IDENTIFICATION OF ROADWAYS AT RISK FROM SEA LEVEL RISE

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### APPROVED SPM

| A2.6 | Datasets spanning 1970–2010 show that the open ocean has lost oxygen by a very likely range of 0.5–3.3% over the upper 1000 m, alongside a likely expansion of the volume of oxygen minimum zones by 3–8% (medium confidence). Oxygen loss is primarily due to increasing ocean stratification, changing ventilation and biogeochemistry (high confidence). {5.2.2; Figures SPM.1, SPM.2} |
| A2.7 | Observations, both in situ (2004–2017) and based on sea surface temperature reconstructions, indicate that the Atlantic Meridional Overturning Circulation (AMOC)\(^3\) has weakened relative to 1850–1900 (medium confidence). There is insufficient data to quantify the magnitude of the weakening, or to properly attribute it to anthropogenic forcing due to the limited length of the observational record. Although attribution is currently not possible, CMIP5 model simulations of the period 1850–2015, on average, exhibit a weakening AMOC when driven by anthropogenic forcing. {6.7}. |

### IPCC SR Ocean and Cryosphere

| A3 | Global mean sea level (GMSL) is rising, with acceleration in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets (very high confidence), as well as continued glacier mass loss and ocean thermal expansion. Increases in tropical cyclone winds and rainfall, and increases in extreme waves, combined with relative sea level rise, exacerbate extreme sea level events and coastal hazards (high confidence). {3.3; 4.2; 6.2; 6.3; 6.8; Figures SPM.1, SPM.2, SPM.4, SPM.5} |
Problem: Sea Level Rise

As relative sea level increases, it no longer takes a strong storm or a hurricane to cause coastal high tide flooding. High tide flooding causes frequent road closures, overwhelmed storm drains, and compromised infrastructure.

Such coastal flooding is increasing in frequency, depth and extent in many areas of the U.S. due to ongoing increases in local relative sea level. For example, the report finds that the Southeast Atlantic coast is currently experiencing the fastest rate of increase in annual high tide flood days, with more than a 150 percent increase since 2000 predicted in 2018 at most locations.

1. During the 2017 meteorological year (May 2017-April 2018), the U.S. average number of high tide flooding days was the highest measured at 98 NOAA tide gauges. More than a quarter of the coastal locations tied or broke their individual records for high tide flood days.
Sea Level Rise in South Florida

- "King Tide" 2 - 5 times a year by 2030
- Increase as much as 17 inches by 2030
- By 2060, 9 - 24 inches of SLR
Groundwater in South Florida
Roadway Base Clearance & Sea Level Rise

Current Conditions

Future Conditions
(with sea level rise)

Base Clearance Design Criteria
= 1 ft - 3 ft min.

Base Saturation

Graphic Source: Miami-Dade Co
# FDOT Base Clearance Design Criteria

## Table 2.6.3 Criteria for Grade Datum

<table>
<thead>
<tr>
<th>TYPE FACILITY</th>
<th>REQUIRED CLEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways and Rural Multilane Mainline</td>
<td>3 ft.</td>
</tr>
<tr>
<td>Ramps (proper)</td>
<td>2 ft. ( ^1 )</td>
</tr>
<tr>
<td>Low Point on Ramps at Cross Roads</td>
<td>1 ft. ( ^1 )</td>
</tr>
<tr>
<td>Rural Two-lane with Design Year ADT Greater than 1500 VPD</td>
<td>2 ft. ( ^1 )</td>
</tr>
<tr>
<td>All Other Facilities Including Urban</td>
<td>1 ft. ( ^1 )</td>
</tr>
</tbody>
</table>

1. This clearance requires a reduction in the design resilient modulus (see the *Flexible Pavement Design Manual*). Notify the Pavement Design Engineer that the clearance is less than 3 feet.
Sea Level Rise Groundwater Projection

- Current District 6 DHW = 0.5 ft NAVD
- Study DHW Set By District = 1.0 ft NAVD
- Equivalent to sea level rise of 9 inches above the NOAA tide datum
LIDAR-Derived Digital Elevation Model (DEM)

- Raster elevation layer
- 10 foot pixel resolution
- Stated vertical accuracy of 0.6 feet
- Vertical accuracy compared to FDOT survey monuments
The Mode of the distribution was near 0.0; most DEM elevations were nearly equal to the survey.

The Mean (-0.314) and Median (-0.159) differences indicated that the DEM was often slightly lower than actual ground.

Standard deviation (1.031 feet) showed relatively low variability; ~68% of all differences would be between +1 and -1 feet of the mean of -0.314 feet.
GIS Screening Spatial Model
GIS Screening of State Highways Impacted by the Design High Water and Base Clearance Requirements in Miami-Dade County, FL

Contract No. C-9066
TWO #19, FRID No. 230739-3
Florida Department of Transportation, District Six
November 2, 2016

<table>
<thead>
<tr>
<th>Roadway Section</th>
<th>Begin MP</th>
<th>End MP</th>
<th>Length (Miles)</th>
<th>Length (Feet)</th>
<th>Functional Classification</th>
<th>Required Min. Base Clearance (Feet)</th>
<th>Meets Criteria?</th>
</tr>
</thead>
</table>
Study Area

This map illustrates the results of the DHW Base Clearance Evaluation for US-1 in Monroe County and southern Miami-Dade County. A single uniform 1.6 FT NAVD88 future DHW groundwater elevation was used for the entire study area to reflect future sea level rise conditions. The roadway centerline identifies those road segments that have Acceptable (2) or Unacceptable (1) base clearance from the future DHW groundwater level. The scenario on the left employed a 1 foot "DEM Uncertainty Factor" to account for the variability of elevations in the DEM ground surface. The Uncertainty Factor made the analysis...
Follow-On Steps

- Phase 1 GIS Screening Results
  - Maps
  - Table

- Phase 2 Detailed Analysis
  - Use as-built roadway profiles
  - Refine DHW elevation to be sensitive to topography
  - Evaluate for several future years (2030, 2040, 2050, 2060)
Follow-On Steps

- **Phase 3 – Project Scoping\NEPA Study**
  - Project-specific analysis of DHW, topography, and pavement design
  - Identify Design Variations for Base Clearance criteria
  - Analyze alternative solutions to be implemented at design

- **Phase 4 – Final Design**
  - Rehabilitation Projects – Designer to follow Scoping Report recommendation
  - Reconstruction Projects – Designer to follow NEPA Study, Preferred Alternative
For More Information

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