National Park Service
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Natural Resource Stewardship and Science

Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Dry Tortugas National Park

Summary of Results

NPS 364/190212, May 2023

PROGRAM FOR THE STUDY OF DEVELOPED SHORELINES

Western Carolina UNIVERSITY

ON THE COVER
Fort Jefferson with moat and counterscarp
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Program for the Study of Developed Shorelines
Western Carolina University
Cullowhee, North Carolina 28723

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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 Dry Tortugas National Park (DRTO) in 2023. In this VA, we evaluate the vulnerability (as a combination of exposure and sensitivity) of NPS buildings and transportation assets[1] to identified coastal hazards and climate change factors, approximately to the year 2050 (for full methodology, see Peek et al. 2022). We assessed 43 buildings/structures (including Fort Jefferson, two lighthouses, historical buildings, a visitor center, housing, maintenance facilities, comfort stations, landscapes, systems, and campground facilities) and four transportation assets (including a bridge and waterfront facilities) at DRTO. Over one-third (36%) of assets analyzed have high vulnerability to the evaluated coastal hazards and SLR, 36% have moderate, 26% have low, and only 2% have minimal. These results include post-Hurricane Ian (2022) flooding and damage data. Scoring details and results for all assets evaluated at DRTO 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, extreme event flooding, and reported coastal hazards (Table 1).

Table 1. Exposure indicators and hazard data sources used.

Exposure Indicator (Description)	DRTO Data (Citation)
Flooding potential (1% annual-chance)	Preliminary FEMA VE & A zones (FEMA 2019), Dry Tortugas Elevation Survey (NPS 2022)
Shoreline change (coastal proximity)	35-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050 proxy*)	NPS 2100 4.5 RCP SLR model, 0.54 m (Caffrey et al. 2018), SLR South Florida 99th Percentile (NPS and Others 2016), Dry Tortugas Elevation Survey (NPS 2022)
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), Dry Tortugas Elevation Survey (NPS 2022)
Reported coastal hazards (historic flooding)	Questionnaire results & discussions (Peek et al. 2022)

*See Unique Considerations

[1] Listed in the NPS Facility Management Software System (FMSS) database. Assets are defined as Real or personal property which the NPS desires to track and manage as a distinct identifiable entity. It may be 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 (NPS 2005).

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.

The majority (83%) of assets evaluated at DRTO have either high or moderate exposure to coastal hazards and SLR (Table 2). Over half (57%) have high exposure, while 26% have moderate exposure. These results are a direct result of the low-lying geomorphology of the Florida Keys, which generally have high exposure to coastal and extreme event flooding. Most high exposure assets are located on Garden Key, with a few along the waterfront of Loggerhead Key and Key West (Figure 1).

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

	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	23	53%	12	28%	7	16%	1	2%	43
Transportation	4	100%	0	0%	0	0%	0	0%	4
All Assets	27	57%	12	26%	7	15%	1	2%	47

Eight assets (five buildings/structures and three transportation) at DRTO are within all evaluated exposure zones, including Fort Jefferson, Fort Jefferson Counterscarp and Moat, Garden Key Dock House, Garden Key Wastewater System, Garden Key and Loggerhead water fronts, Loggerhead Boat House, and M/V Jefferson Berth. Seven assets at DRTO have low exposure (all located on Loggerhead Key) and one (Key West Visitor Center) has minimal exposure.

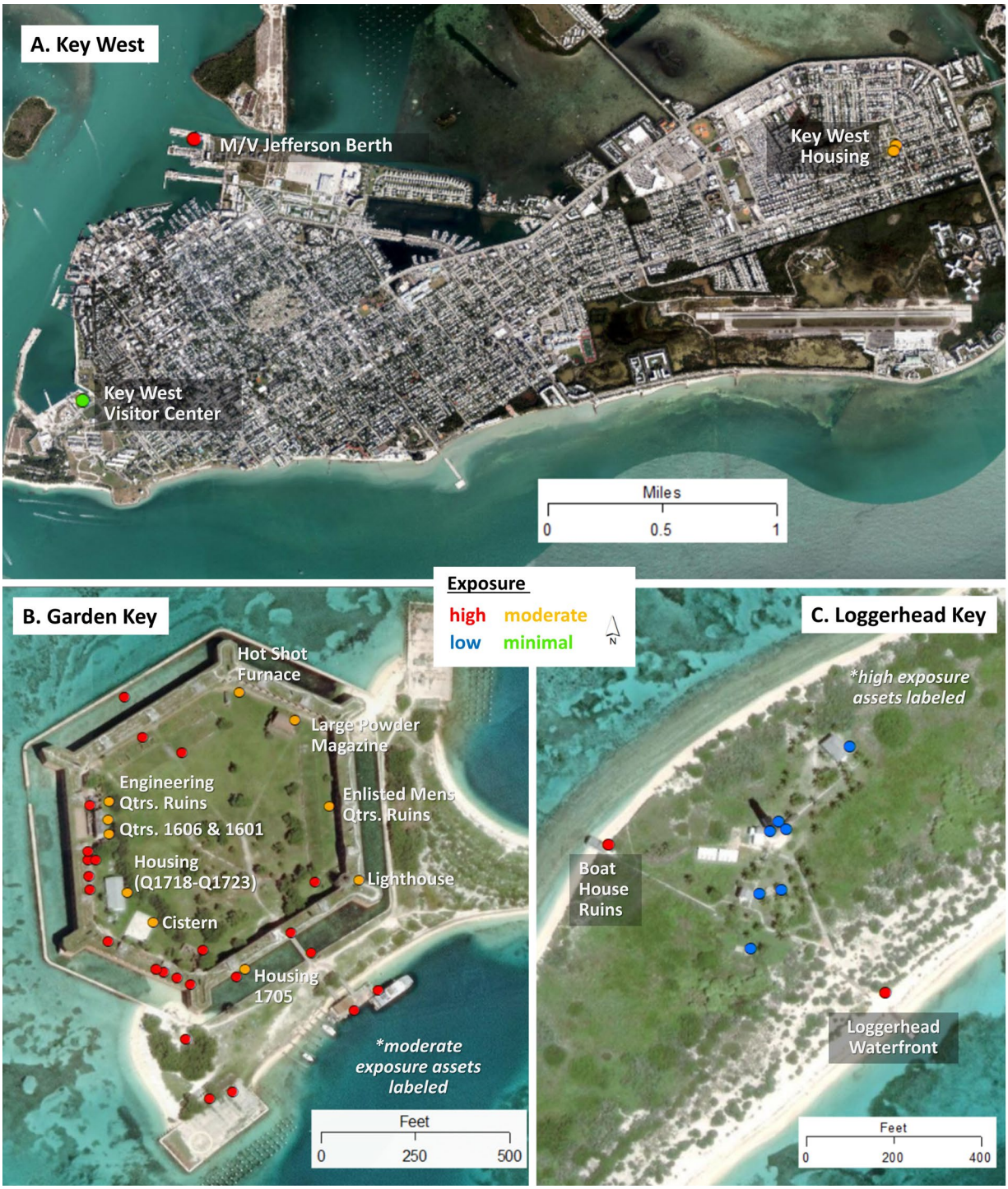

Figure 1. DRTO exposure results. A) Results for the Key West area. B) Results for the Garden Key area; only moderate exposure assets are labeled. C) Results for the Loggerhead Key area; only high exposure assets are labeled. Background map is ESRI streaming imagery.

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 one asset at DRTO).

Twenty-nine assets analyzed at DRTO 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. Seven assets at DRTO received an unfavorable score for all sensitivity indicators, including the Fort Jefferson Counterscarp and Moat, Fort Jefferson Bridge, Garden Key Wastewater System, Garden Key Dock House, Garden Key Water Front, Loggerhead Water Front, and Loggerhead Boat House.

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

	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**#**
Buildings	5	12%	21	50%	16	38%	42	1
Transportation	3	75%	0	0%	1	25%	4	0
All Assets	8	17%	21	45%	17	38%	46	1

*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.

The majority (72%) of assets evaluated at DRTO have high or moderate vulnerability to coastal hazards and SLR, and over a quarter (26%) have low vulnerability (Table 4). Only one asset has minimal vulnerability. Reflecting their exposure, all the high vulnerability assets are located on Garden Key and along the waterfront areas of Loggerhead Key (Figures 2-4).

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

	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	14	33%	16	37%	12	28%	1	2%	43
Transportation	3	75%	1	25%	0	0%	0	0%	4
All Assets	17	36%	17	36%	12	26%	1	2%	47

Eleven of the assets evaluated have high vulnerability and a high asset priority index (API ≥ 70, as reported in FMSS). These include the Counterscarp and Moat, Bridge, Parade Grounds & Brick Walk, Campground, Comfort Station, Wastewater Treatment Plant, Electrical Generators, and Water Front on Garden Key, as well as the Water Front and Boat House on Loggerhead Key. Seven assets have both high exposure and high sensitivity including the Fort Jefferson Counterscarp and Moat, Campground, Water Front, and Wastewater Treatment Plant on Garden Key, as well as the Water Front and Boat House on Loggerhead Key.

Figure 2. DRTO vulnerability results summary for the Key West area. Background is ESRI streaming imagery.

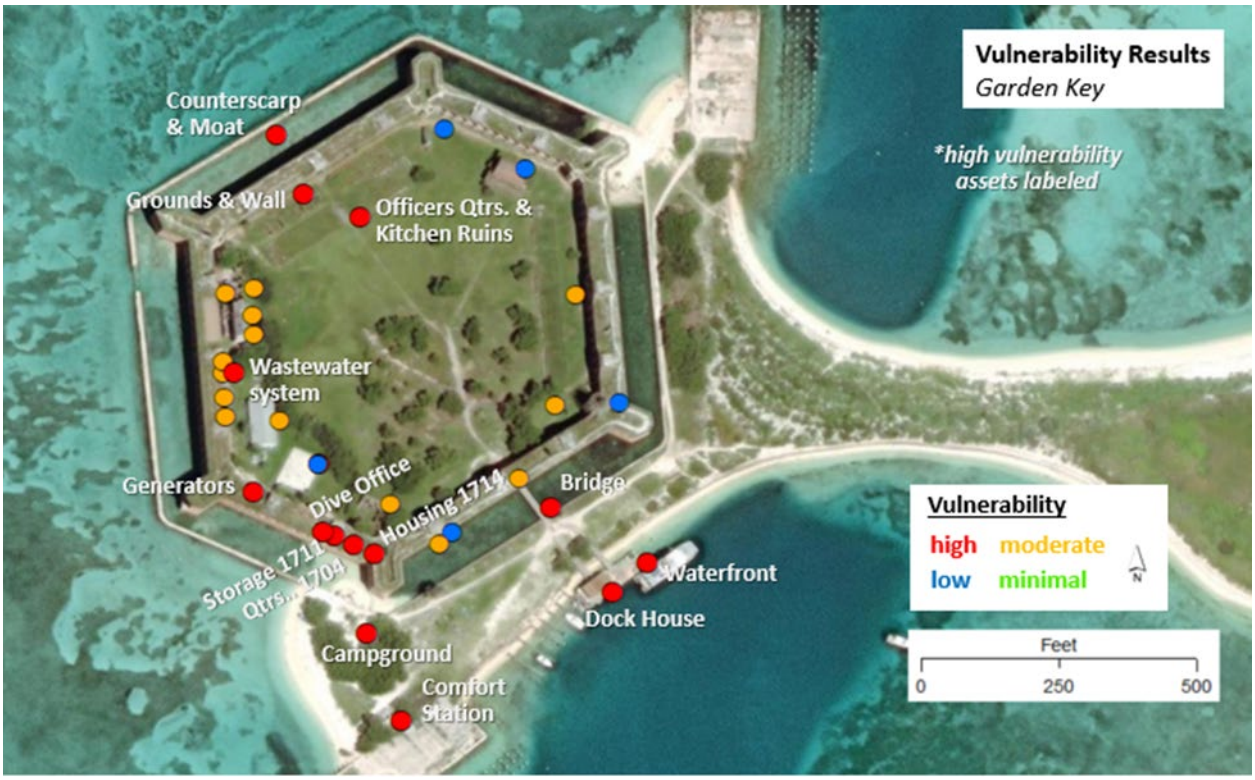

Figure 3. DRTO vulnerability results summary for the Garden Key area. Only high vulnerability assets are labeled. Background is ESRI streaming imagery.

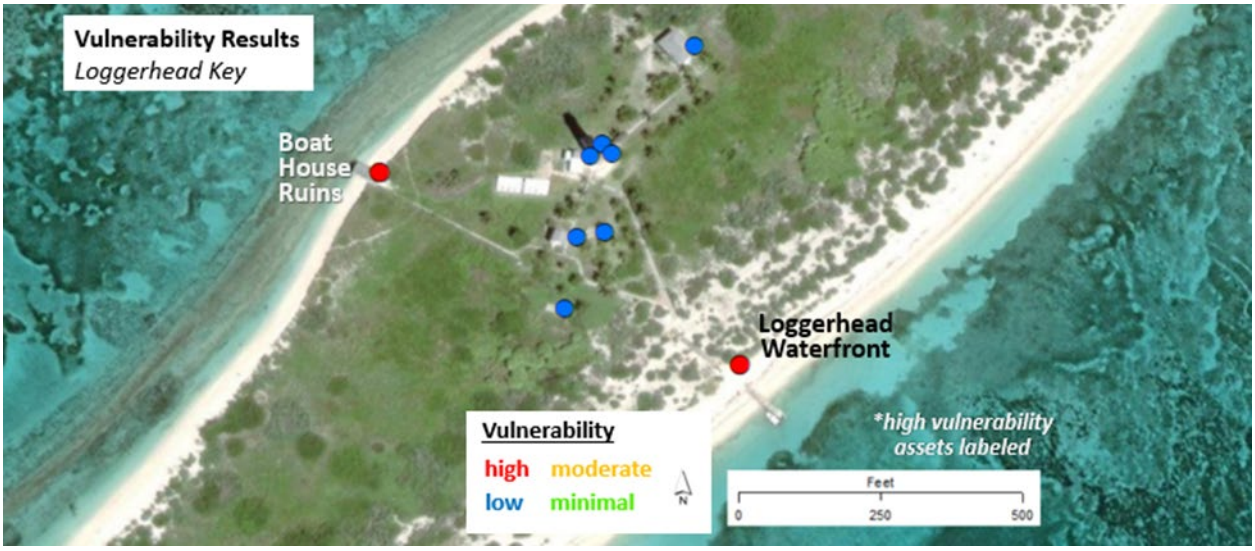

Figure 4. DRTO vulnerability results summary for the Loggerhead Key area. Only high vulnerability assets are labeled. Background is ESRI streaming imagery.

DRTO Unique Considerations

Data coverage: Data availability and consistency is a challenge at DRTO. The park extends over 60 miles from Key West to Loggerhead Key and some models and datasets do not cover the entire area. For each island, we used the best available datasets specific to that portion of the park.

Flooding potential: We used preliminary Federal Emergency Management (FEMA 2019) data to determine flood exposure on Key West. However, FEMA data are not mapped for Garden and Loggerhead keys. On those islands, we used a digital elevation model surveyed by NPS (NPS 2022), and an estimated Base Flood Elevation (BFE) to determine flood exposure and sensitivity. FEMA has mapped the rest of the Florida Keys and similar low-lying islands as Special Flood Hazard Areas (SFHAs), so for flood exposure we interpreted both Garden and Loggerhead keys as SFHAs. Specifically, areas outside the fort and closest to the coast on both islands we interpreted as VE zones, and areas inside the fort and further inland on Loggerhead Key as AE zones. For the sensitivity analysis on Garden and Loggerhead keys, we estimated a BFE of 5 feet based on historical flooding reports. We consider this 5-foot BFE on Garden and Loggerhead keys to be conservative because FEMA BFEs for the entirety of Key West are all higher than 5 feet.

Shoreline change: United States Geological Survey or other shoreline erosion rate data are not available for the coastlines within DRTO. 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 (see Peek et al. 2022).

SLR inundation: We used SLR data from multiple sources for DRTO. On Key West we used the 2100 4.5 Representative Concentration Pathway (RCP) SLR projection (0.54 m rise) and inundation model (Caffrey et al. 2018) developed specifically for NPS units. This model was used as a proxy for 2050 and was not available for other areas of the park. On Loggerhead Key we used SLR scenarios developed for national parks in South Florida (NPS and others 2016). On Garden Key we used a digital elevation model surveyed by NPS (NPS 2022) in combination with the National Oceanic and Atmospheric Administration (NOAA 2022) intermediate SLR projection for Key West (1.12 feet / 0.34 m for the year 2050).

Extreme event flooding: Throughout the park we used storm surge data from multiple sources. On Garden Key we used a high-resolution digital elevation model (NPS 2022) combined with recent storm surge records. On Loggerhead Key we used storm surge models produced by NPS (Caffrey et al. 2018), as well as elevation and storm records. On Key West we used the NOAA SLOSH category 3 high tide inundation model (National Storm Surge Hazard Maps - Version 3; Zachry et al. 2015).

Threshold elevation: We incorporated asset elevation data (collected by the NPS) into the Flood Damage Potential sensitivity indicator for 39 assets at DRTO (see Peek et al. 2022).

Hurricane Ian: We were in the final stages of preparing this report when Hurricane Ian passed directly over DRTO as a category 4 storm on September 27, 2022. We consulted the post-storm

damage assessment (Schwadron and Lockman 2022) and updated historical flooding and damage results accordingly.

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