Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Cape Lookout National Seashore

Updated Summary of Results

NPS 623 187597, February 2023

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Program for the Study of Developed Shorelines
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Executive Summary

In 2017, Western Carolina University completed the initial **Coastal Hazards & Sea-Level Rise (SLR) Asset Vulnerability Assessment (VA)** of Cape Lookout National Seashore (CALO; Peek et al. 2017). Two years later, Hurricane Dorian impacted the park as a category 2 storm, bringing nearly two meters of surge to the park's barrier islands. Dozens of buildings were damaged or destroyed in multiple districts including Portsmouth Village, Long Point Campground, Cape Lookout Village, and North Core Banks. These impacts caused significant changes to the park's asset portfolio and sensitivity (e.g., condition, historic damage). This document presents results for the updated VA at CALO completed in 2021, following these impacts from Hurricane Dorian.

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 139 buildings/structures (including visitor centers, a lighthouse, historic buildings, cabins, maintenance buildings, restrooms, sheds, and shelters) and 69 transportation assets (roads, road segments, parking lots, boardwalks, waterfront systems, marinas, and fuel systems) at CALO.

Nearly three-quarters (73%) of assets analyzed at CALO have high vulnerability to the evaluated coastal hazards, 20% have moderate vulnerability, and only 7% have low vulnerability. No assets have minimal vulnerability. Eighty-seven assets (38 buildings and 49 transportation) have both high exposure and high sensitivity. Compared to the initial VA (Peek et al. 2017) at CALO, these results show a 6% increase in assets with high vulnerability. This increase is primarily due to changes in exposure scores resulting from updated hazard data. Scoring details and results for all assets evaluated 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). The exposure data used within this VA differ slightly from Peek et al. (2017), as updated datasets were used for the shoreline change/coastal proximity, SLR inundation, and extreme event flooding indicators (see Unique Considerations & Updates).

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[1] 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."

Table 1. Exposure indicators and hazard data sources used.

Exposure Indicator (Description)	CALO Data (Citation)
Flooding potential (1% annual-chance)	Effective FEMA VE & A zones (FEMA 2003)
Shoreline change/coastal proximity	NC DCM long-term erosion rates (NC DCM 2019), 30-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050 proxy) *	NPS 2100 4.5 RCP SLR model, 0.61 m rise (Caffrey et al. 2018), NOAA 2-foot SLR zone (NOAA 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)
Reported coastal hazards (historic flooding)	Questionnaire results & discussions (Peek et al. 2022)

*See Unique Considerations

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.

Most assets analyzed at CALO have either high (69%) or moderate (25%) exposure to the evaluated coastal hazards (Table 2, and Figures 1-5). Few assets (6%) have low exposure, most of which are in the maintenance area of Harkers Island. These results are primarily a factor of the park's high exposure to coastal flooding, as indicated by the widespread Federal Emergency Management Agency (FEMA) AE zone (1% annual chance flood) and modeled category 3 surge extent. In addition, over 80% of assets have been flooded by previous storms.

All assets in the Les & Sally's, Long Point Campground, and North Core Banks areas have high exposure. Twenty-eight assets (nine buildings and 19 transportation) are within all evaluated exposure zones, including two bridges and five historic buildings at Portsmouth Village (the Gaskill, Dixon, and Pigott houses, and the Life-Saving Station and Kitchen), three shade shelters, the Les and Sally's VRP Shed, the boardwalk at the Cape Keeper's Quarters, nine sand-road segments, and all docks/marinas.

Compared to the Peek et al. (2017) analysis, significantly more assets (approximately 20%) are now scored as high exposure. These assets changed from moderate to high exposure due to more extensive SLR and erosion hazard zones (see Unique Considerations & Updates).

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

Assets	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
	#	%	#	%	#	%	#	%	#
Buildings	87	63%	41	29%	11	8%	0	0%	139
Transportation	56	81%	11	16%	2	3%	0	0%	69
All Assets	143	69%	52	25%	13	6%	0	0%	208

Figure 1. Exposure results for the Harkers Island area of CALO. Only high exposure assets are labeled. Background is ESRI streaming imagery.

Figure 2. Exposure results for the Light Station area of CALO. Only moderate exposure assets are labeled. Background is ESRI streaming imagery.
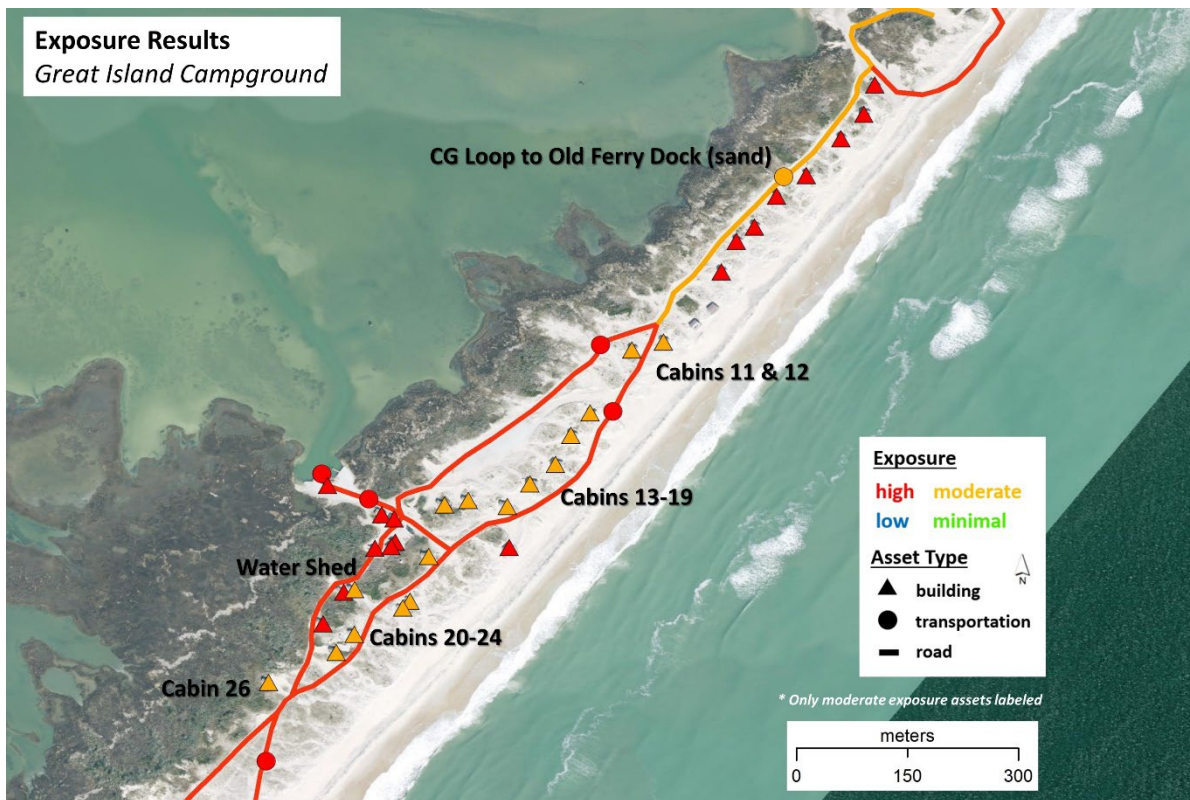

Figure 3. Exposure results for the Great Island Campground area of CALO. Only moderate exposure assets are labeled. Background is ESRI streaming imagery.
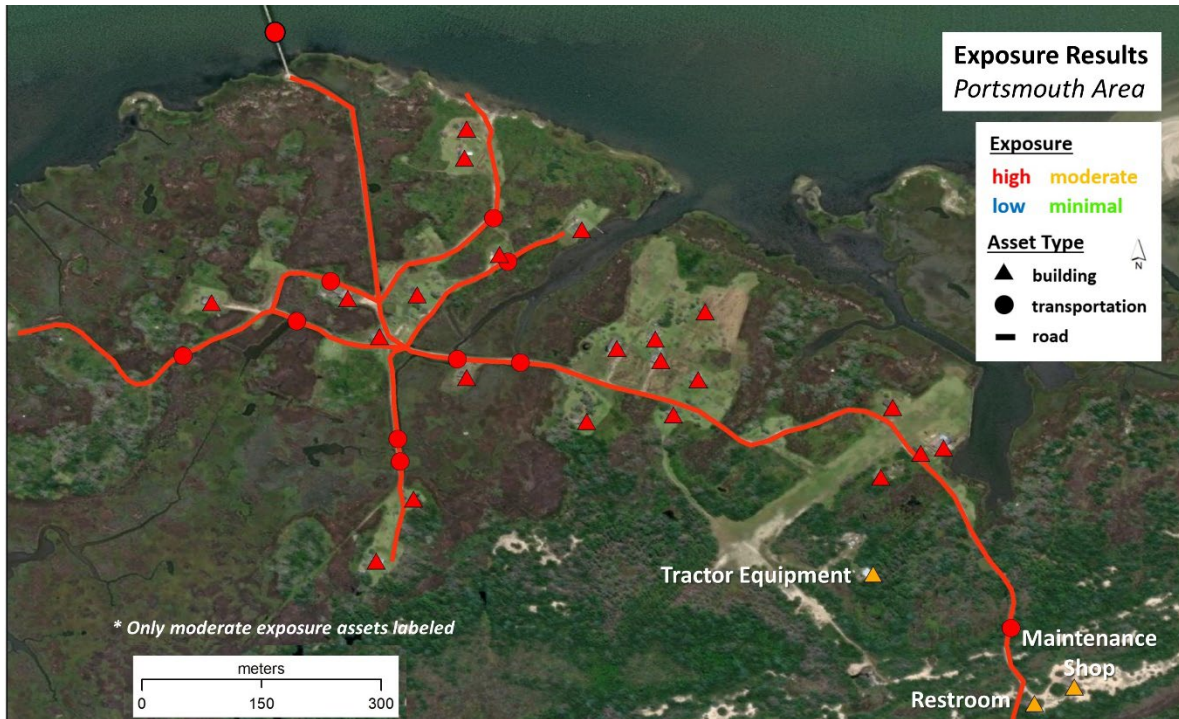
Figure 4. Exposure results for the Portsmouth area of CALO. Only moderate exposure assets are labeled. Background is ESRI streaming imagery.

Figure 5. Exposure results for the Cape Lookout Village area of CALO. Select moderate and low exposure assets are labeled. Background 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.

Nearly half (48%) of the assets analyzed at CALO have high sensitivity to coastal hazards, half (50%) have moderate sensitivity, and 2% have low sensitivity (Table 3). Most assets that have high sensitivity are not elevated, not storm resistant, have been damaged by past storms, and lack protective engineering. Thirty-nine assets received an unfavorable rating for all sensitivity indicators, including 22 buildings (19 at Portsmouth Village, two at Cape Lookout Village, and one at Davis Island), five bridges, two boardwalks, four marinas/waterways, and six sand-road segments.

There are only slight differences in these sensitivity results compared to Peek et al. (2017); there was only a 3% increase in the number of high sensitivity assets. This is due to the decommissioning and removal of assets after Hurricane Dorian and the fact that most assets impacted were already high sensitivity.

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

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded
	#	%	#	%	#	%	#	#
Buildings	46	33%	90	65%	4	3%	139	0
Transportation	54	78%	15	22%	1	1%	69	0
All Assets	100	48%	105	50%	5	2%	208	0

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).

Nearly three-quarters (73%) of assets analyzed at CALO have high vulnerability to the evaluated coastal hazards, 20% have moderate vulnerability, and only 7% have low vulnerability (Table 4, and Figures 6-11). No assets have minimal vulnerability. Eighty-seven assets (38 buildings and 49 transportation) have both high exposure and high sensitivity; most of these are historic buildings in Cape Lookout and Portsmouth villages and sand-road segments along North Core and South Core

banks. Forty-three transportation assets have both high vulnerability and a high asset priority index (API ≥ 80, as reported in FMSS), including the Cape Lookout Historic District Marine/Waterway, Bridge Historic District Cape, Bridge Lighthouse Cape, and multiple sand-road segments. None of the high vulnerability buildings at CALO had a high API (>70).

Compared to Peek et al. (2017), there is a 6% increase in the percentage of high vulnerability assets, and a 6% reduction in moderate vulnerability assets. This is primarily due to changes in exposure scores resulting from updated hazard data (see CALO Unique Considerations & Updates).

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

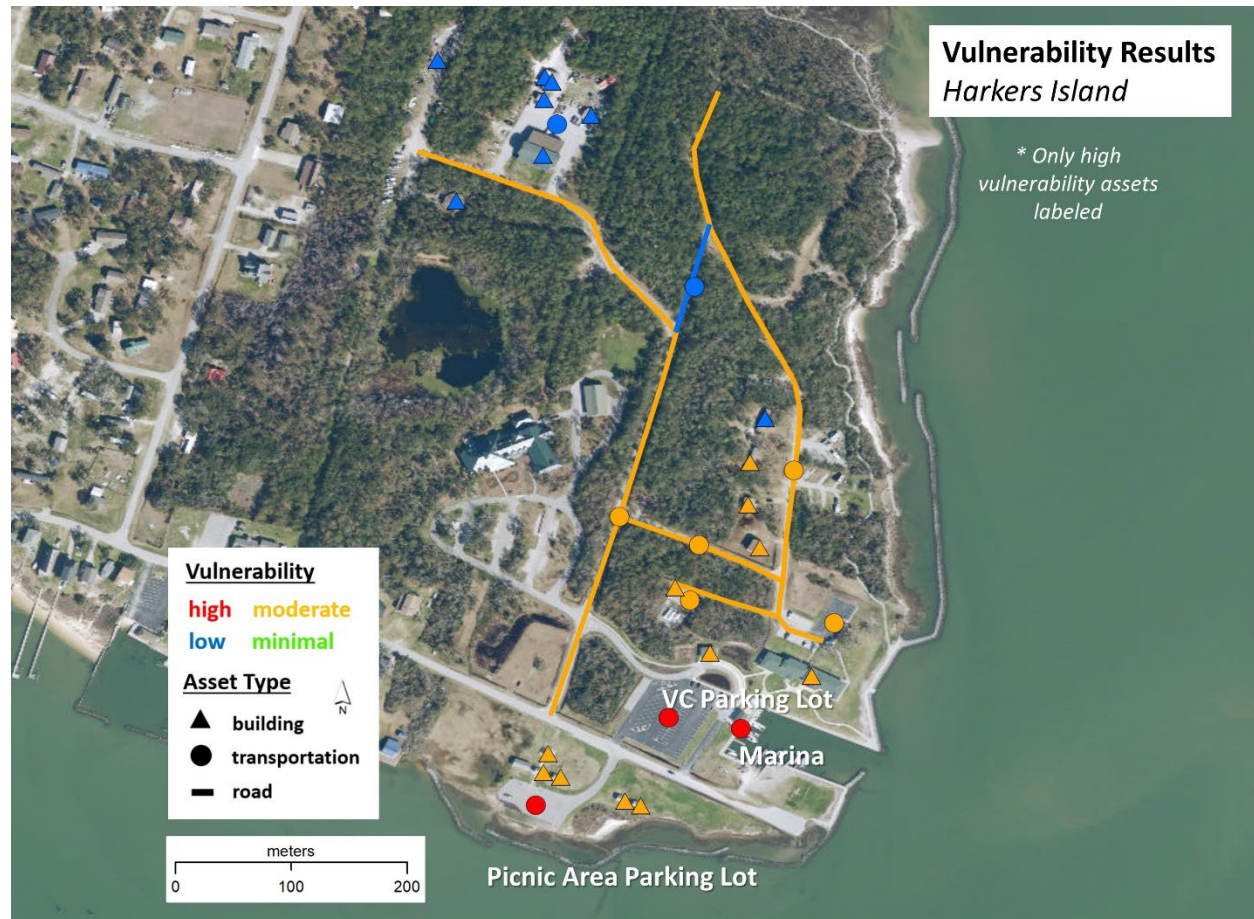| Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
	#	%	#	%	#	%	#	%	#
Buildings	90	65%	37	27%	12	9%	0	0%	139
Transportation	61	88%	5	7%	3	4%	0	0%	69
All Assets	151	73%	42	20%	15	7%	0	0%	208

Figure 6. Vulnerability results for the Harkers Island area of CALO. Only high vulnerability assets are labeled. Background is ESRI streaming imagery.
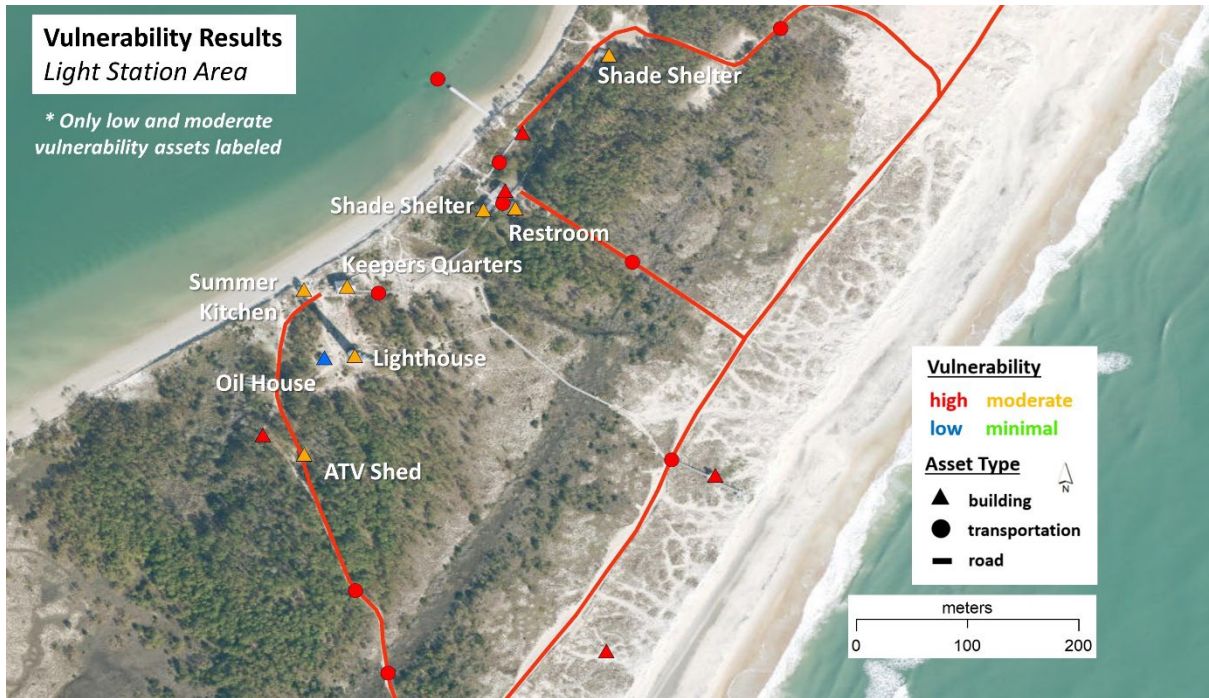
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Figure 7. Vulnerability results for the Light Station area of CALO. Only low and moderate vulnerability assets are labeled. Background is ESRI streaming imagery.
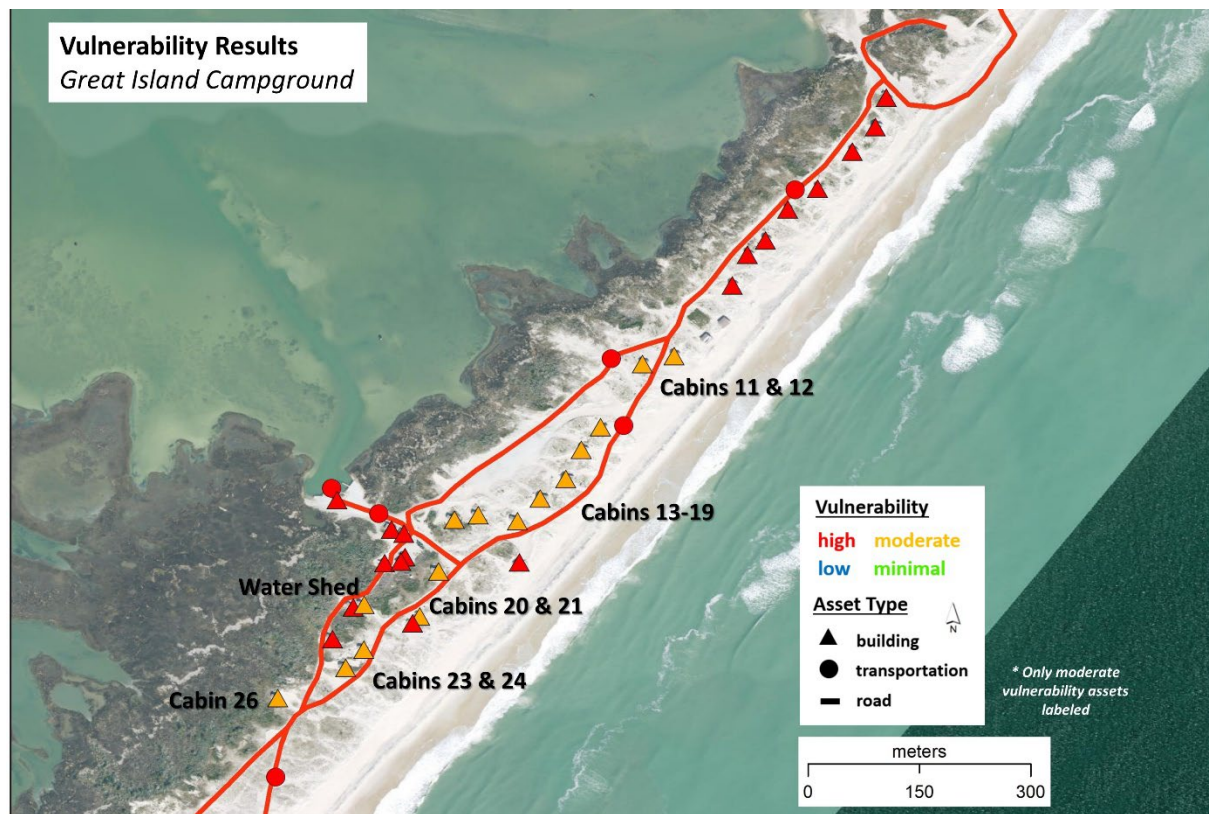

Figure 8. Vulnerability results for the Great Island Campground area of CALO. Only moderate vulnerability assets are labeled. Background is ESRI streaming imagery.
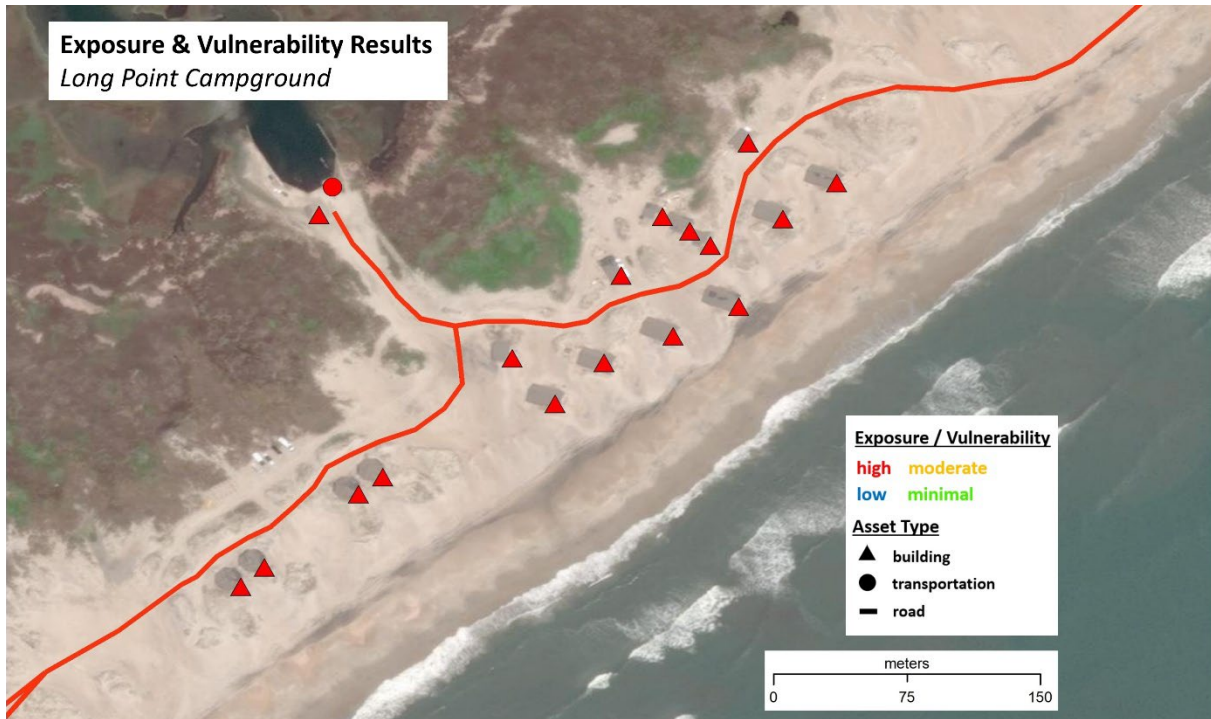
Figure 9. Exposure and vulnerability results for the Long Point Campground area of CALO. Background is ESRI streaming imagery.
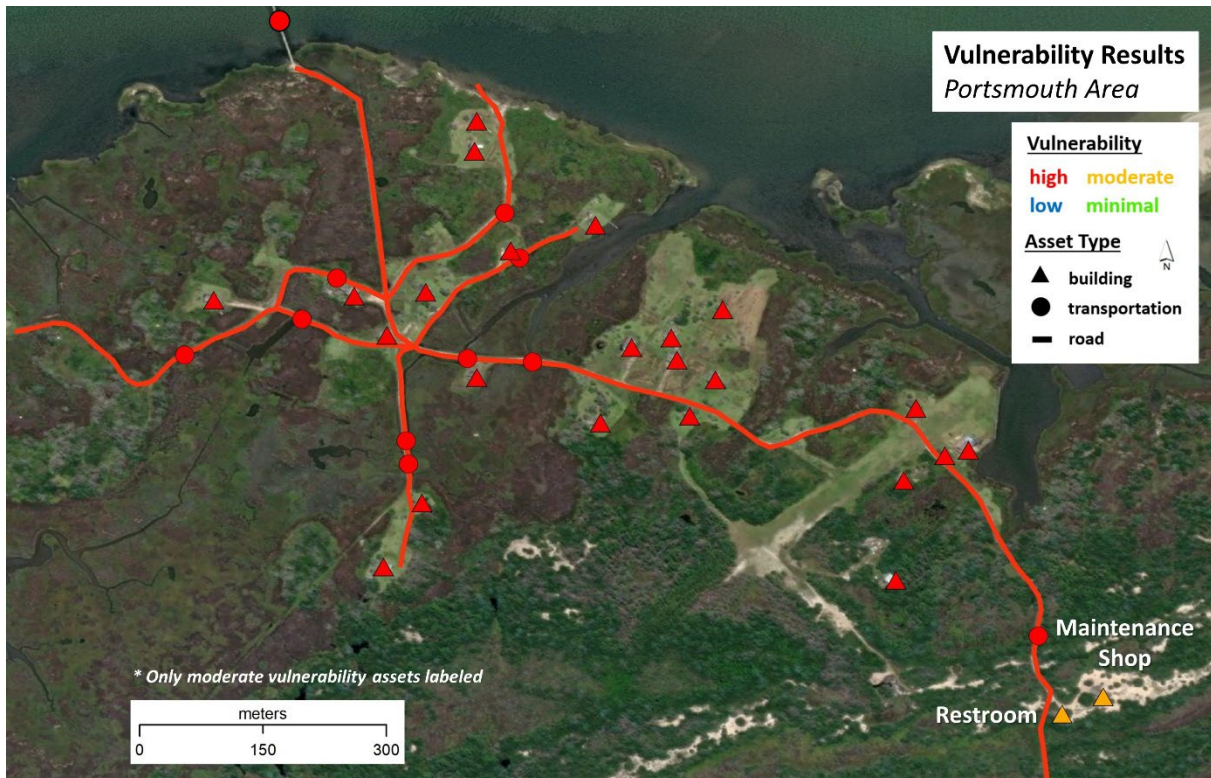

Figure 10. Vulnerability results for the Portsmouth area of CALO. Only moderate vulnerability assets are labeled. Background is ESRI streaming imagery.
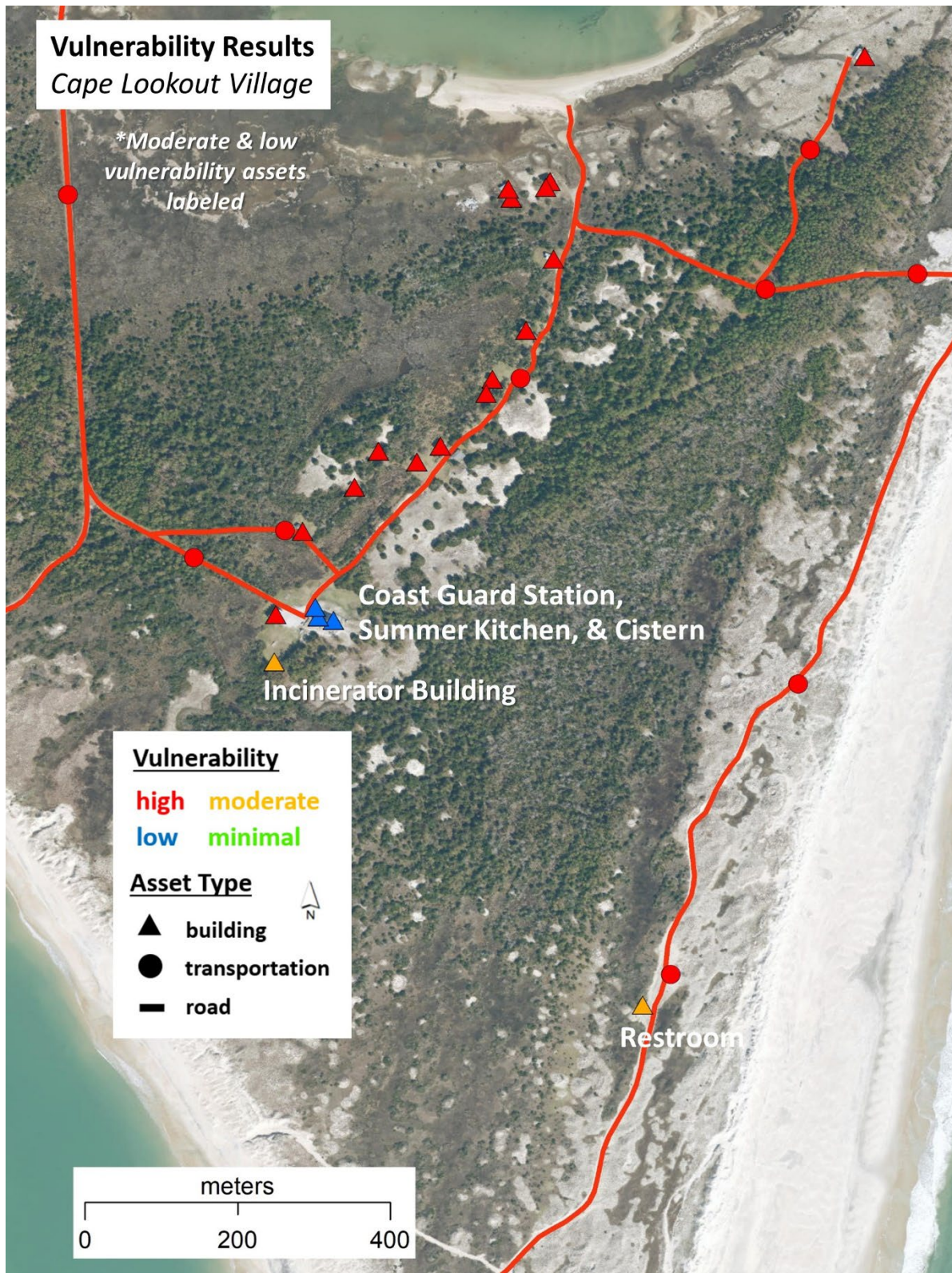
Figure 11. Vulnerability results for the Cape Lookout Village area of CALO. Only moderate and low vulnerability assets are labeled. Background is ESRI streaming imagery.

CALO Unique Considerations & Updates

FMSS assets: Peek et al. (2017) evaluated 152 buildings and 70 transportation assets, while in this updated VA, we evaluated 140 buildings and 70 transportation assets. This change in the number of buildings is due to a combination of new construction and decommissioning/removal over several years (FMSS data was obtained in 2015 and again in 2020). Two buildings (Great Island Ranger Station and Harkers Island Maintenance Building) were not listed in the 2020 FMSS but were still active and included in this VA (2015 FMSS attribute data is reported in the Excel results).

Linear assets: Due to length and exposure variability, we divided the three sand roads listed in FMSS (North Core Banks Sand Road, South Core Banks Sand Road, and Cape Lookout Historic District Sand Road) into multiple 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). Any statistics or estimates of value represent the entire road, even if only a small portion has high exposure or vulnerability.

Park questionnaire: The park completed an updated questionnaire in 2020 for historic flooding (exposure), condition (sensitivity), and historic damage (sensitivity) to capture changes since the initial Peek et al. (2017) VA.

Flood damage potential data: The FEMA VE Zone for CALO is not well mapped near Cape Lookout (see Figure 5, Peek et al. 2017), while the AE zone is fairly well mapped. For the areas where the VE zone was missing or incomplete, it was assumed that assets seaward of the AE zone were in fact located in the VE zone. The data for this exposure indicator have not changed since Peek et al. (2017).

Shoreline change data: We used a digital shoreline and updated shoreline change rate data from the North Carolina Division of Coastal Management (NC DCM 2019) to create erosion buffer zones for the oceanfront shorelines of CALO (see Peek et al. 2022 for methodology). For locations where shoreline change data were not available, we used a simple 30-m proximity buffer (updated from 35 m in the 2017 analysis).

SLR data: In the initial VA, we used the 2050 8.5 Representative Concentration Pathway (RCP) SLR projections and inundation model (0.27 m rise for CALO) from Caffrey et al. (2018) to score this exposure indicator. In this updated VA, we used the 2100 4.5 RCP SLR projections and inundation model (0.61 m rise). These data are used as a proxy for 2050 SLR to accommodate higher SLR projections recently released by the National Oceanic and Atmospheric Administration (NOAA; see Peek et al. 2022).

Extreme event flooding data: We use storm surge models produced by NPS (Caffrey et al. 2018) within this protocol. In this updated VA, we also consulted the NOAA category 3 high tide inundation model (National Storm Surge Hazard Maps - Version 2; Zachry et al. 2015).

Threshold elevation data: We incorporated building threshold elevation data (collected by the NPS Information System Services) into the Flood Damage Potential sensitivity indicator for 89 assets at CALO (see Peek et al. 2022). These data have not changed since Peek et al. (2017).

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