



Coastal Hazards & Climate Change Asset Vulnerability Assessment Protocol: *Project Description & Methodology*



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Introduction & Summary

The National Park Service (NPS) maintains some of the most iconic buildings and monuments in the United States. Many of these structures and assets are located in coastal areas that are highly vulnerable to sea level rise and coastal flooding, among other stressors. In response to this, the NPS Sustainable Operations and Climate Change Branch in partnership with Western Carolina University's (WCU) Program for the Study of Developed Coastlines (PSDS) have developed a **Coastal Hazards and Climate Change Asset Vulnerability Assessment Protocol and Tool**. This protocol establishes a standard methodology and set of best practices for conducting vulnerability assessments in the built environment. Standardizing the methodologies and data utilized in these assessments allows managers to compare the vulnerability of coastal park assets across local, regional, and national levels.

The assessments are currently focused on assets at risk to coastal hazards and sea-level rise within coastal parks. Coastal vulnerability was chosen as a starting point in the development of vulnerability assessments because of digital data availability and a good understanding of the trends in the major climate stressors (e.g., sea level). Ultimately, the general methodology can be applied to additional natural hazards and climate stressors in non-coastal parks, as long as georeferenced hazard data exists or can be mapped.

A proposed standardized approach to assessing climate change vulnerability was described in a multiple agency (NOAA, NPS, USGS, DOD, NWF, and USFS) document titled "Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment (Glick et al., 2011)." This document defines the vulnerability of natural resources to climate change as: the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change impacts. Vulnerability under this approach is comprised of three equally weighted metrics or components: exposure, sensitivity, and adaptive capacity:

Vulnerability = Exposure + Sensitivity + Adaptive Capacity

- ✓ **Exposure** refers to whether a resource or system is located in an area experiencing direct impacts of climate change, such as temperature and precipitation changes, or indirect impacts, such as sea-level rise.
- ✓ **Sensitivity** refers to how a resource or system fares when exposed to an impact.
- ✓ **Adaptive Capacity** refers to a resource's or system's ability to adjust or cope with existing climate variability or future climate impacts.

While this formula has been successfully applied to natural systems, some aspects are less appropriate for application in the built environment (i.e., buildings, roads, etc.). For example, structures cannot inherently adapt to climate change or other hazards, while natural resources often can (a salt marsh can adapt to changes in sea level by migrating upland, whereas a building cannot). Therefore, WCU and NPS have modified the methodology and formula for conducting vulnerability assessments of assets within national parks. The new modified formula for the vulnerability of the built environment (assets, infrastructure, buildings, transportation, etc.) is as follows:

Vulnerability = Exposure + Sensitivity

The adaptive capacity of an asset is evaluated separately and is not included in the vulnerability score. This does not mean that understanding the adaptive capacity of an asset is not important. The range of

adaptation strategies or options available for key vulnerable assets within a national park is the final and perhaps most important step in the overall analysis, as any adaptation actions taken for an asset will help reduce its exposure or sensitivity, which reduces vulnerability.

One of the primary goals of this protocol is to standardize methods for evaluating the exposure of NPS assets to coastal hazards and climate change. This includes the standardization of data inputs (i.e., widely available, established data) that will allow the application of a consistent methodology among units. Another goal is to create a more complete and effective set of factors or indicators for assessing the sensitivity of assets to coastal hazards. The current focus for this protocol is on structures and transportation assets within the NPS asset database (Facilities Management Software System; FMSS), however, other resources will likely be included in future work. This methodology need not be applied solely in parks, but could also be utilized in municipalities, subdivisions, or even resort developments.

Protocol Workflow & Methodology

The **Coastal Hazards and Climate Change Asset Vulnerability Assessment Protocol** has four primary steps:

- 1) Exposure Analysis and Mapping
- 2) Sensitivity Analysis
- 3) Vulnerability Analysis
- 4) Adaptation Strategies Analysis

Step 1: Asset Exposure Analysis & Mapping

The first step in the protocol is to analyze the exposure of NPS assets to coastal hazards and climate change. The goal of this methodology is to standardize the data sources for exposure analysis, using widely available and regularly updated sources (when possible). Standard exposure indicators have also been determined by WCU; these indicators represent the primary factors or hazards that should be evaluated to assess an asset's exposure (over the short-term, to the year 2050). The five exposure indicators are: flooding, storm surge, sea-level rise, erosion/coastal proximity, and historical flooding. Table 1 summarizes these indicators, as well as likely data sources that are to be used for each.

Table 1. Exposure Indicators for Asset Coastal Hazards and Climate Change Vulnerability

Exposure Indicator	Data Sources
☒ Flooding	FEMA Flood Maps (primary); LiDAR DEM or other elevation model
☒ Storm Surge	NPS-specific SLOSH model results (primary); LiDAR DEM or other elevation model
☒ Sea Level Rise	NPS-specific SLR modeling (primary); LiDAR DEM or elevation other model
☒ Erosion/Coastal Proximity	State/USGS erosion rate buffers (primary); shoreline proximity buffers
☒ Historical Flooding	Park surveys/questionnaire results (primary); storm imagery/reconnaissance

The exposure analysis utilizes data imported into Geographical Information Systems (GIS) format, as exposure is directly dependent on location (whether the area experiences the hazard) and mapped hazard data. Digital hazard data are gathered for each of the exposure indicators, such as the online georeferenced FEMA flood map layers. The only dataset that does not come from a widely available, well established source is the historical flooding layer, which is derived from storm imagery, reconnaissance, and direct communication with park personnel. Each of these exposure data layers thus represents an exposure indicator hazard zone for a particular park. Each asset that falls within a particular zone (exposed) is assigned a higher score than assets outside the hazard zone (unexposed). After scores are given for each exposure indicator, they are summed and binned to get a total exposure

score for each asset. Final binned exposure scores fall into one of four ranking categories based on the number of exposure zones: minimal exposure (asset does not lie within any mapped hazard zone), low exposure (1 zone only), moderate exposure (2-3 zones), and high exposure (4-5 zones). Any assets that obtain an exposure ranking of minimal are not analyzed further. Finally, all asset types (transportation and structures) are analyzed for exposure using the same methodology.

Step 2: Asset Sensitivity Analysis

The second step in the protocol is to analyze the sensitivity of NPS assets to coastal hazards and climate change. Similar to exposure, a set of indicators was determined for asset sensitivity. Unlike exposure, sensitivity is evaluated independent of location (only exposure is location-dependent). Sensitivity refers to how that asset would fare when exposed to the hazard, which is a function of the inherent properties or characteristics of the asset. While the sensitivity indicators for structures and transportation assets are generally the same (Table 2), how sensitivity is addressed during design and construction is very different.

Bridges are considered transportation assets, but have additional factors that must be considered when analyzing sensitivity to coastal hazards and climate change. Table 2 summarizes the four general sensitivity indicators (for all assets), as well as the four additional bridge indicators.

Table 2. Sensitivity Indicators for Asset Coastal Hazards and Climate Change Vulnerability

Sensitivity Indicator	Data Sources
☒ Flood Damage Potential (Elevated)	Asset questionnaire; direct measurements of threshold elevation
☒ Storm Resistance & Condition	Asset questionnaire; FMSS database
☒ Historical Damage	Asset questionnaire; discussion with park staff
☒ Protective Engineering	Asset questionnaire; field & aerial imagery analysis; WCU Engineering Inventory
Additional Bridge Indicators	
☒ Bridge Clearance	National Bridge Inventory (item 39)
☒ Scour Rating	National Bridge Inventory (item 113)
☒ Bridge Condition	National Bridge Inventory (item 59 & 60)
☒ Bridge Age	National Bridge Inventory (item 27); FMSS database

Because digital data are not generally available, the primary data source for much of the sensitivity analysis is an asset questionnaire developed by WCU. This questionnaire contains detailed questions related to the various sensitivity indicators (e.g., is the structure elevated above base flood elevation). It is distributed to appropriate personnel within each unit— typically individuals that possess long institutional memory and familiarity with park facilities. Where appropriate, sensitivity data is also obtained from FMSS, the National Bridge Inventory, aerial imagery, and site visits by WCU.

Each asset is given a score for the applicable sensitivity indicators. These scores are summed to obtain a total score for sensitivity, then binned into three categories reflective of the number of indicators: low sensitivity, moderate sensitivity, and high sensitivity.

Step 3: Asset Vulnerability Analysis

To obtain a vulnerability score for each asset, the exposure and sensitivity scores are summed, and then binned into four vulnerability ranking categories. The ranking categories are as follows: N/A (assets with minimal exposure and not included in the sensitivity analysis), low vulnerability, moderate vulnerability, and high vulnerability. A subset of the assets from the completed vulnerability analysis will be chosen for development of adaptation strategies (step 4).

Step 4: Adaptation Strategies Analysis

After the vulnerability analysis is complete, adaptation strategies will be analyzed for key assets within each park. FMSS data such as Asset Priority Index (API) and Optimizer Band (OB) can help select the assets to analyze for adaptation strategies. Assets analyzed will likely include those with high vulnerability and high priority and/or high criticality (API/OB), as well as high vulnerability assets with low priority and/or criticality. This adaptation analysis begins with discussions with the park, or by way of a questionnaire. This portion of the analysis focuses on the options available to the park to reduce the overall vulnerability of key assets. An outline of potential adaptation strategies to reduce coastal hazards and climate change vulnerability has been compiled by WCU for both structures and transportation assets (see table 3 below).

Table 3. Adaptation Strategies to Reduce Vulnerability of Assets to Coastal Hazards/Sea-Level Rise

Adaptation Action	Effect on Vulnerability and Rationale
☑ Elevate	Reduces the sensitivity of the asset; elevating a structure (and critical utilities) or transportation asset (i.e., a road) reduces the risk of flood damage.
☑ Relocate	Reduces the exposure of the asset; relocating the asset to a lower risk area reduces the likelihood that it will experience impacts from coastal hazards/SLR.
☑ Protect/Engineer	Reduces the exposure and/or sensitivity of the asset; protecting the asset with an engineered structure or landscape modifications (i.e., drainage) can reduce the likelihood that the asset will experience, or obtain damage from, coastal hazards/SLR.
☑ Decommission & Remove	Eliminates the vulnerable asset.
☑ Storm-Resistant Redesign	Reduces the sensitivity of the asset; redesigning the asset to be more storm resistant can reduce the likelihood of damage from coastal hazards/SLR.
☑ Engineering Downgrade (transportation assets only)	Reduces the sensitivity of the asset; downgrading the amount of engineering (i.e., replacing paved parking lot with shell material lot) can reduce the cost of rebuilding after damage and gives more flexibility for replacement.

This protocol is designed solely to assess the vulnerability of physical infrastructure. However, there are other adaptation actions for vulnerable assets that would not reduce the vulnerability of the physical asset, but instead its function. For example, a park might consider moving the critical contents within a building to a higher floor to reduce potential flood damages. Similarly, parks may decide to shift an asset's function to a less vulnerable asset. These adaptation actions do not change the vulnerability of the original asset (i.e., exposure and sensitivity remain the same); instead these actions change the criticality of the asset, potentially making it less of a concern to the park.

Additional NPS Climate Change Resources

Additional efforts are being made by NPS to address climate change in the coastal zone, as well as other critical environments. A number of these studies aim to improve the understanding of overall trends in climate change stressors, while others have focused on recording the specific effects of those stressors on natural and cultural resources within parks. Using this research and the latest climate science, the NPS is guiding adaptation efforts at units nationwide. Below are some of the climate change related resources at NPS:

- General Climate Change at NPS: <http://www.nps.gov/subjects/climatechange/index.htm>
- Climate Change Adaptation for Cultural Resources: <http://www.nps.gov/subjects/climatechange/adaptationforculturalresources.htm>
- Coastal Adaptation: <http://www.nps.gov/subjects/climatechange/coastaladaptation.htm>
- NPS Climate Change Adaptation Plan: http://www.nps.gov/orgs/ccrp/upload/NPS_CCActionPlan.pdf

Deliverables & Data Accessibility

The results of the exposure, sensitivity, and vulnerability analysis will be provided to the parks/regions in three primary formats. Most of the deliverables will be housed on the NPS SharePoint site and/or ArcGIS Online and available for parks/regions to download. Data provided includes:

- 1) **Excel datasheets.** All results, as well as asset specific scoring, are provided in tabular form. The exposure, sensitivity, and vulnerability scores are reported alongside the FMSS data for each asset, as well as the scores for each step of the analysis.
- 2) **GIS Maps and Layers.** All GIS data, including the exposure layers, exposure results, and final vulnerability results will be sent to the park as a separate file.
- 3) **Park Specific Vulnerability Results Summary Document.** This document, which explains the deliverables, results, adaptation strategies, and methodology will also be provided.

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