factored into the minimum road elevation will provide some freeboard for the early years of the pavement system, which will diminish over time as the water levels increase.

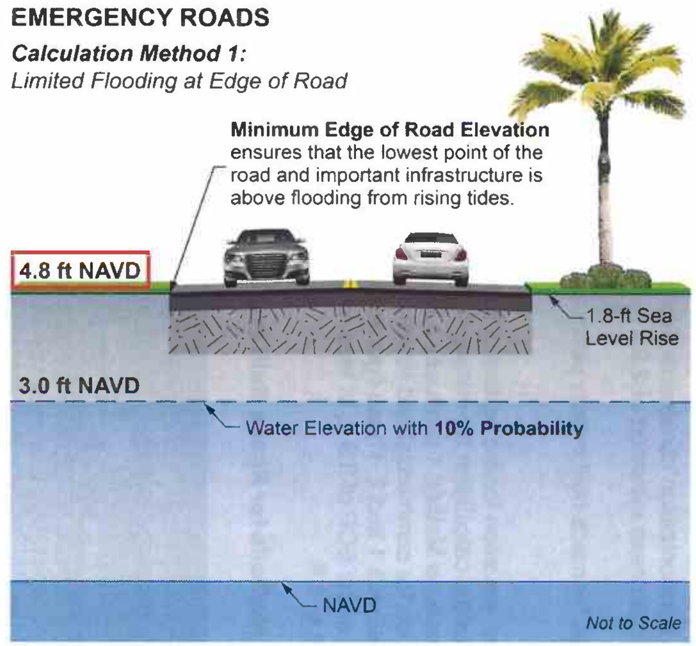
NOAA = National Oceanic and Atmospheric Administration

SHGWT = seasonal high groundwater table



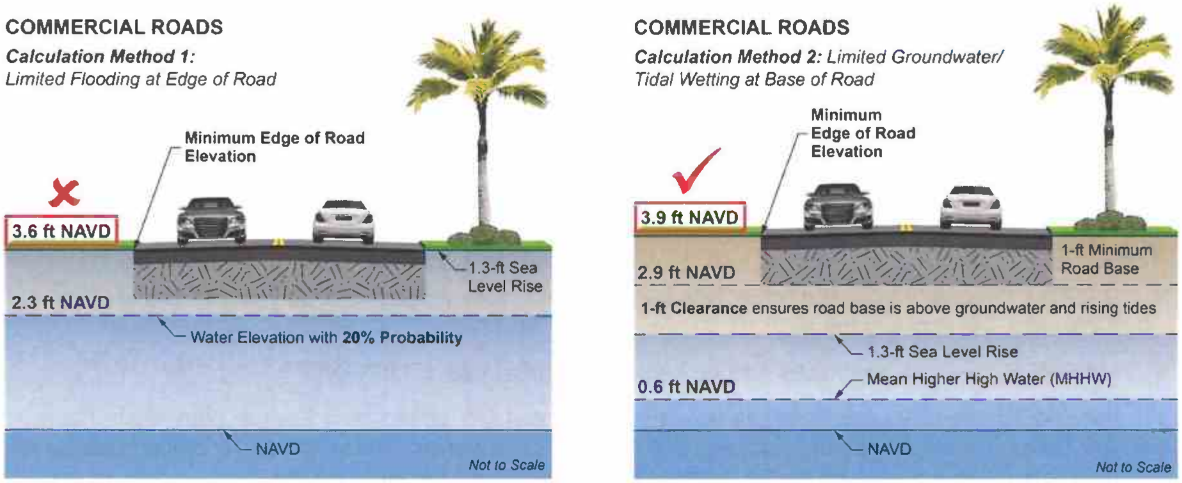
Method 2 is used to set Minimum Elevation of the Bottom of Road Base: 2.5 ft NAVD for projects built in 2020.

Figure ES-1. Minimum Bottom of Road Base Elevation



For Emergency Roads, Method 1 results in higher Minimum Elevation at the Edge of Road for projects built in 2020.

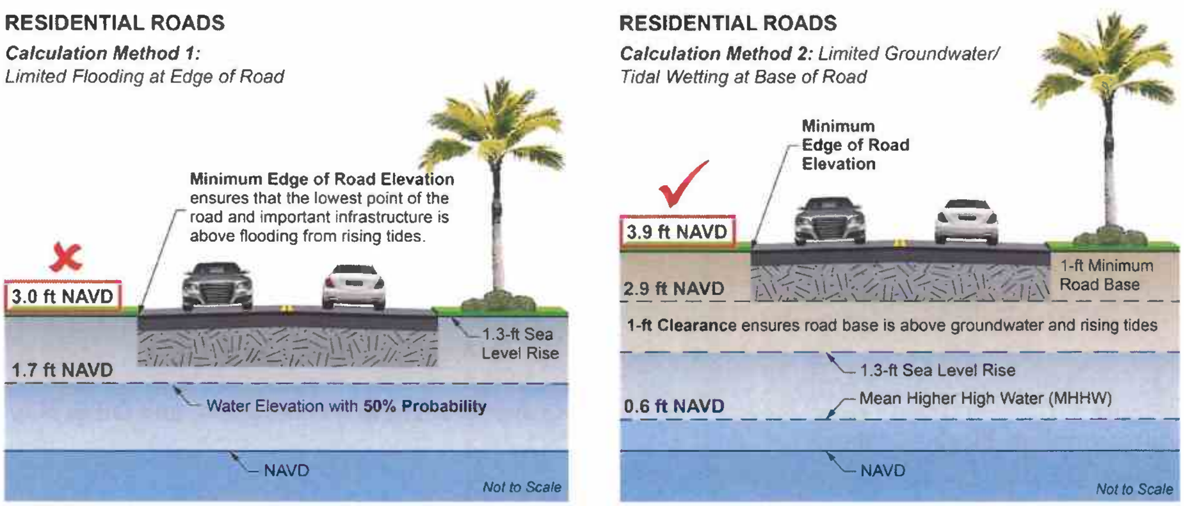
Figure ES-2. Minimum Edge of Road Elevation for Emergency Roads is Set by Method 1, as it results in Higher Elevation than Method 2



For Commercial Roads, Method 2 results in higher Minimum Elevation at the Edge of Road, assuming projects with 1-ft road thickness and built in 2020.

Figure ES-3. Comparison for Commercial Roads of Minimum Edge of Road Elevation Calculation by Both Methods 1 and 2

Method 2 results in higher elevation than Method 1 and should be selected.



For Residential Roads, Method 2 results in higher Minimum Elevation at the Edge of Road, assuming projects with 1-ft road thickness and built in 2020.

Figure ES-4. Comparison for Residential Roads of Minimum Edge of Road Elevation Calculation by Both Methods 1 and 2

Method 2 results in higher elevation than Method 1 and should be selected.

1. Introduction

1.1 Background

The current design road elevation (DRE) target for the City of Miami Beach (hereafter, the "City") is for the crown of the road to be at or above 3.7 feet (ft) NAVD (North American Vertical Datum of 1988). This DRE guidance was set in 2013 (referred to below at DRE13) based on the following assumptions and data inputs:

- DRE13 = (Highest Measured "King Tide") + (Sea Level Rise projected in 30 years) + (Base Clearance), as outlined below:
- For DRE13, the City estimated that the highest king tide[2] was 1.7 ft NAVD
- For DRE13, the City calculated sea level rise (SLR) of 1.0 ft, based on a 30-year planning horizon, with the U.S. Army Corps of Engineers 2015 High SLR curve included in the 2015 Unified Sea Level Rise Projection adopted by the Southeast Florida Regional Climate Compact.[3]
- For DRE13, the City referred to Florida Department of Transportation (FDOT) guidance of at least 1 ft for minimum base clearance above high water to the crown of the road.[4]

The resulting DRE13 guidance is road elevations should be set at 3.7 ft NAVD, as illustrated on Figure 1.

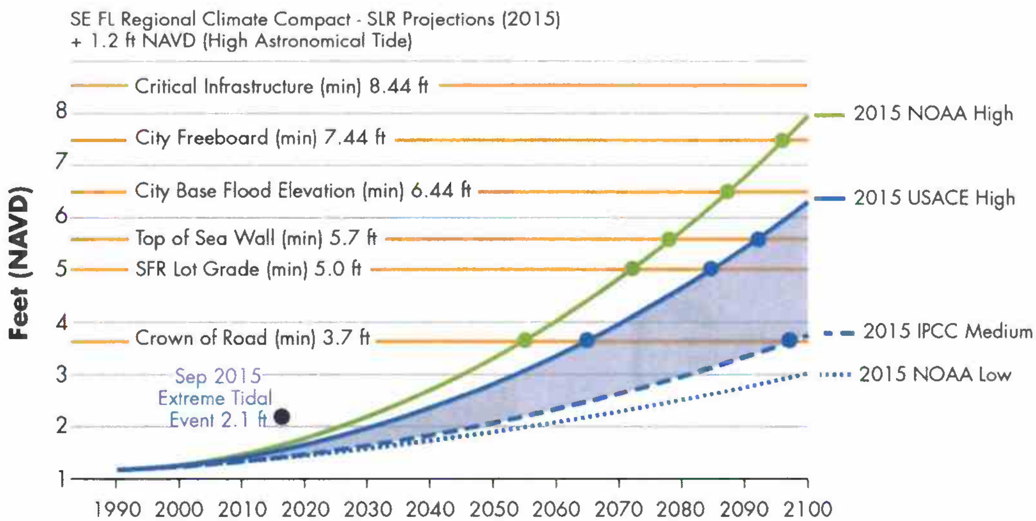


Figure 1. Current Design Road Elevation Basis for Crown of Road in Miami Beach, and Other Key Infrastructure Elevation Metrics

These elevation standards were established in 2013.

[2] The term "King Tide" used previously by the City was not technically accurate. Tidal water surface elevations are based on lunar cycles, referred to as "astronomical tide." It does not include any variations in water surface elevations that result from wind strength and direction, which can vary from increases in water level to significant increases associated with tropical storms, generally referred to as "storm surge." King tides technically only refer to the highest astronomical tides, when lunar high tides are at their greatest (typically in September through October), independent of any wind-driven water level increase. The City's previous 1.7 ft king tide includes some wind-driven increase in water elevations, as explained herein.

[3] Southeast Florida Regional Climate Change Compact. 2015. Sea Level Rise Work Group. *Unified Sea Level Rise Projection for Southeast Florida*. August 12.

[4] Florida Department of Transportation. 2019. *STRUCTURES DESIGN GUIDELINES*. January. https://www.fdot.gov/structures/structuresmanual/currentrelease/structuresmanual.shtm

1.2 Purpose and Outline

This section outlines recommendations for updated DREs, referred to hereafter as DRE2020+[5], based on updated analysis and/or data for:

- Frequency of high-water surface elevations (WSEs), irrespective of whether high WSEs are driven by astronomical tide or wind-driven water level increases
- SLR projections
- Clearance requirements are based on protecting road strength vs. minimizing road flooding at either the edge of road/edge of pavement (EOP) or crown of road

The updated recommendations in this section are not based on a single target DRE. Instead, DRE recommendations vary based on road type:

- Emergency access roads
- Commercial
- Residential[6]

Rather than specifying a one-size-fits-all DRE guidance, this approach balances the cost of road raising with the criticality of the roads in question and/or number of residents/businesses served.

The DRE guidelines outlined herein should be viewed as target road elevations. The target road elevations are considered guidelines that can be adjusted downward if warranted by local harmonization constraints between road edge and adjacent drainage infrastructure, sidewalks, and building finished floor elevations. However, Jacobs recommends that if lower elevations are adopted that the approximate level of service (LOS) provided (current and project frequency of flooding) be reviewed before a variance is allowed.

The elevations presented herein presume road construction in 2020. Attachment A presents tabular recommendations for road elevations assuming road construction in subsequent years, based on the SLR curves discussed below and in Attachment B.

Road surface elevation recommendations specified herein relate only to flooding from rising sea levels related to tide and/or storm surge. It does not address frequency of flooding and LOS recommendations related to rainfall runoff and associated drainage infrastructure.

2. Methodology and Updates to Key Input Variables

2.1 Three Components of Road Elevation Guidance

As previously stated, the recommended DRE approach includes three different factors, resulting in different DRE values for each of three road categories. The three factors are:

1) LOS – essentially the frequency of flooding that would be allowed at the end of planning horizon for road service life, assumed to be 30 years.
2) SLR between project implementation and the end of the 30-year planning horizon.
3) Controlling elevation on road section: EOP or bottom of road base. For a given road, two types of calculations should be conducted based on different locations along the road section. The higher of the two elevations that are calculated should be controlling:

[5] The "DRE2020+" acronym is meant to convey that it applies to projects implemented in either 2020, or has a sliding scale that allows for upward increases in the DRE for projects implemented after 2020 (thus, the "+" sign).

[6] These three categories are meant to be generic for ease of communication. They are assumed to apply to the following road classifications used by the City: emergency roads include "Principal Arterial" and "Major Collector" roads; commercial roads include "Minor Arterial" and "Minor Collector" roads; and residential roads include "Local" roads.

a) Calculate the minimum road elevation at the EOP. Using the EOP allows for flooding in the gutter pan of the road during high sea level conditions (high tide or wind-driven surge events)

b) Calculate minimum road elevation based on bottom of the road base. The thickness of the road base would then determine the elevation of the EOP. Road slope would then determine the crown elevation. The thickness of the road depends on road construction materials.

Figure 2 outlines the decision-making process to arrive at a DRE for a given type of road.

The basis for the numerical values for each parameter is detailed in section 3.2 to 3.4.

2.2 Level of Service – Historical Frequency of High-Water Levels

As previously stated, the recommended approach includes three different target LOS for frequency of flooding, such as 50-percent chance (flooding approximately once every 2 years), 20-percent chance (flooding approximately once every 5 years), and 10-percent chance (flooding once every 10 years). Those frequencies are determined based on analysis of historical water surface elevation data.

Table 1 and Figure 3 show an analysis of the long-term records available at NOAA's Virginia Key tide gage station adjacent to Miami Beach, which summarizes the probability of a given water surface elevation.[7] Table 1 is based on all high water elevation data, irrespective of whether data are from tidal variations (astronomical tides due to lunar cycles) or from wind and surge. For example, Table 1 shows that a maximum water surface elevation of 3.0 ft NAVD has a 10-percent chance of occurring any given year.

Table 1. Probability of High-Water Surface Elevations in Miami Beach[a]

Annual Probability	Return Period (yr)[b]	Extreme Water Surface Elevation (ft NAVD)
200%	0.5	1.4
100%	1	1.5
20%	5	2.3
10%	10	3.0
4%	25	4.2
2%	50	5.6
1%	100[c]	7.1

[a] Based on extreme value analysis, Virginia Key (1994 to 2018 record length = 25.5 years). Includes all water surface elevation data, tidal and wind/surge related.

[b] The term "return period" is more commonly used, and is interchangeable with probability. For example, at 5-year storm is equal to 100/5 or 20%. However, the term "return period" is discouraged because it can lead to incorrect interpretations that a 5-year storm, for instance, will only occur once in 5 years, when in fact it means that it has a 20% chance of occurring in any given year on average.

[c] It is typically required that the data length be at least three times the largest return period sought, 100/3 = 33.3 yr. Therefore, the results for the 100-year event has more uncertainty associated with its estimation and should be used with caution.

[7] NOAA. Tides & Currents. https://tidesandcurrents.noaa.gov/datums.html?id=8723214

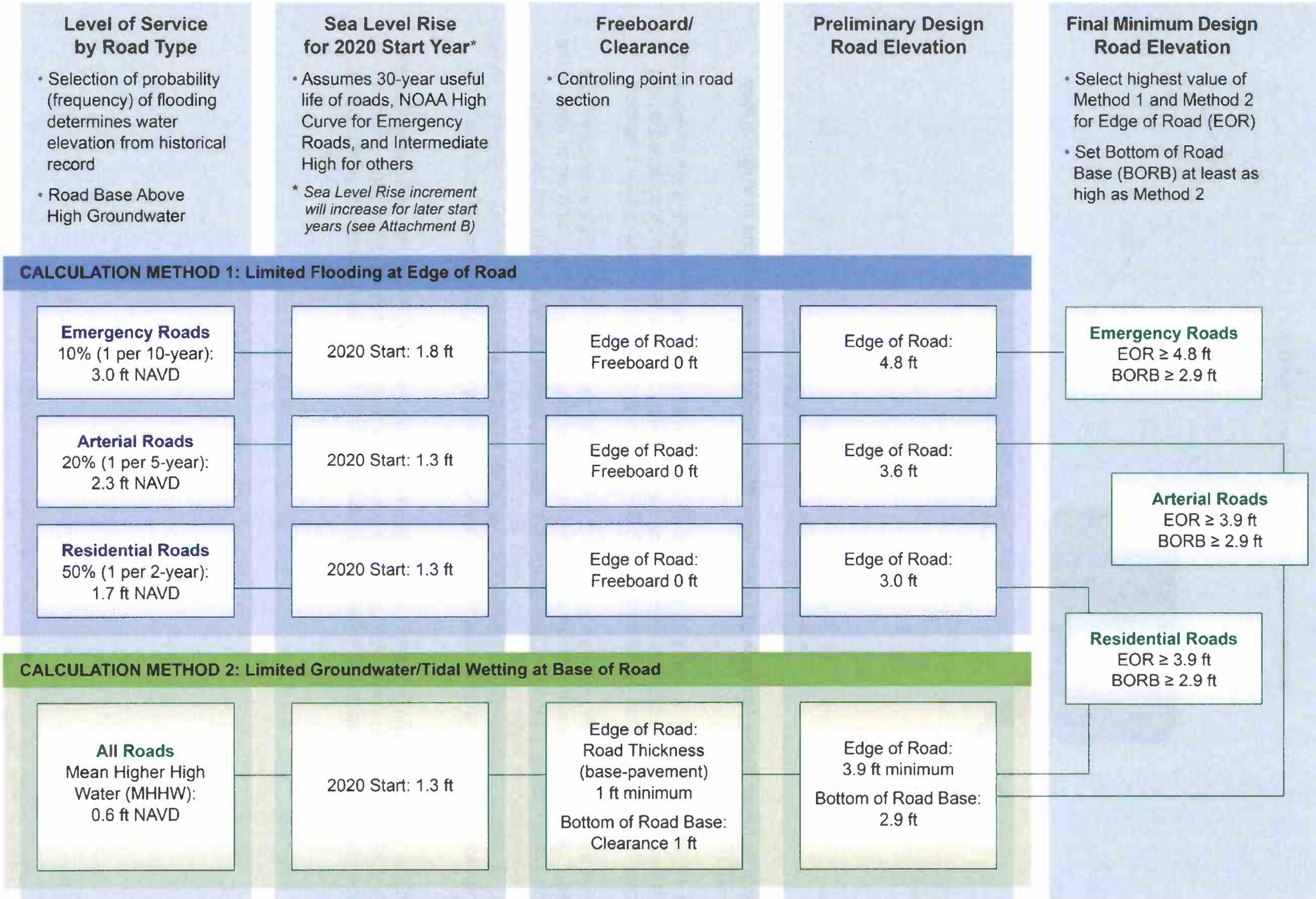


Figure 2. Decision Making Process for Design Road Elevations

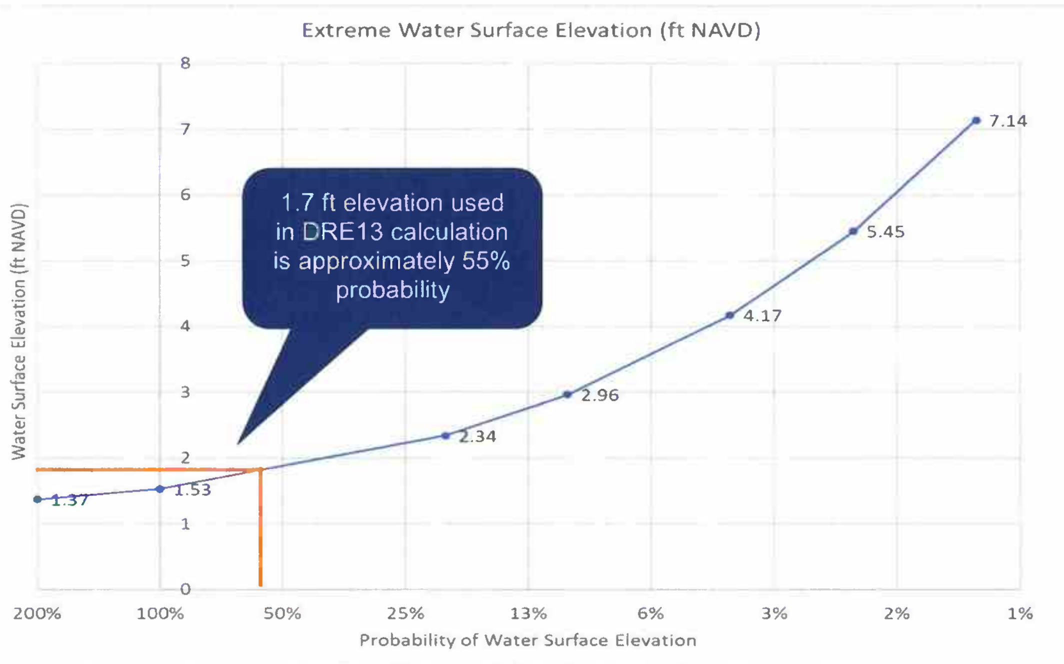


Figure 3. Extreme Value Analysis of Long-Term Water Surface Elevation Data at Virginia Key (1994–2018)

Figure 4 shows the maximum water surface elevation observed each year for the 25 years of record at Virginia Key. The highest recorded water surface elevation was 3.84 ft NAVD, which occurred during Hurricane Irma in 2017. That elevation of 3.84 ft NAVD has a probability of approximately 5 percent.

Note that the City incorrectly referred to the 1.7 ft NAVD WSE used in the DRE13 determination as a "king tide". A king tide is the maximum astronomical tide that occurs when the sun and moon align in the fall. This water elevation can be increased by local weather, leading to wind-driven and barometric pressure increases in water surface elevations. Similarly, the previous WSE used by the City was 1.7 ft NAVD, which has approximately a 55-percent probability in any given year (see Table 1). Figure 3 shows this graphically. The highest king tide predicted by NOAA during the 25-year period of record is 1.1 ft NAVD.

The NOAA tide station data indicates that the mean higher high water (MHHW) for the Virginia Key tide gage is 0.20 ft NAVD.[8] However, that value was based on a tidal epoch from 1983 to 2001, which is outdated given SLR. An update MHHW was calculated as 0.6 ft NAVD, as described in Attachment C.

[8] NOAA. Tides & Currents. https://tidesandcurrents.noaa.gov/datums.html?id=8723214

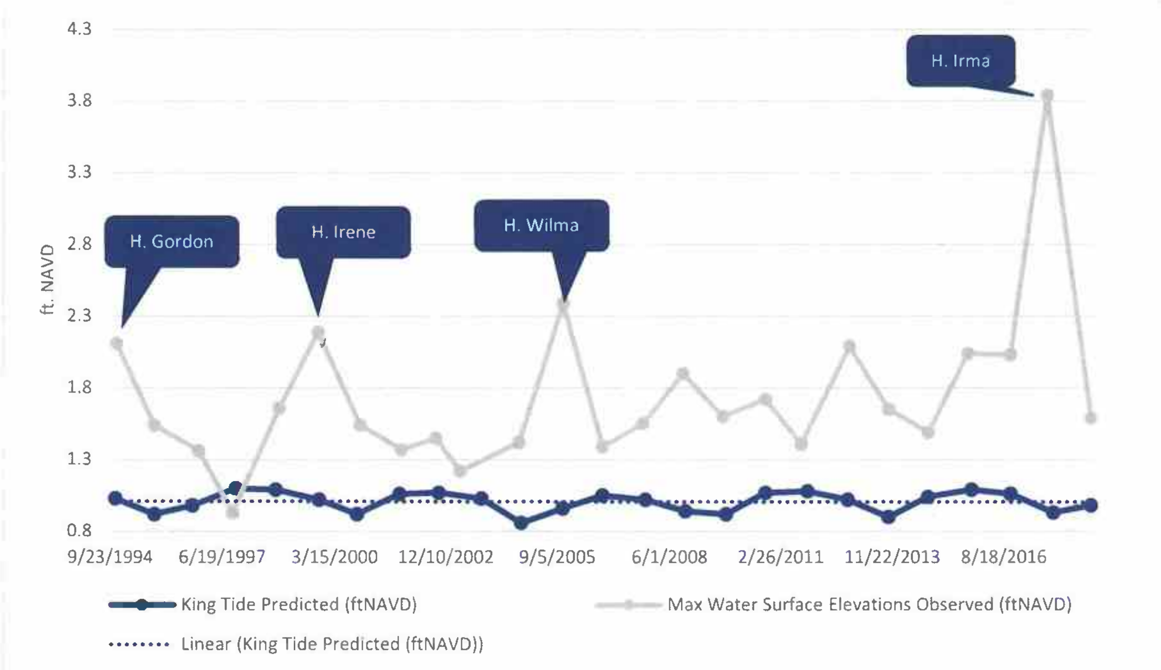


Figure 4. Annual Maximum Water Surface Elevation and Predicted King Tides (Highest Astronomical Tide) Each Year at Virginia Key (1994–2018)

The LOS for roads in Miami Beach is a choice the City needs to make based on a balance of risk versus cost. A higher LOS equates to a lower probability of flooding and a higher road elevation. The higher the road elevation, the higher the cost both in road construction and in harmonization. Table 2 provides Jacobs' recommendations on LOS to provide for the three categories of road and the corresponding probabilities of flooding and water surface elevations.

Table 2. LOS Recommendations by Road Type

Historical water surface elevations for each assumed probability of flooding target

Road Type	Level of Service – Probability of Flooding in a Given Year	Water Surface Elevation for Given LOS
Residential Roads	50% chance (2-year storm)	1.7 ft NAVD
Commercial Roads	20% chance (5-year storm)	2.3 ft NAVD
Emergency Roads	10% chance (10-year storm)	3.0 ft NAVD

Note: All water surface elevations reflect current historical estimates for a given probability of flooding (LOS).

2.3 Sea Level Rise – Projection Curve Selection and Planning Design Horizon

The previous design road elevation guidance for the City was based on the most current approved set of SLR projection curves that were adopted in region, the 2015 Unified Sea Level Rise Projection adopted by the Southeast Florida Regional Climate Compact (SEFLCC).[9] More recent sea level rise projections were published by NOAA in 2017.[10] These NOAA 2017 projections are used in this guidance document. However, the framework presented herein can be readily updated when new projections are available from SEFLCC, as is expected in December 2019.

[9] Southeast Florida Regional Climate Change Compact. 2015. Sea Level Rise Work Group. *Unified Sea Level Rise Projection for Southeast Florida*. August 12.

[10] NOAA. 2017. *GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES*. NOAA Technical Report NOS CO-OPS 083. January.

Figure 5 and Table 3 summarize SLR projections available from NOAA 2017. Figure 5 shows all five curves available from NOAA 2017, which are relative to 2000 baseline. Table 3 has converted the top four curves to a tabular format and adjusted the start year baseline to 2020.

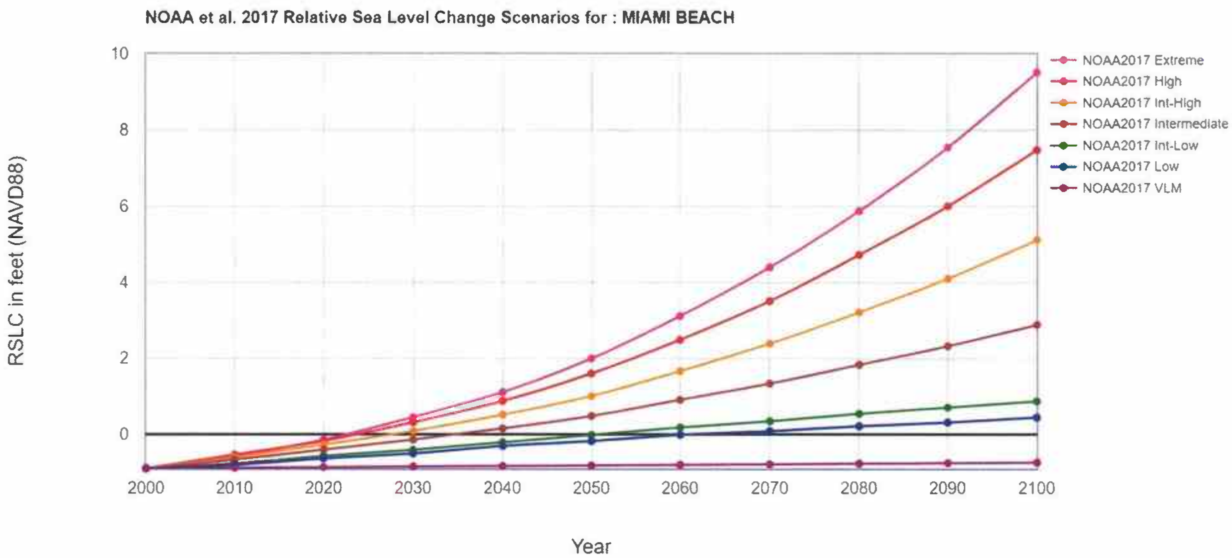


Figure 5. NOAA 2017 Relative Sea Level Rise Projections for Miami Beach

Table 3. Relative Sea Level Rise Projections for Miami Beach

		SLR Increment from 2020 NOAA (2017) Curve			
Year	Road Useful Life	Intermediate	Intermediate-High	High	Extreme
2020	0	0	0	0	0
2030	10	0.3	0.4	0.5	0.6
2035	15	0.4	0.6	0.8	0.9
2040	20	0.6	0.8	1.1	1.3
2045	25	0.7	1.0	1.4	1.7
2050	30	0.9	1.3	1.8	2.1

Source: NOAA. 2017. *GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES*. NOAA Technical Report NOS CO-OPS 083. January.

All numbers have been rounded to nearest 0.1 ft.

Deciding which SLR projection to use for setting road design elevations includes two key considerations:

- Determining the useful life of the road
- Deciding which SLR projection curve to use

The useful life of a road is between 20 and 30 years, depending a range of factors including materials, traffic loads, and wet/dry cycles. This includes the entire road section, not just the top pavement layer, which generally has a shorter useful life of approximately 15 years. Jacobs agrees with earlier City assumption that the SLR for road elevation calculations can be based on a 30-year useful life of the road.

Jacobs recommends adopting the Intermediate-High Curve with a 30-year useful life of roads for less critical commercial and residential roads and adopting the High Curve for critical emergency access roads. This is consistent with the framework presented by the SEFLCC where higher SLR projection curves are recommended for more critical infrastructure. Therefore, for a residential or commercial road built in 2020, a rise of 1.3 ft should be considered and for an emergency access road built in 2020 a rise of 1.8 ft should be considered.

The choice of SLR curve to use should recognize that there is uncertainty in the climate science that is the source of the projections, just as there is uncertainty in all master planning projections of population and economic growth. Attachment B summarizes probabilities associated with the different SLR projection curves, as well as recent scientific literature providing evidence of acceleration in measured rates of SLR both in Florida and in global mean sea level.

2.4 Summary of Design Road Elevation at Edge of Road (Method 1) and Bottom of Road Base (Method 2)

As previously indicated, two different road elevation constraints should be evaluated for any given road to determine the final design road elevation:

- The road elevation at the EOP that allows for limited flooding, based on LOS and SLR specified by road type
- The road elevation at the bottom of the road base that prevents wetting of the bottom of the road section resulting from high groundwater (from high tide with SLR)

Of these two methods, the one resulting in the highest elevation should be used. Table 4 summarizes the two methods of calculating design road elevations for all categories of roads. Based on the assumptions given in Table 4, Method 2 should be used for all roads except emergency roads. Therefore, the DRE for roads built in 2020 should be 3.9 ft NAVD for residential or commercial roads and 4.8 ft for emergency roads, unless harmonization constraints prevent using those targets.

It should be noted that Method 2 lists an assumption of a clearance of 1 ft from groundwater elevation at high tide, given by MHHW, to the bottom of the road base. However, at the beginning of the 30-year life of a road, there actually is a greater clearance including the allowance for SLR. For example, for residential roads that clearance is 1.3 + 1 = 2.3 ft. It should also be noted that Method 2 assumes a road thickness of 1 ft for the base and pavement layers.

As presented in Attachment A, DREs should increase for roads built after 2020 reflecting the increasing rate of SLR, as shown on Figure 5.

Figure 6 illustrates the calculation of the minimum elevation for the bottom of road base (Method 2), which applies to all road types.

Figure 7 illustrates the calculation for minimum elevation of the EOPs with Method 1, which applies to emergency roads because Method 1 produces a higher elevation than Method 2.

Figures 8 and 9 illustrate the calculation for commercial and residential roads, respectively, of minimum elevation of the EOP with both Methods 1 and 2. These figures show that Method 2 should be selected because it results in a higher elevation at the EOP of 3.9 ft (assuming a 2020 project start and a minimum road base of 1 ft).

Table 4. Summary of Design Road Elevation Methods for Roads Built in 2020
All elevations are in NAVD88.

	Method 1 – Limited Flooding at Edge of Road[a]			Method 2 – Limited Tidal Wetting of Road Base[a]
Applicability	Residential Roads	Commercial Roads	Critical Access Roads	
Level of Service	Minimum Standard to Avoid Flooding from 50% Chance Tide + Surge Event (2-yr), with SLR for 30 Years	Minimum Standard to Avoid Flooding from 20% Chance Tide + Surge Event (5-yr), with SLR for 30 Years	Minimum Standard to Avoid Flooding from 10% Chance Tide + Surge Event (10-yr), with SLR for 30 Years	All Roads, Road Base + Road Thickness
Current Probability of Flooding	50%	20%	10%	MHHW
Baseline Water Surface Elevation	1.7 ft	2.3 ft	3.0 ft	0.6 ft
Sea Level Rise	1.3 ft	1.3 ft	1.8 ft	1.3 ft
SLR Rationale	30 years, NOAA 2017 Intermediate-High Curve	30 years, NOAA 2017 Intermediate-High Curve	30 years, NOAA 2017 High Curve	30 years, NOAA 2017 Intermediate-High Curve
Road and Base Thickness (varies)	N/A	N/A	N/A	1.0 ft[b]
Road Base Clearance Above SHGWT (freeboard)	N/A	N/A	N/A	1.0 ft
Min. Road Elev. (edge of pavement)	**3.0 ft[c]**	**3.6 ft**	**4.7 ft**	**3.9 ft[b]**

[a] The higher design road elevation calculated by the two methods should be selected.

[b] Where road design thickness is greater than 12 inches (1.0 ft) inclusive of base material and pavement (base and wear course), the difference in additional thickness should be added to the minimum road elevation.

[c] Road elevations less than 3.5 ft using Method 1 will be influenced by Method 2 as the limiting factor.

Note:

A 1-ft freeboard above the seasonal high groundwater elevation is highly recommended for all road base materials, although the effects on hardened base materials will be minimal compared to conventional base materials.

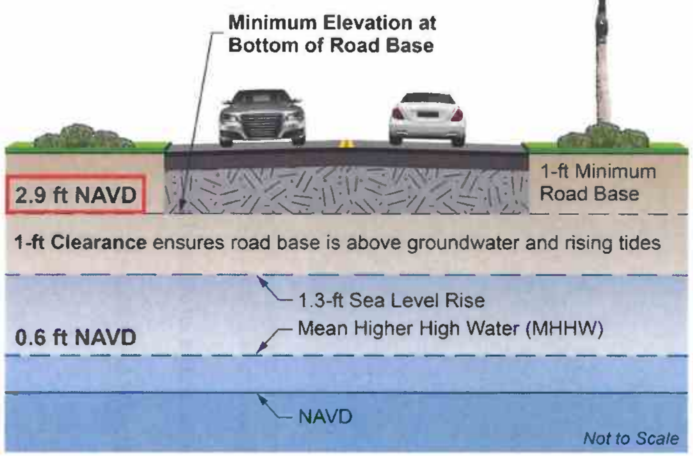
The SLR projection factored into the minimum road elevation will provide some freeboard for the early years of the pavement system, which will diminish over time as the water levels increase.

NOAA = National Oceanic and Atmospheric Administration

SHGWT = seasonal high groundwater table

ALL ROADS: MINIMUM ELEVATION AT BOTTOM OF ROAD BASE

Calculation Method 2: *Limited Groundwater/ Tidal Wetting at Base of Road*

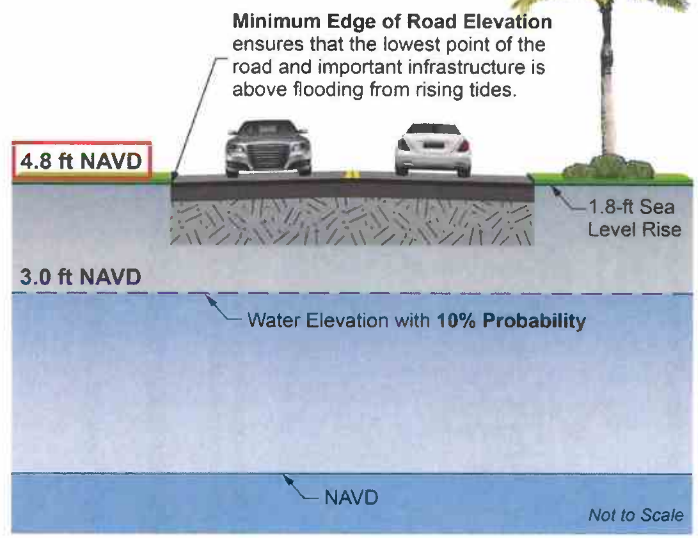


Method 2 is used to set Minimum Elevation of the Bottom of Road Base: 2.5 ft NAVD for projects built in 2020.

Figure 6. Minimum Bottom of Road Base Elevation

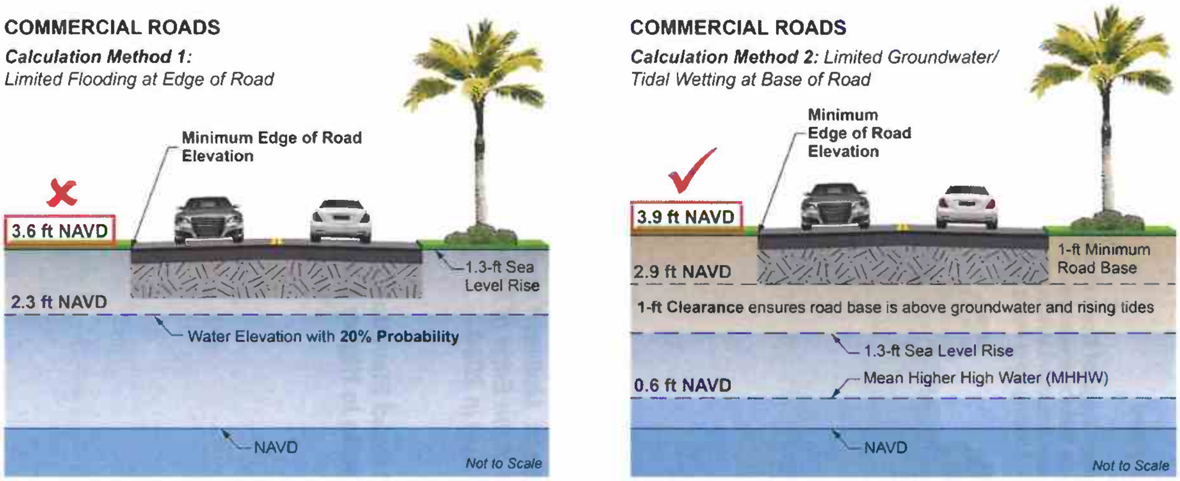
EMERGENCY ROADS

Calculation Method 1:
Limited Flooding at Edge of Road



For Emergency Roads, Method 1 results in higher Minimum Elevation at the Edge of Road for projects built in 2020.

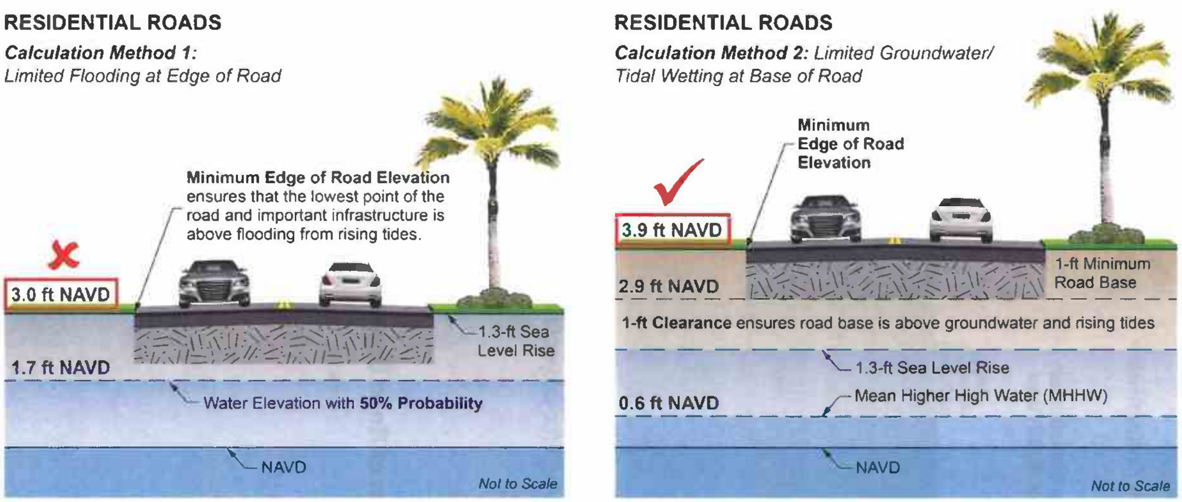
Figure 7. Minimum Edge of Road Elevation for Emergency Roads is Set by Method 1, as it results in Higher Elevation than Method 2



For Commercial Roads, Method 2 results in higher Minimum Elevation at the Edge of Road, assuming projects with 1-ft road thickness and built in 2020.

Figure 8. Comparison for Commercial Roads of Minimum Edge of Road Elevation Calculation by Both Methods 1 and 2

Method 2 results in higher elevation than Method 1 and should be selected.



For Residential Roads, Method 2 results in higher Minimum Elevation at the Edge of Road, assuming projects with 1-ft road thickness and built in 2020.

Figure 9. Comparison for Residential Roads of Minimum Edge of Road Elevation Calculation by Both Methods 1 and 2

Method 2 results in higher elevation than Method 1 and should be selected.

2.5 Road Miles Potentially Requiring Road Raising

Table 5 includes a summary of the road miles potentially requiring road raising given the minimum elevations recommended in Table 4. Figure 10 shows the probabilities of the flood elevations with 1.3 ft of SLR.

Table 5. Road Miles Below Minimum Design Road Elevation by Road Classification

Road Classification	Road Type for Elevation Target	Road Minimum Elevation	Miles Below Minimum Elevation	Total Miles in Category	Percentage Below Minimum Elevation
Principal Arterial	Emergency	4.8 ft NAVD	15.4	27.6	56%
Minor Arterial	Commercial	3.9 ft NAVD	12.0	14.2	84%
Major Collector	Emergency	4.8 ft NAVD	19.3	22.2	87%
Minor Collector	Commercial	3.9 ft NAVD	7.7	9.2	84%
Local	Residential	3.9 ft NAVD	77.7	113.6	68%
Total for All Roads	**All Types**	**varies**	**132.1**	**186.8**	**71%**

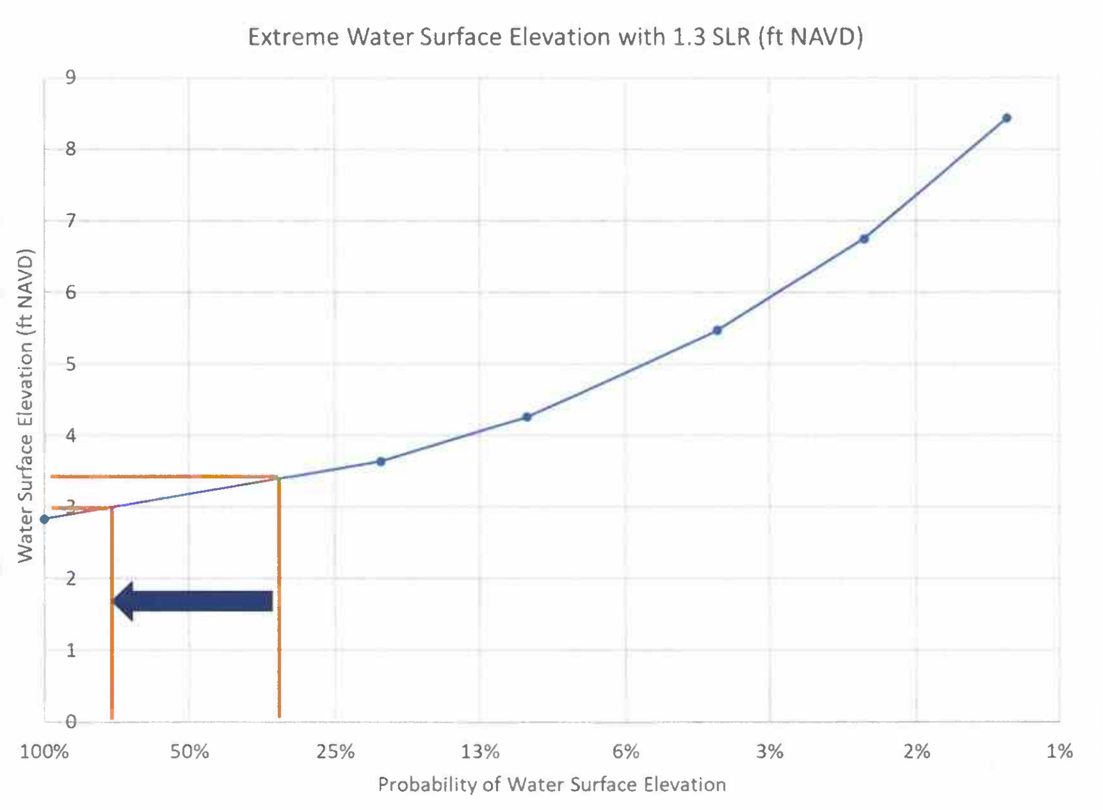


Figure 10. Water Surface Elevations vs. Probability, with Addition of 1.3 ft of SLR
Can be used to estimate decrease in LOS (increase in probability of flooding) for lower minimum design road elevation.

Attachment A
Impacts of Later Project Start Date on Design Road Elevation Recommendations

Attachment A. Impacts of Later Project Start Date on Design Road Elevation Recommendations

All City road projects are anticipated to follow this policy once adopted. The policy is expected to be administered by the Public Works department who will issue final approval for road elevation, prior to issuance of the final construction permits. Any hardship requests (variances) must be submitted in writing to Public Works for review.

The proposed minimum road elevations are based on conditions and future projections as of the date of this memorandum, and future road elevation projects may require a revised set of criteria to meet the objectives of this policy. Therefore, any new road project should consider the anticipated construction date of the roadway and select the appropriate minimum elevations associated with that time horizon. This will promote improved road performance over its service life with the awareness that future flood and groundwater conditions are expected to be higher. Table 2 provides guidance for future road projects in 5-year increments.

Minimum Road Elevations for Future Road Projects

All elevations shown are proposed edge of pavement minimum road surface elevations in ft NAVD88.

		2020	2025	2030	2035	2040
1	Emergency Roads	4.8	5.2	5.7	6.2	6.7
2	Commercial Roads	3.6[a]	3.9	4.2	4.6	5.0
3	Residential Roads	3.0[a]	3.3[a]	3.7[a]	4.0	4.4
4	Method 2 – Road Base protection from SHGWT	3.9	4.2	4.6	4.9	5.3

[a] For elevations below 3.9 ft, the minimum road elevation may be determined based on the groundwater elevation and minimum base clearance. See above road elevation criteria for more info.

Notes:

SLR projections are based on NOAA 2017 Intermediate High for application on commercial and residential roads and Method 2.

Emergency roads are based on NOAA 2017 High SLR projections.

Attachment B
Sea Level Rise Projections and Recent Trends in Measured SLR

Attachment B. Sea Level Rise Projections and Recent Trends in Measured SLR

As with all climate projections, it is useful to quantify the uncertainty to the degree possible and then evaluate what level of risk is appropriate given the criticality of infrastructure. Fortunately, for sea level rise (SLR) projections, the NOAA 2017 report that is the source of the projections used herein included a probability associated with each curve.[11] The probability is expressed in terms of the likelihood that a given SLR projection curve will be exceeded (that is, the likelihood that the projection is too low). The probability is further qualified based on the assumed greenhouse gas emission scenarios that are assumed, which are referred to as Representative Concentration Pathways (RCPs). RCP8.5 represents the highest emission scenario, which is consistent with recent observed data on emissions and a "do nothing" assumption that all global emissions will continue to increase at a rate consistent with current economic and population growth.

Table 4 the NOAA 2017 report summarizes the probability of exceeding each of the six global mean sea level (GMSL) rise scenarios. The NOAA 2017 report describes this table as follows:

> "The six GMSL rise scenarios are also shown (Table 4) relative to the probability of exceedance in 2100 as assessed by the RCP-based probabilistic projections of Kopp et al. (2014). ***Note that the GMSL rise scenarios assume that the rate of ice-sheet mass loss increases with a constant acceleration; however, this might not be the case (DeConto and Pollard, 2016), so it is, for example, possible to be on the Intermediate scenario early in the century but the High or Extreme scenario late in the century***."

The second sentence (italics added) provides an important caveat on selection of a given curve. Recent advancements in climate science, as published in the latest Intergovernmental Panel on Climate Change (IPCC) reports and elsewhere have all pointed to increases in SLR projections with each successive refinement of SLR projections.

Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%

B.1 Recent Trends in SLR in Florida and in Global Mean Sea Level

SLR has been well-documented for many years with authoritative data analysis for long periods of sea level data, as described by Church and White.[12] Church and White use data from 1880 to 2009 and find not only considerable global SLR (approximately 210 millimeters [mm]) during that period but also statistically significant acceleration in the most recent period analyzed. Since its publication in 2011,

[11] NOAA. 2017. *GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES.* NOAA Technical Report NOS CO-OPS 083. January.

[12] Church, J. A. and N.J. White. 2011. "Sea-Level Rise from the Late 19th to the Early 21st Century". *Surveys In Geophysics* 32:585–602. September.

additional research has been conducted confirming an acceleration on SLR. This research is consolidated and reported in the most recent IPCC report on oceans and cryosphere where GMSL is found to be rising, with acceleration in recent decades because of increasing rates of ice loss from the Greenland and Antarctic ice sheets, as well as continued glacier mass loss and ocean thermal expansion.[13] The report indicates that, globally, the recent rate of increase in sea level is approximately 2.5 times the rate that was observed in the 1901 to 1990 period:

"Total GMSL rise for 1902–2015 is 0.16 m (likely range 0.12–0.21 m). The rate of GMSL rise for 2006–2015 of 3.6 mm yr–1 (3.1–4.1 mm yr–1, very likely range), is unprecedented over the last century (high confidence), and about 2.5 times the rate for 1901–1990 of 1.4 mm yr–1 (0.8– 2.0 mm yr–1, very likely range)." (IPCC, 2019). The report attributes the acceleration mostly to the sum of ice sheet and glacier contributions over the period 2006–2015, exceeding the effect of thermal expansion of ocean water. Figure A-1 below illustrates the approximation of different rates of rise historically.

One of the most recent papers on SLR acceleration[14] includes Dr. Gary Mitchume from University of South Florida who has conducted local research on sea levels across coastal Florida. In his research, he has concluded that the global SLR projections can be used as a basis and reference for the SLR in Florida.[15] Figure B-1 shows the historic analysis of global SLR.

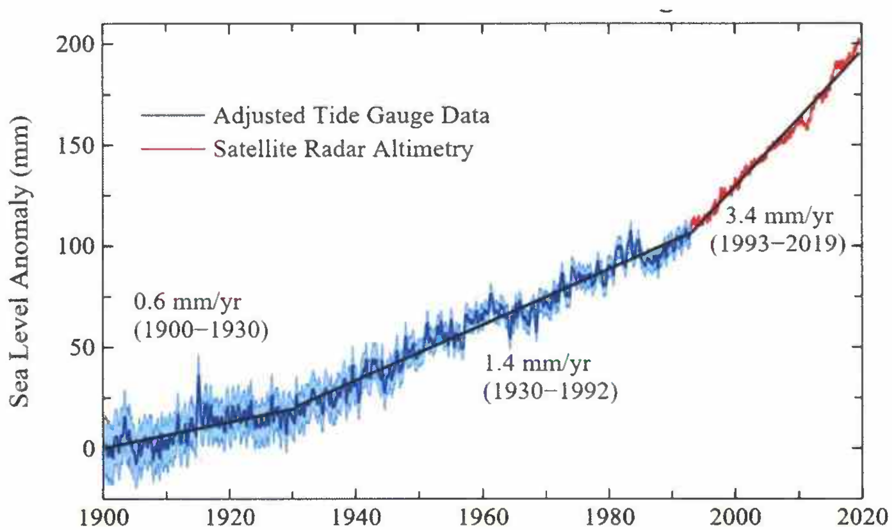


Figure B-1. Global Mean Sea Level Change from 1900 to 2020
Source: http://www.columbia.edu/~mhs119/SeaLevel

[13] Intergovernmental Panel on Climate Change. 2019. *The Ocean and Cryosphere in a Changing Climate*. September 24. https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf

[14] R. S. Nerema,1, B. D. Beckleyb, J. T. Fasulloc, B. D. Hamlingtond, D. Mastersa, and G. T. Mitchume (2018). Climate-change–driven accelerated sea-level rise detected in the altimeter era. Proceedings of the National Academies of Science PNAS February 27, 2018 115 (9) 2022-2025; first published February 12, 2018.

[15] Mitchum, G., Dutton, A., Chambers, D. P., & Wdowinski, S. (2017). Sea Level Rise. Florida's Climate: Changes, Variations, & Impacts. Retrieved from http://purl.flvc.org/fsu/fd/FSU_libsubv1_scholarship_submission_1515511935_d1ea45d2

Attachment C
Calculation of Updated Mean Higher High Water (MHHW)

Attachment C. Calculation of Updated Mean Higher High Water (MHHW)

C.1 Background

The nearest active tide gauge operated by National Oceanic and Atmospheric Administration (NOAA) to the City of Miami Beach is Station # 8723214 Virginia Key, Biscayne Bay, Florida, where the available measured data of water level date back to January 28, 1994. Table C-1 lists the published tidal datums at the station for the previous tidal epoch (1960 through 1978) and the present tidal epoch (1983 through 2001). As shown in Table C-1, there has been an increase in the datum elevation in the order of 0.2 ft across the board, assuming that the vertical elevation of the Station Datum, which is the absolute zero of the measuring tide gauge, remains unchanged.

Table C-1. Published Tidal Datums, Virginia Key Station, FL

Source: https://tidesandcurrents.noaa.gov/datums.html?id=8723214

Datum	Elevations (ft Station Datum)		
	Previous Tidal Epoch (1960–1978)	Presents Tidal Epoch (1983–2001)	Difference (Present - Previous, in ft)
MHHW	12.19	12.36	0.17
MHW	12.12	12.30	0.18
MSL	11.05	12.30	0.20
MLW	10.02	10.27	0.25
MLLW	9.89	10.14	0.25
NAVD88	NA	12.15	
Tidal Datum Analysis Periods	02/01/1994–09/30/1997	01/01/1998–12/31/2013	
	12/01/1997–12/31/1999	02/01/2015–01/31/2016	
		04/01/2016–03/31/2017	

Thus, it is conceivable that this documented rise in MHHW may continue into the post-2001 period and it is essential that this rise in MHHW that is not captured in the present tidal epoch be accounted for.

C.2 Purpose

The purpose of the assessment is to estimate the rise in MHHW from 2001 through the present that may be captured in the measured water level data by conducting harmonic analysis of the measured time series to filter out the non-tidal components and calculating the resulting MHHW of the filtered time series that contains astronomical tide signals only.

C.3 Methodology

After recasting the filtered time series in ft NAVD, the following two methods were employed to calculate the updated MHHW, which serve as a check against each other. The two methods are outlined below.

1) First method: 5-year bands

a) Divide the available post-2001 data into 5-year bands (that is, 2001–2005, 2006–2010, 2011–2015, and 2016–2020).

b) Select the mid-year measurement (referenced to the Station Datum) to do the harmonic analysis to generate the associated tidal constituents (that is, for year 2003, 2008, 2013, and 2018 using a tide utility available in the MIKE 21 Toolbox.[16]

c) Use each set of derived tidal constituents in (b) to reconstitute predicted tides for the period 2002 –2020.

d) Calculate the MHHW for each data set of (c)

e) Use the published Station Datum – NAVD relationship in the tidal datum table for 1983–2001 (see Table C-1) to convert to ft NAVD. Note that National Geodetic Survey will replace the North American Datum of 1983 (NAD 83) and the North America Vertical Datum of 1988 (NAVD 88) with a new geometric reference frame and geopotential datum in 2022.[17]

f) Plot the variation of MHHW in (e) with time as shown in the Figure C-1, which shows an approximately linearly increasing trend to reach a value of 0.6 ft NAVD in 2018 (that is, a rise of 0.4 ft compared to that for the tidal epoch 1983–2001 [0.2 ft NAVD]).

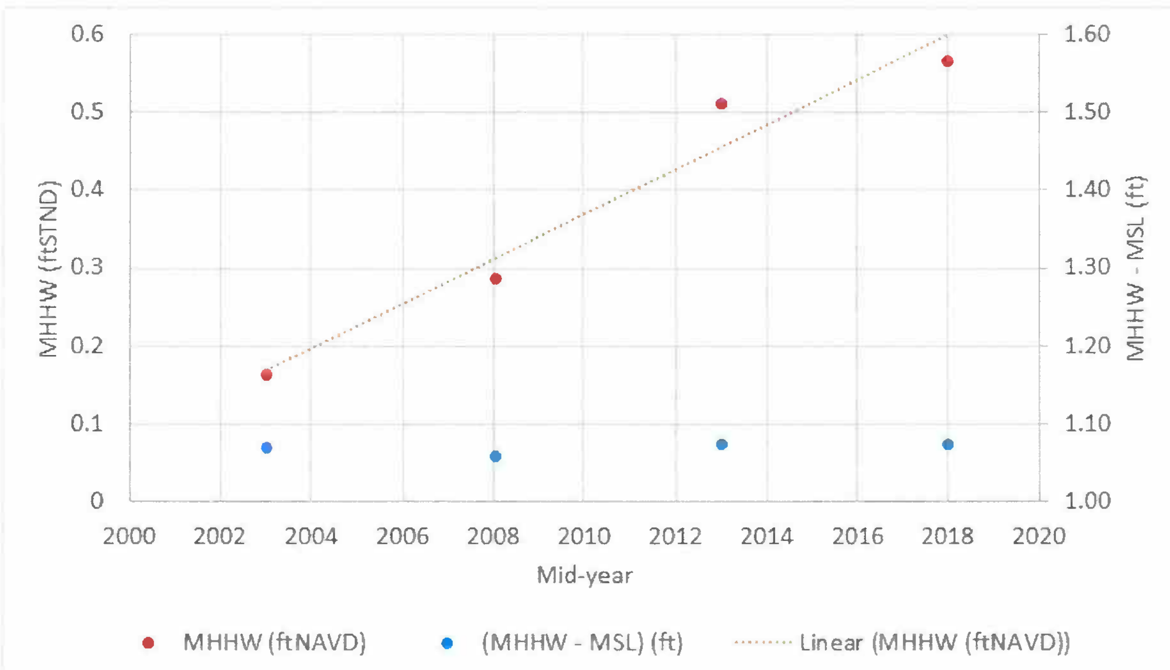


Figure C-1. Variation of MHHW over time, First Method

2) Second Method: Annual MHHW

a) For each complete year of data (2002–2018, referenced to the Station Datum), calculate the predicted tides for the year using the same tide utility above.

b) Calculate MHHW for each annual tide series.

c) Use the published Station Datum – NAVD relationship in the tidal datum table for 1983–2001 (see Table C-1) to convert to ft NAVD.

[16] MIKE Powered by DHI. 2019. *MIKE Toolbox User Manual.* https://www.mikepoweredbydhi.com/mike-2019

[17] https://www.ngs.noaa.gov/datums/newdatums/index.shtml

d) Plot the variation of MHHW in (c) with time as shown in the Figure C-2, which shows an approximately linearly increasing trend to reach a value of 0.6 ft NAVD in 2018 (that is, a rise of 0.4 ft compared to that for the tidal epoch 1983–2001 [0.2 ft NAVD]).

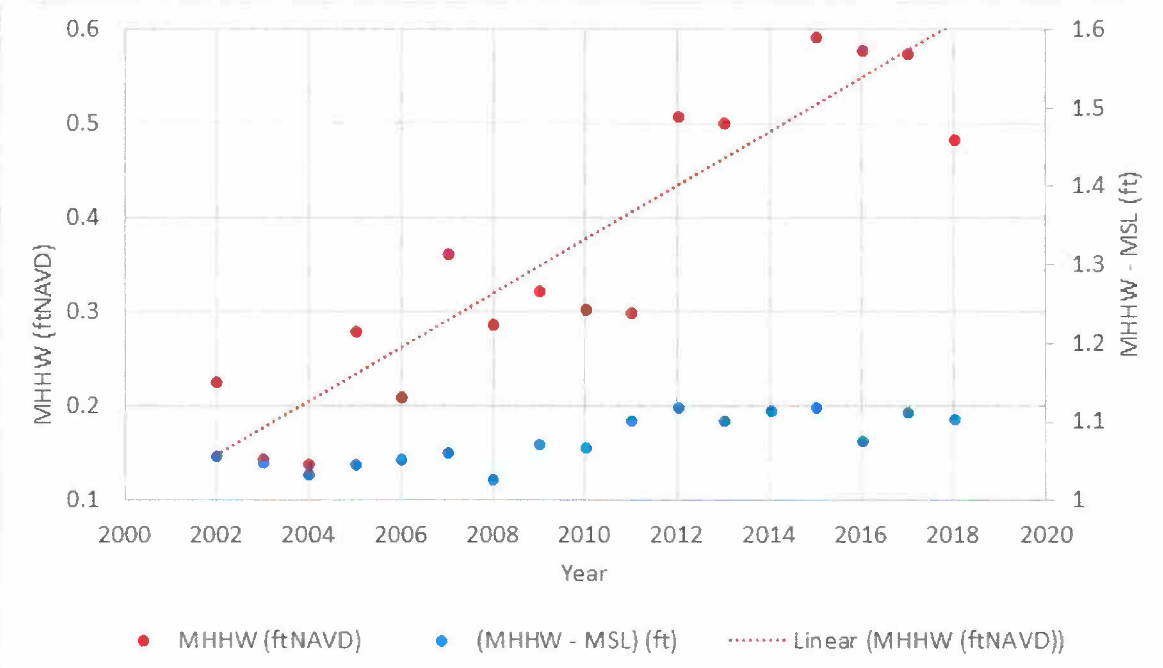


Figure C-2. Variation of MHHW over time, Second Method

C.4 Results and Recommendation

Both methods yield the same MHHW of 0.6 ft NAVD in 2018. Figures C-1 and C-2 also show the respective time variation in the excursion of MHHW above mean sea level (MSL), which shows minor variation over time when compared to those seen in the MHHW curve. This may suggest that the MSL is rising in step over the same time span as is the trend evident from Table C-1 (that is, the increase in MHHW may be a reflection of sea level rise [SLR] and therefore potentially embedded in the SLR analysis conducted independently).

Therefore, Jacobs recommends that an MHHW of 0.6 ft NAVD be adopted and to use 2019/2020 as the start year to calculate the SLR projections.

Appendix B
Road Hardening and Typical Sections

JACOBS

Memorandum

3150 SW 38th Avenue, Suite 700
Miami, FL 33146
T 305.441.1846
F 305. 443.8856
www.jacobs.com

Subject	**Proposed Road Hardening Strategy**
Project Name	City of Miami Beach Integrated Water Management, WO-1, Task 2, Proposed Road Hardening Strategy
Attention	City of Miami Beach
From	Jacobs
Date	October 18, 2019

1. Background

According to the Urban Land Institute's Advisory Services Panel Report for the City of Miami Beach (hereafter, the "City"), Miami Beach's low elevation "is one of its key vulnerabilities" and "over 20 percent of the properties in Miami Beach lie below 3.7 feet [ft] NAVD, with 93 percent within the FEMA-designated Special Flood Hazard Area".[1]

The following typical cross-section of Miami Beach illustrates the City's low ground elevation, providing typical ground elevations (in feet NAVD) for different sections of the City. These typical ground elevations are in some cases only a few feet above the Mean Sea Level of -0.90 ft NAVD for Biscayne Bay, recorded at the National Oceanographic and Atmospheric Administration (NOAA) Virginia Key tidal datum station.

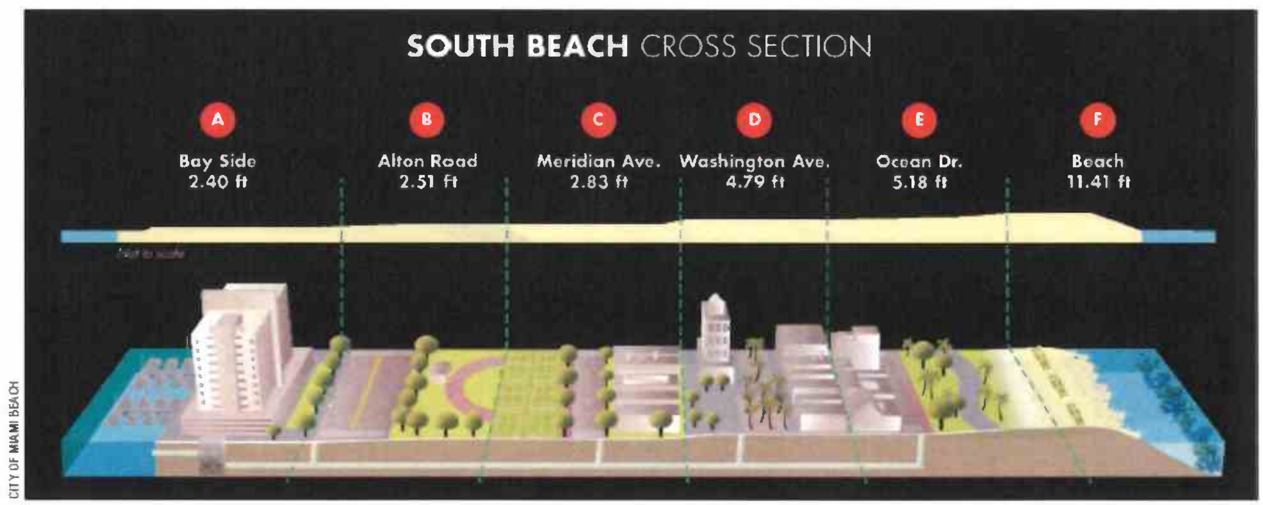


Figure 1. Miami Beach Cross Section
Source: Stormwater Management and Climate Adaptation Review *(ULI, 2018)*

[1] Urban Land Institute (ULI). 2018. *Stormwater Management and Climate Adaptation Review*. A ULI Advisory Services Panel Report for Miami Beach, Florida. April.

The City's groundwater includes a freshwater zone surrounded by a saltwater zone, which is shown in the following illustration from the ULI report. This freshwater or non-saline zone of groundwater, described as a "freshwater bowl" in the ULI report, is continually being recharged with rainwater that seeps into the ground by gravity. The top of this non-saline groundwater zone fluctuates throughout the year at a level higher than the coinciding tide level and is generally highest during the wet/rainy season from May through October, when rainwater recharge is greatest.

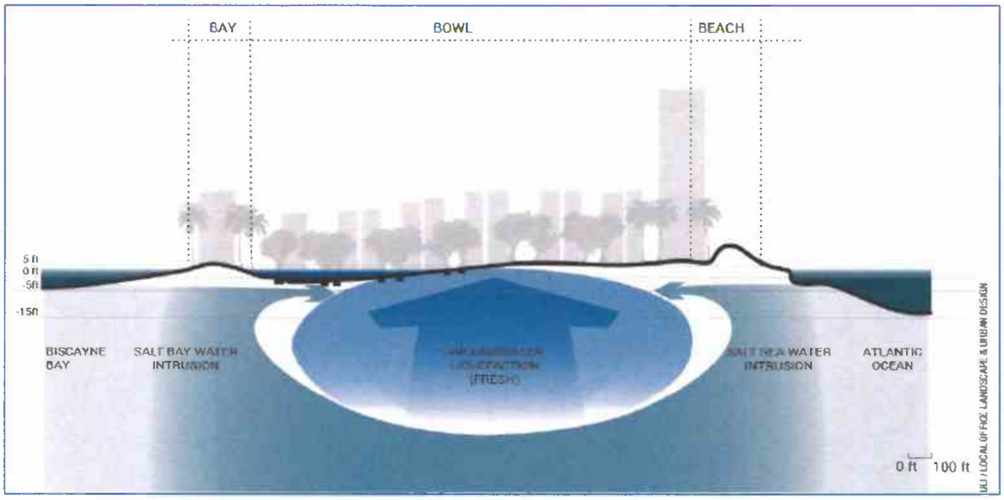


Figure 2. Miami Beach Freshwater Lens

Source: Stormwater Management and Climate Adaptation Review *(ULI, 2018)*

As shown in the results of the City's groundwater monitoring, as well as the boring logs for the Florida Department of Transportation's (FDOT's) Alton Road and Collins Ave. improvement projects, groundwater levels throughout the year fluctuate within only a few feet of the ground surface in many areas of the City. The monitoring results show that as tide levels increase, so do groundwater levels throughout the City. Given the direct influence that tide elevation has on the City's groundwater levels (because of the City's underlying highly permeable/transmissive geologic formations), it is anticipated that as ocean levels continue to rise, the City's groundwater table will also rise at the same rate, bringing the groundwater table even closer to the existing ground surface. This will result in a general decrease in the bearing capacity of the City's surficial soil over time, as it becomes increasingly saturated by a rising groundwater table. This will have a detrimental effect on the durability and strength of roadways as the soil directly beneath them weakens because of increasingly saturated conditions.

2. Recommended Design and Construction Standards for Non-Permeable Asphalt Paved Roadways

The following is a list of recommended design and construction standards for new and reconstructed public roads within the City. These recommendations are intended to minimize pavement distress and structural failure of the City's roads before the end of their design life, caused by over-saturation of their base and subgrade layers resulting from rising groundwater levels. Adopting these road hardening/ resiliency standards may result in an increase in the initial cost of some roadway projects. However, the increased long-term durability and service life of these roads, in future higher groundwater and tidal conditions, will result in a potential decrease in the life-cycle cost of these roads because there will be longer intervals between the required maintenance, rehabilitation, and/or replacement of their pavement systems. These proposed standards address the design and construction of the typical layers of a hot mix asphalt paved road, which are shown in Figure 3, which was derived from Figure 2.1 of the FDOT

FLEXIBLE PAVEMENT DESIGN MANUAL (FPDM).[2] These proposed standards are also recommended for incorporation into the City's Public Works Manual.

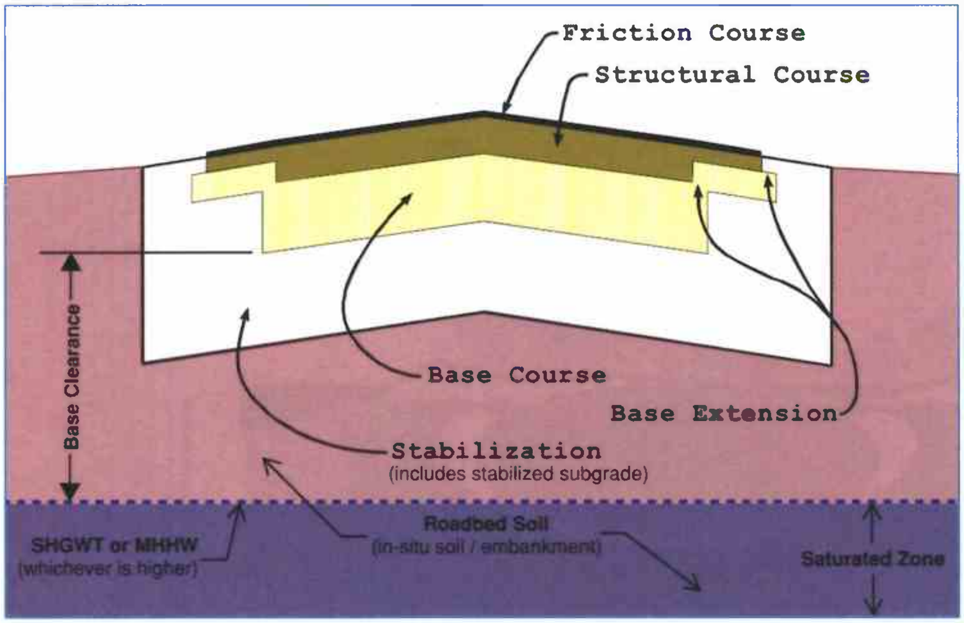


Figure 3. Typical Asphalt Paved Roadway Section
Adapted from FDOT FLEXIBLE PAVEMENT DESIGN MANUAL *(January 2018)*

1) The pavement system for asphalt paved roadways shall be designed in accordance with the requirements and procedures of the latest edition of the FDOT FPDM. The calculation of the required structural number for the roadway pavement system shall be based on the following design variables:
   a) Accumulated traffic loading of roadway during its design life (ESAL value)
   b) Resilient Modulus (M_R) of the roadway subgrade
   c) Minimum Reliability (%R) factor of 90
2) The roadway embankment, stabilized subgrade, base layer, asphalt structural course, and asphalt friction course shall meet the material and construction requirements of the latest edition of the FDOT Standard Specifications for Road and Bridge Construction.
3) As shown in Figure 3, base clearance shall be the vertical distance between the bottom of the roadway base layer and the estimated seasonal high groundwater table (SHGWT) elevation at the road location or the mean higher-high water (MHHW) elevation from the NOAA tidal datum station closest to the road, whichever is higher. The SHGWT and MHHW elevations used for base clearance determinations shall be the SHGWT and MHHW elevations expected at the end of the roadway's design life, factoring in sea level rise (SLR). The degree of SLR used to estimate the SHGWT/MHHW elevation at the end of the roadway's design life shall be based on the City's adopted SLR projection for roadway projects. When the base clearance is less than 3 ft, a reduced M_R shall be used for the pavement structural calculations, as required in the FDOT FPDM. Roads shall be designed to provide a minimum base clearance above the site-specific SHGWT/MHHW elevation of 1 ft or greater.
4) The base layer of all roadway pavement systems shall be supported by a layer of Type B Stabilized Subgrade, with a minimum limerock bearing ratio of 40, per Section 160 of the FDOT standard specifications. The stabilized subgrade layer shall have a minimum thickness of 12 inches, compacted to 98 percent of its maximum dry density per ASTM D1557.

[2] FDOT. 2019. *FLEXIBLE PAVEMENT DESIGN MANUAL*. OFFICE OF DESIGN, PAVEMENT MANAGEMENT SECTION. January

5) The base course for all asphalt paved roads shall be asphalt base, Type B-12.5 (aka, black base), per Section 234 of the latest edition of the FDOT Standard Specifications.

6) Roadway excavation and embankment construction, including requirements for the removal of unsuitable soil, and the placement and compaction of roadway fill materials, shall be in accordance with the City's requirements and the geotechnical report recommendations for the roadway project as well as FDOT's latest standards, which include Section 120 of the FDOT Standard Specifications and Index 120-001 of the FDOT Standard Plans. All fill material placed and compacted beneath the roadway shall be compacted to 98 percent of its maximum dry density per ASTM 1557.

3. Additional Information and Other Considerations Concerning Roadways/Pavement

3.1 Comparison of Strength and Required Layer Thickness of FDOT Standard Roadway Base Materials

The difference between the required thickness for an asphalt base versus a typical granular base for a given structural number is shown in Table 5.6 of the FDOT FPDM. The difference in relative strength (layer coefficient) of asphalt base versus a typical granular base is shown in Table 5.4 of the FDOT FPDM.

3.2 Uses for Geocells

The City should consider the use of geocells to stabilize grassed shoulders/buffer strips along roads where vehicles frequently park to prevent rutting and over-compaction of soil in grassed areas caused by vehicles, which leads to a loss in the permeability and stormwater storage capacity of the soil.

Geocells should also be considered as part of permeable pavement systems for parking lots, whether they are filled with soil for a grassed system or filled with gravel.

3.3 Permeable Pavement Options

At appropriate locations, the City should consider using permeable pavement for sidewalks, shared-use paths, bike lanes, low-volume dedicated use lanes, on-street parking lanes, roadway shoulders, low-traffic-volume residential roads or alleyways as well as parking lots to minimize runoff generated within roadway basins and the resultant stormwater flows to the storm sewer systems. Permeable pavement should be located in areas that are conducive to routine cleaning/ maintenance and should not be located in areas that regularly receive runoff with a heavy silt/sediment load, which can cause clogging and reduce the permeability rate of the pavement. A University of Florida report published in April 2019 provides an overview of typical permeable pavement systems as well as design, construction and maintenance considerations for permeable pavement systems.[3] Figure 4 shows some examples of permeable pavements, which include from left to right: permeable pavers, porous asphalt, pervious (porous) concrete, concrete grid pavers, and plastic reinforcing grids (geocells).

[3] University of Florida. 2019. *Permeable Pavement Systems: Technical Considerations*. April. https://edis.ifas.ufl.edu/pdffiles/AE/AE53000.pdf

Figure 4. Common Types of Permeable Pavement
Source: Permeable Pavement Systems: Technical Considerations.
https://edis.ifas.ufl.edu/pdffiles/AE/AE53000.pdf

Figure 5 shows a typical cross-section of a permeable pavement system for common pavement materials.

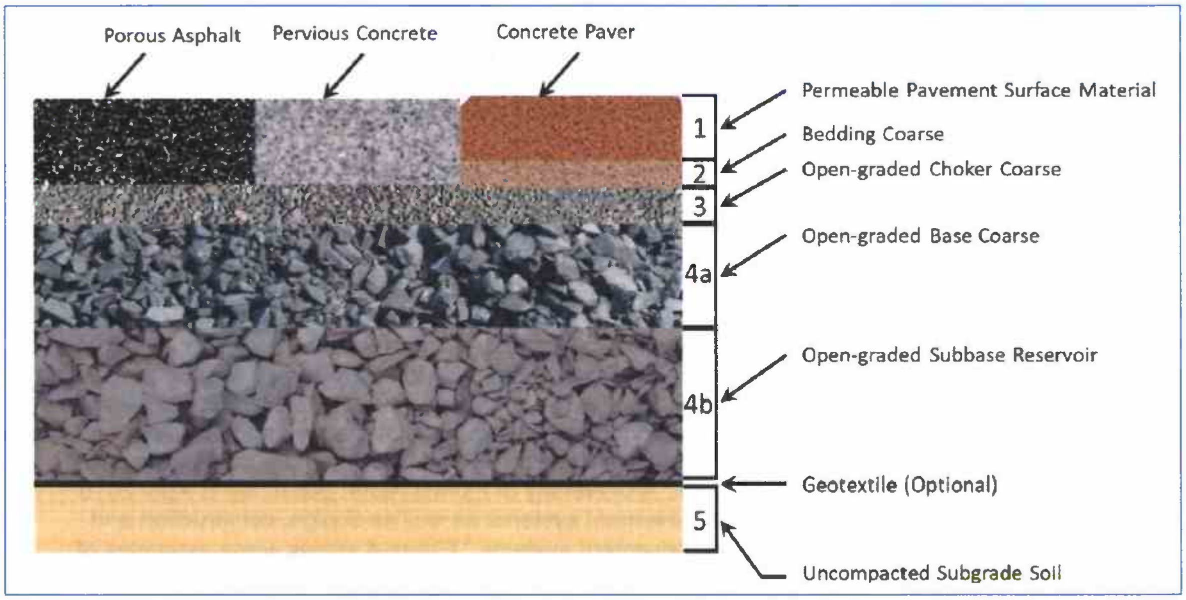


Figure 5. Typical Permeable Pavement Cross-Section for Common Pavement Types
Source: Permeable Pavement Systems: Technical Considerations.
https://edis.ifas.ufl.edu/pdffiles/AE/AE53000.pdf

Because permeable pavement systems are designed to be supported by bound and/or unbound permeable bases, FDOT standard asphalt base will not be compatible with permeable pavements because standard asphalt base is impermeable. However, FDOT standard aggregates may be used where unbound base materials are required for permeable pavement systems. Likewise, FDOT standard bound permeable bases, such as asphalt-treated permeable base and cement-treated permeable base, may be used where bound base materials are required. In addition, FDOT standard Draincrete may be used where bound base materials are required.

FDOT does not have published standards for the design and construction of complete permeable pavement systems. However, the District of Columbia Department of Transportation (DDOT), California Department of Transportation, Connecticut Department of Energy and Environmental Protection, San Diego County Public Works Department, Pinellas County Public Works Department, Sarasota County, West Palm Beach, New York City, Chicago, New Orleans, and other governmental agencies across the U.S. have authorized the use of various types of permeable pavement systems within their jurisdictions and published standards, specifications, and/or guidance documents pertaining to the selection, design, construction and maintenance of permeable pavement systems. In addition, the Federal Highway Administration, the U.S. Environmental Protection Agency, American Society Of Civil Engineers, the University of Florida, and the University of Central Florida have published guidance documents and research papers about permeable pavement systems.

Table 1 provides guidance on selecting the appropriate permeable pavement system for both vehicular use (alleys and roadways) and pedestrian use (sidewalks, trails, covered soil volume/area for plants) for a given type of roadway or walkway (dot indicates that pavement system is appropriate for the roadway/walkway application).

Table 1. Permeable Pavement System

Source: Section 33.14.4.1 of DDOT's Green Infrastructure Standards[4]

Type / Application	Alley	Roadway*	Sidewalk	Covered Soil Volume for Plants	Trail
Porous Asphalt	●	●			●
Pervious Concrete	●	●	●	●	●
Permeable Interlocking Unit Pavers	●	●	●	●	
Other Unit Pavers **				●	
Porous Rubber Paving			●	●	●
Porous Bound aggregate			●	●	
Plastic Grid Pavers	●			●	

* Appropriate for low volume roadways & dedicated parking lanes; Not currently allowed for collectors, arterials, and freeways.

** Spaced to allow infiltration

In addition, Section 33.14.46 of DDOT's *Green Infrastructure Standards* lists the following limitations when considering the use of permeable pavement.

- Bottom of permeable pavement system must be at least 2 ft above the seasonally high water table. [Note this is likely a water quality consideration, not a structural one.]
- Permeable pavements with infiltration are not allowed in Hot Spots, as defined in the District Department of Energy and Environment Guidebook.
- Permeable pavement requires more frequent maintenance if installed in areas where sand and sediment accumulate is expected, such as near the beach. It is important to minimize the build-up of sand and other fine soil particles on permeable pavements so that their infiltration rate is not reduced (and in some cases irreversibly reduced) by clogging. Studies have shown that routine washing and vacuuming of permeable pavements can help to minimize their clogging over time.

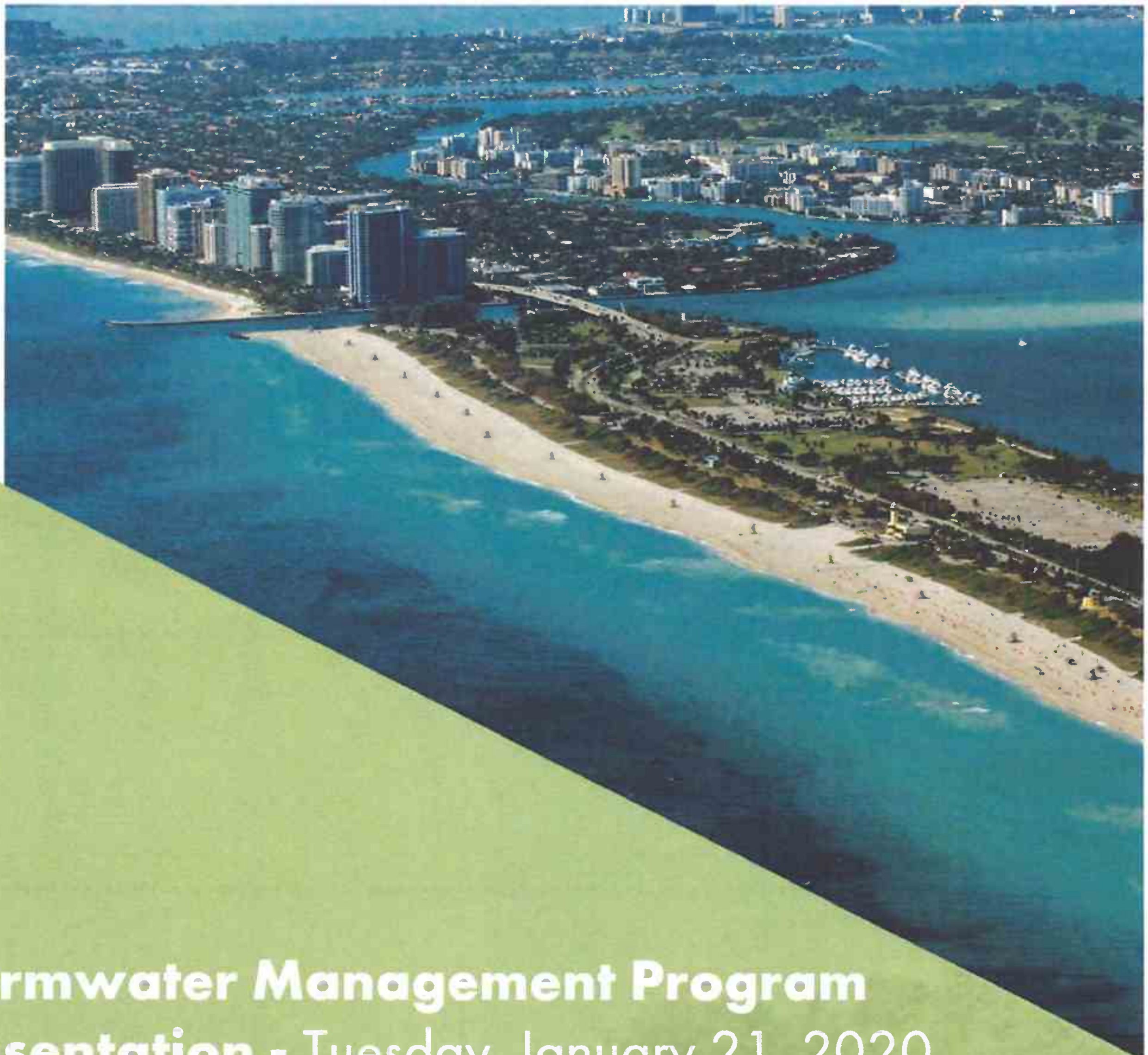
[4] District of Columbia Department of Transportation. *GREEN INFRASTRUCTURE STANDARDS*. 2014. https://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/2014-Final%20DDOT%20Green%20Infrastructure%20Standards.pdf

Appendix C
Tidal Flood Adaptation Projects
(Road Raising Project Summary)

ID	TFAP	Neighborhood
1	10th St	Flamingo/Lummus
2	195 Off Ramp	Bayshore
3	5th St	Flamingo/Lummus, South Pointe
4	5th St N	Flamingo/Lummus, South Pointe
5	69th St	North Shore
6	6th St	Flamingo/Lummus, South Pointe
7	6th St	Flamingo/Lummus, South Pointe
8	Alton Rd 1	West Ave Bay, Rd Flamingo/Lummus, City Center, Bayshore
9	Alton Rd 1	West Ave Bay, Rd Flamingo/Lummus, City Center, Bayshore
10	Alton Rd 2	West Ave Bay, Rd Flamingo/Lummus, City Center, Bayshore
11	Alton Rd 2 W	West Ave Bay, Rd Flamingo/Lummus, City Center, Bayshore
12	Alton Rd 4	South Pointe
13	Alton Rd 6	Bayshore
14	Alton Rd 8	Flamingo/Lummus
15	Bay Dr	Normandy Isles
16	Biarritz Dr	Normandy Isles
17	Bonita Dr	North Shore
18	Byron Ave	North Shore
19	Calais Dr	Normandy Isles
20	Carlyle Ave	North Shore
21	Chase Ave	Bayshore
22	Collins Ave 1	Oceanfront
23	Collins Ave 2	City Center Neighborhood, Oceanfront
24	Collins Ave 3	Oceanfront
25	Collins Ave 4	Oceanfront
26	Crespi Blvd	Biscayne Point
27	Delaware Ave	La Gorce
28	Ed Sullivan Dr	Nautilus Neighborhood
29	Garden Ave	Bayshore
30	La Gorce Cir	La Gorce
31	Marseille Dr	Normandy Isles
32	Meridian Ave	Flamingo/Lummus
33	Michigan Ave 1	Nautilus Neighborhood
34	Michigan Ave 2	Flamingo/Lummus
35	Mitchell St	Normandy Shores
36	Mount Sinai Hospital Pr 1	Nautilus Neighborhood
37	Mount Sinai Hospital Pr 2	Nautilus Neighborhood
38	N Bay Rd 1	La Gorce
39	N Bay Rd 2	Nautilus Neighborhood
40	N Bay Rd 3	La Gorce
41	N Bay Rd 4	La Gorce
42	N Bay Rd 5	La Gorce
43	N Bay Rd 6	La Gorce
44	N Bay Rd 7 5a	Nautilus Neighborhood
45	N Bay Rd 7 5b	Nautilus Neighborhood
46	N Bay Rd 7 5c	Nautilus Neighborhood
47	N Shore Dr 1	Normandy Shores
48	N Shore Dr 2	Normandy Shores
49	Penn Ave	Flamingo/Lummus
50	Prairie Ave	Bayshore
51	Raymond St	Biscayne Point
52	Royal Palm Ave 1	Bayshore
53	Royal Palm Ave 2	Bayshore
54	Royal Palm Ave 3	Nautilus Neighborhood
55	Rue Granville 1	Normandy Isles
56	Rue Granville 2	Normandy Isles
57	Rue Versailles	Normandy Isles
58	S Shore Dr	Normandy Shores
59	Tatum Waterway Dr	North Shore
60	Trouville Esplanade	Normandy Isles
61	Vardon St	Normandy Shores
62	W 29th St	Bayshore
63	W 44th St	Nautilus Neighborhood
64	W Laguna Dr	La Gorce

City of Miami Beach
Tidal Flood Adaptation Projects

Appendix D
Public Meeting Summary



Stormwater Management Program Presentation - Tuesday, January 21, 2020

Public Outreach Report

MIAMIBEACH
RISING ABOVE

Table of Contents

Community Outreach

STORMWATER MANAGEMENT PROGRAM

HOME · CITY HALL · PUBLIC WORKS · OPERATIONS DIVISION · ANNUAL WATER QUALITY REPORT
STORMWATER MANAGEMENT PROGRAM

On Tuesday, January 21, 2020, Jacobs Engineering conducted a public meeting alongside the City of Miami Beach to present tasks 2-3 of their multi-task work order: the road elevation policy and projects prioritization matrix. The meeting provided the following:

- More information about how the recommended road elevation policy will help reduce flooding caused by sea level rise and high tides;
- Insight to the criteria that Jacobs is using to evaluate and prioritize future projects;
- An opportunity for the public to provide feedback before the final recommendations are delivered.

Download the meeting presentation: Jacobs Engineering Tasks 2-3

Review the boards and renderings: Jacobs Engineering Display Boards

Click HERE to watch the recording of the meeting.

For more information please contact:
Liz Bello-Matthews | Public Information Officer | lizbello-matthews@miamibeachfl.gov

What's Next For The City's Stormwater Management Program?

Tonight, January 21| 5:45 PM

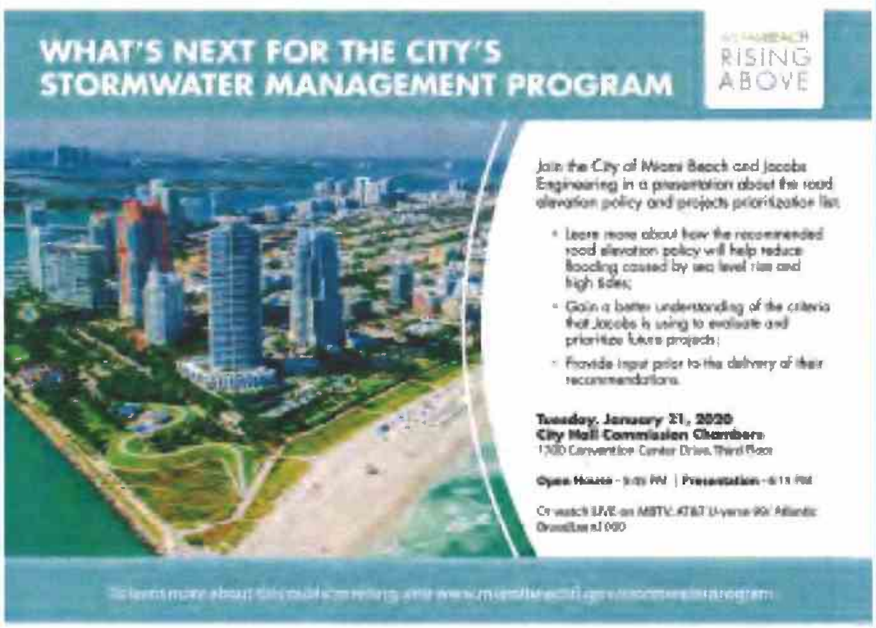
Join the City of Miami Beach and Jacobs Engineering in a presentation about the road elevation policy and projects prioritization list:

- Learn more about how the recommended road elevation policy will help reduce flooding caused by sea level rise and high tides.
- Gain a better understanding of the criteria that Jacobs is using to evaluate and prioritize future projects.
- Provide input prior to the delivery of their recommendations.

Tuesday, January 21, 2020
City Hall Commission Chambers
1700 Convention Center Drive, Third Floor

Open House – 5:45 PM | Presentation – 6:15 PM

Or watch LIVE on MBTV: AT&T U-verse 99/ Atlantic Broadband 660

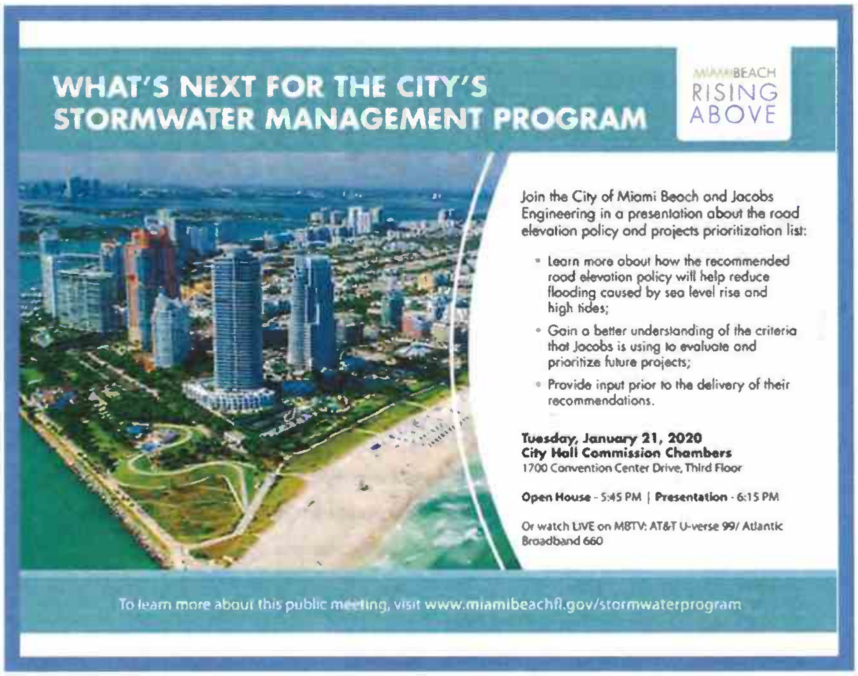


E-blast sent on 1/21/2020 - "Learn What's Next For The City's Stormwater Management Program? - Tonight, 1/21"

Stormwater Management Program Presentation

Community Outreach - E-blast

MIAMIBEACH RISING ABOVE



E-blast sent on 1/3/2020 - "You are Invited"
E-blast sent on 1/13/2020 - "You are Invited"
E-blast sent on 1/20/2020 - "See you Tomorrow"

E-blast sent on 1/22/2020 - "Thank you for joining us!"

City of Miami Beach @MiamiBeachNews · 21 ene.

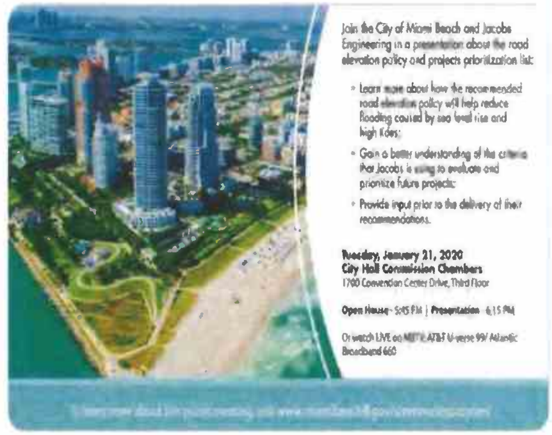
Tonight's stormwater meeting has begun. Stream it live on our Facebook page (facebook.com/cityofmiamibea...) or watch on MBTV (miamibeachfl.gov/government/mbt...) #MBRisingAbove

2 2

Posted on January 21, 2020 - Twitter

City of Miami Beach @MiamiBeachNews · 21 ene.

Come out to our open house on tonight to learn about the road elevation policy and projects prioritization list! #MBRisingAbove



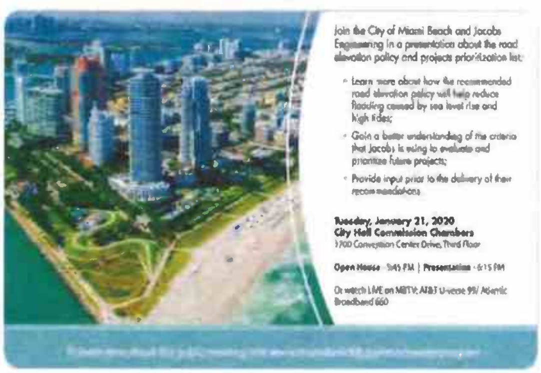
3 5

Posted on January 21, 2020 - Twitter

City of Miami Beach @MiamiBeachNews · 16 ene.

City staff will be presenting with Jacobs Engineering & discussing the road elevation policy & projects prioritization list.

Tuesday, January 21
City Hall Commission Chambers
1700 Convention Center Drive #MBRisingAbove

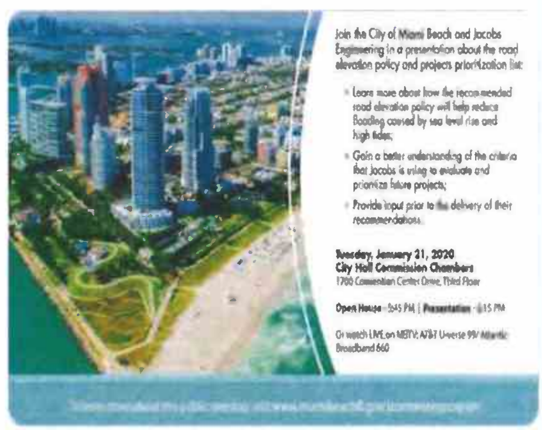


1 7

Posted on January 16, 2020 - Twitter

City of Miami Beach @MiamiBeachNews · 14 ene.

Come out to our open house on Tuesday, January 21 to learn about the road elevation policy and projects prioritization list #MBRisingAbove



4 9

Posted on January 14, 2020 - Twitter

Posted on January 10, 2020 - Twitter

Posted on January 9, 2020 - Twitter

Posted on JJanuary 2020 - Twitter

Posted on January 6, 2020 - Twitter

Posted on January 21, 2020 - Facebook

Posted on January 21, 2020 - Facebook

Posted on January 16, 2020 - Facebook

Posted on January 14, 2020 - Facebook

City of Miami Beach Government
10 de enero a las 12:37

City staff will be presenting alongside Jacobs Engineering and discussing the road elevation policy and projects prioritization list on Tuesday, January 21 at City Hall #MBRisingAbove

5 · 1 comentario

Me gusta · Comentar · Compartir

Posted on January 10, 2020 - Facebook

City of Miami Beach Government
9 de enero a las 12:18

Learn more about how the recommended road elevation policy will help reduce flooding caused by sea level rise & high tides during our upcoming community meeting!

Tuesday, January 21
5:45 PM
Miami Beach City Hall ... Ver más

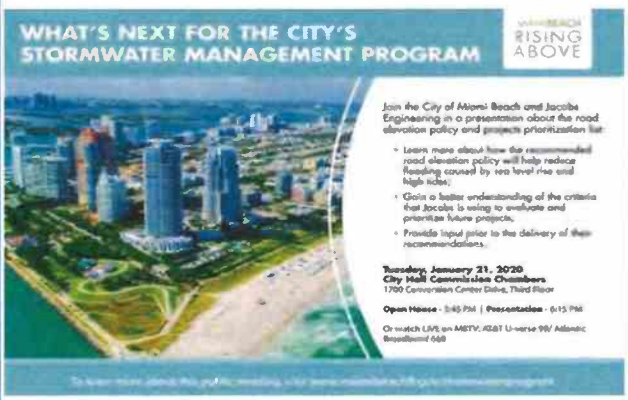
8 · 2 comentarios · 1 vez compartido

Me gusta · Comentar · Compartir

Posted on January 9, 2020 - Facebook

City of Miami Beach Government
7 de enero a las 15:17

Come out to our open house on Tuesday, January 21 to learn about the road elevation policy and projects prioritization list #MBRisingAbove



12 · 2 veces compartido

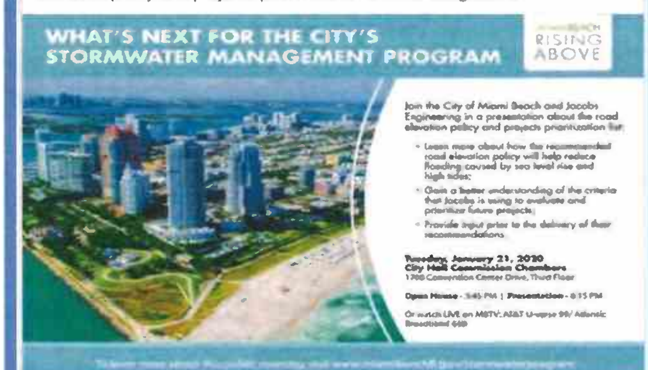
Me gusta · Comentar · Compartir

Posted on January 7, 2020 - Facebook

City of Miami Beach Government
30 de diciembre de 2019

What's next for the city's stormwater management program?

Join us on Tuesday, January 21 at City Hall for a presentation about the road elevation policy and projects prioritization list #MBRisingAbove



6 · 1 comentario · 3 veces compartido

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Posted on December 30, 2019 - Facebook


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HUMANA
Network provider
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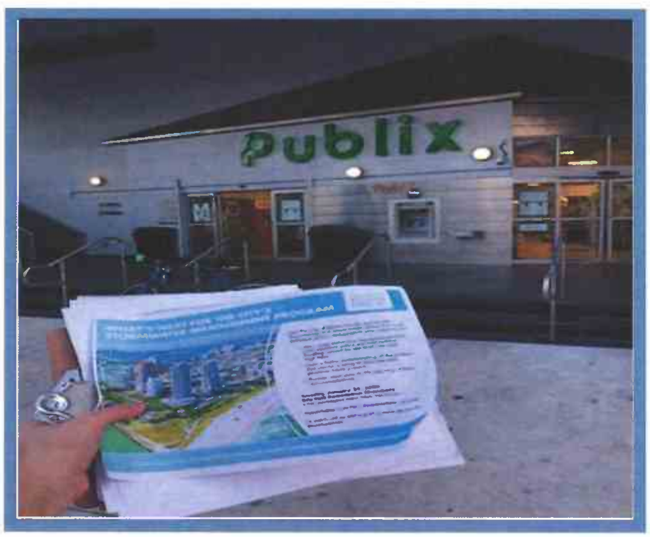
IHOP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· COIN LAUNDRY
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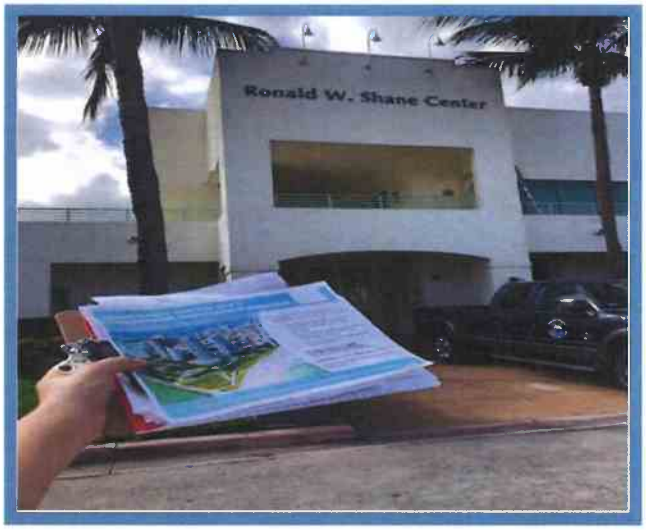
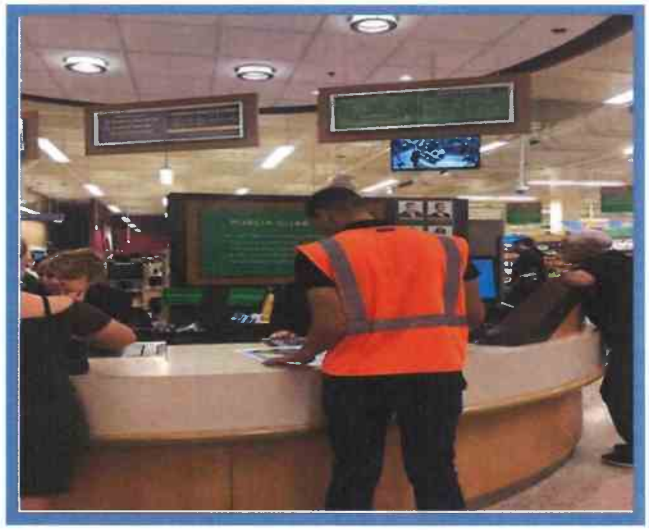
Stormwater Management Program Presentation

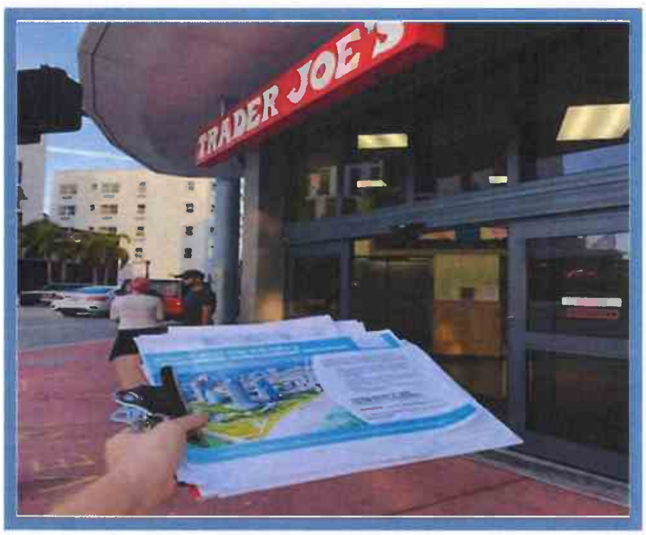
Community Outreach

Door to Door - January 20, 2020

MIAMIBEACH RISING ABOVE


Ronald W. Shane Center




TRADER JOE'S


251
PULL

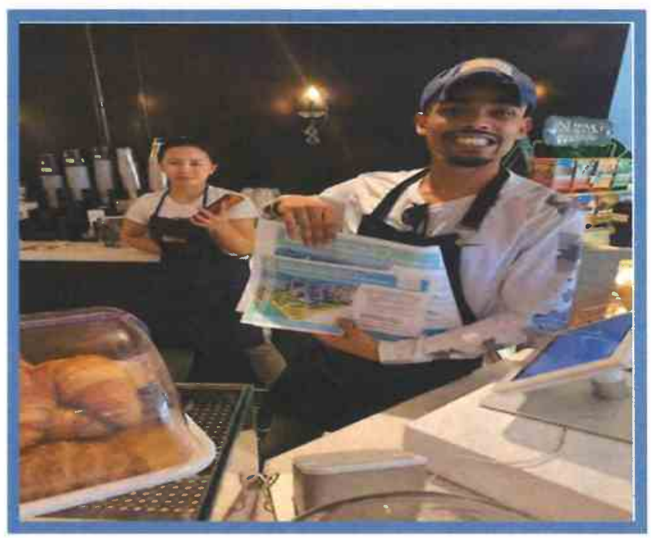

open


MAP


FASTCARE
URGENT
CARE


821
2


UNG'S CHINESE RESTAURANT

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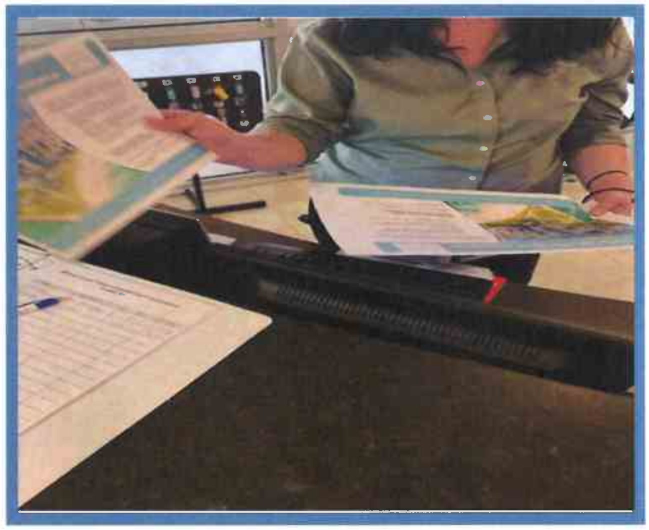


MIRASOL
OCEAN TOWERS
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NO TRESPASSING
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product contains nicotine.
an addictive chemical.

Community Outreach

Door to Door - January 20, 2020

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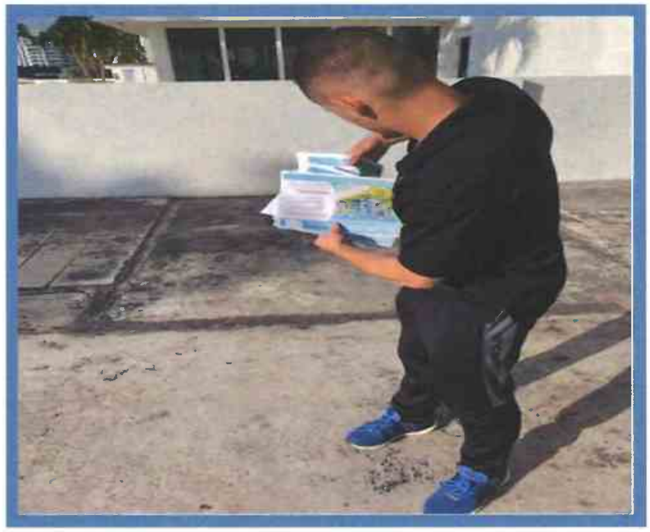
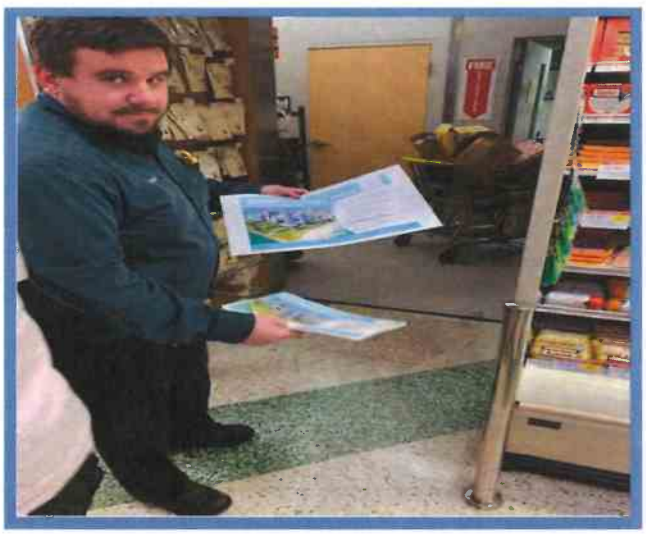




Public Workshop

Discussion Briefing Summary

January 21, 2020 | 5:45 p.m.
City of Miami Beach City Hall Commission Chambers
1700 Convention Center Drive, Miami Beach, FL 33139

Staff:

Jacobs Engineering
Infinite Source Communications
City of Miami Beach Staff
See the attached sign-in sheets for attendees

Key Items Discussed

- Public Works Director Roy Coley started the presentation by giving a brief introduction of The City of Miami Beach plans regarding the project. He also explained the purpose of the meeting, which was to obtain public input about the different elevation strategies. Furthermore, Mr. Coley encourage residents to participate in the comments section to provide their feedback.

Presentation

- Matt Alvarez of Jacobs Engineering thanked the residents for attending the meeting and gave a brief introduction of the topics that will be presented. Mr. Alvarez also mentioned the overall purpose of the meeting, which was to explain different road elevation strategies and invited the public to participate and provide their feedback at the end of the meeting.

- The Jacobs Engineering team members presented each slide and provided a detailed explanation on each topic, as well as encouraged feedback from the audience.

- The following topics were discussed during the presentation:

    - Road Elevation Strategies
    - Neighborhood Project Prioritization
        - Methodology and Criteria

Comments/Notes

- A resident expressed that there is no harmonization in the examples showed for the type of build-up character, as well as for a neighborhood with commercialization. He stated that these strategies are designed for single family neighborhoods, but not for the type of neighborhoods in the city.

- Resident Andres Asion mentioned that it would be helpful to see before and after photos of real-life projects instead of illustrations. Mr. Asion stated that the difference in elevation between the streets and the property driveways can cause significant issues such as losing driveways, flooding, etc.

- Resident Bob Kunst stated that the We Love Lakeview Association invited the team multiple times to Lakeview Vista to speak with the residents directly; however, he said they still have not heard back from the team. Mr. Kunst added that more prevention is necessary such as cleaning pipes more than once a year as well as improving their maintenance program. He stated that lakeview does not flood and that the elevation of the streets will only cause further issues for the residents.

- A resident who lives in Toledo Island, expressed concerns on how the projects are being prioritized. He added that the city should have a better order of priority regarding on-going projects before starting new projects.

- Resident Rick Kendle stated that he has not heard the team talk about swales. He mentioned that there are many neighborhoods with existing swales. He thinks it would be helpful to make these areas lower than the streets. He stated the team should consider incremental improvements rather than directly developing street raising.

- Resident Gustavo Brian mentioned that he is a business owner in the Sunset Harbor area. He explained that he experiences high flooding in his business and that the pumps take a long time to start draining this water. He encouraged the team to look at these issues first, before they continue moving forward with the project.

- Chairman of the city's advisory committee stated that he did not see how the cost of the project was being factored in. He also mentioned that there should be a budget for each of this projects overtime. Another important factor is over how long of a period the city would take to complete this project. He explained that it is not the same to spend a certain amount of money over five years than over 20 years. He added that he wants to make sure that the modeling that the team is presenting shows that type of optimization on the financial piece.

- A resident stated that the team did not present an expected sea level increase for the years that construction will be going on. He suggested the team make a presentation on how they would make a restoration five or ten years from now when things have change slightly.

- A resident stated that there was a point on the presentation that concerned him, which was the 35.8 percent for aesthetics. He mentioned that aesthetics is one of the best things Miami Beach is known for. He recommended the team to try to come up with an idea that includes maintaining the aesthetics of the city. He also mentioned that it would be helpful to have more details on how the project will impact the aesthetics of the city.

- A resident asked why the city continues to prioritize streets over private property. He agreed to keeping streets dry; however, he thinks the main project should be first keeping the properties dry and protecting the living space.

- Resident Chi-Chi Truong thanked the team for the presentation and expressed several questions and recommendations. He asked if the team has considered geogrids and geotextiles to strengthen the pavement section and reduce the thickness. He also asked how these new criteria will impact the on-going Capital Improvement projects.

- A resident asked if the team considered developing seawalls instead of raising the streets.

- A resident mentioned that she did not heard about public parks and natural green spaces. She recommended to push the water into the public green spaces, so when the time of elevating the streets comes, the parks and public spaces can help absorb all the water instead of having this water going into the properties.
    - Mr. Matt Alvarez responded that it was an excellent comment and that they did incorporate green spaces as part of the first meeting.

- Resident Louise Bauer asked the team to look at some completed projects in the city. One was done by Florida Department of Transportation on Alton Road and 20 Street, in the Publix area. She mentioned that the department change the pipes and it was not necessary to raise the streets. The second one was right behind the Bal Harbour Shops; they are also changing their pipes instead of raising the streets. Ms. Bauer asked the city to focus on on-going projects first in order to complete them and then execute new projects.

- A resident mentioned that during the presentation he did not hear anything about what is going to happen with stormwater management. He mentioned Biscayne Bay is dying and that sea grass may never return. He recommended the city look at all the consequences that this is bringing to the ecosystems, tourism etc. He asked what the team is doing about studying the circulation panels on the bay. He suggested the team to include more details on where the stormwater will be discharge.

- A resident stated there is a perfect test case for the team to look at in North Beach Town Center. He mentioned that there is a nine-block area slated for redevelopment, major 74 Street water tanks surrounded by a park ready to go into developing. He further expressed developers are waiting to start because they want to know first what level the streets will be raised to.

- A resident Andres Asion stated that when it rains in Palm Island his property backyard gets about six feet of water, but the streets are dry. Mr. Asion added that for the new properties and new developments street elevation is not an issue, but for existing properties it presents a major issue.

- A resident asked the team where the water will go after they raised the streets. He added that currently the water sits on the streets, but if the streets get elevated that water will go to the properties. He expressed concerns regarding this matter and encouraged the team to bring solutions before going to the next step.

- A resident asked what is needed to provide proper stormwater management for a large geographic area. He asked how the houses, buildings and businesses can be protected once the streets get elevated. He also recommended the team create a master plan for stormwater management.

- A resident expressed that new street infrastructure is needed. He also recommended the team include on the presentation current conditions of the streets and how this project will improve the current conditions.

- Resident Abraan Gonzalez mentioned that since the Blue-Green Infrastructure meeting there has not been any interaction with the community. There is a lot of messages going around and this creates chaos among the community. He added that one thing the team is missing is reaching out to the different homeowners associations. Mr. Gonzalez added that it is important for the team to make sure residents understand all the key points of the project and get as much feedback from the community as possible.

- A resident said every neighborhood has specific needs and that is why is important for the team to reach out to them and listen to their thoughts and opinions. She added that she is asking the City Manager, and the commissioners, to do the same thing they have done in the past with other projects with this project. She stated it is important the team understands what each community issues are to come up with better recommendations.

- A resident expressed concerns regarding the proposed street elevations. He said property values will go down, and this will affect all the residents. He said he asked several questions at the last meeting but did not receive any response back from the team.

- A resident expressed concerns regarding a project on Lincoln Road. She mentioned they are trying to put generators at the park on Lincoln road and the Bay, which will affect all the residents of the area as well as the location.

- Residents inquired on where to find the meeting presentation and further project information.
    - Ms. Monica Diaz responded that the presentation would be available after the meeting, and that a link will be send out through email to all the people who sign-in.

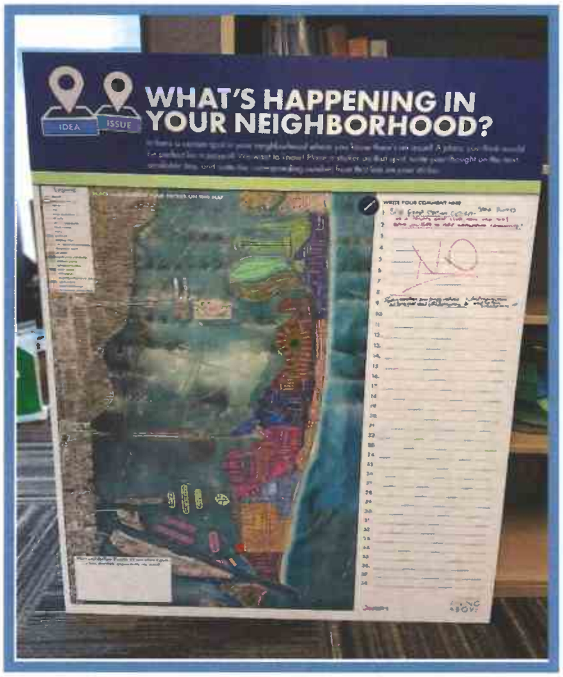
Interactive Boards/Comments

- **Board #1**
    1. Bad pump station design - Dark plumes
    2. As a private golf club, how are they being utilized to help the surrounding community?
    3. NO
    4. Illegible

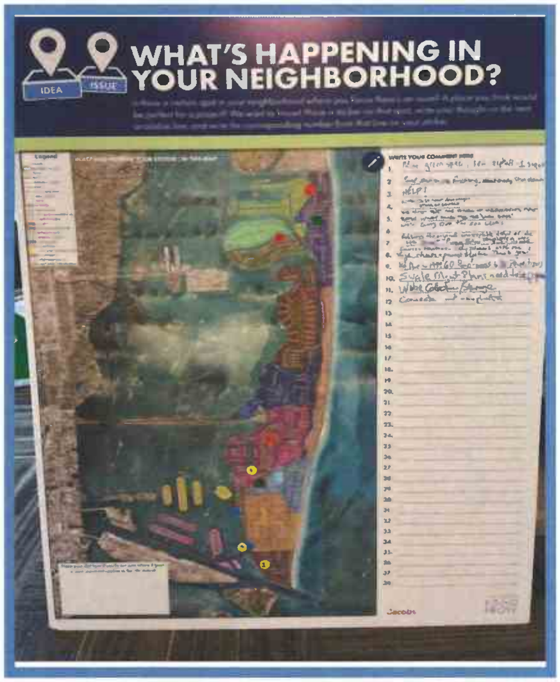
- **Board #2**
    1. More green space, less asphalt - 1st Street
    2. Pump Station not functioning, intentionally shut down. Help!
    3. Alton/5th Street near bus stop stink on sewrge
    4. We must put the future of Miami Beach residents first, before luxury amenities for "snow birds"
    5. Water going over the seawalls
    6. Address the original unacceptable design of 14th Street pumping station. It was one nice park - no more.
    7. Sunset Harbour very pleased with our high streets and pump system. Thank you!
    8. Not done in 1999. G.O. bond - needs to be privatized
    9. Swale Management plans need to be prepared
    10. Water collection/Storage
    11. Concrete not asphalt

- **Board #3**
    1. My street never floods - Sheridan and 45th Street

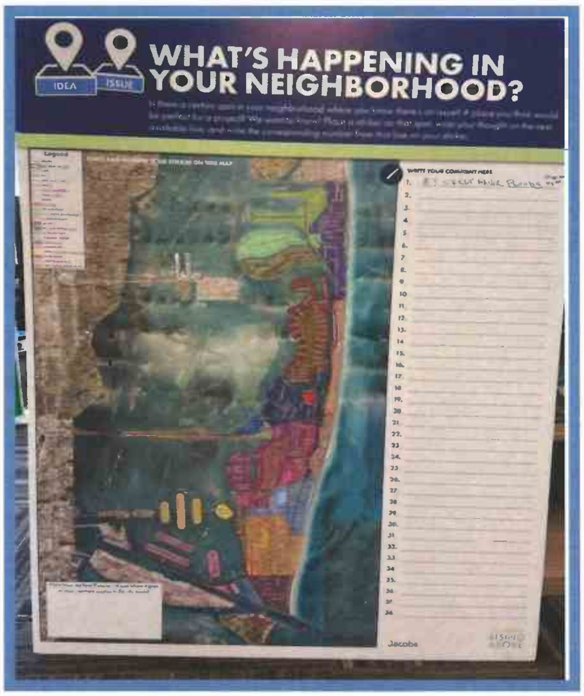
Public Works Director Roy Coley thanked the audience for attending the meeting and for sharing their thoughts and questions with the team.



Board #1



Board #2



Board #3

Stormwater Management Program Presentation

Public Workshop - January 21, 2020

Sign-in Sheets

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STORMWATER MANAGEMENT PROGRAM

PRESENTATION

Tuesday, January 21, 2020/5:45 PM

City Hall Commission Chambers

1700 Convention Center Drive, Third Floor

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Wisler Pyra-Lanz	Self	305 582-1882	pvisler@northmiamifl.gov
Paul Freeman	Self	3059700805	freemanph@aol.com
Jordan Ginelstein	Self	305-610-3711	
Ian Kukoff	Self	305-903-0187	ianjkukoff@aol.com
Shulamit Weinfeld		305 861 7828 773 259 4415	bubazaid@yahoo.com
Barry Miller	Self	305-895-9082	barry@savinomiller.com
Adriana Savino-Miller	Self	305.895.9082	adriana@savinomiller.com
Colleen Martin	Self		deanojunk@hotmail.com
Danny Martin	Self		& " same

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
	GUSTAVO BRIAND STUDIO	786 859 2454	GUSTAVOBRIAND@HOTMAIL.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Melissa Joye	Arcadis	757-478-4795	melissa.joye@arcadis.com
Melissa Beattie	VIHA	305 799 5783	melqbeattie@gmail.com
Peter Coakley	Resident	781-254-1074	COAKLEYKP@GMAIL.COM
Alberto Argudin	A.D.A. Eng	305-551-4608	aargudin@adaeng.net
Christiane Westhoff		786-752 8774	christiane@[illegible]etrailllc.com
Vanessa Vazquez	CMO - CIP	(786) 879-6943	
JASON HAGOPIAN	TSAO DESIGN GROUP	305 215 2739	JHAGOPIAN@TSAODESIGN.com
Rafael A. Velasquez	self	305-303-9098	rv@sunsetrealtymiami.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Henry Blinder	Murano	305-523-9595	henryblinder@gmail.com
Marc Breslow	Self	(305) 992-5282	marc.breslow@Marcum llp.com
Bruce Backman	self	617-513-9954	bruce backman@yahoo.com
DAVE DOEBLER	self	954-415-7434	dave.doebler@gmail.com
Jack Glottmann	Self	305-704-3103	jgpublic@saglo.com
LLOYD MANDELL	SELF	305-978-9662	LLOYD1741@AOL.COM
Jane Gross	self	305-318-5559	jane.gross@gmail.com
Jill Swartz	Self	305 915 7654	jillyswartz@gmail.com
MARIO COrYell	Self	305-773-6530	MARIOCORYELL@GMAIL.COM

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Claudia Sonneck Levy	-	305-785-5044	claudiasonneckley@gmail.com
David McKinney		202/294-2754	daviddmckinney@yahoo.com
Tim CARR		~~[illegible]~~ 410 279 9575	[illegible] @ AOL.Com
FREUNDLICH		(305) 2180817	mefreundlich@gmail.com
Mercedes Padrón		(305) 487-1109	mep1025@gmail.com
Jack Johnson		786-340 2630	JJ[illegible]@gmail.com
Karen + Jeff Miller		786-213-1721	m_KarenL@bellsouth.net
Helena Kristol		305.968-8836	hvcohen@hotmail.com
Drew Kristol		954 647 6029	Drew.Kristol@gmail.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Bruce Bender	Myself	305-975-0002	BB305@aol.com
[illegible] Christoph	EKO 4	918.285.0844	vchristoph@eko4.co.uk
Mark Samuelian	Commission	—	—
Robert Manning	Self	305 538 3270	drmwr@juno.com
Gerry Goldstein	SELF	538 4996	Gerry3040@AOL.com
Laura Quinn	self		lauraquinn[illegible]@gmail.com
Matthew Gultanoff			
Esteban Porcelli	MBNA	917-294-3511	erporcelli@yahoo.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Carmen Datorre		786 285 2625	cochi402008@hotmail.com
Tyler Fontaine	EDENS	954-622-4219	tfontaine@edens.com
Curt Dyer		305-975-0003	CurtDyer305@gmail.com
Chi Chi Truong		954-435-7010	dtruong@shiftin.com
Viviana Villamizar	BCC Eng.	3053109891	vvillamizar@bcceng.com
James W Moore	resident	305-542-7011	Moorealty@gmail.com
KATHY CARNEIRO	RESIDENT	310 384 2624	KMONDERINE@MSN.COM
Andres Asion	Resident	(305) 613-3669	Andres@AndresAsion.com
Brian Harris	SOFNA	917-226-2846	brian@bdharris.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Luis Casas	Sulzer/ABS	305-951-7286	luis@hydraservice.NET
Alex Vazquez	BCC ENG	~~786~~-412-2688	AVAZQUEZ@BCCENG.com
John Rutherford	self	617-283-0901	rutherford.kiwi@gmail.com.
WILLIAM PLATT	Self	305 4982451	PlattP@BELLsouth.NET
Omar Herrera	300 Engineering	305 904 6218	ojherrera@300engineering.com
Alexander Zaslera	Climate Crusader	904-314-5096	zaslera@gmail.com
Jorge Lopez	MB	305-975-6186	Jorge Lopez 9340@GMA. com
ROBERTO CARNEIRO	HOME OWNER/RESIDENT	310 733 7998	ROBMCARNEIRO@GMAIL.COM
Amy Litos	HOME OWNER	305 2061215	a-litos@icloud.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Franklin A. Torrealba	300 Engineering	305-763-9829	fatorrealba@300engineering.com
ERIC SHEPHERD	HIMSELF	203 253 2022	ERICSHEPHERD@OUTLOOK.COM
Patrick Kavanagh	Chen Moore	31338 7451	pkavanagh@chenmoore.com
Stephen [illegible]	Munro	3052985780	Steve@munroMD.com
Joe Ortega	GHD	305 962-2034	joe.ortega@ghd.com
Jo Manning	myself	786-269-4087	jomanning1940@gmail.c
Adrian Gonzalez	Cardoven	305 206 8249	adrian@[illegible].com
Esther Overton	SOFNA	3-606-9071	—
Ripley Raubenolt	Wade Trim	740 590 1190	RRaubenolt@Wadetrim.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
CHRIS Perez		973-493-7726	CHRISTIAN122543@HOTMAIL.COM
JAY R LEVY		305-785-7847	Jayrlevy@coldwellbanker.com
SOPHIA SIECZKOWSKI	self		SOPHIASIECZ@YAHOO.com
Greg Tocel	RESIDENT	305 812 7974	grtoga@gmail.com
Larry Walkard		305 321 6705	larryw77@yahoo.com
ALEC JIMENEZ	RESIDENT	303/815/0748	alecjjimenez@gmail.com
Shawn Patrick Bryant	WAVNA		WAVNA305@gmail.com
Terry Bienstock	Sunset 384	305 903-4000	tbienstock@tbienstock.com
David Muller	Wade trim	813-431-2785	DMuller@wadetrim.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Neil Bienstock	Lakeview	786 566 2831	bienstock@gmail.com
Aaron DeMayo	FVS	-	AARONDEMAYO@GMAIL.com
MICHAEL FRYD			
Roger Miller	Lakeview	~~786~~ 305 793-4610	rmiller@millergd.com
Judith Frankel	UNBR HOA	305-867-1313	JFrankel@the-beach.net
Daniel Veitia			
Irina Katz		305.588.3050	kaniri8@yahoo.com
FRANK ERILE[illegible]			
JESSE DAVIS	GHD	786-447-7972	jesse.davis@ghd.com

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
BRADLEY COLMER	DECO CAPITAL INC	305-749-0921	BRAD@DECOCAPITAL.COM
Bob Kunst	We Love Lakeview	305-864-5110	[illegible]@mindspring.com
Teresa Morell	resident	305 742 7440	[illegible]morellsa@yahoo.com
Louis Acostanza	CAPRI SB	~~570~~ 786 233 3170	LAC3355@AOL.com
Galen Treuer			galen.treuer@miamidade.gov
Kevin Burgoyne		305	Pkburgoyne@yahoo.com
Karen Rico			

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Melissa Tabares	Sonelle Realty	(917) 862-5595	meli.tabaram@gmail.com
MARYANN ZIMMERMANN	LINCOLN CT. ASSN	973-471-1117	MAZKOSOFF@GMAIL.COM

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NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
+ Stephen Mader Peter Caldwell	(homeowners) ourselves	(416) 345-8077	petecaldwell2000@gmail.com
Duane Costanzo		570-905-5001	dmc5592@aol.com
RH Sasso	Coastal Syst.	305-989-1048	rhsasso@coastalsystemsint.com
Orestes Betancourt	Coastal Systems	305 525 6461	obetancourt@coastalsystemsint.com
FRANCOIS MONOT		786 212 7631	FRANCOISMONOT@YAHOO.FR
Josefina Borges	"me"	305-978-0850	borgesjo@msn.com

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STAFF SIGN-IN

NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Laurens van der Tak	Jacobs	301-204-2436	Laurens.vandertak@jacobs.com
JASON BIRD	JACOBS	970-214-1475	jason.bird@jacobs.com
Joe Rozza	Jacobs	404 667 0964	joe.rozza@jacobs.com
Maria Aboud Barzola	ISC	973-220-2697	mabou016@fiu.edu
Raymond Sciortino	Jacobs	561-799-3855	Raymond.Sciortino@Jacobs.com
Olga Mikhalchishina		347 205 4865	mihdelga@gmail.com
~~[illegible]~~			
Rody de la Torre	CMB-PW		
Roy Coley	CMB-PW		

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STAFF SIGN-IN

NAME	REPRESENTING	TELEPHONE NUMBER	EMAIL ADDRESS
Amy Knowles	CMB		
Judy Hoanshelt	CMO	(305)673-7010	
Melissa Vinales	Arcadis	787 307 5983	
GUSTAVO BRIAND	Gustavo Briand Studio	786 359 2454	
J. Dunc Friedez	Bayshore HOA		

Stormwater Management Program Presentation

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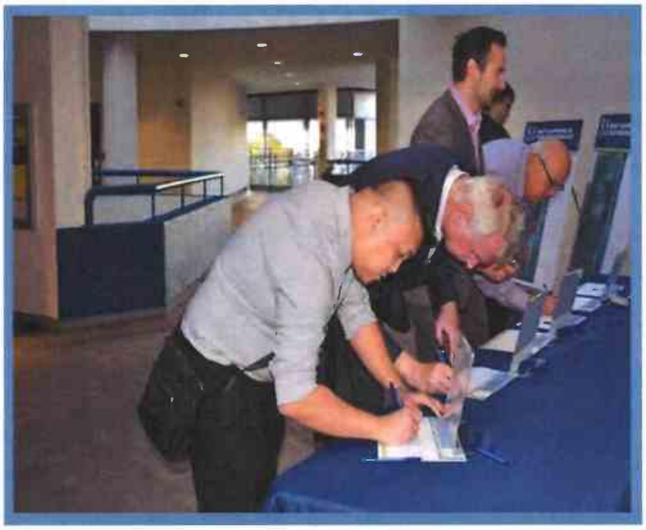
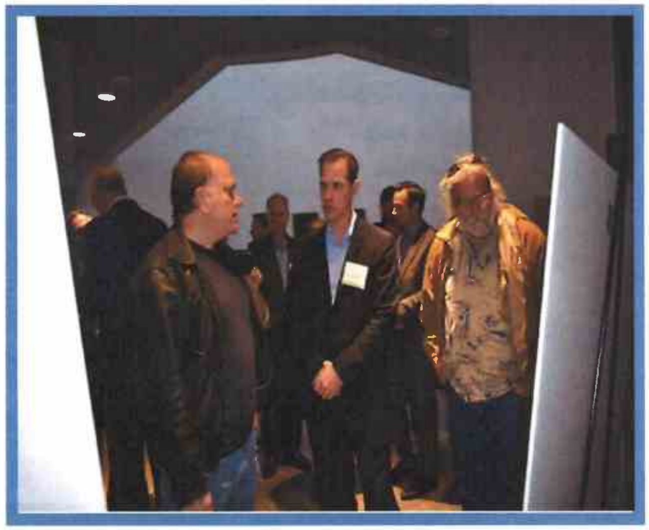
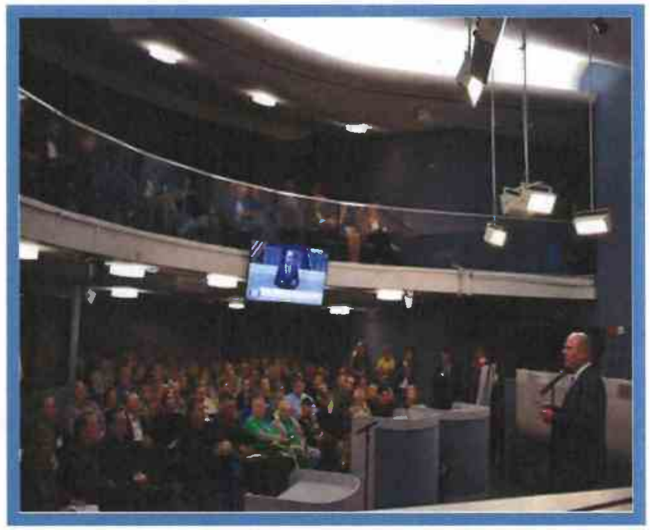
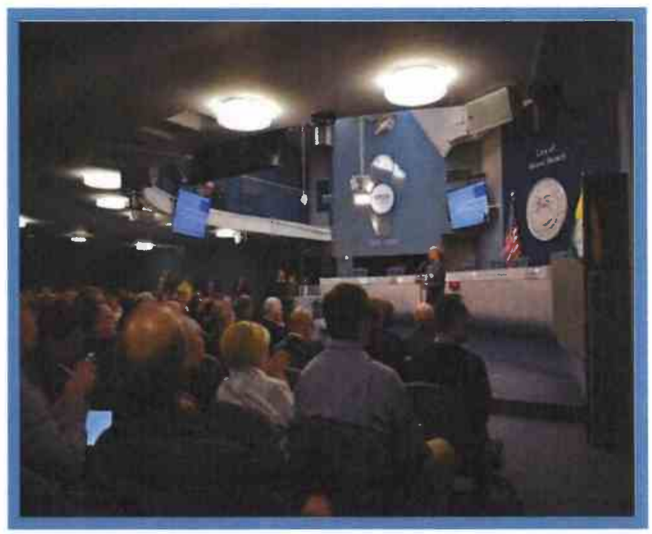
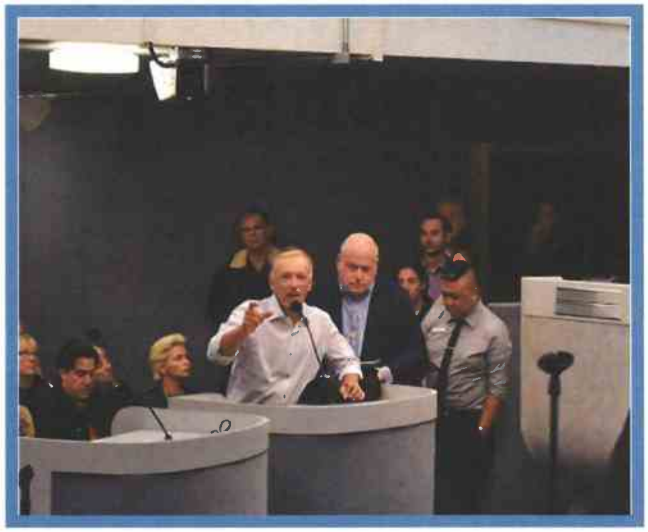


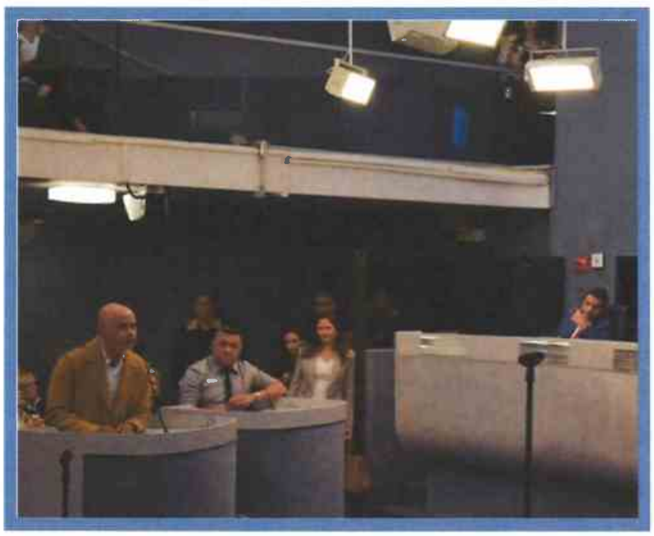







WHAT'S HAPPENING IN YOUR NEIGHBORHOOD?
WHAT'S HAPPENING IN YOUR NEIGHBORHOOD?





APPENDIX

Road Elevation Strategy and Neighborhood Project Prioritization

January 21, 2020

Jacobs

MIAMIBEACH
RISING ABOVE

Meeting Outline

- Purpose
  - Jacobs is finalizing their recommendations
  - Our team is here to listen
  - Use comments/questions received to inform final recommendations
- Providing a comment
  - Speak during the meeting, or
  - Submit comments/questions after the meeting
- Comment ground rules during meeting:
  - Form a line to ask a comment/question
  - Speakers are limited to 2 minutes
- Online viewers email questions to: MBRisingAbove@miamibeachfl.gov

Comments After the Meeting

- Open comment period through January 24, 2020
- Questions on Citywide Stormwater Management? Please contact:

  Liz Bello-Matthews
  Public Information Officer – Public Works Department
  305-673-7000 ext. 6902
  E-mail: LizBello-Matthews@miamibeachfl.gov

Project Leadership

25 years

23 years

Juan Aceituno
Deputy Project Manager/
Implementation Task Lead

30 years

Laurens van der Tak
Climate Adaptation
Advisory Panel

20 years

Jason Bird
Planning Task Lead

25 years

Joe Rozza
Blue-Green & Sustainability

15 years

Monica Diaz
Public Outreach

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ABOVE

Agenda

- Road Elevation Strategy
- Neighborhood Project Prioritization
  - Methodology and Criteria
- Questions and Comments

Task 2
Road Elevation Strategy

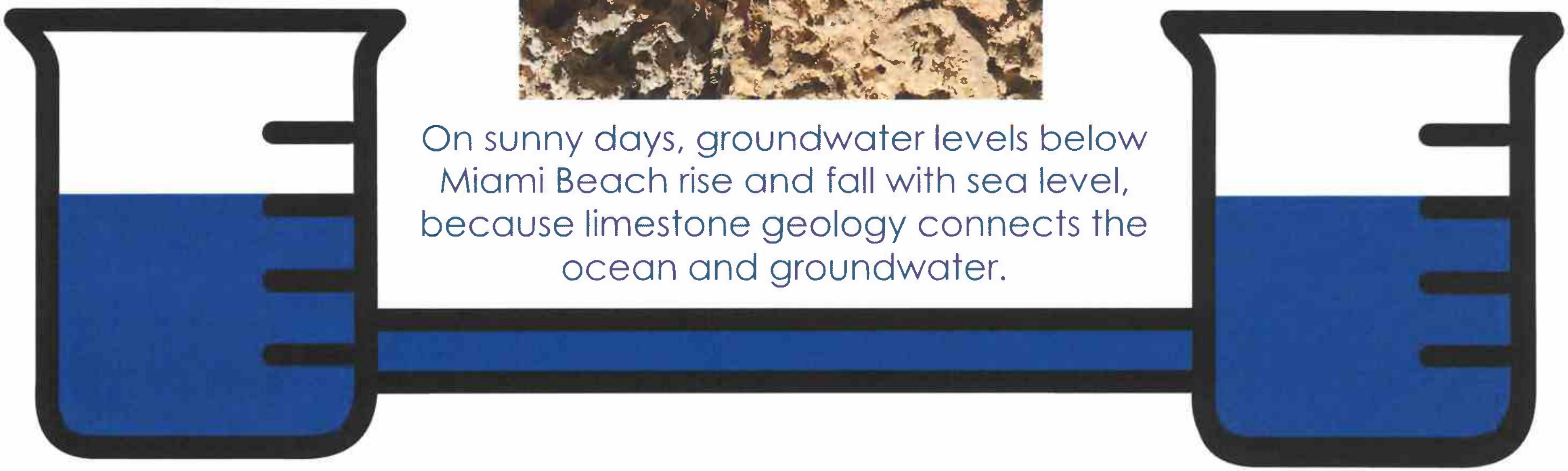
MIAMIBEACH
RISING ABOVE

Jacobs

Water seeks its own level

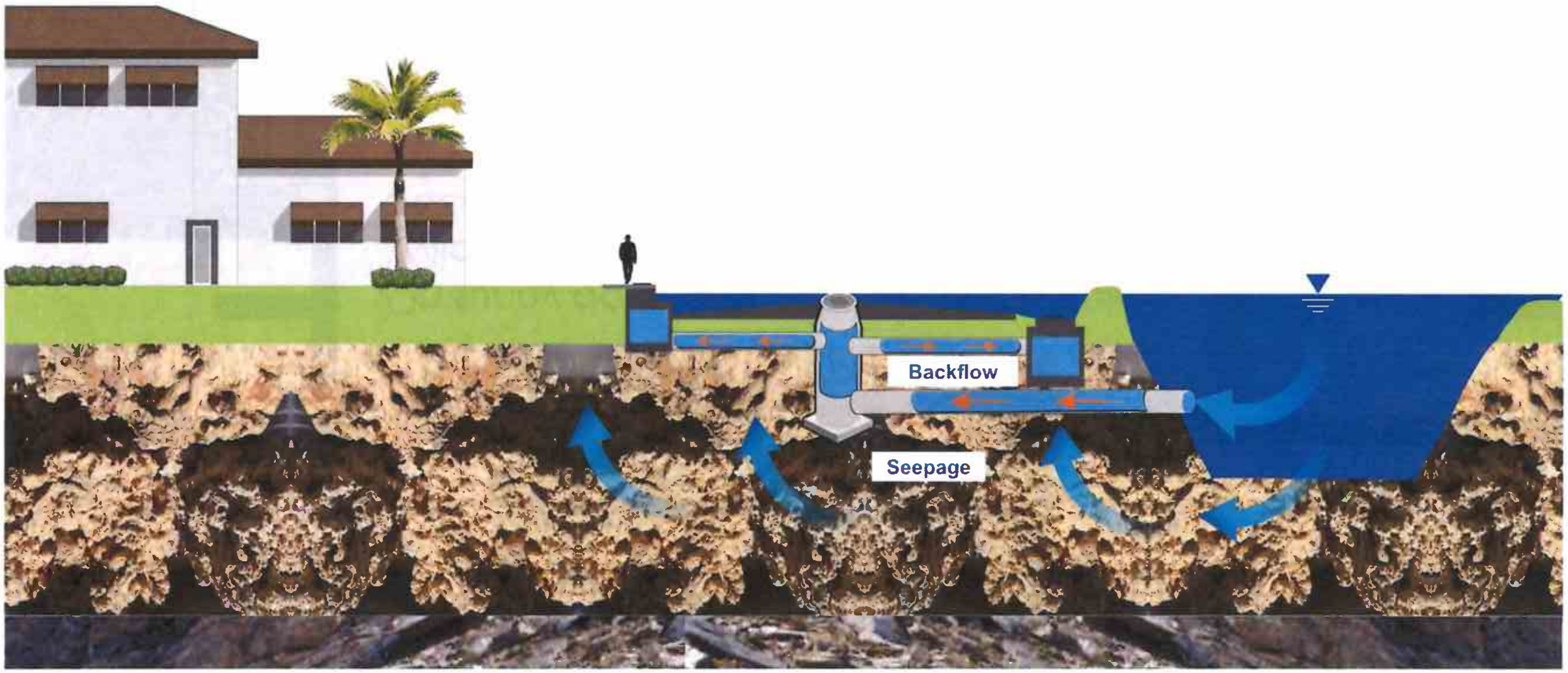
Sea Level

Groundwater



On sunny days, groundwater levels below Miami Beach rise and fall with sea level, because limestone geology connects the ocean and groundwater.

Tidal flooding is problematic in low-lying areas



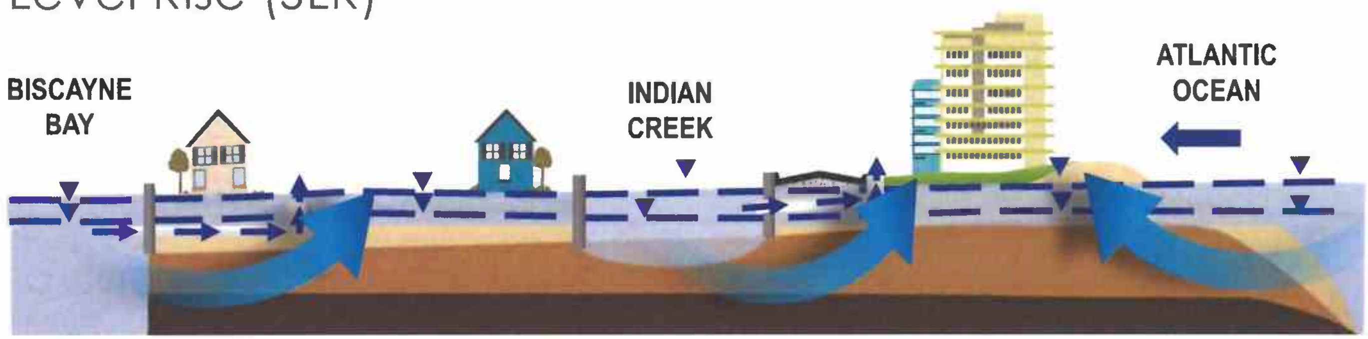
Tidal Flooding increased with Rainfall

Long Term Strategy includes Elevated Roads, Sea Walls and Pumps

BI0909191410MIA

Raising roads is an important strategy to address sunny day tidal flooding in public right-of-way

- Through storm drains
- Through groundwater
- Through overtopping of coastal barriers (e.g., seawalls)
- Exacerbated by Sea Level Rise (SLR)



Road Elevation Strategy Overview

ROADWAY HARMONIZATION:
A roadway design approach that maintains private property access, stormwater management, and neighborhood aesthetics through adaptable design standards.

- **Intent of Updated Policy**
  - Incorporate updated tide data and SLR projections
  - Improve harmonization with private property
- **Current Policy**
  - Minimum road crown elevation for all roads: 3.7 ft NAVD (established 2014)
- **Draft Policy Approach**
  - Flexible design options to address local needs and conditions
  - Address access, stormwater, and aesthetics while reducing flood risk
  - Tiered road elevations based on road classification
  - Alternative strategies to design road elevation below minimum elevation criteria if constrained by harmonization with private property

Guiding Principles of New Road Raising Strategy

- Support keeping road surfaces above the king tide elevation to avoid sunny day tidal flooding
- Establish new minimum elevations for City roads based on updated tidal records and SLR projections
- Address increasing groundwater elevations and concern for poor pavement performance, including premature pavement failure related to saturated road base
- Address concern for private property harmonization
- Standardize application so policy is unbiased, objective, and transparent
- Consider cost implications

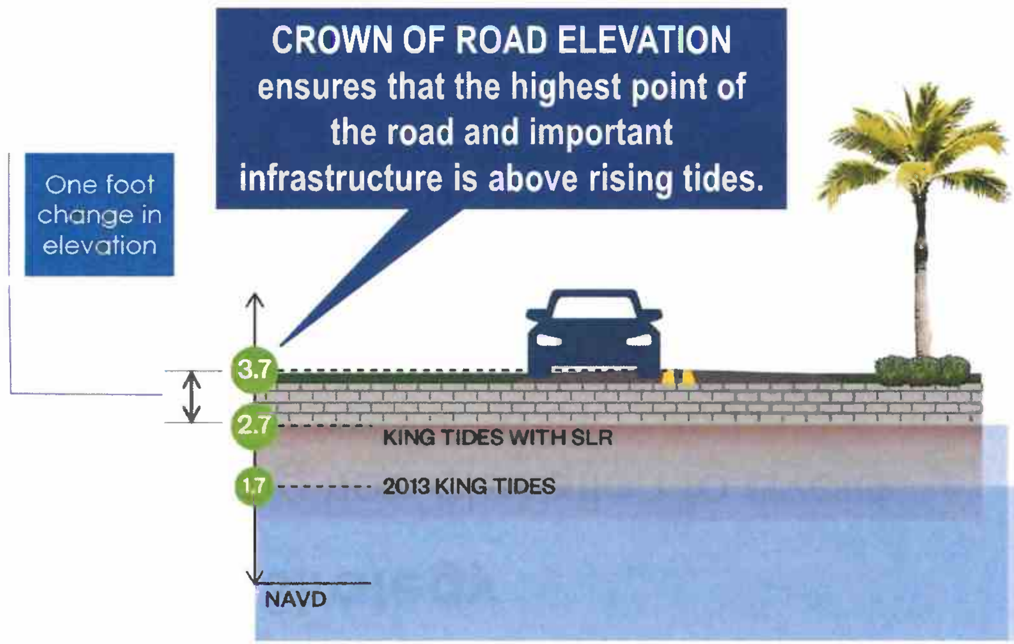
Key Factors that Influenced Current 2014 Road Elevation Design Guidelines

Recommended Road Elevation = A + B + C

A. Historical "King Tide" = 1.7 ft NAVD*

B. Sea Level Rise for assumed Service Life of 30 years: 1.0 ft

C. Freeboard (1 ft assumed for road cross-slope, drainage, and road base)



*NAVD = North American Vertical Datum

Summary of Key Factors that Determine Minimum Road Elevation Criteria

- Evaluates elevations at edge of road (EOR), not crown, and at bottom of road base (BORB), and picks the most protective standard
- Assumes 30-year road service life
- Updated Sea Level Rise projections
- Target frequency of flooding (applies at end of road service life):
  - **Local Roads**: 50% chance per year (includes roads classified by City as "Local", mostly residential roads)
  - **Major Roads**: 20% chance per year (includes roads such as Washington Ave. classified as "Minor Arterial" and "Minor Collector")
  - **Emergency Roads**: 10% chance per year (includes roads such as Alton Rd. classified as "Evacuation Route and access to First Responders)

Updated decision process calculates minimum road elevations at two points on road section

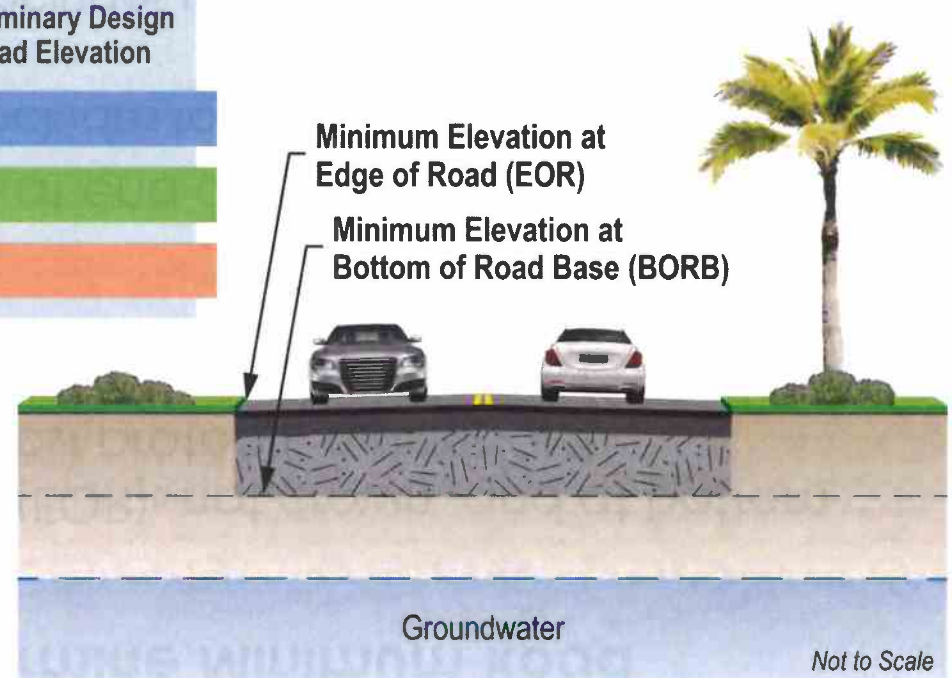
Level of Service by Road Type	Sea Level Rise for 2020 Start Year*	Freeboard/ Clearance	Preliminary Design Road Elevation

CALCULATION METHOD 1: Limited Flooding at Edge of Road

CALCULATION METHOD 2: Limited Groundwater/Tidal Wetting at Base of Road

METHOD 3: Roadway Harmonization with Adjacent Property

** Sea Level Rise increment will increase for later start years*



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ABOVE

Calculation Method 1: Limited Flooding at Edge of Road (EOR)

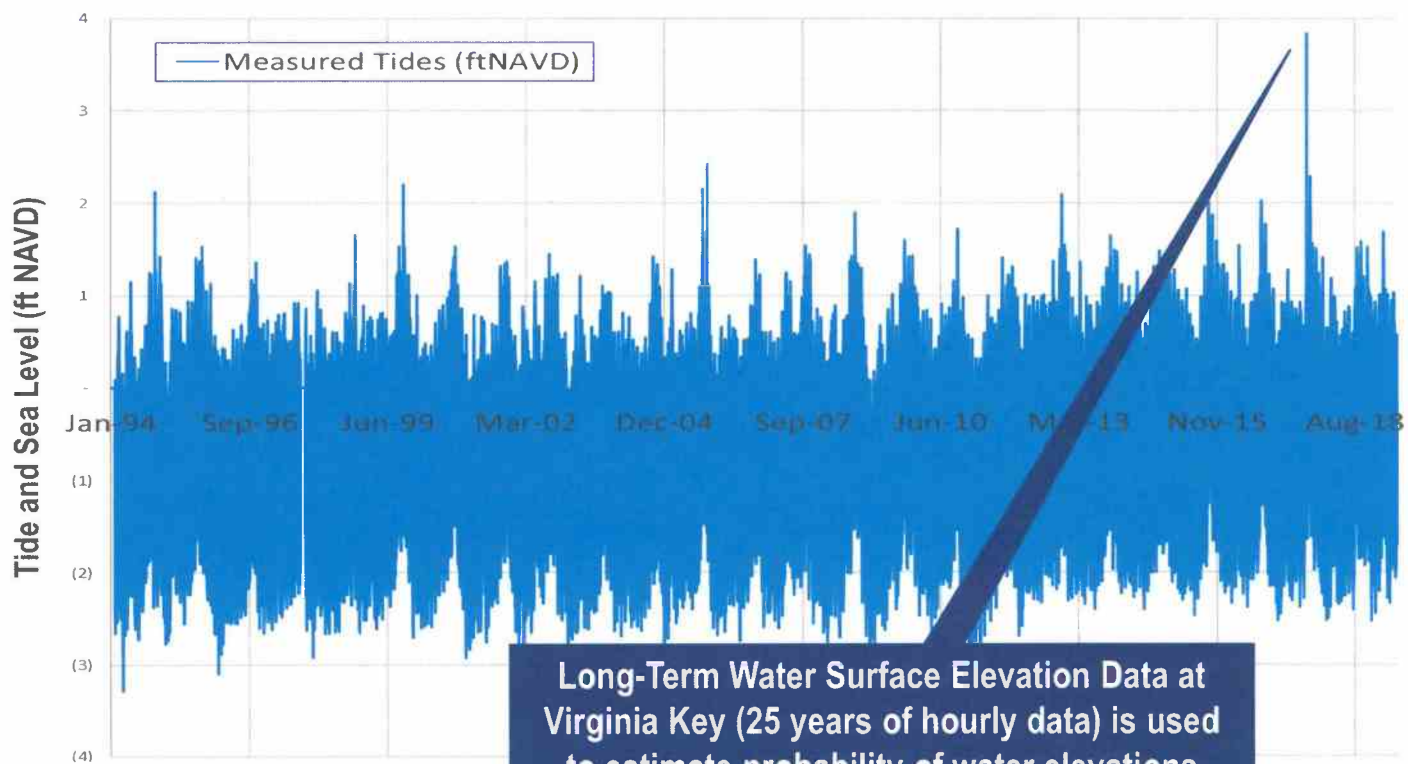
Level of Service by Road Type

CALCULATION METHOD 1

Emergency Roads
10% (1 per 10-year):
3.0 ft NAVD

Major Roads
20% (1 per 5-year):
2.3 ft NAVD

Local Roads
50% (1 per 2-year):
1.7 ft NAVD



Long-Term Water Surface Elevation Data at Virginia Key (25 years of hourly data) is used to estimate probability of water elevations being exceeded.

Calculation Method 1: Limited Flooding at Edge of Road (EOR)

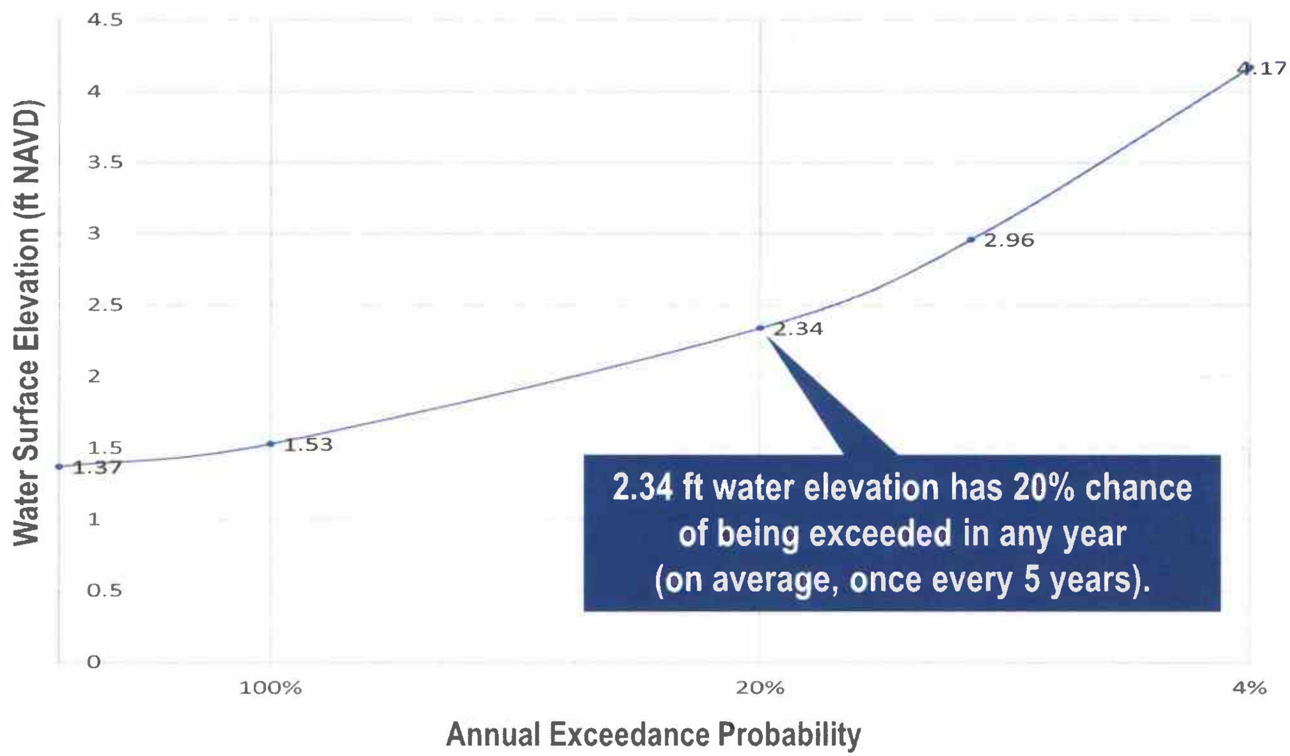
Level of Service by Road Type

CALCULATION METHOD 1

Emergency Roads
10% (1 per 10-year):
3.0 ft NAVD

Major Roads
20% (1 per 5-year):
2.3 ft NAVD

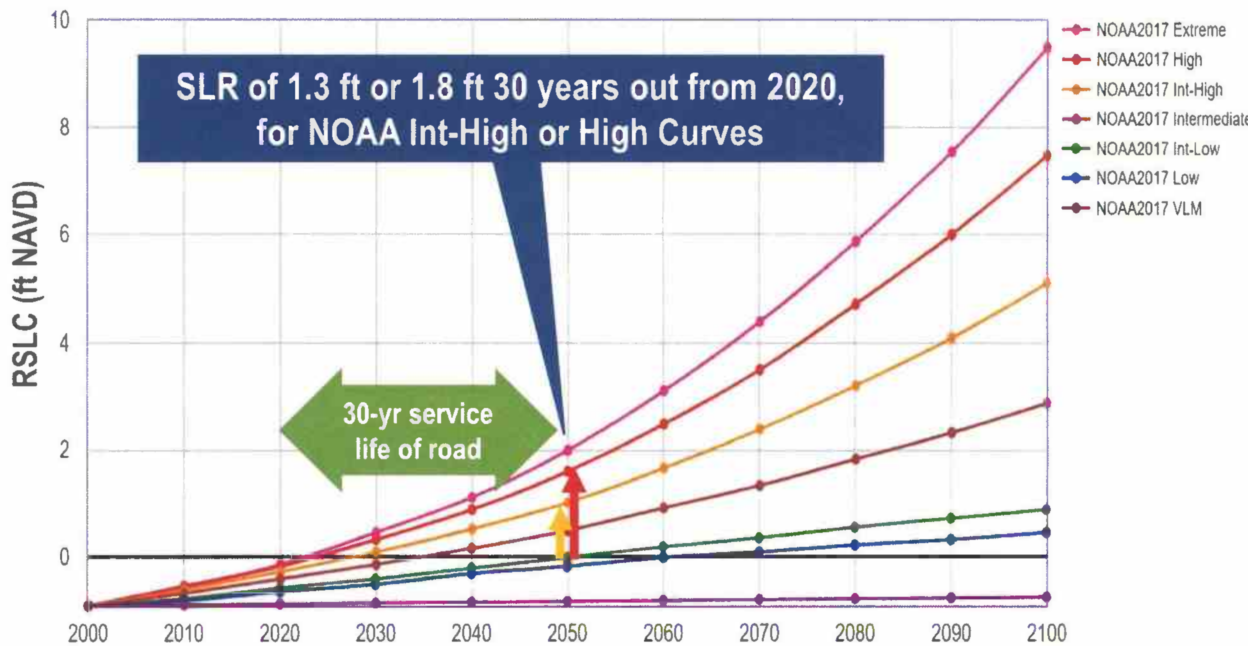
Local Roads
50% (1 per 2-year):
1.7 ft NAVD



Calculation Method 1: Limited Flooding at Edge of Road (EOR) results in EOR Minimum Elevation of 3.0 ft to 4.8 ft NAVD

Level of Service by Road Type	Sea Level Rise for 2020 Start Year*
CALCULATION METHOD 1	
Emergency Roads 10% (1 per 10-year): **3.0 ft** NAVD	2020 Start: **1.8 ft**
Major Roads 20% (1 per 5-year): **2.3 ft** NAVD	2020 Start: **1.3 ft**
Local Roads 50% (1 per 2-year): **1.7 ft** NAVD	2020 Start: **1.3 ft**

** Sea Level Rise increment will increase for later start years*



*NOAA = National Oceanic and Atmospheric Administration

Calculation Method 1: Limited Flooding at Edge of Road (EOR) results in EOR Minimum Elevation of 3.0 ft to 4.8 ft NAVD

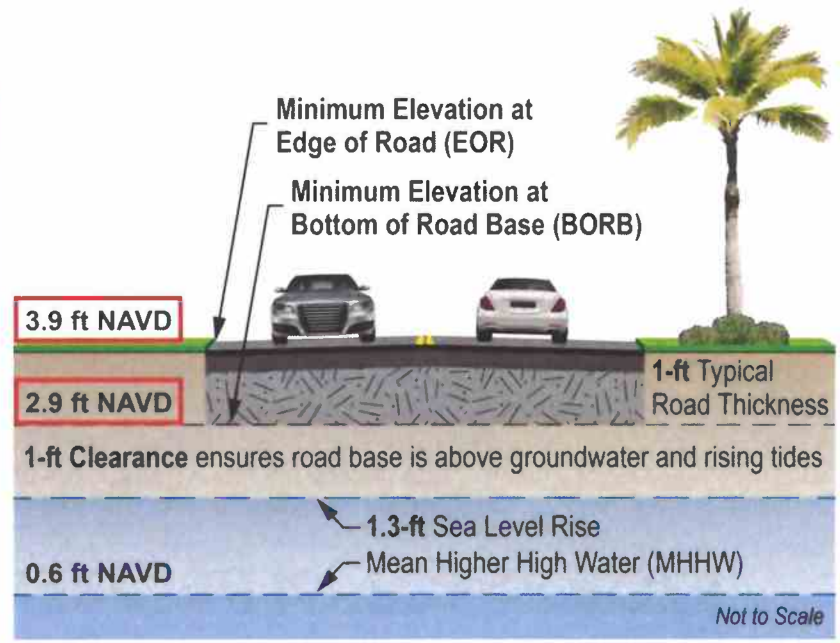
Level of Service by Road Type	Sea Level Rise for 2020 Start Year	Freeboard/ Clearance	Preliminary Design Road Elevation
CALCULATION METHOD 1: Limited Flooding at Edge of Road			
Emergency Roads 10% (1 per 10-year): **3.0 ft** NAVD	2020 Start: **1.8 ft**	Edge of Road: Freeboard **0 ft**	Edge of Road: **4.8 ft**
Major Roads 20% (1 per 5-year): **2.3 ft** NAVD	2020 Start: **1.3 ft**	Edge of Road: Freeboard **0 ft**	Edge of Road: **3.6 ft**
Local Roads 50% (1 per 2-year): **1.7 ft** NAVD	2020 Start: **1.3 ft**	Edge of Road: Freeboard **0 ft**	Edge of Road: **3.0 ft**

** Sea Level Rise increment will increase for later start years*

Calculation Method 2: Limited Groundwater Wetting at Road Base during High Tide (MHHW) Results in Bottom of Road Base (BORB) Minimum Elevation of 2.9 ft NAVD

Level of Service by Road Type	Sea Level Rise for 2020 Start Year	Freeboard/ Clearance	Preliminary Design Road Elevation
CALCULATION METHOD 2: Limited Groundwater/Tidal Wetting at Base of Road			
All Roads Mean Higher High Water (MHHW): **0.6 ft** NAVD	2020 Start: **1.3 ft**	Typ. Road Thickness (Base & Pavement): **1 ft** Bottom of Road Base: Clearance **1 ft**	Edge of Road: **3.9 ft** minimum Bottom of Road Base: **2.9 ft**

NOAA Published MHHW of 0.2 ft NAVD for 1983-2001 epoch was updated to 0.6 ft NAVD based on recent tidal data.

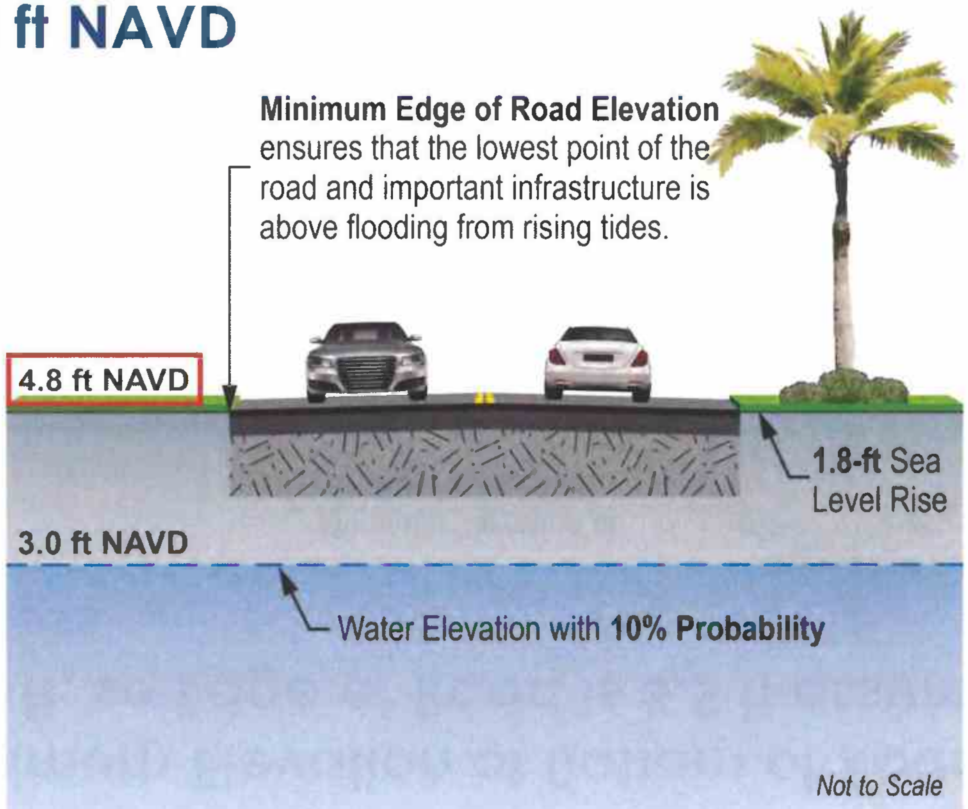


Higher of two calculation methods is selected for EOR or BORB

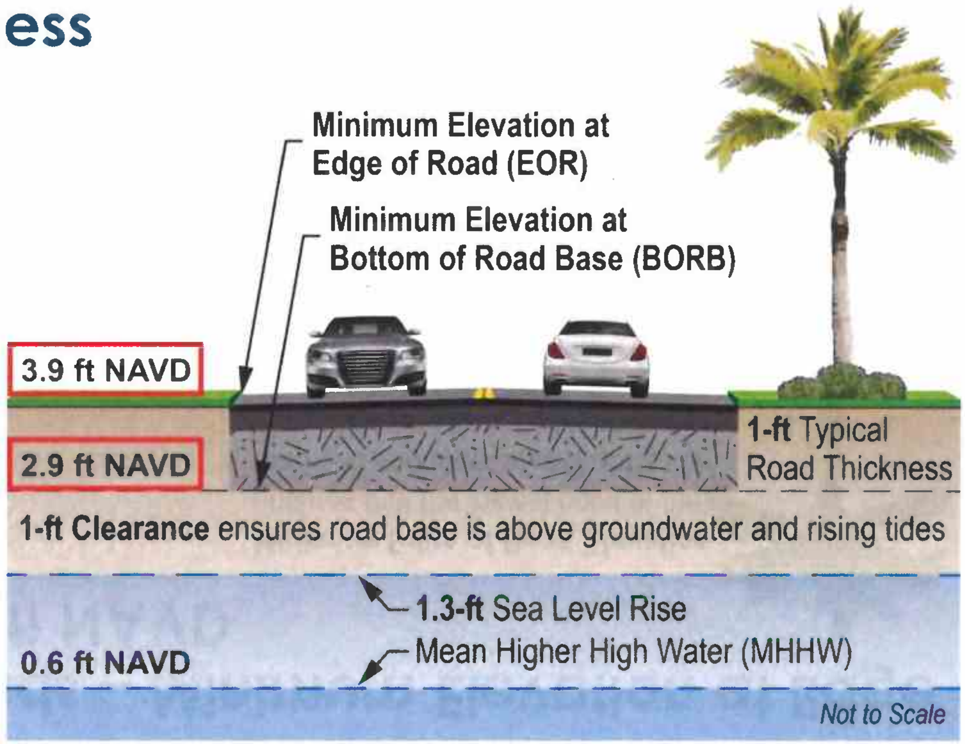
Level of Service by Road Type	Sea Level Rise for 2020 Start Year*	Freeboard/ Clearance	Preliminary Design Road Elevation	Final Minimum Design Road Elevation
CALCULATION METHOD 1: Limited Flooding at Edge of Road				
Emergency Roads 10% (1 per 10-year): **3.0 ft** NAVD	2020 Start: **1.8 ft**	Edge of Road: Freeboard **0 ft**	Edge of Road: **4.8 ft**	**Emergency Roads** EOR ≥ **4.8 ft** BORB ≥ **2.9 ft**
Major Roads 20% (1 per 5-year): **2.3 ft** NAVD	2020 Start: **1.3 ft**	Edge of Road: Freeboard **0 ft**	Edge of Road: **3.6 ft**	**Major Roads** EOR ≥ **3.9 ft** BORB ≥ **2.9 ft**
Local Roads 50% (1 per 2-year): **1.7 ft** NAVD	2020 Start: **1.3 ft**	Edge of Road: Freeboard **0 ft**	Edge of Road: **3.0 ft**	**Local Roads** EOR ≥ **3.9 ft** BORB ≥ **2.9 ft**
CALCULATION METHOD 2: Limited Groundwater/Tidal Wetting at Base of Road				
All Roads Mean Higher High Water (MHHW): **0.6 ft** NAVD	2020 Start: **1.3 ft**	Typ. Road Thickness (Base & Pavement): **1 ft** Bottom of Road Base: Clearance **1 ft**	Edge of Road: **3.9 ft** minimum Bottom of Road Base: **2.9 ft**	
METHOD 3: Roadway Harmonization with Adjacent Property				

** Sea Level Rise increment will increase for later start years*

Emergency Roads – Minimum Elevation at Edge of Road (Method 1): 4.8 ft NAVD

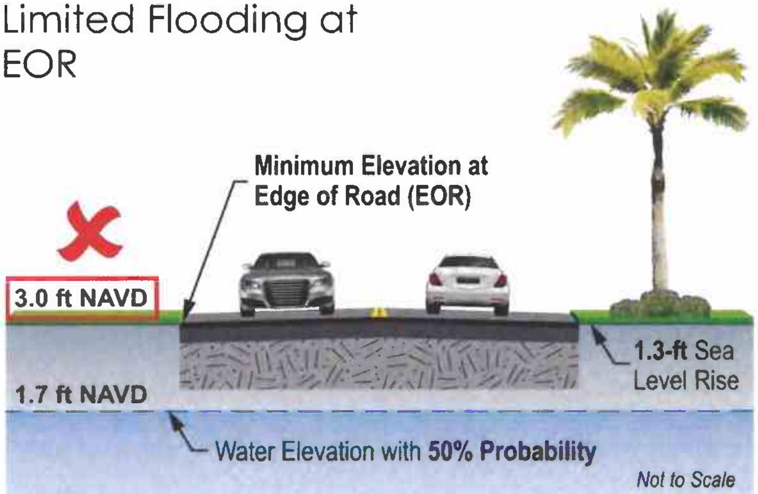


All Roads – Minimum Elevation of Bottom of Road Base (Method 2): 2.9 ft, so Edge of Road is 3.9 ft assuming 1-ft road thickness

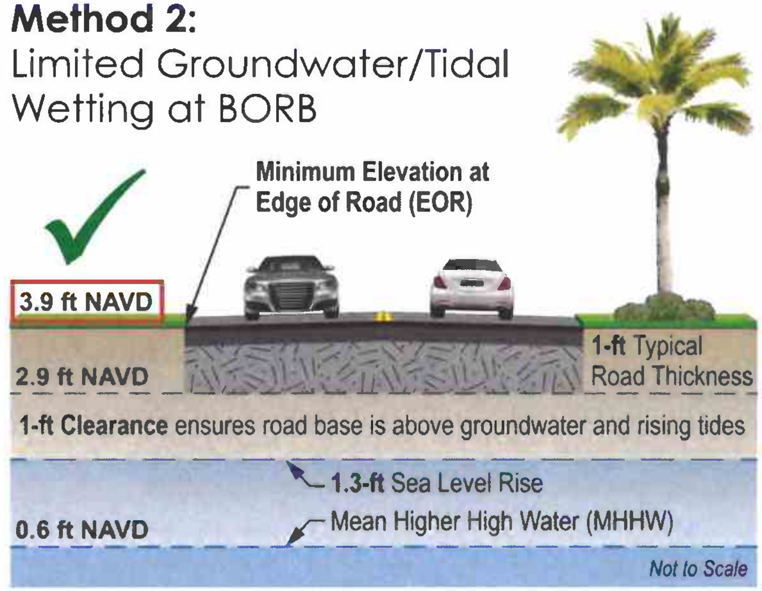


Major Roads – Minimum Elevation of Edge of Road (Method 1): 3.6 ft NAVD, so Bottom of Road Base (Method 2): 3.9 ft NAVD is preferred

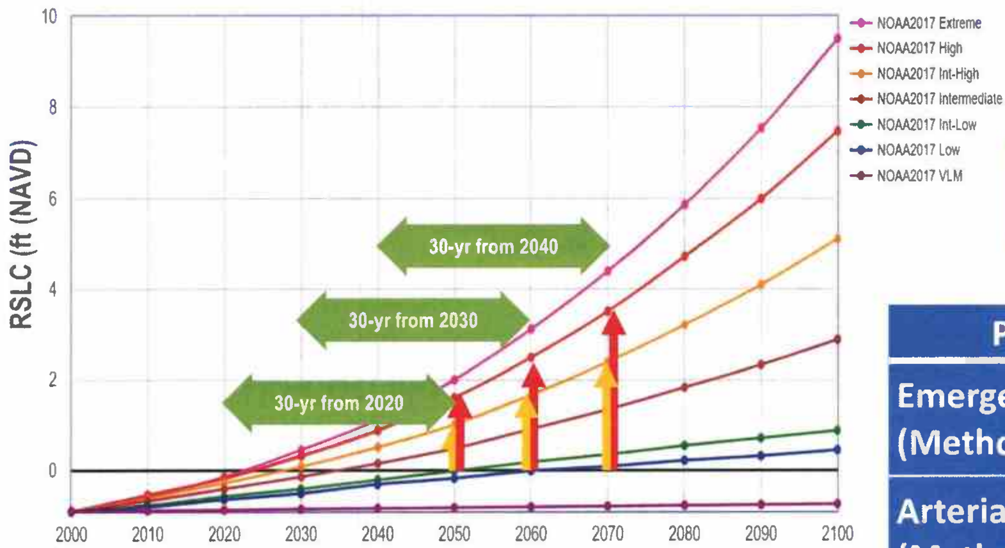
Method 1:
Limited Flooding at EOR



Method 2:
Limited Groundwater/Tidal Wetting at BORB



Road raising strategy for future projects increases in recognition of accelerating Sea Level Rise projections



SLR of 1.8 ft or 1.3 ft 30 years out from 2020

SLR of 2.7 ft or 1.9 ft 30 years out from 2030

SLR of 3.7 ft or 2.7 ft 30 years out from 2040

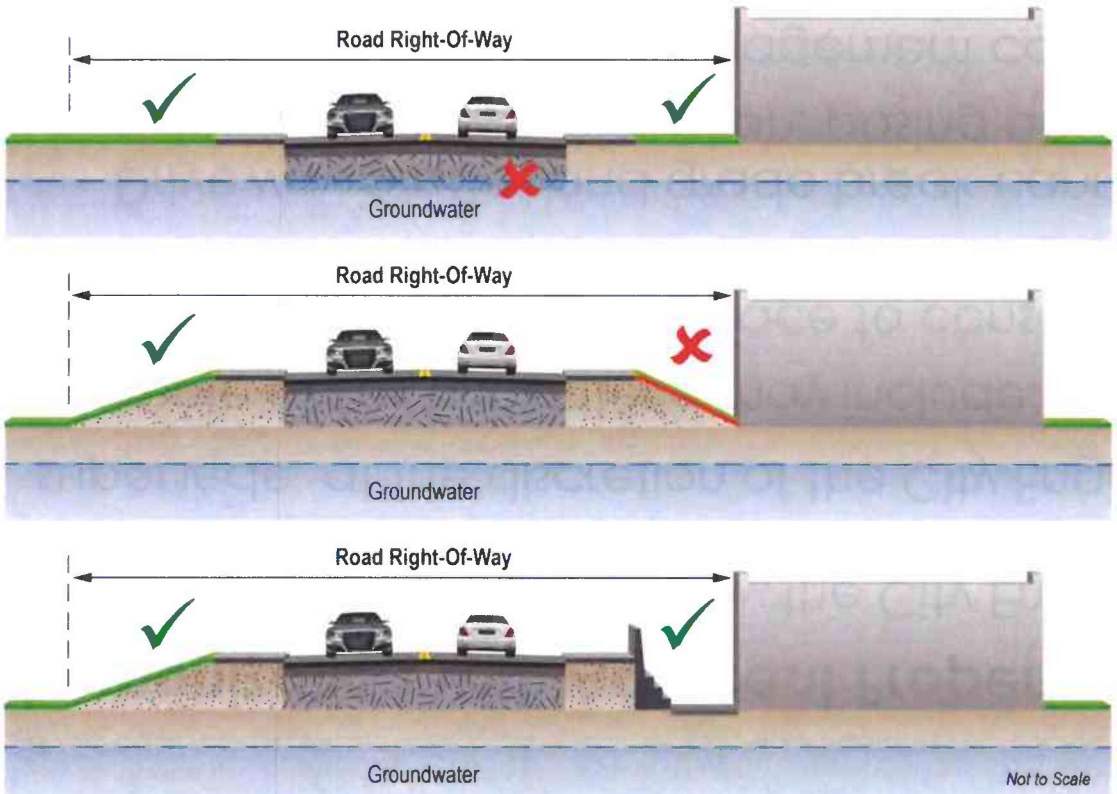
Project Start Date	2020	2025	2030	2035	2040
Emergency Roads (Method 1)	4.8	5.2	5.7	6.2	6.7
Arterial and Local Roads (Method 2) *	3.9	4.2	4.5	4.9	5.3

* Method 2 assumes 1 ft road thickness above bottom of road base.

Harmonization with Adjacent Property

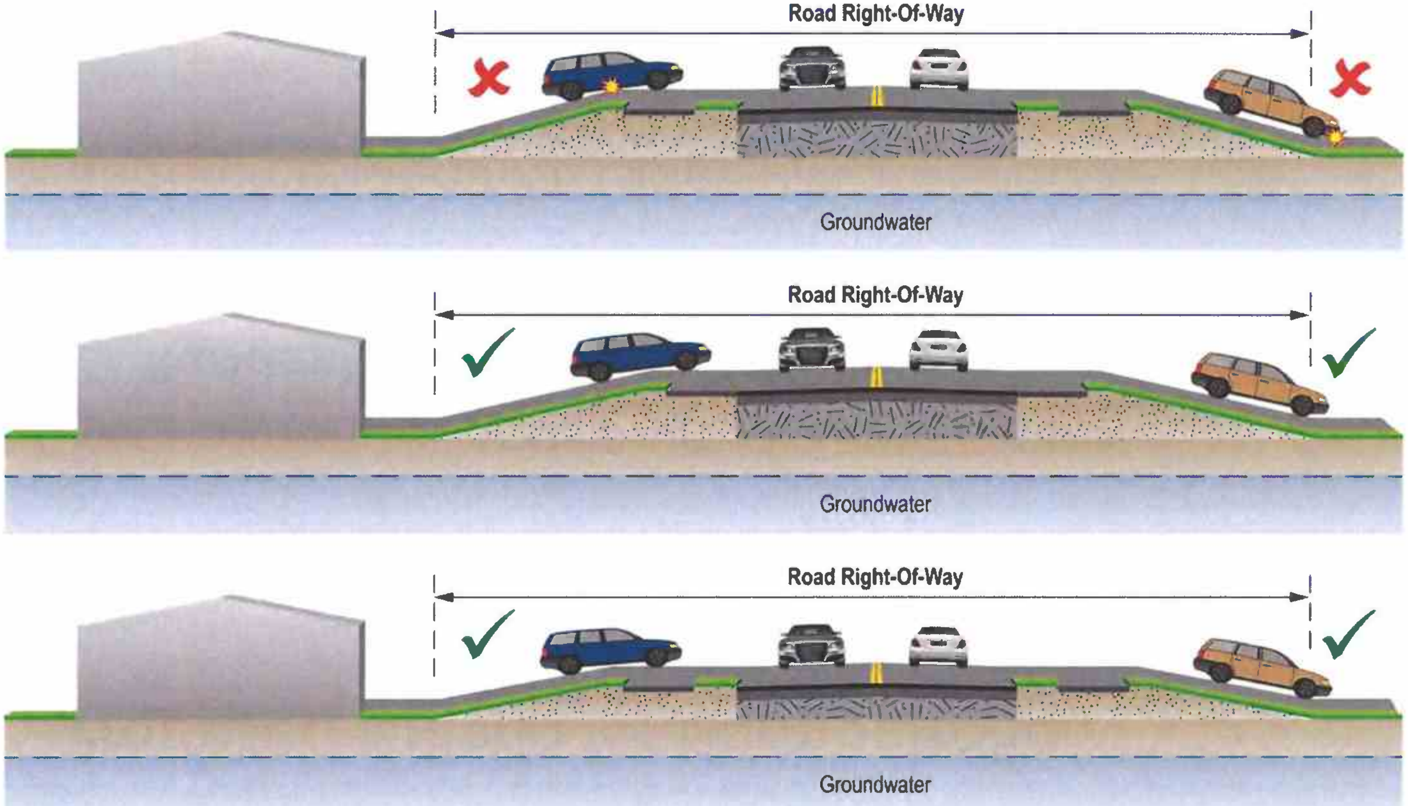
- If constraints are identified by the City Engineer, as a result of the minimum road elevation, then harmonization exception criteria supersede, at the discretion of the City Engineer.
- Example exception criteria may include:
  - Inadequate horizontal space to construct road improvements and tie back to existing grade
  - Driveway grades and grade break cannot meet City standards at new elevation, posing access concerns
  - Adverse stormwater management conditions created

Harmonization with Adjacent Commercial Property



- Existing issue (saturated base causing road system failures)
- Proposed road elevation creates conflicts with buildings
- Harmonization solution includes use of edge treatment to mitigate

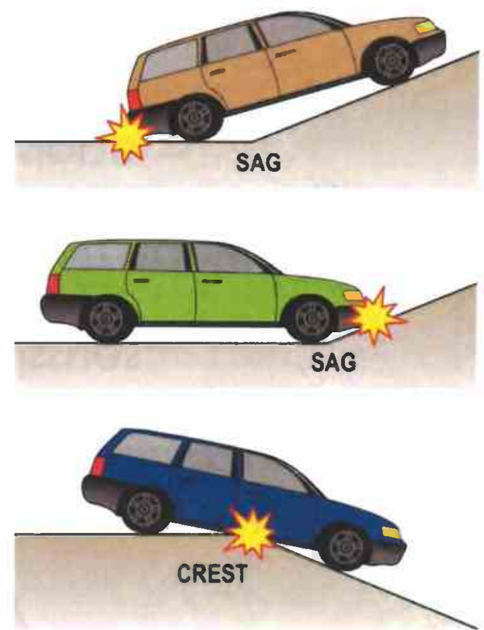
Harmonization with Adjacent Residential Property



- Proposed road elevation may create driveway access issues.
- Shift sidewalks to decrease angle of slope.
- Raising sidewalk and roadway less to decrease angle of slope.

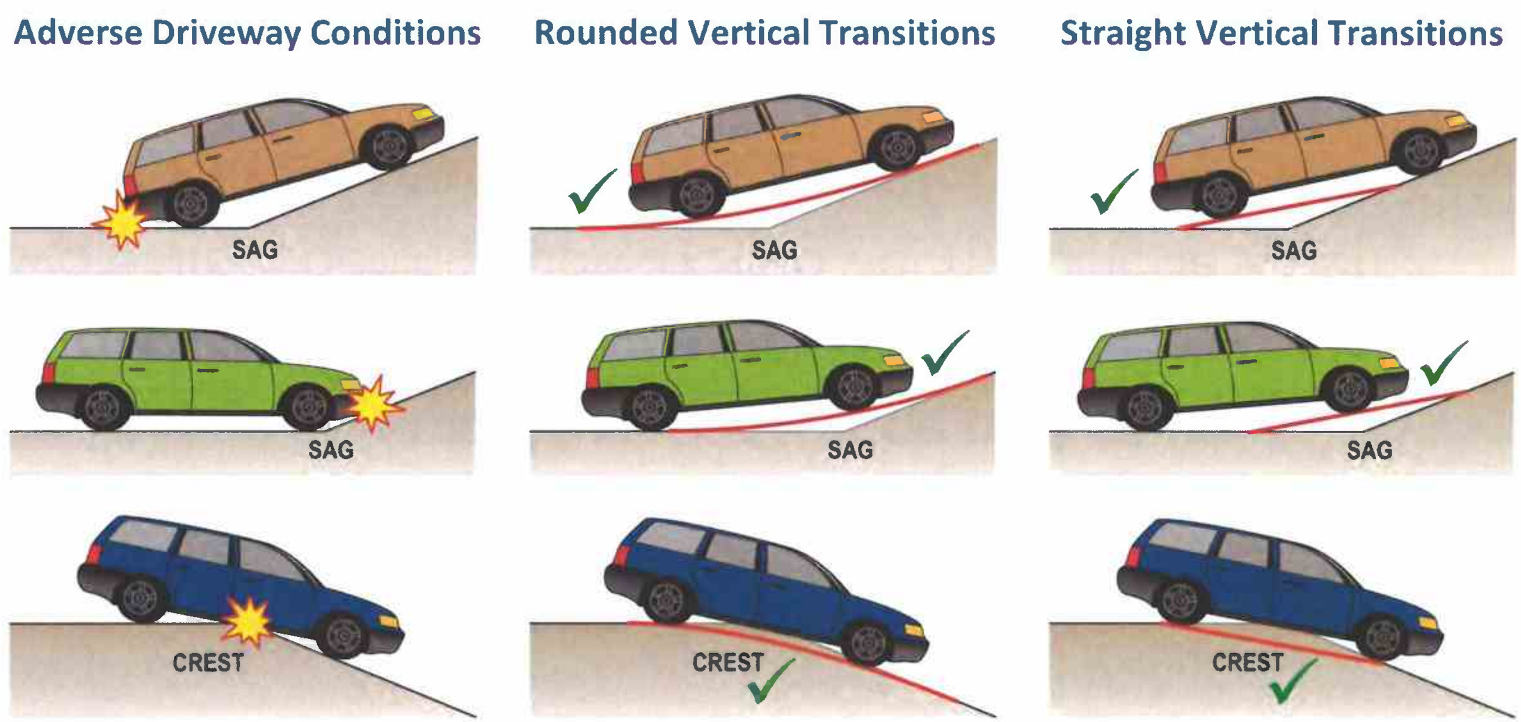
Proposed Criteria for Harmonization

- Driveway slopes within FDOT standards to avoid adverse conditions.
- Recommended maximum driveway slopes
  - **Residential: 12.5%** (1V:8H)
  - **Commercial: 10.0%** (1V:10H)
- Recommended max. sidewalk cross-slope = 1.5%



Proposed Criteria for Harmonization

If driveway slope changes more than 14.0% at a crest or sag, a vertical transition will be provided.



Proposed Harmonization Solutions (Examples)

- Alternative road treatments (retaining walls, steps, ADA ramps, etc.)
- Temporary construction easement to reduce slope of driveways.
- Lower sidewalk at driveway to improve driveway grades.
- Collect stormwater from behind sidewalk, into storm drainage system.
- Don't raise roadway as high as minimum standard.

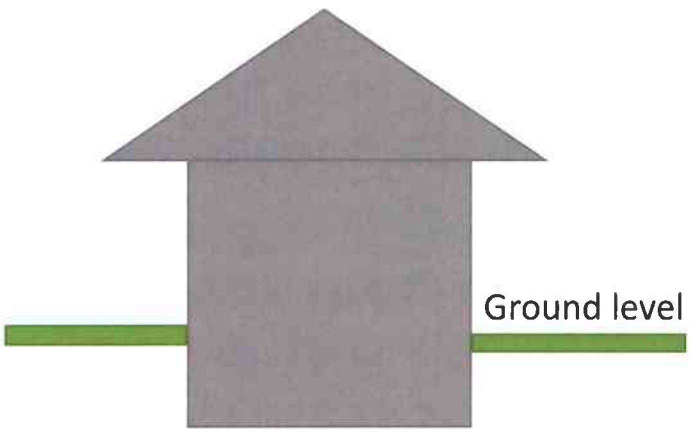
(solutions vary between residential and commercial property)

Basements Defined

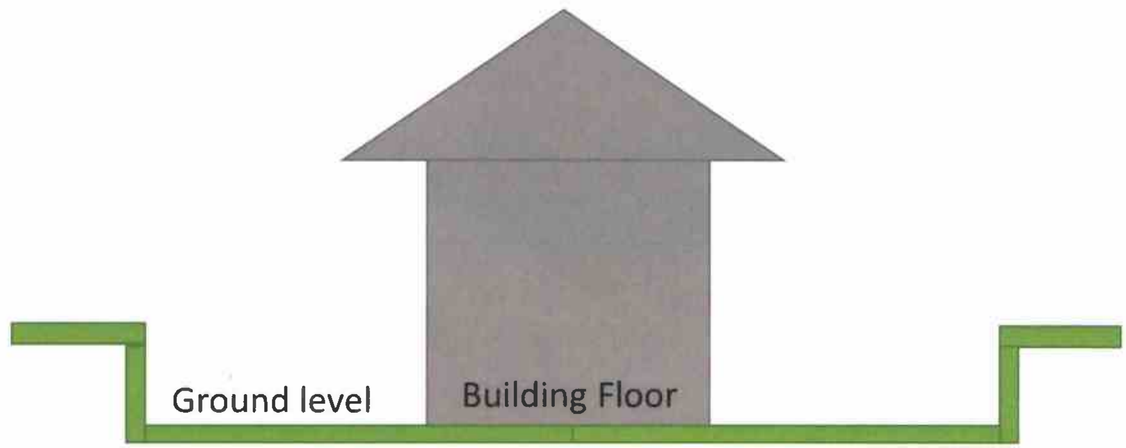
FEMA Definition:

Any area of a building having its floor subgrade (below ground level) on all sides.

(Definition adopted and codified by City of Miami Beach, Ordinance Section 54-35)



Basement Condition



Not a Basement

Purpose of Pumps, for Stormwater Management

- Maintain stormwater discharge during high tide, allowing streets and properties to drain.
- Elevating roads mitigates against high tides and groundwater.