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1

URBAN LAND INSTITUTE (ULI)

ULI OBSERVATIONS: "Acted with courage to fix sunny day and stormwater flooding"

Urban Land Institute

"Applied good practice for initial pump rollout – engineering and prioritization, initiated street elevations, designed for mid-level climate risk, raised funds through fees, crafted thoughtful communications... collaborated... implemented multiple levers including policy changes, examining cost/benefits..."

April 2018

Introducing the ULI Panel…

ULI Advisory Services Panel

VISION

- *Integrate stormwater management into the larger resilience strategy*
- *Enhance trust, trust the public, increase transparency*
- *Elevate aesthetics and function to perpetuate city's cultural relevance*
- *Actively use green and open spaces for sponge function*
- *Increase long term financial and comprehensive protection*
- *Go big on the resilience brand – distinguish yourself from your coastal competitors*

ULI Recommendations

STORMWATER & CLIMATE ADAPTATION PRINCIPLES

- *Maintained urgency,*
- *incrementalism & evaluation,*
- *transparency,*
- *ecological health,*
- *financial pragmatism,*
- *co-benefits,*
- *social equity,*
- *cultural identity,*
- *living with water,*
- *long-term and regional perspective*

ULI Recommendation 1

Infrastructure:

- Blue/green infrastructure
- Water quality enhancements
- Enhanced, integrated and multi-risk modeling
- Living with water pilot projects
- Level of service
- Income generating solar power
- Blue corridor

ACTIONS TO DATE

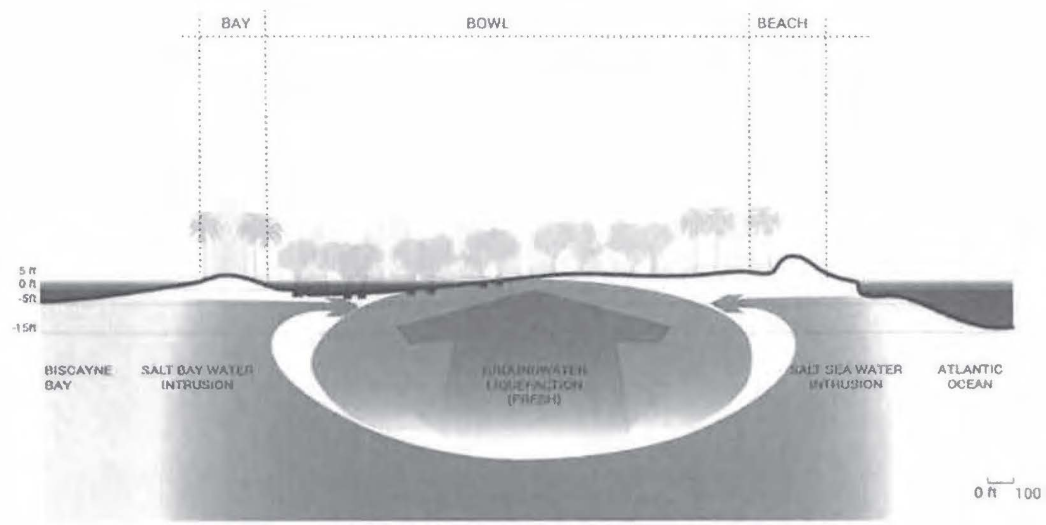
- READY Team (convened April 2018)
- 100 RC Resilience Accelerator for West Avenue (August 2018)
- RFQ for a Comprehensive & Integrated Stormwater Master Plan and Design Criteria Professional (underway)
- Integrated Water Modeling Market Research (underway)
- Dr. Charles Rowney Water Quality Analysis (complete)
- Street Tree Management Plan (underway)
- Amending Land Use Regulation (Policy discussion)

ULI Recommendation 2

ACTION: Under staff review

Design Typologies:

- Golf course as underused greenspaces
- Enhance road permeability
- Solar and renewable opportunities



ULI Recommendation 3

Creative placemaking:

- Partner with local arts and culture stakeholders
- Incorporate public art into stormwater strategy
- Involve artists in design

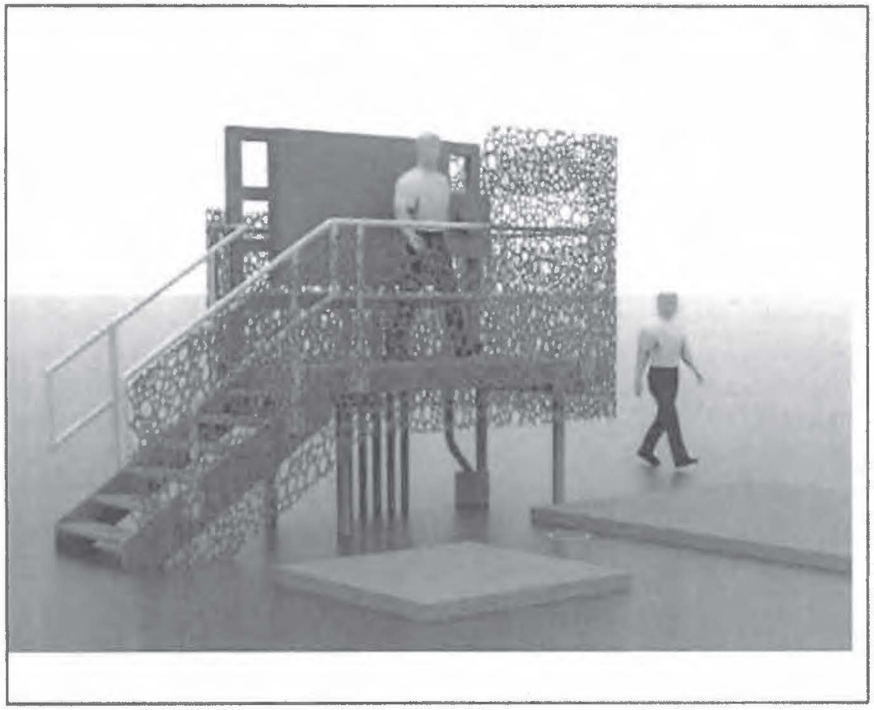
ArtCenter SOUTH FLORIDA

ACTION

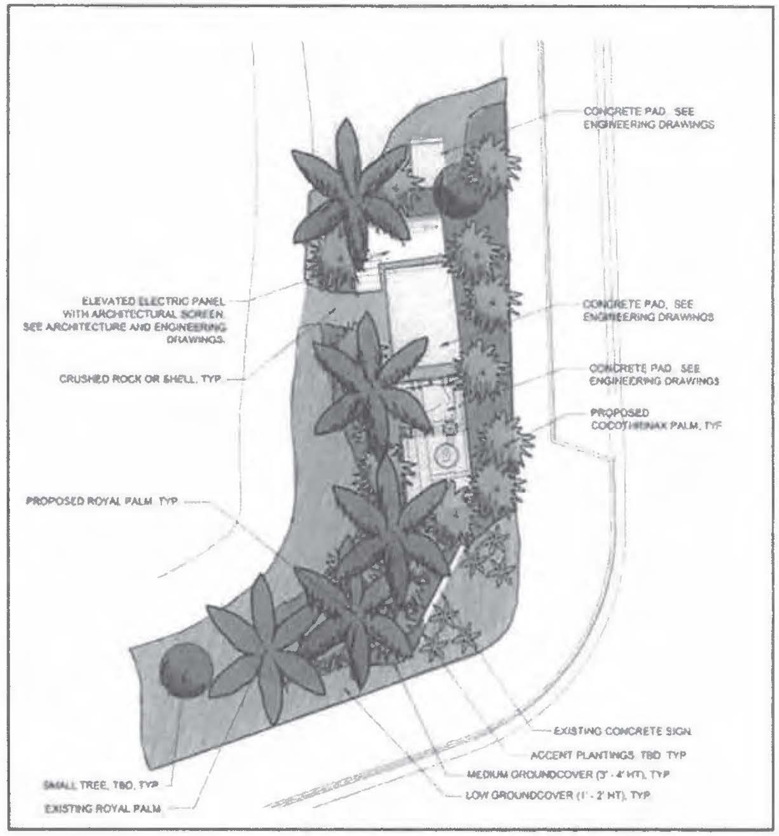
- Resilience Artist in Residency (underway)
- West Lots Planning (underway)
- 41st Street Master Plan (underway)
- Design Review Board-approved pump-station screening (underway)
- Further develop Miami Beach Rising Above Resiliency App (funding needed in FY 19/20)

Design Review
Board-approved pump-station screening (approved)

ARCHITECTURAL SCREENING MATERIAL



LANDSCAPED SCREENING



ULI Recommendation 4

Governance:

- Identify, redirect or reorganize staff for:
  - Rising Above Delivery Office
  - Agency for Public Investment & Development in Resilience
  - Risk Transfer Department
- Create a scientific advisory panel
- Create a Community Adaptation Fund
- Align for historic preservation & climate strategies

ACTION

- Negotiating contract with the consultant to develop Design Guidelines for Historic Preservation in the face of Climate Change (underway)
- Other recommendations under staff review

"New adaptation and mitigation tools are needed to support communities as they respond to the new normal."
– The National Trust for Historic Preservation

ULI Recommendation 5

Financing:

- Assessment districts (BID, HOA)
- Incremental finance districts – community reinvestment areas
- Risk management function should be driven a total cost of risk approach (TCOR)
- Engage private financial stakeholders
- Adjust stormwater fees based on runoff
- Community adaptation fund for low interest adaptation loans
- Insurance as a form of risk transfer
- Integrate finance into communications strategy

ACTION

- Business case analysis first task order (underway)
- Exploring parametric insurance for resort taxes (underway)
- City's Financial Advisor is engaged with rating agencies, reports on sea level rise risk, and the progress and continuous improvement of our stormwater program (June 2018)
- Exploring Special Assessment Districts for sea walls (underway)

ULI Recommendation 6

Regulations:

- Embed water management goals in the development regulations
- Leverage and reform regulatory boards
- Establish specific measurable water management goals at district level
- Adjust stormwater fees
- Create island-wide sea barrier through some form of an assessment rather than leaving this up to individual owners
- Continue to support elevation for new construction

ACTION

- Build upon recent changes to land use boards requiring a sea level rise and resilience review of pending developments (July 2017)
- Requires further policy/legislative change

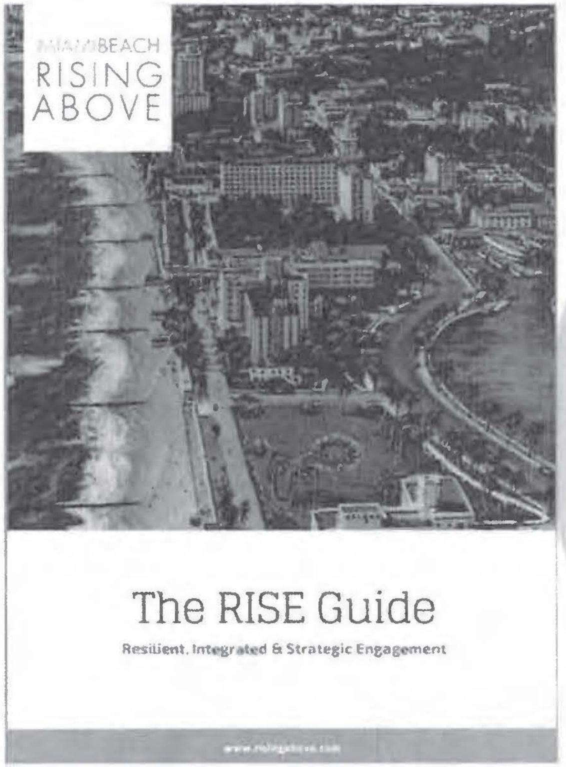
ULI Recommendation 7

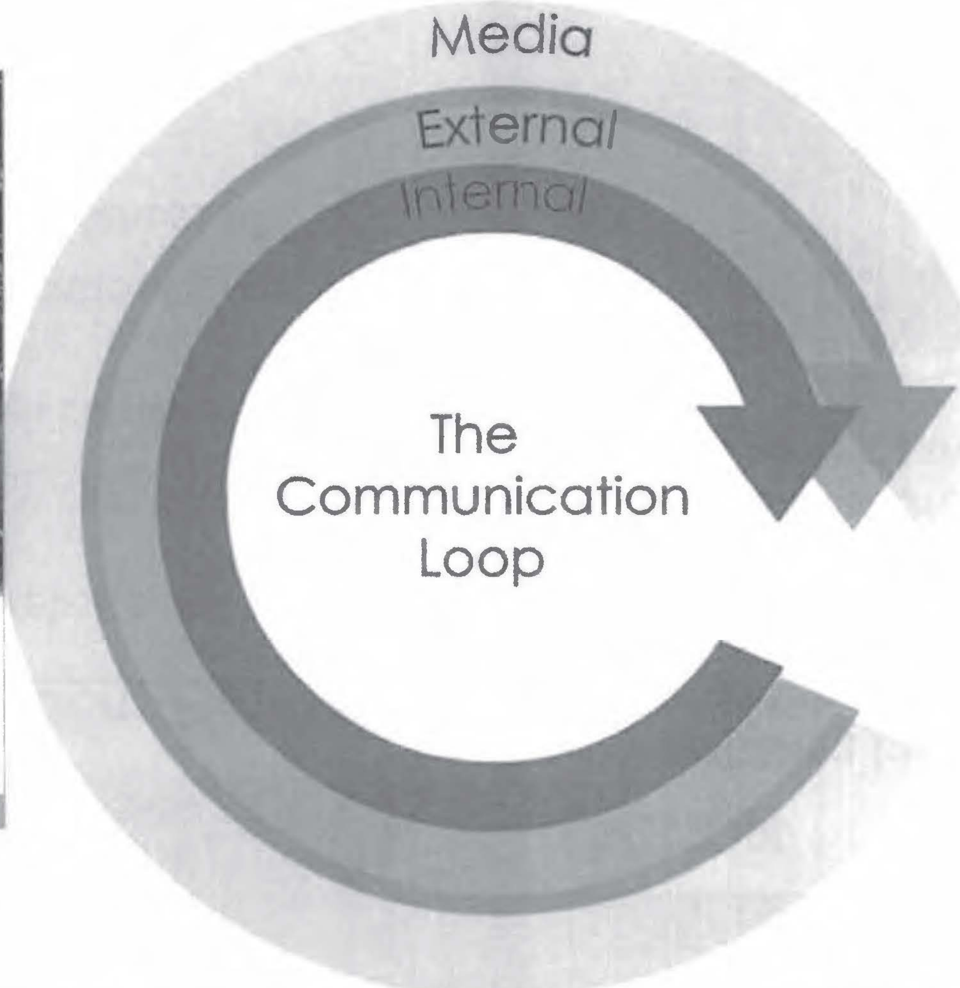
ACTION

- Developing tools for internal integration and internal communications (underway)
- Developing integrated external communications plan for stakeholder engagement (underway)

Integrated Communications Plan:

- Promote Rising Above website as the primary resource
- Be bolder in communications strategy
- Build public trust through clarity and transparency
- Create a broad communications plan
- Increase diversity and robustness of communications
- Solicit community input
- Recognize achievements and successes





"Designed to increase message consistency, trusting relationships, and knowledge sharing among our government and members of the community".

IMPLEMENTATION STRATEGY

Urban Land Institute

Miami Beach Advisory Services Panel Report: Summary of Recommendations

Topic	LEAD	SUPPORT	Recommendation	TYPE (administrative, legislative, research needed)	Committee	LEAD (person-owner/champion)	Support (team)	$$ FUNDING NEEDS (yes/no)	STATUS (recent action, next action)
Infrastructure	PWD,CIP	E&S, PLANNING, COUNTY(?)	1 Improve flexibility and robustness of current stormwater system						
			2 Create an integrated, hydrodynamic computer model to better inform decision making on flooding issues and risk						
			Engage an owner's representative to consult on product selection						
			Purchase integrated modeling software						
			Add "flood risk model manager" position to ensure most productive						
			3 Implement blue and green infrastructure to advance a more holistic living-with-water						
			4 Ensure appropriate modeling, study, and funding availability for green						
			5 Implement living-with-water pilot projects						
			6 Create tools for living-with-water projects at the building level						
			7 Consider a level-of-service concept to guide future decision making						
			8 Address water quality concerns						
			9 Improve communications about engineering and infrastructural solutions						

Next Steps

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- October City Commission for report acceptance
- Monthly updates at the Commission's Sustainability and Resilience Committee (SRC) to develop legislative and policy actions items and to consider budget implications
- Bi-weekly review at the City Manager's READY Team
- Develop and use recommendation tracking chart


Thank you!
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Exhibit 5

JACOBS

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

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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.

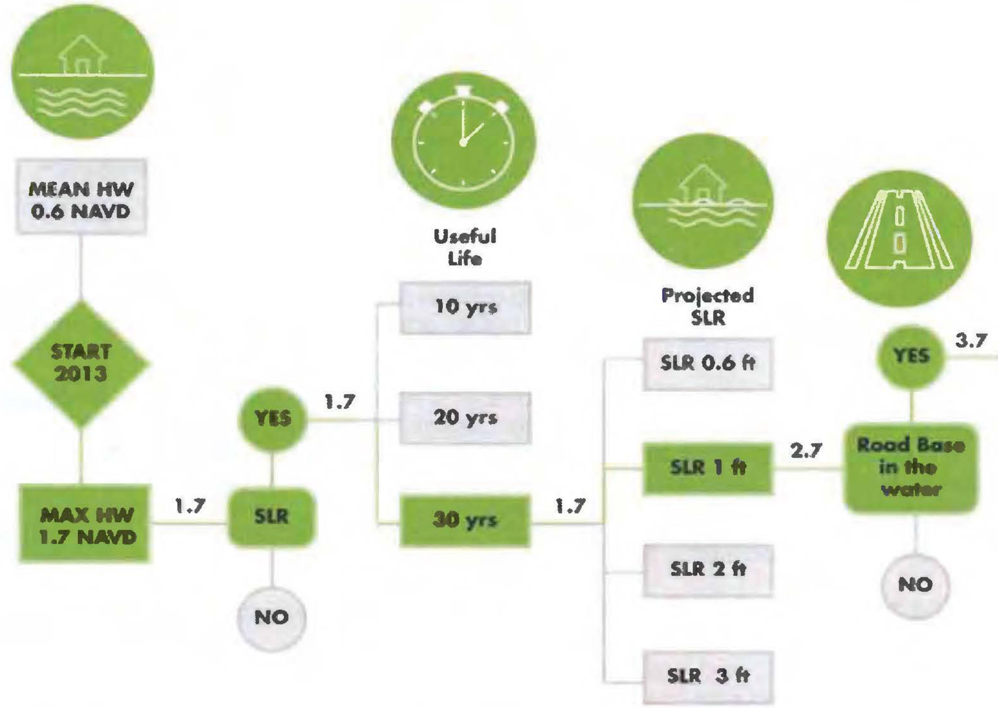

Figure 1. City of Miami Beach 2013 Road Elevation Policy Decision Tree

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.

[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

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[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.

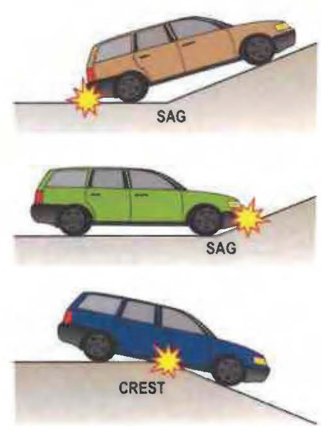
Note: TCE is a temporary construction easement established along one or both sides of a road ROW to allow for harmonization work outside of the road ROW during road construction. A permanent maintenance easement (PME) refers to a permanent maintenance easement established to allow the City to access, 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.

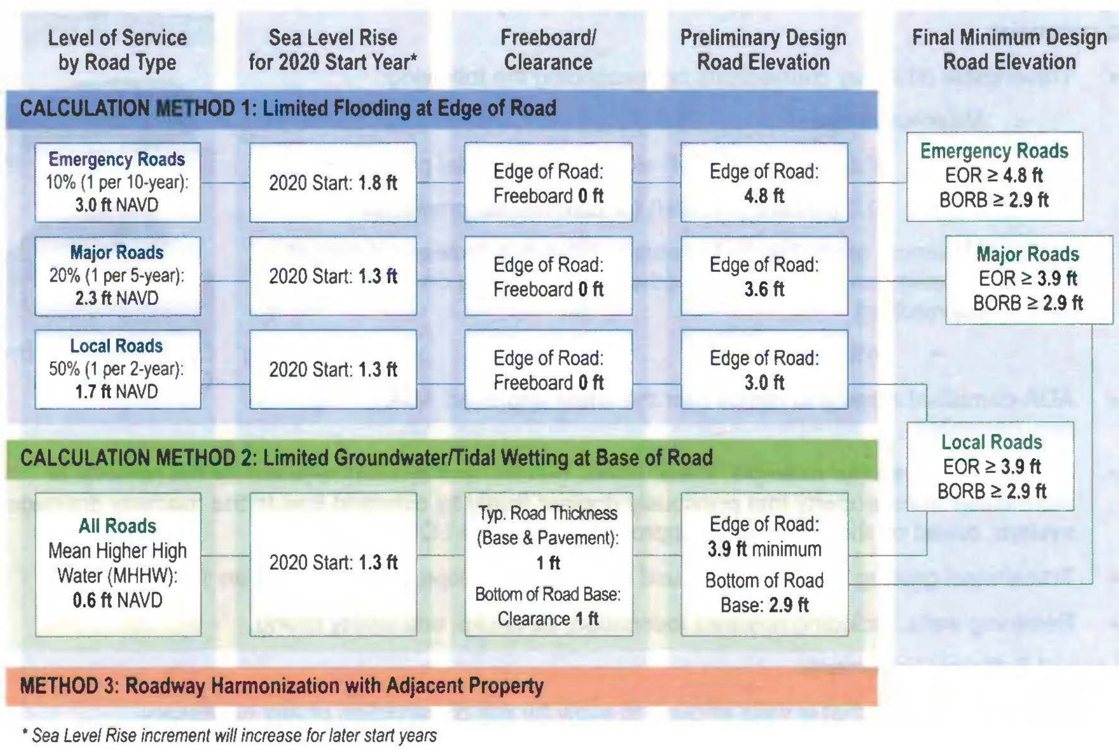


Figure 2. Road Elevation Policy Summary Chart

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.

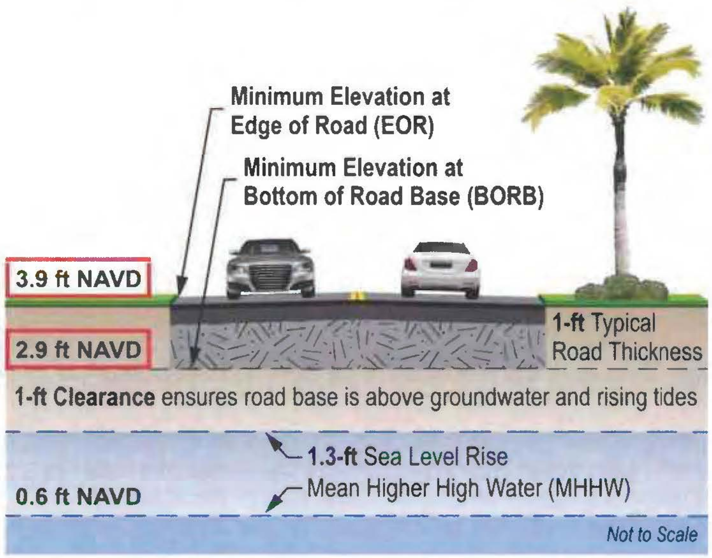


Figure 3. Minimum Elevation for the Bottom of Road Base is 2.9 ft NAVD for all Roads

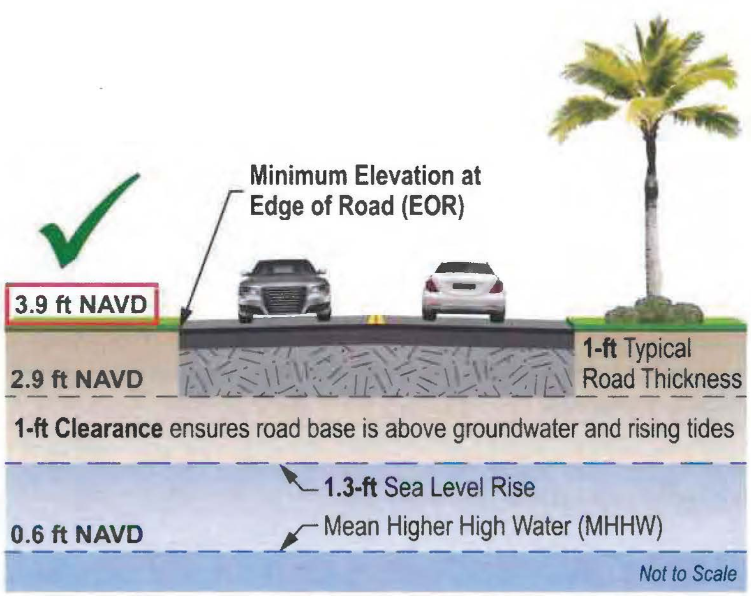


Figure 4. Minimum Elevation for the Edge of Road is 3.9 ft NAVD for all Major and Local Roads

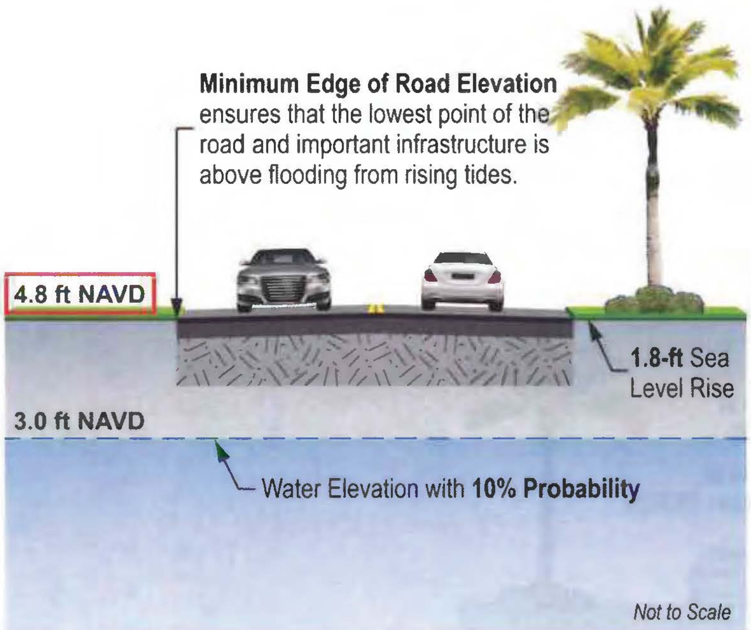


Figure 5. Minimum Elevation for the Edge of Road is 4.8 ft NAVD for all Emergency Roads

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.

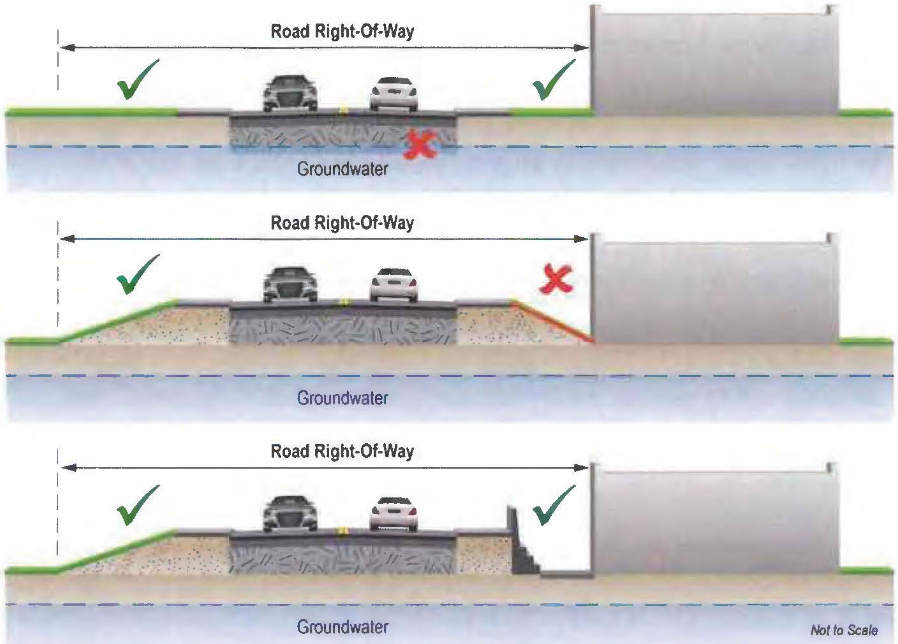


Figure 6. Example of Commercial Property Harmonization

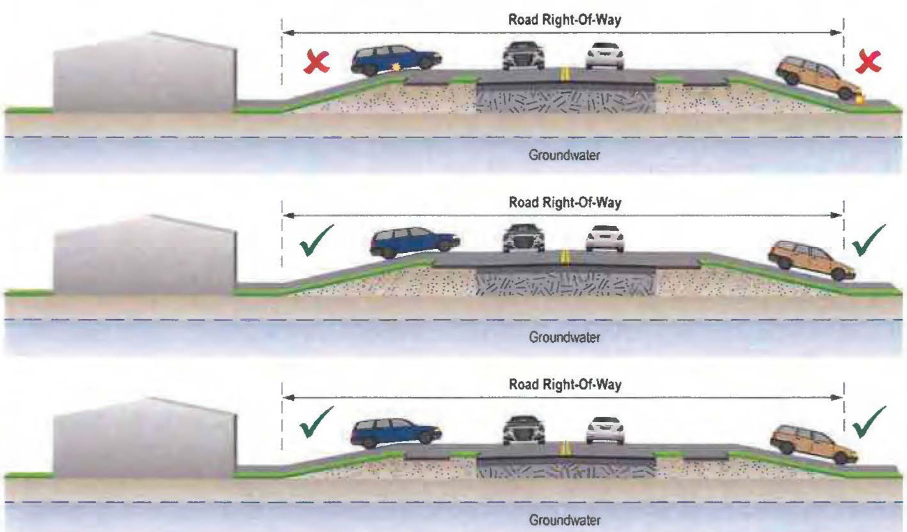


Figure 7. Example of Residential Property Harmonization

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 90th to 95th 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.

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.

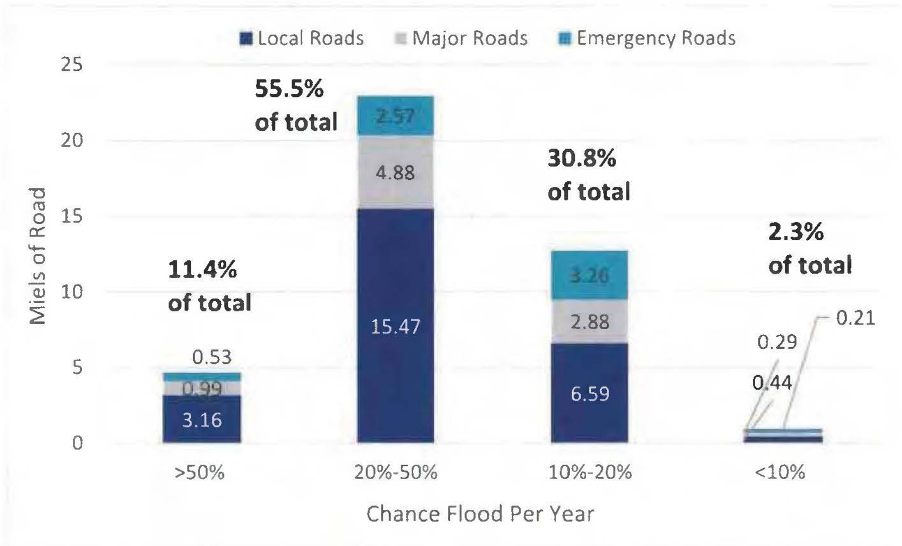

Figure 10. Distribution of Length of Roads by Type and Risk Category Combined for All Tidal Flood Adaptation Projects

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.

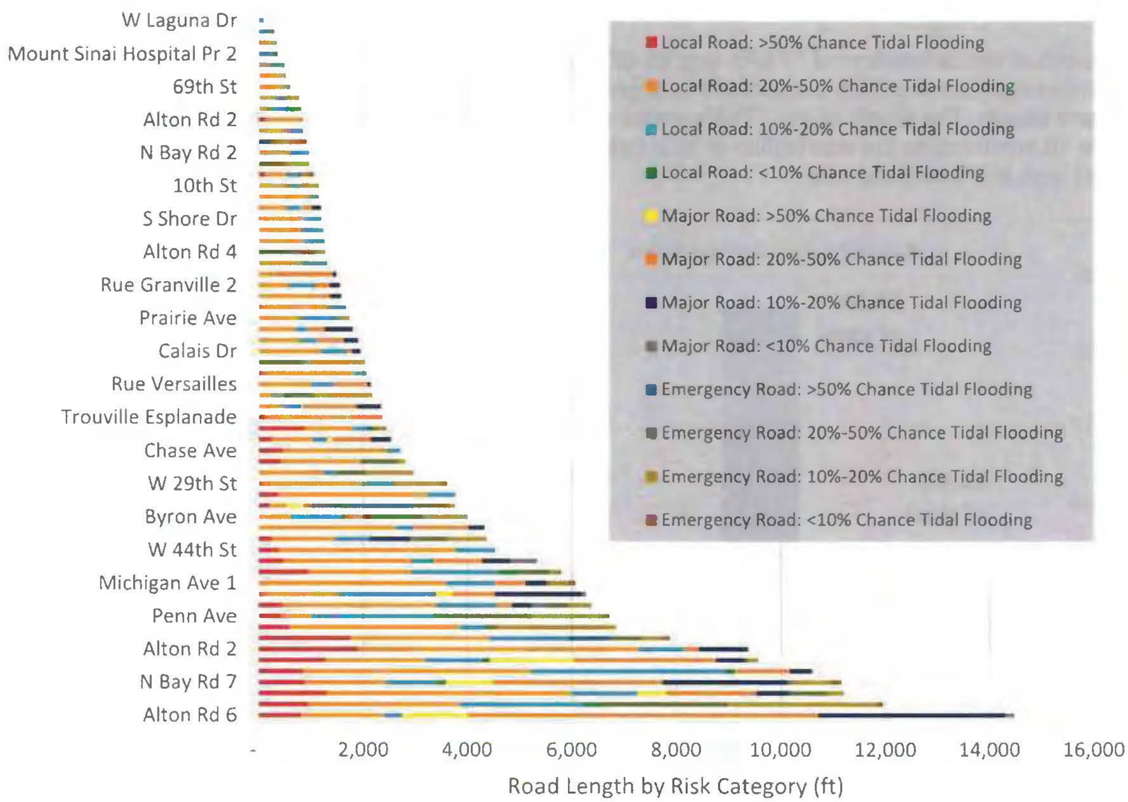

Figure 11. Length of Roads by Type and Flood Risk by Tidal Flood Risk Adaptation Project

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.

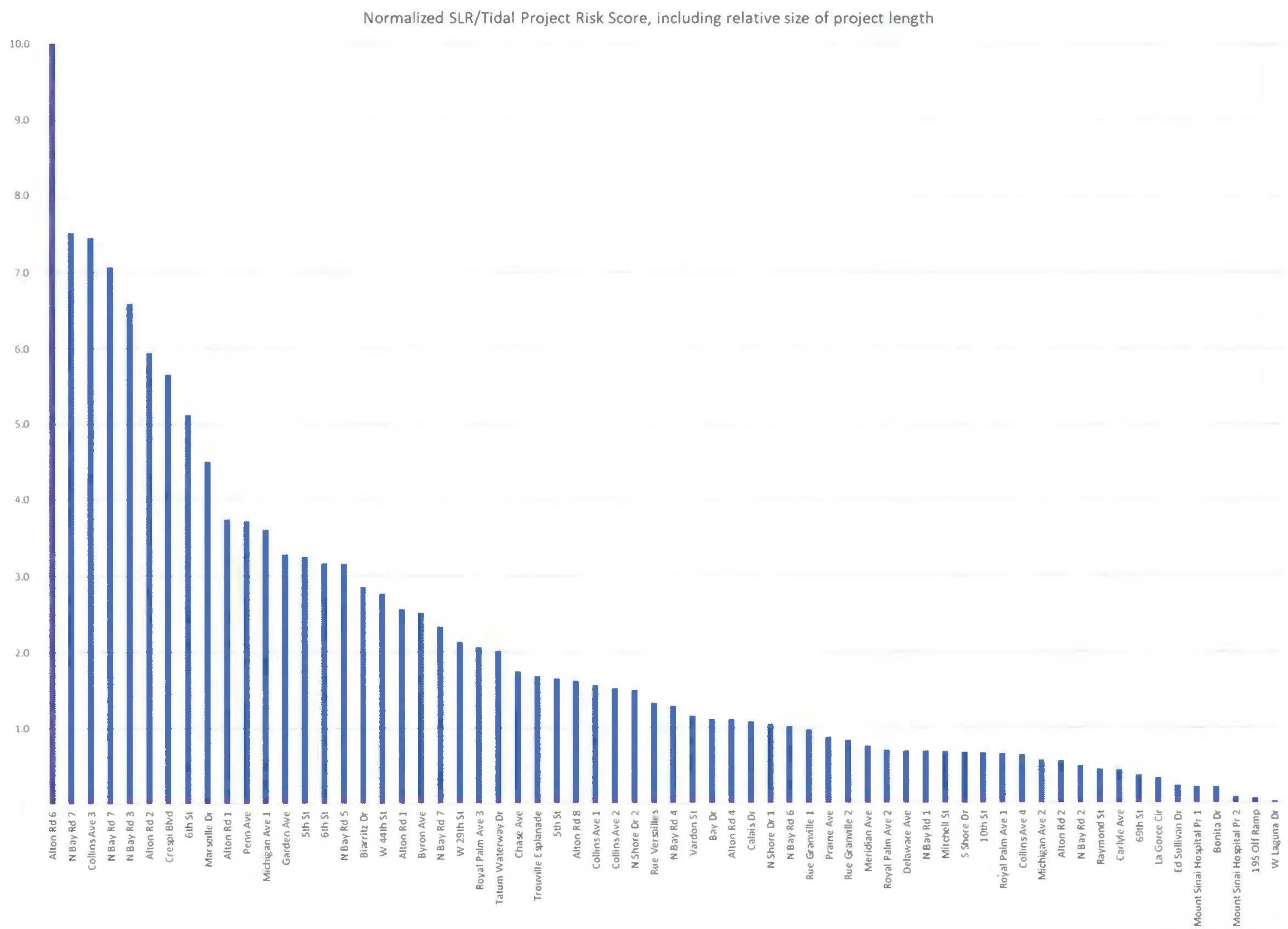

Figure 12. Weighted Risk Score for All Tidal Flood Adaptation Projects, Normalized by Project Total Length

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

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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.

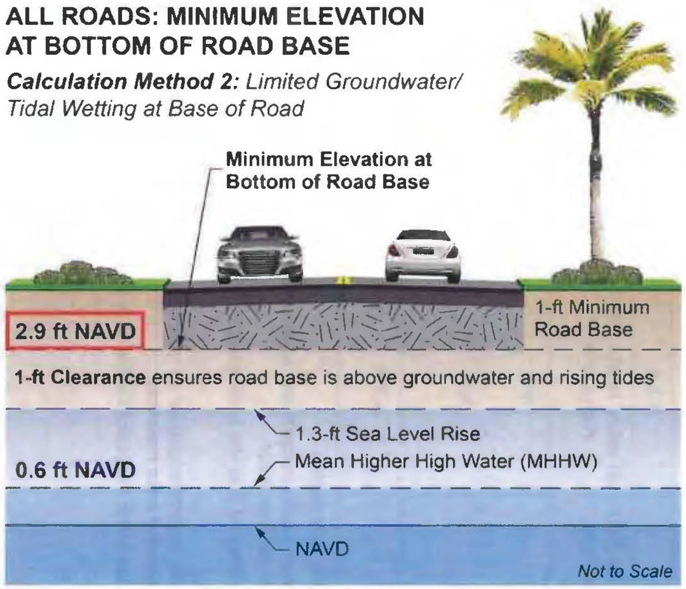
Note:

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.

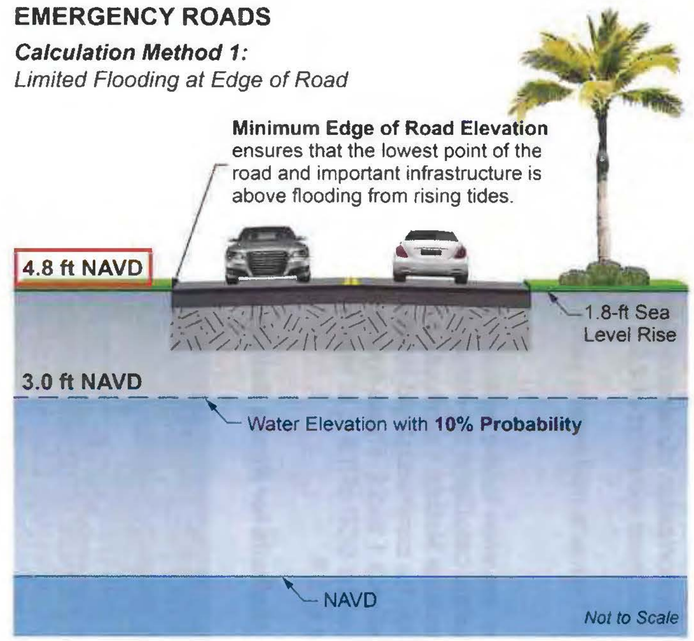
NOAA = National Oceanic and Atmospheric Administration

SHGWT = seasonal high groundwater table



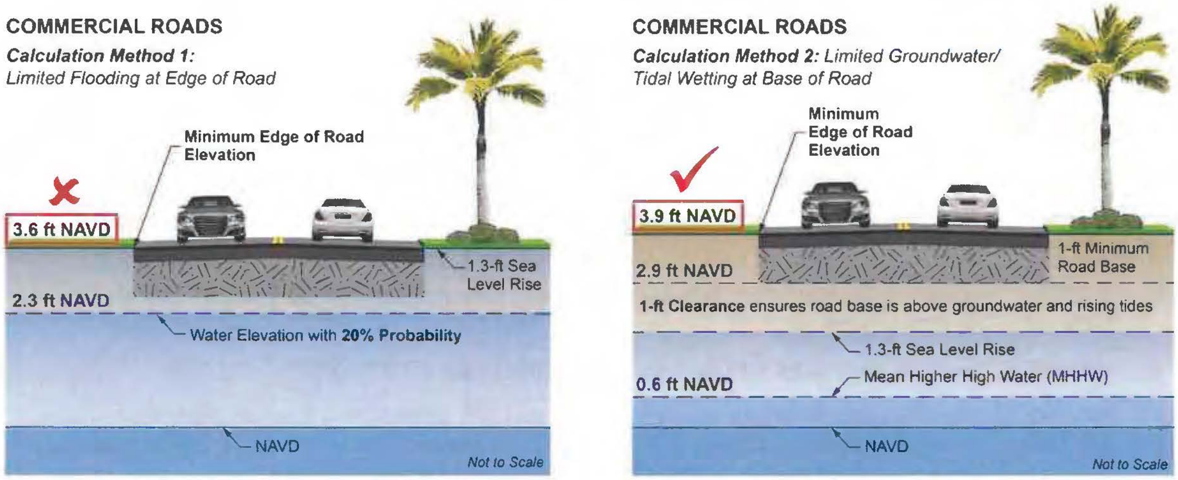
Method 2 is used to set Minimum Elevation of the Bottom of Road Base: 2.5 ft NAVD for projects built in 2020.

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.

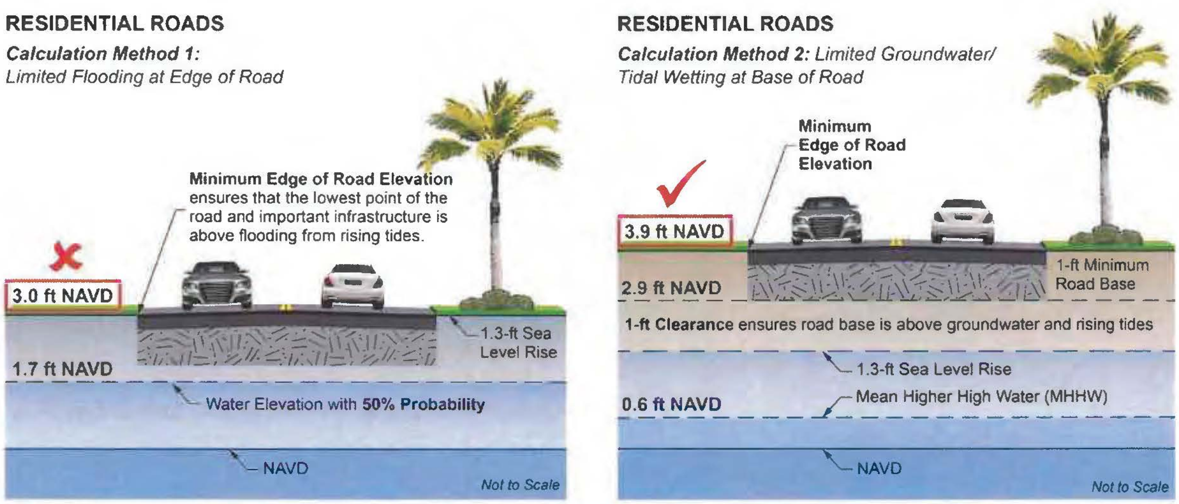
Figure ES-2. Minimum Edge of Road Elevation for Emergency Roads is Set by Method 1, as it results in Higher Elevation than Method 2



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.