



# Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Everglades National Park

## *Summary of Results*

NPS 160/186783, November 2022



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**ON THE COVER**

Ernest Coe Visitor Center at Everglades National Park

Photo credit: NPS

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Program for the Study of Developed Shorelines  
Western Carolina University  
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# Executive Summary

This document presents the results of the **Coastal Hazards & Sea-Level Rise (SLR) Asset Vulnerability Assessment (VA)** completed by Western Carolina University at Everglades National Park (EVER) in 2021. In this VA, we evaluate the vulnerability (as a combination of exposure and sensitivity) of NPS buildings and transportation assets<sup>1</sup> to identified coastal hazards and climate change factors, approximately to the year 2050 (for full methodology, see Peek et al. 2022).

We assessed 212 buildings/structures (including visitor centers, offices, housing, comfort stations, eco-tents, chickee huts, and amphitheaters) and 158 transportation assets (roads/road segments, parking lots, trails/trail segments, bridges, boardwalks, docks, marinas, and waterfronts) at EVER. Almost 60% of assets analyzed have high vulnerability to the evaluated coastal hazards and SLR, while only 2% have minimal vulnerability (are not in any of the evaluated hazard zones). Scoring details and results for all assets evaluated at EVER are reported in the provided Excel sheets.

## Exposure Results

Exposure is a measure of the character, magnitude, and rate of changes a target may experience (e.g., from the impacts of climate change or a natural hazard influenced by climate change; NPS 2021). In this VA, we evaluate the exposure of each asset to the following coastal hazard indicators: flooding potential, shoreline change, SLR inundation, extreme event flooding, and reported coastal hazards (Table 1).

**Table 1.** Exposure indicators and hazard data sources used.

<b>Exposure Indicator (Description)</b>	<b>EVER Data (Citation)</b>
Flooding potential (1% annual-chance)	Preliminary FEMA VE & A zones (FEMA 2019; 2021)
Shoreline change (coastal proximity)	35-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050)	NPS 8.5 RCP SLR model (Caffrey et al. 2018), SLR South Florida 99th Percentile (NPS and Others 2016), NOAA SLR Viewer (NOAA 2021)
Extreme event flooding (category 3 surge)	NPS storm surge inundation model (Caffrey et al. 2018), NOAA national storm surge hazard maps (Zachry et al. 2015)
Reported coastal hazards (historic flooding)	Questionnaire results & discussions (Peek et al. 2022)

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<sup>1</sup> The NPS Facility Management Software System (FMSS) database defines assets as “...a physical structure or grouping of structures, land features, or other tangible property that has a specific service or function, such as a farm, cemetery, campground, marina, or sewage treatment plant. The term ‘asset’ shall also be applied to movable items, such as vehicles and equipment.”

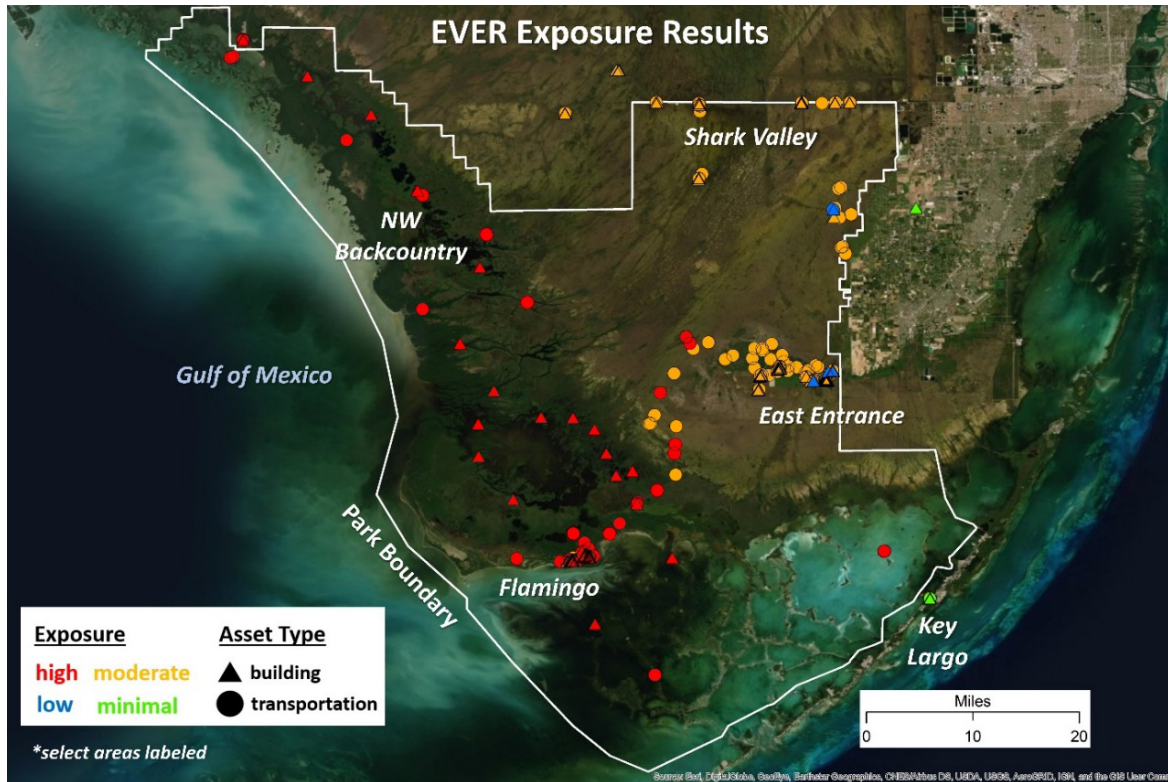
Assets with high exposure are within at least four exposure indicator hazard zones. Assets with moderate exposure are within two or three exposure indicator hazard zones. Assets with low exposure are within only one exposure indicator hazard zone. The asset could still be seriously impacted by this hazard. Assets with minimal exposure are not in any exposure indicator hazard zone. This does not mean that the asset has no exposure to coastal hazards, but it is not within the exposure hazard data used in this study.

Over 95% of assets evaluated at EVER have either high or moderate exposure to coastal hazards and SLR (Table 2, and Figure 1). Over one-third of all assets have high exposure, while nearly two-thirds have moderate exposure. These results are primarily a factor of the park’s high exposure to coastal flooding, as indicated by the widespread FEMA VE and AE flood zones (1% annual chance flood, ± wave velocity), as well as the modeled Category 3 storm surge inundation extent across EVER.

**Table 2.** EVER exposure results. Sum of percentages may not equal 100 due to rounding.

Assets	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
	#	%	#	%	#	%	#	%	#
Buildings	64	30%	133	63%	9	4%	6	3%	212
Transportation	62	39%	93	59%	1	1%	2	1%	158
All Assets	126	34%	226	61%	10	3%	8	2%	370

Most high exposure assets are in the northwestern and southwestern areas of the park (e.g., Northwest Backcountry and Flamingo), where elevations are commonly less than 5 feet above sea level and much of the land area is comprised of mangrove swamps. Twenty-eight assets (10 buildings and 18 transportation) at EVER are within all evaluated exposure zones (scored the highest possible raw score), including the Flamingo Ranger Station, Guy Bradley Visitor Center, Whitewater Bay Marina, Florida Bay Marina, Flamingo VC Waterfront, and Everglades City Waterfront. Only 10 assets at EVER have low exposure, and 8 have minimal exposure. Most of these lower exposure assets are located near the park’s eastern entrance and in the Key Largo area.



**Figure 1.** EVER exposure results summary. Only select areas are labeled. Background map is ESRI streaming imagery.

## Sensitivity Results

Sensitivity reflects the degree to which a resource is affected by exposure (NPS 2021). In this VA, we assess the following sensitivity indicators: flood damage potential/elevated, storm resistance and condition, historic damage, and protective engineering. In general, assets with high sensitivity have unfavorable determinations for 3 or 4 of these indicators, moderate-sensitivity assets have unfavorable determinations for 2 indicators, and low-sensitivity assets have unfavorable determinations for 0 or 1 indicator. Assets with minimal exposure are not analyzed for sensitivity (this is the case for eight assets at EVER).

All but 11 assets analyzed at EVER have high or moderate sensitivity to coastal hazards and SLR (Table 3). In most cases, the assets with high sensitivity (as opposed to moderate) are in poor condition and have been significantly damaged by coastal flooding in the past. Over 2.5 times more transportation assets have high sensitivity than buildings; this is largely due to the high number of transportation assets that are not storm resistant and have been previously damaged by flooding and. In fact, 28 of the evaluated transportation assets at EVER received an unfavorable rating for all sensitivity indicators, including the Flamingo B & C-Loop Road, Whitewater Bay Marina, Florida Bay Marina, Pine Island Airboat Ramp, Tamiami Dock, and Hidden Lake Dock. Only a small percentage of assets at EVER are currently elevated above flood levels or protected by engineering (e.g., seawalls, bulkheads).

**Table 3.** EVER sensitivity results. Sum of percentages may not equal 100 due to rounding.

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
	#	%	#	%	#	%	#	#
Buildings	45	22%	153	74%	8	4%	206	6
Transportation	107	69%	46	29%	3	2%	156	2
All Assets	152	42%	199	55%	11	3%	362	8

\*Minimal exposure assets were excluded from the sensitivity analysis; total number analyzed is different for sensitivity.

## Vulnerability Results

Vulnerability is a measure of the degree to which park resources and assets are “susceptible to harm from direct and indirect effects of climate change, including variability and extremes” (NPS 2021). In this VA, we evaluate the vulnerability of infrastructure assets as a simple combination of exposure and sensitivity ratings. It should be noted that the vulnerability of any asset can change with time (e.g., due to adaptation actions or the result of geomorphic change).

Over 90% of assets evaluated at EVER have high or moderate vulnerability to coastal hazards and SLR, and only a few assets have low or minimal vulnerability (Table 4, and Figures 2-4). Almost two-thirds of EVER assets have high vulnerability, while approximately one-third have moderate vulnerability. Reflecting their high exposure, a large portion of the high vulnerability assets are in the Flamingo and Northwest Backcountry areas of the park. However, high vulnerability assets are also distributed throughout all other areas of EVER.

**Table 4.** EVER vulnerability results. Sum of percentages may not equal 100 due to rounding.

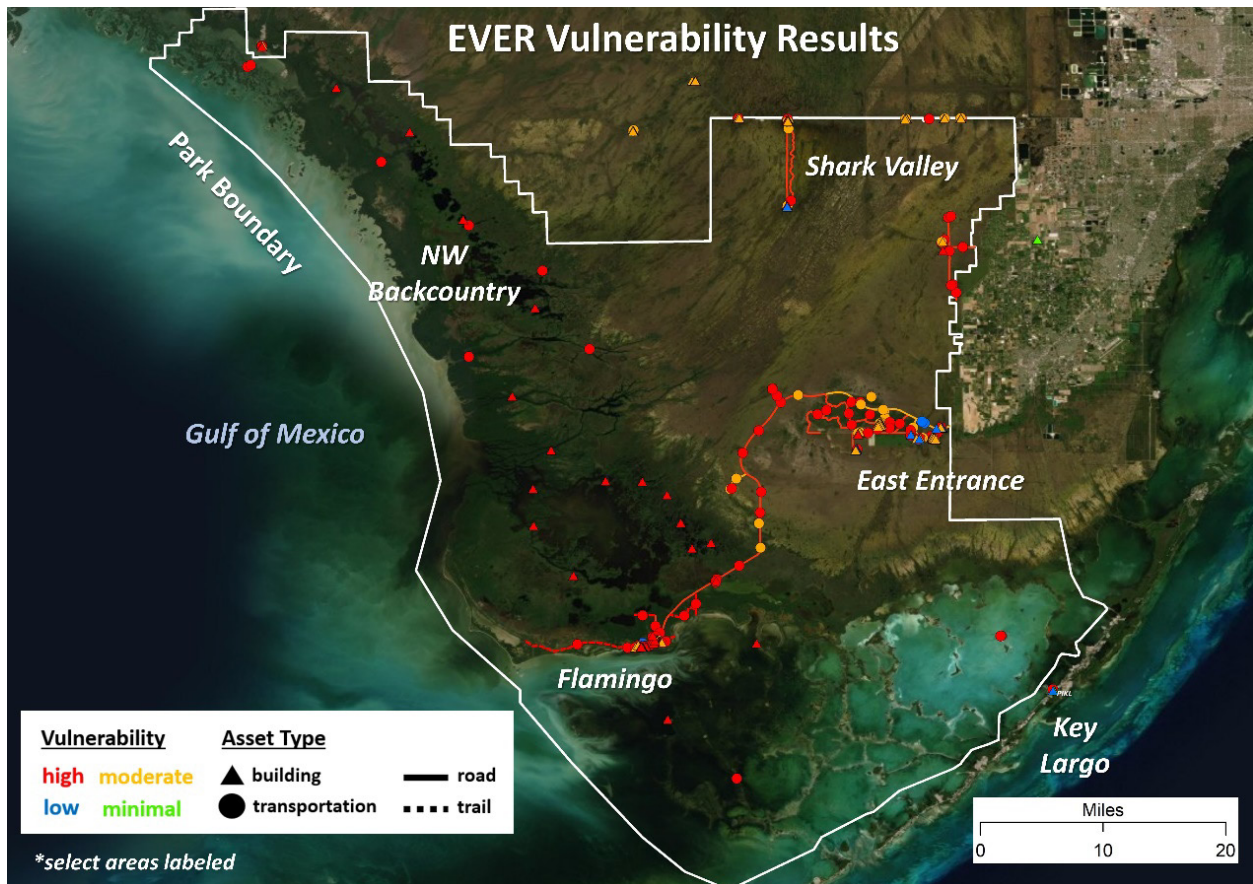
Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
	#	%	#	%	#	%	#	%	#
Buildings	91	43%	101	48%	14	7%	6	3%	212
Transportation	120	76%	33	21%	3	2%	2	1%	158
All Assets	211	57%	134	36%	17	5%	8	2%	370

Transportation assets at EVER are particularly vulnerable to coastal hazards and SLR. In fact, over 85% of roads (or road segments), 76% of parking lots, and 56% of trails evaluated at EVER have high vulnerability. Of the three bridges at EVER, only the Buttonwood Bridge in the Flamingo area has high vulnerability, while the other two (located near the park’s east entrance) have low vulnerability.

More than 50 of the assets evaluated have high vulnerability and a high asset priority index (API  $\geq$  80, as reported in FMSS). This includes multiple buildings in the Flamingo area (including over a

dozen chickees), the MBR Equipment Building, the Wastewater Treatment Plant, the Guy Bradley Visitor Center, and the Flamingo Rangers Station (Former VC/LE Building). Twenty-one transportation assets have high vulnerability and the highest possible API (100), including several segments of the Main Park Road and Flamingo Route 10.

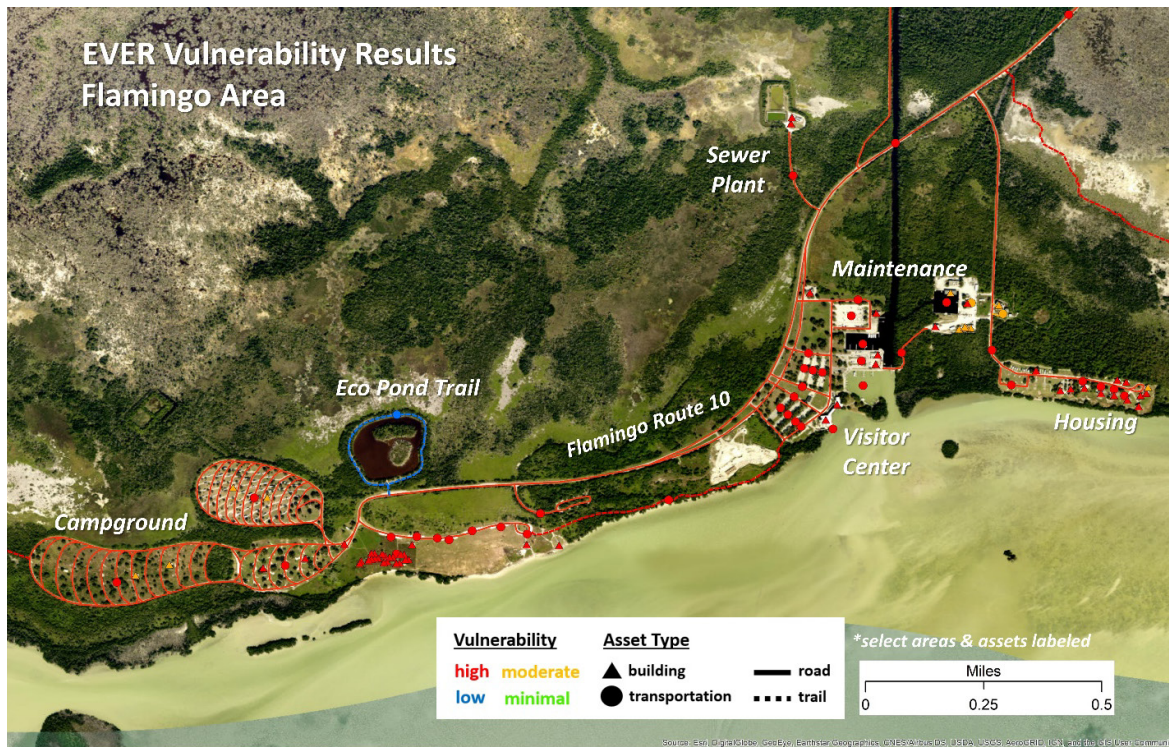
Sensitivity plays an important role in the overall vulnerability of assets at EVER. A significant portion of assets are high vulnerability (29 buildings and 58 transportation) due to high sensitivity (were not scored as high exposure). Many of these assets could become moderate vulnerability with adaptation or actions that address sensitivity, such as raising the elevation (the building or ground level), improving the condition/storm resistance, or adding protective engineering.



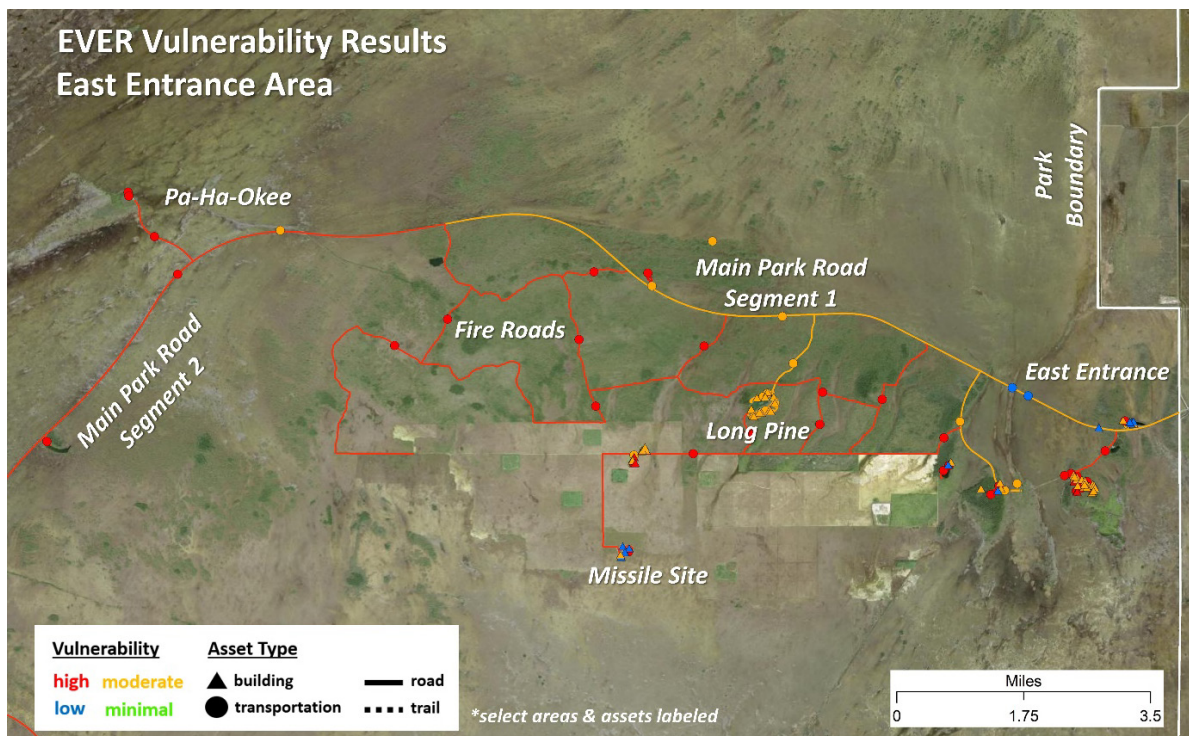
**Figure 2.** EVER vulnerability results summary. Only select areas are labeled. Background is ESRI streaming imagery.

The park currently has several major projects in progress (or planned) that address the sensitivity of assets to coastal hazards, including infrastructure changes in Everglades City, Shark Valley, and Flamingo. Due to the geomorphology of EVER, most areas of the park are highly exposed to flooding, and SLR will only increase this exposure over time. Therefore, considering sensitivity factors in all infrastructure projects will be vital for the continuation of visitor access and park operations.





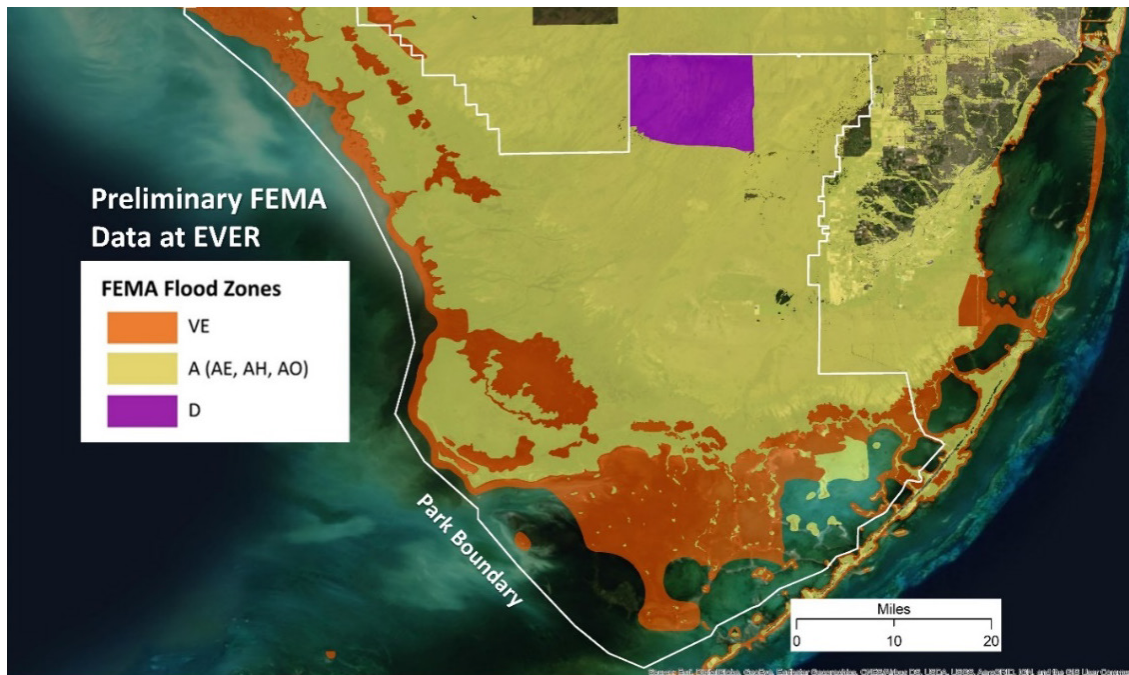
**Figure 3.** EVER vulnerability results summary for the Flamingo area. Only select areas and assets are labeled. Background is ESRI streaming imagery.



**Figure 4.** EVER vulnerability results summary for the East Entrance area. Only select areas and assets are labeled. Background is ESRI streaming imagery.

## EVER Unique Considerations

**FEMA data:** We used the preliminary FEMA data for both Miami-Dade (2021) and Monroe (2019) counties to evaluate exposure to flooding (FEMA 2019; 2021). A small portion of the park near Shark Valley is mapped as FEMA D zone (possible but undetermined flood hazards; Figure 5). We interpreted assets in this area to be within the FEMA A zone, based on adjacent FEMA mapping, historical flooding information, and park geomorphology.



**Figure 5.** Preliminary FEMA data in the EVER area of south Florida. Note the presence of the D zone (purple shade) in the northeastern portion of the park. Background is ESRI streaming imagery.

**Shoreline change:** USGS shoreline erosion rate data are not available for the coastlines within EVER. As a result, we used a simple coastal proximity buffer of 35 meters, which accommodates an erosion rate up to 1m/year and assumes that infrastructure near the coast is likely to experience multiple coastal hazards within the 35-year (2050) timeframe of this analysis (Peek et al. 2022).

**SLR data:** We used the SLR and Inundation Scenarios for National Parks in South Florida (NPS and Others 2016) to determine the SLR exposure for the year 2050. These data include SLR projections for EVER, BISC, DRTO, and BICY based on the IPCC RCP 8.5 greenhouse gas emission scenario. We used these data at the request of the park, as these data were the most detailed and current at the time this analysis began.

**Storm surge data:** In most cases, we use storm surge models produced by NPS CCRP (Caffrey et al. 2018) within this protocol; however, these data show almost no variability across the park and appear to be an overestimate of potential flooding. As a substitute, we used NOAA's SLOSH Category 3 high tide inundation model (National Storm Surge Hazard Maps - Version 2; Zachry et al. 2015).

**NBI data:** All three bridges in EVER are listed in the National Bridge Inventory (NBI), which contains several attributes that were used as additional sensitivity indicators (clearance, scour rating, condition, and age). We use a different scoring system (see Peek et al. 2022 for details) for bridges with additional NBI sensitivity indicators.

**Road segments:** Due to the length of the Main Park Road and Flamingo Route 10, we divided each of these roads into three smaller segments. We evaluated each segment individually for exposure, sensitivity, and vulnerability, and assigned each segment a modified location code (segments share the same FMSS attributes).

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