Technical Memorandum

Project:	FPID 449007-1-22-01, PD&E Study SR 934/NE 79th Street Causeway, from west of Pelican Harbor Drive to east of Adventure Avenue
Date:	December 7, 2023
To:	FDOT District 6
From:	HDR
Subject:	**Sea Level Rise Calculation Method to meet FDOT Design Criteria for Bridge Vertical Clearance and Roadway Base Clearance (DRAFT)**

1.0 Purpose

The purpose of this project is to evaluate bridge replacement alternatives to address the structural deficiencies of four existing bridges (two bridge pairs) along State Road 934 (SR 934)/NE 79th Street/John F. Kennedy Causeway. The project limits extend from west of Pelican Harbor Drive to east of Adventure Avenue. The western bridge pair, comprised of Bridge Identification (ID) Numbers 870083 (westbound) and 870549 (eastbound), is located just west of North Bay Island/Harbor Island. The eastern bridge pair, comprised of Bridge ID Numbers 870084 (westbound) and 870550 (eastbound), is located between North Bay Island/Harbor Island and Treasure Island. Proposed bridges are an important link in the SR 934/79th Street Causeway linking the City of Miami, North Bay Village, and the City of Miami Beach. An additional project goal is to maintain emergency evacuation capabilities.

This Memorandum documents the FDOT design criteria and calculation method used to estimate Sea Level Rise (SLR) and establish the proposed bridge & roadway profile.

2.0 Alternatives

This Project Development and Environment (PD&E) Study considers the following Build Alternatives:

- Alternative 1a: Minor Rehabilitation
- Alternative 1b: Major Rehabilitation
- Alternative 2a: Full Replacement (Match Existing Bridge Profile)
- Alternative 2b: Full Replacement (Raise Bridge Profile)

Alternative 2a proposed to reconstruct the bridges to match the existing profile with sub-standard bridge vertical clearance. Alternative 2b proposes to fully comply with the minimum FDOT standards and maximize the bridge lives. Alternative 2b meets the FDOT design criteria for minimum bridge vertical clearance and roadway base clearance. This Memorandum is only applicable to Alternative 2b.

3.0 FDOT Design Criteria and Guidelines

3.1 FDOT Drainage Manual (2024)

The FDOT Drainage Manual (2024), Section 3.4.1, Sea Level Rise, states:

> *The design of coastal projects (including new construction, reconstruction, and projects rebuilding drainage systems) must incorporate sea level rise analysis to assess the vulnerability of flooding over the design life of the facility. Use the relative sea level trend data from historical tidal records gathered by the National Water Level Observation Network (NWLON) and managed by NOAA:*
> *https://tidesandcurrents.noaa.gov/sltrends/sltrends_states.html?gid=1238*
> *NOAA manages tidal gage stations located around the state of Florida. Use the station nearest the site for analysis. Analysis must consist of straight-line extrapolation based on the design service life of the project. Consider existing system criticality/vulnerability and project costs when implementing this best practice analysis.*

3.2 FDOT Design Manual (FDM) (2024)

Bridge Vertical Clearance

The proposed bridges along SR 934/NE 79th Street Causeway requires a minimum vertical clearance of 2 feet above the design flood stage and 6 feet above the Mean High Water per FDM Section 260.8.1, Bridges over Water, Vertical Clearance:

> *Drainage:*
> *The minimum vertical clearance between the design flood stage and the low member of a bridge is 2 feet. This clearance is necessary to allow the majority of debris to pass without causing damage to the structure. This requirement does not apply to culverts and bridge-culverts.*
> *Navigation:*
> *Provide the following minimum vertical clearance for navigational purposes:*
> *(1) 6 feet above the Mean High Water (MHW) for tidewater bays and streams*

Roadway Base Clearance

The proposed roadway reconstruction along SR 934/NE 79th Street Causeway requires a minimum base clearance of 1-foot, per FDM Section 210.10.3, Vertical Clearance:

> *(2) Minimum clearance from the bottom of the roadway base course to the Base Clearance Water Elevation is 3 feet, except as noted below. These exceptions will require a reduction in the design resilient modulus in accordance with the Flexible Pavement Design Manual. Coordinate with the Pavement Design Engineer for the following facilities:*
>
> > *(c) All other facilities in context classifications C4 through C6 may be reduced to a 1-foot clearance.*

In this project, SR 934 is designated Context Class C5, requiring a minimum roadway base clearance of 1 foot, using a pavement design with reduced resilient modulus.

3.3 FDOT Structures Manual (2024)

The FDOT Structures Manual (2024), Volume 1 - Structures Design Guidelines (SDG) Section 1.4.3 states the splash zone applies to marine structures and is defined as the vertical distance from 4-feet below Mean Low Water (MLW) to 12-feet above Mean High Water (MHW) and/or areas subject to wetting by personal watercraft (e.g., jet skis) or other activities and features. The proposed new bridges for all alternatives will be within the splash zone and the corrosive effects require mitigation through the use of non-corrosive pre-stressing in the superstructure.

3.4 FDOT District 6 Design Guidelines (2020)

The District 6 Exfiltration Trench Reference Manual (ETRM) (2020), Section 3.2.3.2 provides guidelines to determine the Design High Water (DHW) Elevation considering sea level rise.

> *For projects in Monroe County and coastal areas in Miami-Dade County, the DHW is established using the tidal elevation and the Mean Higher-High Water (MHHW) elevation, which are determined using the current projected sea level rise rate. The MHHW is established by the National Oceanic and Atmospheric Administration (NOAA) by using the closest tidal datum to the project location. However, it should be noted that NOAA tidal station records are based on a period of record (epoch) that extends from 1983 to 2001. The next update to the tidal datums was anticipated to be in 2019, but has not yet been released. Therefore, an estimated sea level rise must be applied to the MHHW to approximate the sea level rise that has occurred from 2001 to the current year of the project design phase. In addition, FDOT District 6 requires that the sea level rise be projected using an estimated 20-year project service life be applied to establish the DHW, to account for a certain amount of sea level rise that will occur during the life of the project.*
>
> *For FDOT District 6, sea level rise will be projected using the rate of sea level rise defined by NOAA using fourteen tidal gauge stations located around the state of Florida. For the coastal areas of Miami-Dade and Monroe Counties, NOAA approximates a sea level rise rate of 2.39 millimeter (mm) per year (0.00784 feet/year). Therefore, the DHW elevation for coastal areas of Miami-Dade and Monroe Counties can be determined using Equation 3.2.3.4-1:*
>
> > *DHW = (MHHW Elevation) + [(Year of project design – 2001)* 0.00784] + (20* 0.00784)*
>
> *FDOT District 6 also recommends that the designer verify if there are more stringent requirements established by local coastal municipalities. For example, the City of Miami Beach imposes a higher DHW than what is defined by Equation 3.2.3.4-1. Prior to implementing a higher DHW as outlined in this subsection, the designer must coordinate with and obtain approval from the FDOT District 6 Drainage Engineer.*

The District 6 ETRM cites a sea level rise linear trend of 2.39 mm/year based on the historic record from the NOAA Miami Beach tide station (8723170) for the period from 1931 to 1981. The calculations for this project use the latest sea level rise linear trend of 3.10±0.22 mm/yr published by NOAA at Station 8723214 (Virginia Key) for the period from 1931 to 2022; this trend is based on the combined historic record at Station 8723214 (Virginia Key) from 1994 to 2022, Station 8723080 (Haulover Pier) from 1981 to 1992, and Station 8723170 (Miami Beach) from 1931 to 1981.

The District 6 ETRM Equation 3.2.3.4-1 starts the sea level rise projection at 2001, the end of the tide epoch 1983-2001. The sea level rise calculations for this project start at 1992, the mid-point year of the tide epoch 1983-2001, consistent with guidelines from NOAA.

The District 6 ETRM cites a 20-year project service life for the proposed roadway design. The sea level rise calculations for this project also consider the 75-year service life for the proposed bridge design.

4.0 NOAA Sea Level Trends

NOAA maintains one active primary tide station within Miami-Dade County: Station 8723214 at Virginia Key, with tide data from 1994 to the present. The previous primary tide station 8723170 at Miami Beach recorded historic tide data from 1931 to 1981. Tide station 8723080 at Haulover Pier also recorded historic tide data from 1981 to 1992. **Figure 1** shows the latest sea level rise historic linear trend for the historic period from 1931 to 2022 and published by NOAA. **Figure 2** shows the 50-year relative sea level rise trends published by NOAA; for example, the 1960 value represents the 50-year trend from 1935 to 1985, and the 1995 value represents the 50-year trend from 1970 to 2020.

Figure 1 – Historic Relative Sea Level Trend

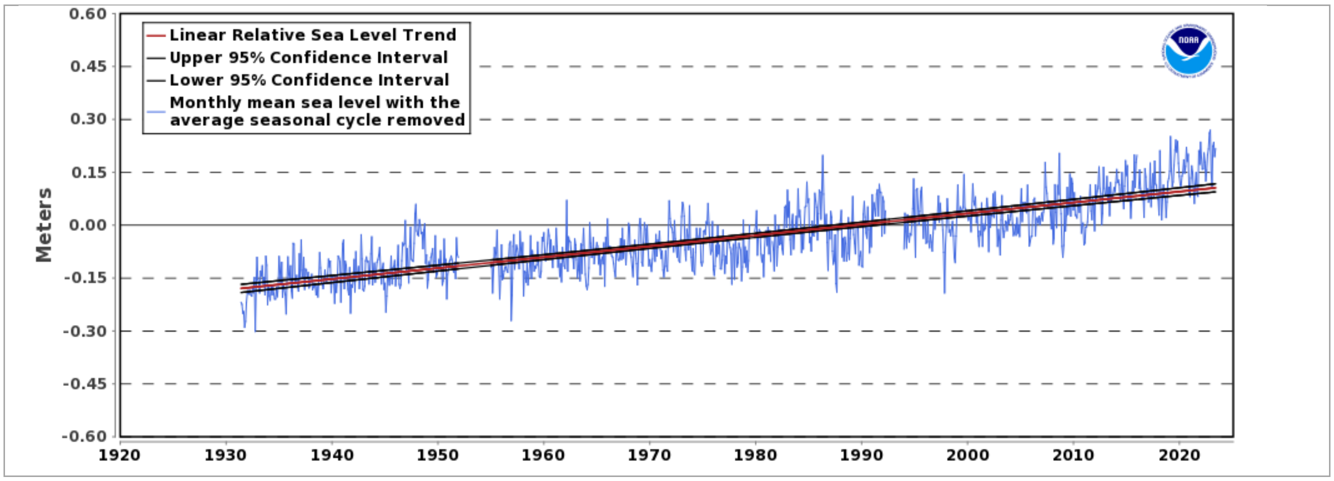
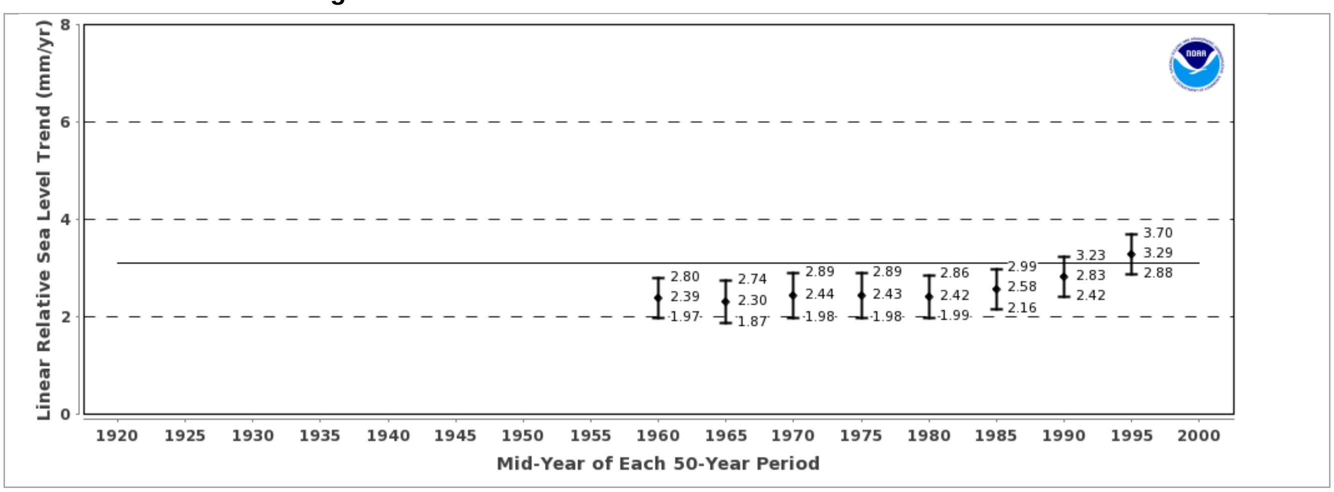


Figure 2 – Variation of 50-Year Relative Sea Level Trends



5.0 <u>Proposed Project Approach</u>

5.1 Calculation Method

<u>Step 1 – Establish the Proposed Design Year</u>

This project is currently in the PD&E Phase. The project is scheduled to begin the Preliminary Engineering/Design phase in 2025 with an estimated construction Letting Date of February 2028. The estimated Opening Year is 2030. FDM Section 201.3 requires a design period of 20 years for reconstruction projects. The estimated Design Year is 2050 for the roadway design. The FDOT Structures Design Guidelines requires a 75-year design service life for bridges. The estimated Design Year is 2105 for the bridge design.

- Estimated Opening Year = 2030
- Estimated Design Year (Roadway) = 2050 (20 years)
- Estimated Design Year (Bridges) = 2105 (75 years)

<u>Step 2 – Establish a Tide Datum</u>

Table 1 lists the NOAA tide datums at Station 8723214 (Virginia Key). The FDM requires the bridge vertical clearance for navigation purposes measured above the Mean High Water (MHW) Elevation for tidewater bays and streams. The District 6 ETRM recommends establishing the Base Clearance Water Elevation (BCWE) in coastal areas based on the Mean Higher-High Water (MHHW) Elevation. In coastal areas where groundwater is tidally influenced, groundwater will tend to maintain its minimum level at mean high tide, due to the speed of the groundwater movement relative to the tide cycle.

Table 1 – Tide Datum Elevations at NOAA Station 8723214 (Virginia Key)

	Tide Datum Elevations (1983-2001 NTDE)	
	m NAVD	ft NAVD
Mean Higher-High Water (MHHW) Elevation	0.069	0.23
Mean High Water (MHW) Elevation	0.047	0.15
Mean Sea Level (MSL) Elevation	-0.272	-0.89
Highest Observed Tide (September 10, 2017, Hurricane Irma)	1.157	3.79

<u>Step 3 – Establish the Baseline Year and Elevation</u>

The District 6 Equation 3.2.3.4-1 starts the sea level rise projection at 2001, representing the end year of the NOAA National Tide Datum Epoch (NTDE) from 1983 to 2001. The sea level rise calculations for this project start at 1992, the mid-point year of the tide epoch 1983-2001, consistent with guidelines from NOAA.

<u>Step 4 – Estimate the Sea Level Rise Rate</u>

The latest historical sea level rise linear trend published by NOAA is 3.10±0.22 mm/yr (0.0102±0.00072 ft/yr) at Station 8723214 (Virginia Key), as shown in **Figure 1**. This trend combines the historic record at Station 8723214 (Virginia Key) from 1994 to 2022, Station 8723080 (Haulover Pier) from 1981 to 1992, and Station 8723170 (Miami Beach) from 1931 to 1981.

<u>Step 5 – Calculate the Estimated Water Elevation</u>

The future sea level rise for this project is calculated using a straight-line extrapolation based on the design service life of the project, as required by the FDOT Drainage Manual. The bridge vertical clearance is measured from the MHW, extrapolated to the year 2015. The roadway base clearance measured from the MHHW, extrapolated to the year 2050. The calculations are summarized in **Table 2** and **Table 3.**

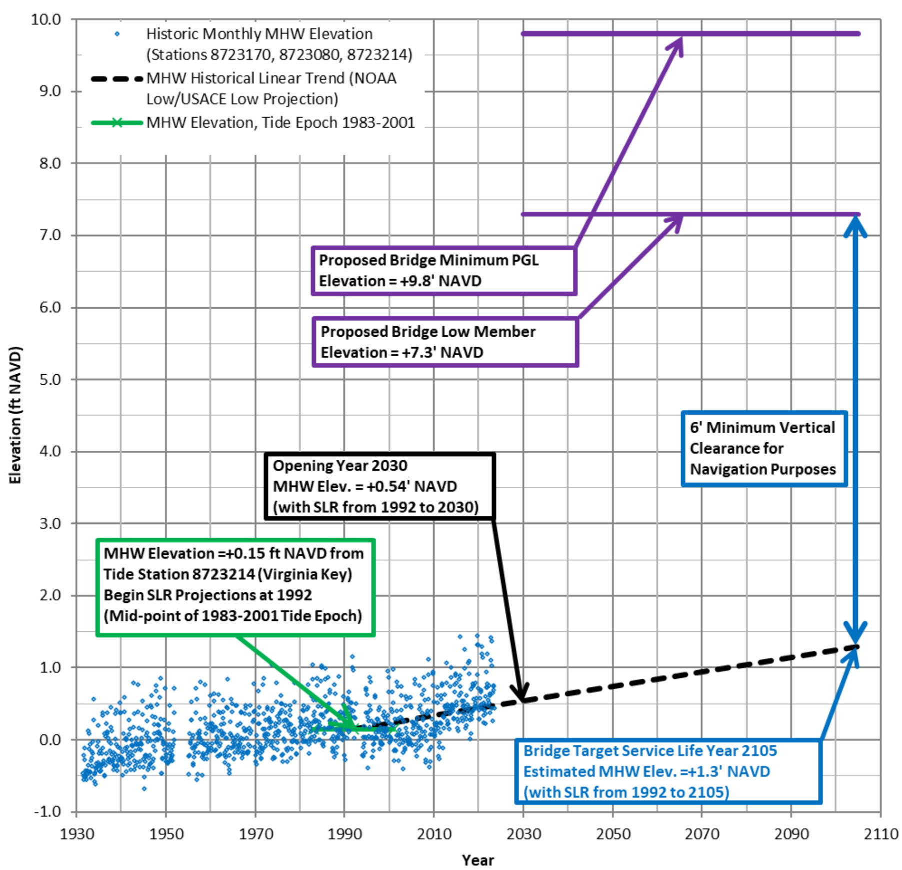
5.2 Bridge Vertical Clearance Calculation

The bridge vertical clearance calculations are summarized in **Table 2** and shown in **Figure 3** below.

Table 2 – Bridge Vertical Clearance Calculation with Estimated Sea Level Rise

		Tide Station 8723214 (Virginia Key)
Tide Datums (1983-2001 Epoch, Mid-Point Year 1992)	Mean Sea Level (MSL)	-0.89 ft NAVD
	Mean High Water (MHW)	+0.15 ft NAVD
Historic Linear Sea Level Rise (SLR) Rate (1931-2022)		0.0102±0.00072 ft/yr
Proposed Opening Year		2030
Proposed Design Year		2105 (Bridges)
Estimated MHW Elevation for Opening Year 2030		+0.54 ft NAVD
Estimated Sea Level Rise from 1992 to 2105		1.15 ft
Estimated MHW Elevation for Bridge Design Year 2105		+1.3 ft NAVD
Proposed Minimum Bridge Vertical Clearance for Navigation		6.0 ft
Existing Bridge Low Member Elevation		+3.8 ft NAVD
Minimum Proposed Bridge Low Member Elevation		+7.3 ft NAVD
Proposed Structure Depth (12”x59” CFRP Florida Slab Beams and 6” topping)		1.5 ft
Proposed Elevation Difference from PGL to edge of bridge deck		0.95 ft
Proposed Bridge Minimum Profile Grade Line (PGL) Elevation		+9.8 ft NAVD

Figure 3 – MHW Elevation with Linear Projection at Tide Station 8723214 (Virginia Key)



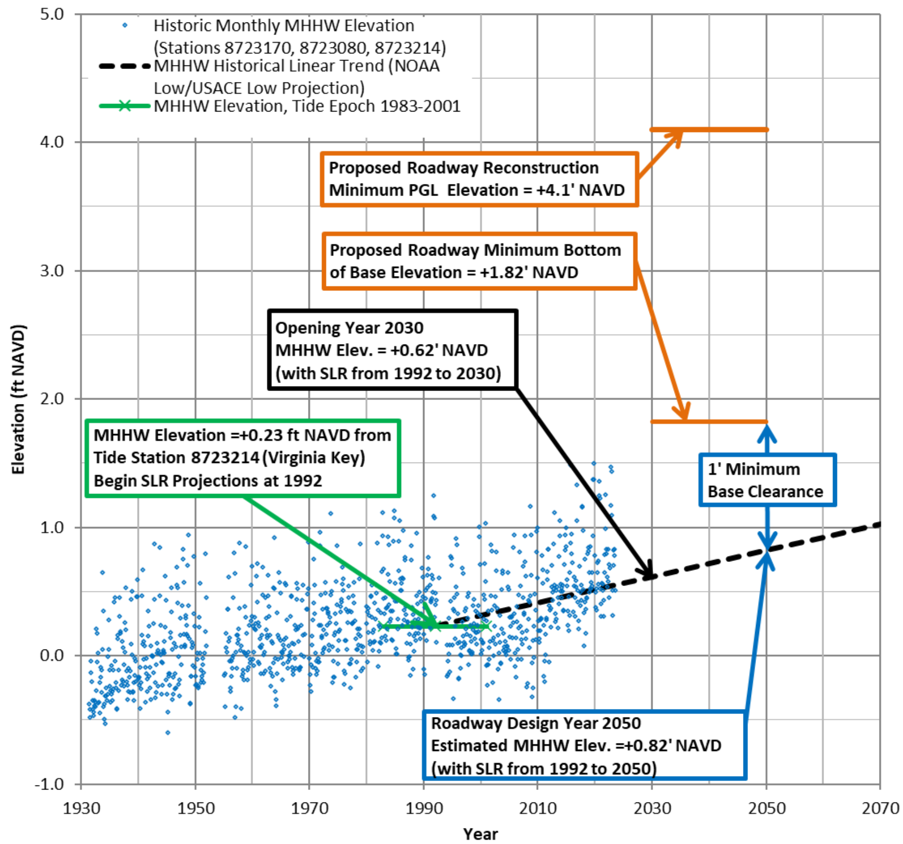
5.3 Roadway Base Clearance Calculation

The roadway base clearance calculations are summarized in **Table 3** and shown in **Figure 4** below.

Table 3 – Roadway Base Clearance Calculation with Estimated Sea Level Rise

		Tide Station 8723214 (Virginia Key)
Tide Datums (1983-2001 Epoch, Mid-Point Year 1992)	Mean Sea Level (MSL)	-0.89 ft NAVD
	Mean Higher-High Water (MHHW)	+0.23 ft NAVD
Historic Linear Sea Level Rise (SLR) Rate (1931-2022)		0.0102±0.00072 ft/yr
Proposed Opening Year		2030
Proposed Design Year		2050 (Roadway)
Estimated MHHW Elevation for Opening Year 2030		+0.62 ft NAVD
Estimated Sea Level Rise from 1992 to 2050		0.59 ft
Estimated MHHW Elevation for Roadway Design Year 2050		+0.82 ft NAVD
Minimum Bottom of Roadway Base Elevation (1' Base Clearance for Context Class C5, pavement design requires reduced resilient modulus)		+1.82 ft NAVD
Estimated Roadway Pavement Thickness		1.34 ft
Proposed Elevation Difference from PGL to edge of pavement		0.94 ft
Proposed Minimum Profile Grade Line (PGL) Elevation at roadway reconstruction areas		+4.8 ft NAVD
Existing Minimum Profile Grade Line (PGL) Elevation		+4.4 ft NAVD

Figure 4 – MHHW Elevation with Linear Projection at Tide Station 8723214 (Virginia Key)



5.4 Proposed Concept

- The Alternative 2b bridge profile proposes a minimum PGL elevation of 9.8 feet NAVD, to provide a minimum 6 feet vertical clearance for navigational purposes above the estimated future Mean High Water (MHW) for the year 2105 to comply with FDM Section 260.8.1.
- The Alternative 2b roadway profile proposes a minimum PGL elevation of 4.1 feet NAVD or greater in reconstruction segments to provide a minimum 3 feet of base clearance above the estimated future Mean Higher-High Water (MHHW) elevation for the Design Year 2050, to comply with FDM Section 210.10.3.

5.5 Proposed Bridge Concept

Please see the Bridge Analysis Report (BAR) for evaluation of multiple alternatives for addressing the existing bridge conditions.