



Integrated Coastal Climate Change Vulnerability Assessment

George Washington Birthplace National Monument



Photograph of Potomac River at George Washington Birthplace National Monument.
NPS/DENNIS SKIDDS

Integrated coastal climate change vulnerability assessment: George Washington Birthplace National Monument

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Abstract

Through a series of workshops, a team of National Park Service, University of Rhode Island and related experts conducted a climate change vulnerability assessment to integrate issues across natural resources, cultural resources, and facilities for George Washington Birthplace National Monument (NM). This assessment used existing methods (Ricci et al. 2019a) and data, and expert knowledge to understand the general trends in current (2022) and future (2050, 2100) vulnerability and adaptive capacity. Climate stressors included sea level rise (SLR), storm surge, flooding, erosion rates, and precipitation and temperature changes. The results of the assessment are presented for each of the three workgroups: cultural resources, natural resources, and facilities, as well as for two key geographic focal areas – the Shoreline and the Memorial Core. Cultural landscapes, historic features and archeological sites that comprise the core values of the park are already being impacted by ongoing erosion, sea level rise, and storms, all of which are accelerated by climate change. The Ice Pond Dam was identified as a critical feature, both as a cultural resource and a facility asset, which is vulnerable to flash flooding and serves as a weak link for critical systems of communications, electricity, and access. Bluff monitoring designed to identify paleontological resources can benefit archeological resources as well. As erosion rates increase, newly uncovered archeological resources may drive a push for excavation. However, undercutting of the bluff makes any excavation or information reconnaissance on the archeological sites more difficult or dangerous due to the possibility of bluff edge sloughing or collapse. There is a recognized need to strengthen tribal partnerships to understand the priority for management of these resources. Tribal consultations initiated by the park are now underway. Any archeological excavation will result in loss of context and require additional storage capacity. Evaluation of potential shoreline stabilization techniques would need to consider how they would impact the viewshed and cultural landscape. Recommendations also included conducting an updated cultural landscape plan for the Memorial Core to consider tree management, including tree replacement in consideration of wind damage potential and because of the likelihood that extended warm seasons will lead to a longer period of pest activity. The vulnerability assessment data and maps can be a valuable resource for jumpstarting the adaptation planning process and integrating into existing planning processes. They can be used to engage with partners and help them appreciate the underlying vulnerability issues and changes over time.

Executive Summary

We conducted a climate change vulnerability assessment between March and July 2022 to integrate issues across natural resources, cultural resources, and facilities for George Washington Birthplace National Monument (NM). This rapid assessment used existing data and expert knowledge to understand the general trends in current and future vulnerability across three time frames – 2022, 2050, and 2100 – and the risks to the park’s resource management goals. In this context, vulnerability is the degree to which a resource, asset or process is susceptible to adverse effects of climate change, including climate variability and extremes. Climate stressors used to assess vulnerability included sea level rise (SLR), storm surge, flooding, erosion rates, and precipitation and temperature changes. This assessment combined the three resource types (natural, cultural and facilities), broadly covering all resources in George Washington Birthplace NM, to improve understanding of the issues and opportunities for timely and sufficient action.

The results of the assessment are presented for each of the three workgroups: cultural resources, natural resources, and facilities and are shown for all three together in Figure 1. This topical review is followed by more in-depth analysis of the two key geographic focal areas selected during the workshops – the *Shoreline* and the *Memorial Core*. Each section in the main report describes the value and importance of the resources, presents the overall vulnerability and the adaptive capacity of the resources, and finally, offers recommendations for next steps or management actions. We provide summary tables and examples of outputs for the natural resources, cultural resources and facilities program areas. The full [dataset and supporting materials](#) are available from the NPS data repository, the [Integrated Resource Management Applications](#) (Ricci et al. 2024).

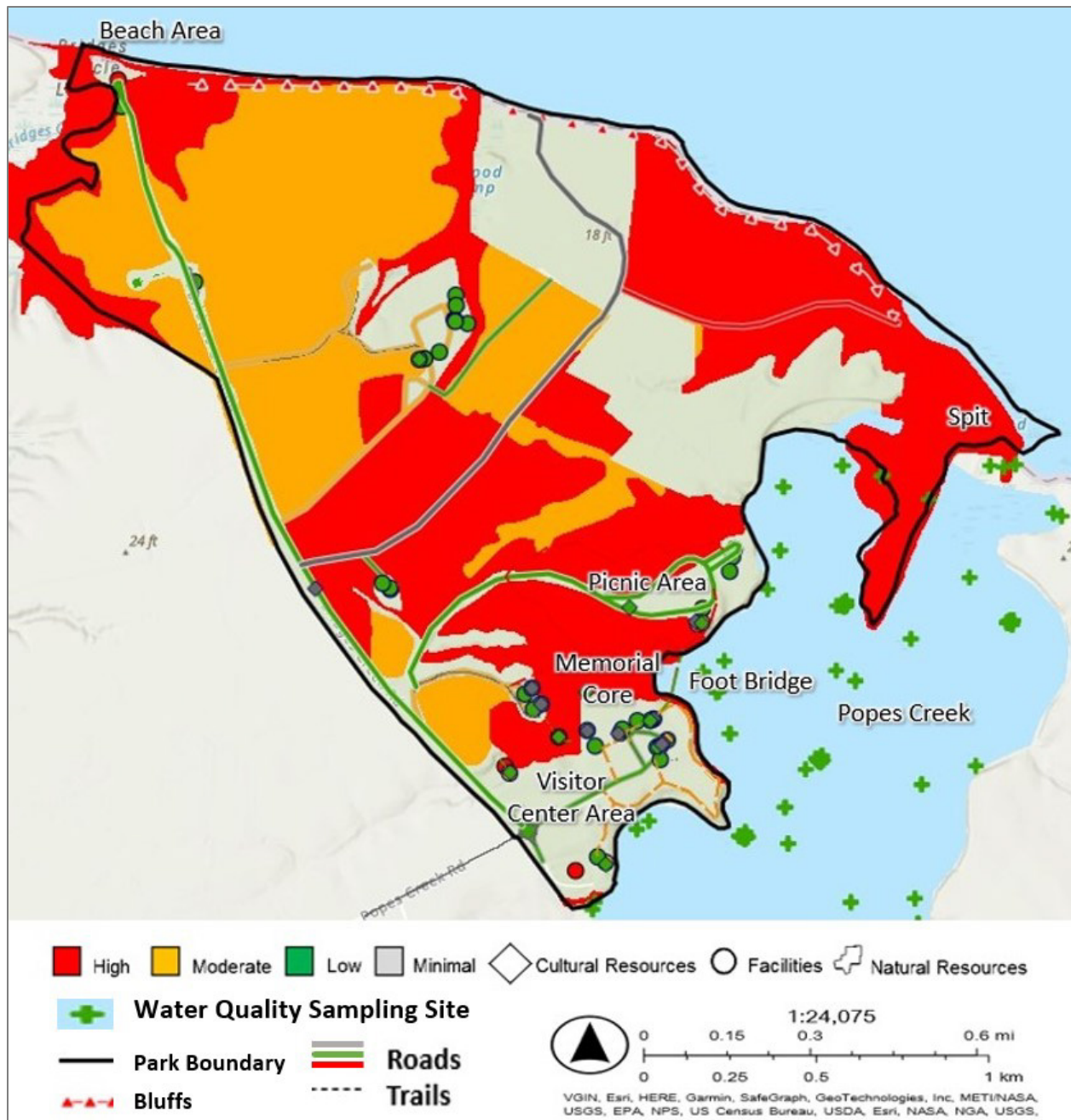


Figure 1. Overview of vulnerability scores of all resource types based on climate projections for 2050 at George Washington Birthplace National Monument.

Cultural Resources

- Cultural landscapes, historic features and archeological sites that comprise the core values of the park are already being impacted by ongoing erosion, sea level rise, and storms, all of which are accelerated by climate change.

- Urgent action needs to be taken along the shoreline to determine the best treatment for coastal archeological resources. In particular, priorities for action must be determined through tribal consultations.
- While individual elements of the cultural landscape, including cedar groves, are not highly vulnerable, the cumulative effect on the cultural landscape could be substantial and should be monitored and planned for. The workgroup identified the stressor of wind which drives tree falls as one of the most threatening climate change impacts on the cultural resources of the park.
- The Memorial House Museum is moderately vulnerable because of its museum collections; however, it does have adaptive capacity because the items could be relocated.

Natural Resources

- Several shoreline natural resources are already highly vulnerable. Those natural resources that are projected to increase in vulnerability are all projected to do so by mid-century, with no further change between the 2050 and 2100 time frames.
- None of the natural resources have high adaptive capacity. The workgroup made this determination on account of the comparatively lower significance of natural resources to the park's purpose, and hence the unlikelihood of attracting additional focused funding to protect these resources.
- The connections in the sediment system between the Beaches, Bluffs, Freshwater Ponds, and Tidal Wetlands are complex, and additional research is necessary to understand the potential for threshold changes that can affect other resources.

Facilities

- Facilities (consisting of building and transportation assets) in George Washington Birthplace NM play a critical role in protecting and providing public access to the valued cultural and natural resources at the park. Most of the buildings have low vulnerability (88%) to climate change due to the topography of the park on a bluff over the Potomac River (Figure 1). Transportation assets located closer to the shoreline or in low lying areas are more vulnerable.
- Of the 57 facility assets assessed, only the Beach Parking Lot saw a shift in vulnerability scores over the three time frames of the assessment – shifting from moderate to high vulnerability by 2050. Most of the historic buildings have low vulnerability, including those in the Memorial Core, due to their location at a higher elevation and sufficiently far from large trees. The Visitor Center, Ice Pond House, and Log House were the only buildings with moderate vulnerability. All the facility assets have moderate to high adaptive capacity due to the qualities of these assets, though action is contingent upon timely funding and decisions on long-term strategies to provide safe access to the park.
- Areas of concern for facilities include the Ice Pond Dam which is vulnerable to flash flooding and serves as a weak link for critical systems of communications, electricity, and access. The

Visitor Center's basement, which houses its mechanical systems, is vulnerable to flooding. Transportation assets like roads and trails are vulnerable to flooding and erosion along the shoreline. This vulnerability is most pronounced in the Beach Parking Lot and on sections of the Nature and Historic Trails along the shoreline. Adaptation options are viable for resolving many of these key vulnerabilities while maintaining cultural, natural and visitor use values.

Findings and Recommendations for Focal Areas

Shoreline

- The workgroup recommended coordinating paleontological and archeological monitoring and inventory plans with monitoring of natural resource shoreline change. Bluff monitoring designed to identify paleontological resources can benefit archeological resources as well, at least to monitor bluff condition at the base if not to identify the archeological resources which are higher in the bluff.
- Further, the NPS should consider how potential shoreline stabilization techniques would impact the viewshed and cultural landscape.
- The workgroup recommended updating the Ethnographic Resources Inventory and entering the information into the NPS Cultural Resource Inventory System (CRIS). It is unknown if human remains are part of the archeological sites. They also identified a need to understand the connection between the distribution of the Coastal Dry Plain Calcareous Forest, which is a rare habitat dependent on calcareous substrate, with the location of shell mound archeological sites. The priority for protecting these forests, which have a rating of low adaptive capacity, may be elevated if associated with archeological sites. There were also questions from the Natural Resources Workgroup if some Tidal Wetlands may have higher adaptive capacity due to their importance as ethnographic resources.
- The workgroup recommended exploring the possibility of piloting the USGS Coastal Change Likelihood tool (Sterne et al. 2022) as a case study in the Beach and Spit areas.

Memorial Core

- While the Visitor Center is usually treated separately from the Memorial Core, the workgroup felt the interpretations, facility, and access provided by the Visitor Center to the Memorial Core cultural landscape made it a critical resource in this focal area discussion. A timeline needs to be established for moving utilities out of the basement or establishing flood mitigations and managing dangerous storm water flooding in the parking lot.
- Critical facilities of cultural value including the Memorial House Museum, Outbuilding, and the Log House require routine, adaptive maintenance to maintain their adaptive capacity.
- The workgroup identified the Ice Pond Dam as a critical feature for assuring access to the rest of the site and as a conduit for major utilities. Conducting a structural study of the Ice Pond Dam may be necessary in order to substantially reinforce the dam before future storm events damage it again.
- The workgroup also recommended conducting an updated cultural landscape plan for the Memorial Core to consider tree management, including tree replacement in consideration of

wind damage potential and because of the likelihood that extended warm seasons will lead to a longer period of pest activity.

- The walking trails are a popular and important resource to access many other resources within the park. The NPS may need to consider relocation of trails or accept that trails will not always be accessible.
- As erosion rates increase, newly uncovered archeological resources may drive a push for excavation. However, undercutting of the bluff makes any excavation or information reconnaissance on the archeological sites more difficult or dangerous due to the possibility of bluff edge sloughing or collapse. There is a recognized need to make tribal partnerships stronger to understand the priority for management of these resources, as many Tribes prefer not to disturb culturally significant sites that may contain human remains. Tribal consultations initiated by the park are now underway and the Virginia Department of Historic Resources will hire a Tribal Outreach Coordinator. In addition, any archeological excavation will result in some loss of context and require additional storage facilities.

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List of Acronyms

AC	Adaptive capacity
CRIS	Cultural Resources Inventory System
DOI	Department of Interior
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FMSS	Facilities Management Software System
GEWA	George Washington Birthplace National Monument
HML	High, moderate, low
IPCC	Intergovernmental Panel on Climate Change
IRMA	Integrated Resource Management Applications
LiDAR	Light Detecting and Ranging
NOAA	National Atmospheric and Oceanic Administration
NM	National Monument
NPS	National Park Service
NRCA	Natural Resource Condition Assessment
POSE	Adaptive capacity categories: physical, organizational, social, economic
RCP	Representative Concentration Pathway
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SLR	Sea level rise
SOP	Sustainable Operations Program
USGS	United States Geological Survey
WCU	Western Carolina University

Introduction

As a riverfront coastal site with low lying areas combined with an elevated forested core, George Washington Birthplace National Monument (NM or GEWA) faces a variety of issues now which will likely increase in the coming decades due to climate change. Before undertaking adaptation planning, George Washington Birthplace NM worked with the National Park Service (NPS) Northeast Region and the Coastal Resources Center at the University of Rhode Island (URI) to undertake this vulnerability assessment to understand integrated vulnerability across natural resources, cultural resources, and facilities.

Purpose of the Assessment

We conducted an integrated climate change vulnerability assessment to gain a deeper understanding of how the park is vulnerable and identify key linkages among the program areas of natural resources, cultural resources and facilities. George Washington Birthplace NM is the third in the NPS system to test and refine an integrated vulnerability assessment for a coastal park targeting these three program areas, based primarily on the effective use of available information (Ricci et al. 2019a). In the case of George Washington Birthplace NM, the same process was followed as the previous assessments, however it was compressed into two workshops.

The goals of the assessment were to evaluate vulnerability of monument resources and assets to climate changes and identify key vulnerabilities, or those that most threaten achievement of the monument's management objectives. Managers will also be able to determine investment priorities for resources that are highly vulnerable but have low adaptive capacity. This report is intended to both support parkwide planning efforts and to be a useful tool for each program area to use for its own purposes.

At the conclusion of this project, the expectation was that park staff would be able to:

- Identify the timing of changes likely to occur across the park in the time frames of 2022, 2050, and 2100;
- Explain the major linkages across the natural resources, cultural resources, and facility assets;
- Identify the co-benefits across these three program areas for potential action;
- Provide recommendations on actions that can be taken to keep adaptation options available.

The vulnerability assessment relied primarily on existing data, local knowledge, and subject matter expertise. Many existing science products contributed to the feasibility of applying the methodology, though the challenges of working across different resources and scales in a relatively rapid process meant that a variety of valuable data was not able to be included (Schmelz et al. 2019; Hardaway et al. 2009; Blank et al. 2007; NPS 2018; Peek et al. 2022; EA Engineering, Science, and Technology, Inc., PBC. 2023). The process combined this best available science and tools with qualitative expert judgment captured through the workshops.

The assessment broadly covers the entire park area with further attention to focal areas for integrated discussion. Each workgroup selected which resources and assets to include differently; details can be found in the accompanying methods document (Ricci et al. 2019a).

Setting overall priorities for adaptation within George Washington Birthplace NM will require taking the vulnerability of its natural resources, cultural resources, and facility assets into account. The vulnerability scoring should assist each program area when setting planning priorities or targeting funding sources and for park-wide planning where there are opportunities and trade-offs among resources.

Climate change impacts, such as sea level rise (SLR), on cultural and natural resources as well as infrastructure are addressed in the George Washington Birthplace NM Resource Stewardship Strategy (NPS 2018), which recognized concerns about SLR, storm surge increases, increased frequency and intensity of coastal storms, temperature increases, and precipitation changes (NPS 2018). Associated with these climate threats were rapid erosion of shoreline bluffs and riverbanks (up to 3 feet per year in certain areas), looting of resources facilitated by shoreline erosion, and invasive and nonnative plants and animals. Climate change impacts have become specific concerns in light of increased frequency and intensity of climate related events impacting park and adjacent infrastructure, changing natural resource features and wildlife habitats, and causing loss of or damage to sensitive cultural resources.

The three different resource types (Natural, Cultural, Facility) required different indicators of exposure, sensitivity, and adaptive capacity (AC). For cultural resources, the method tailors sensitivity indicators to each cultural resource type: archeological resources, cultural landscapes, ethnographic resources, museum collections, and historic structures. Assessment of cultural resources incorporates information from the Cultural Resource Inventory System (CRIS), including archaeological condition assessments, Cultural Landscape Reports, and historic structures information from the List of Classified Structures. Facilities methods development was greatly enhanced by the coordination with the NPS's Sustainable Operations Program (SOP) to incorporate the methods derived from the Coastal Hazards & Climate Change Asset Vulnerability Assessment Protocol (Peek et al. 2022) and its implementation concurrent with this project (Peek et al. 2023). The major natural resources methods difference was including an intrinsic component of Adaptive Capacity within the Physical category. Workshop participants discussed whether this could apply to some cultural resources, though was ultimately decided it was not applicable. A similar conclusion to eliminate intrinsic adaptive capacity was made regarding some natural resources as well.

Context of Integrated Studies in NPS

Since park management decisions are often interdisciplinary across program areas, an integrated approach to assessing resource vulnerability is needed. Clear and well-tested methods for doing this are still being developed, including as part of this study. Examples of this approach completed to date include a review of existing vulnerability assessments for coastal parks in the Northeast Region and a handbook by NPS for coastal adaptation strategies (Ricci et al. 2017; Beavers et al. 2016). The work at George Washington Birthplace NM was the third application of this method of integrating cultural resources, natural resources, and facilities, following the pilot at Colonial National Historical Park

(Ricci et al. 2019b). Previous assessments have integrated cultural and natural resources (Amberg et al. 2012).

The idea for developing a relatively rapid assessment method was to use the best available science and capture existing knowledge into a system that could be iteratively updated as new information becomes available. To gather expert judgement, a broad team of experts was assembled, which included park, regional, and headquarters NPS staff, partners such as the Naval Support Facility Dahlgren and academic research collaborators. The vulnerability assessment set out from the beginning to engage all three program areas of the park both in information gathering and the workshop process by creating workgroups to prepare for and help lead the two assessment workshops. These provided opportunities for each program area to advance the assessment as well as for the entire group to listen, engage, and reflect on aspects of the assessment in plenary and mixed group exercises.

Participants found it useful to customize analysis of park resources within the context of each of the three park program areas. These different approaches are reflected in the data. Thus, this report includes differing levels of descriptive detail, in order that it can be a useful document for each program area to use on its own, as well as for the integrated vulnerability discussion.

Methods

Assessment Framework

Scanning the Conservation Horizon (Glick et al. 2011) has served as a guidance document for vulnerability assessments in many national parks and conservation areas. Glick et al. (2011) and much of the natural resource literature on vulnerability has come to a consensus definition that vulnerability is a combination of exposure, sensitivity, and adaptive capacity. However, within the NPS, methods to define vulnerability for facility assets and non-living cultural resources recommend not including adaptive capacity within vulnerability, and instead defining vulnerability as the combination of exposure and sensitivity (NPS 2021; NPS 2016; Rockman et al. 2016). This assessment applied the previously developed methodology (Ricci et al. 2019a) of defining adaptive capacity of a resource more broadly than in other frameworks by including extrinsic factors that ultimately express the capacity of resource and asset managers to manage vulnerability. Key factors include non-living physical, social, organizational, and economic capacities. Since these factors are not inherent to the resource, we chose to assess adaptive capacity separately from vulnerability, even for natural resources.

Vulnerability is the degree to which a resource, asset or process is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes. Climate change vulnerability is determined by evaluating the components in Figure 2, where vulnerability is determined by the target's exposure and sensitivity, and this may be modified by adaptive capacity. Exposure is the magnitude of change in climate and other stressors that a resource, asset, or process has already or may experience in the future. Exposure was calculated using climate projections in 2022, 2050, and 2100 for a range of climate stressors. A climate stressor is a condition, event or trend related to climate variability and change that can exacerbate hazards. Sensitivity is the degree to which a resource, asset, or process is or could be affected, either adversely or beneficially, by climate variability or change. Adaptive capacity was assessed separately and used as a tool to bridge the vulnerability assessment and future adaptation planning processes.

Details of the overall methodology are available in the supporting report (Ricci et al. 2019a). Further explanation about adaptive capacity is provided here. To estimate adaptive capacity, each workgroup carried out an analysis using a simple framework that divided the concept into four key types of capacities – Physical, Organizational, Social, and Economic (POSE) (adapted from Bruneau et al. 2003). Every resource/asset received an adaptive capacity score, except for facility assets that were not exposed and thus did not receive a sensitivity or an adaptive capacity score.

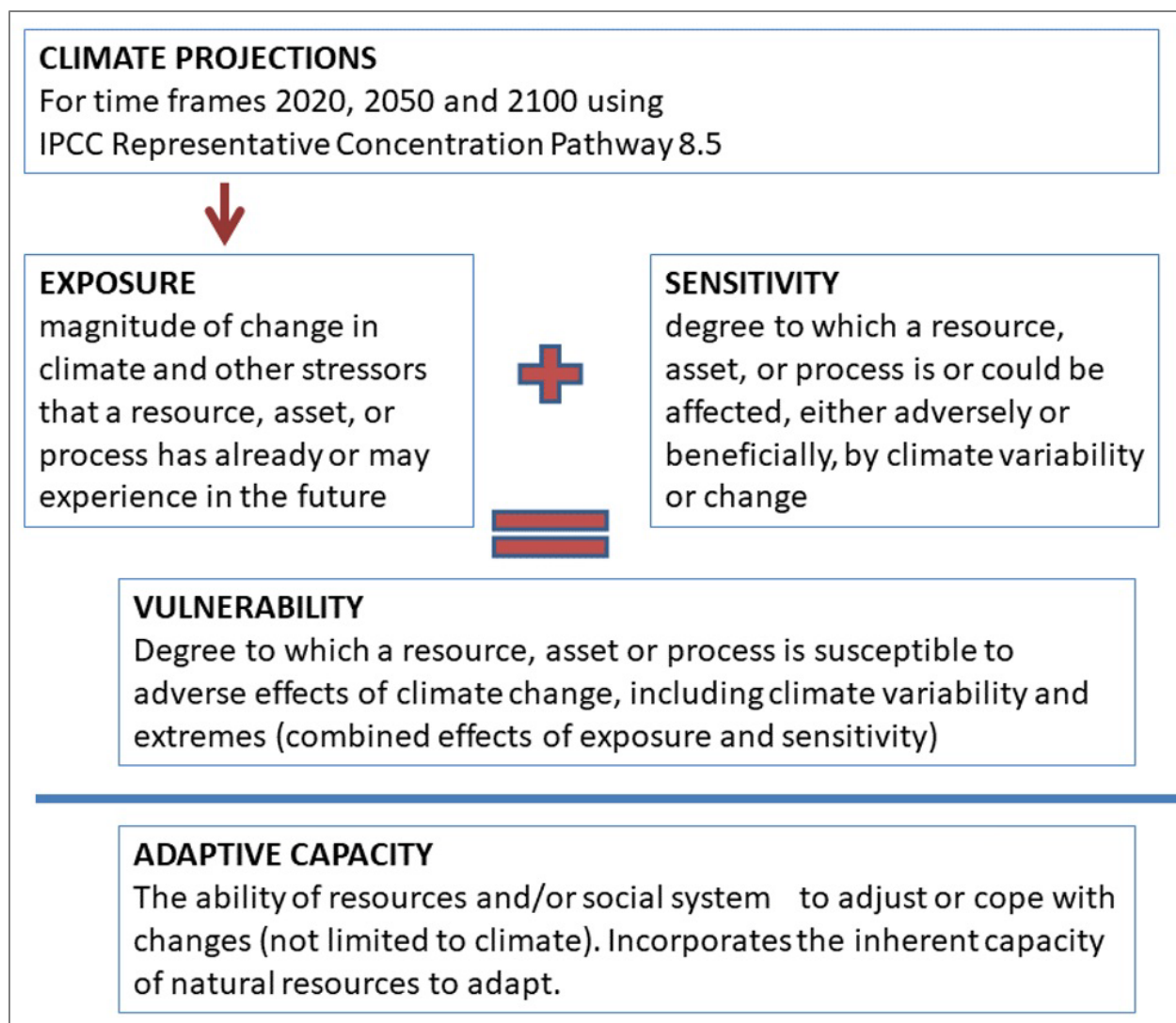


Figure 2. Overview of the climate change assessment framework.

Physical capacity refers to the physical properties of systems, including the ability to resist damage and loss of function or to evolve into a new desired functional state. Physical properties include natural characteristics (e.g., wetlands that can vertically accrete or migrate upland) and infrastructure (vehicles, boats, gear, facilities). The method distinguishes between two following aspects of physical adaptive capacity:

Intrinsic capacity, sometimes referred to as natural adaptive capacity, is the ability of the species or habitat to resist climate impacts or re-establish itself in a changed environment. This is the component that for natural resources is usually included in vulnerability (Glick et al. 2011). The Natural Resources Workgroup considered including it in vulnerability, but it was decided to keep separate for consistency with other workgroups. For natural systems within the park, the assessment of sensitivity to climate impacts includes some consideration of short-term response; the adaptive capacity analysis takes a longer-term perspective. The ability to shift range outside of the park

boundaries was considered in the larger landscape context and not just whether a species would only persist within the park.

Technology/Infrastructure refers to the availability of engineered or technical means to resist impact or to aid in migration, re-establishment or creation of similar habitat or the availability of infrastructure needed to adapt (vehicles, boats, gear, facilities), such as to move a resource.

Organizational Capacity relates to the organizations and institutions that manage the physical components of the systems. This domain encompasses measures of organizational capacity, planning, training, leadership, experience, and information management that improve organizational performance and problem solving. This includes factors such as legal mandates or prohibitions and the need for conflict resolution among competing priorities.

Social Capacity considers the degree of public interest and support for adaptation actions, potential conflicts with neighboring land uses, and competing values of maintaining the cultural landscape versus allowing ecological processes to proceed. NPS sites often contribute to a community's sense of place and the local economy, and community members frequently develop strong interests in the preservation of the resources. These can influence the NPS's willingness to act or not act even when they have the authority to do so. Non-local communities interested in the asset should also be considered as they could be influential in the ability to act.

Economic Capacity is the financial cost of implementing climate adaptation measures or the loss caused from damage due to climate impacts. For example, shore protection structures may provide temporary protection but are expensive, while allowing wetlands to migrate as impacts occur would be low cost. Protecting visitor centers and historic structures is also a significant economic activity which includes maintenance and recovery from hazard events. The NPS can also utilize partner funding so the discussion should include all sources of likely funding.

To guide the scoring of adaptive capacity within each of the POSE categories, relevant factors were identified to focus discussion; which and how many of these were considered varied by resource as listed below.

Physical factor examples:

- Natural-intrinsic
 - Health
 - Abundance
 - Protection
 - Sensitivity to current impacts
- Infrastructure
 - Transportation (boats/vehicles)
 - Facilities
 - Shoreline structures

- Monitoring protocols
- Technology

Organizational factor examples:

- Laws/Authority
- Coordination
- Agreements (formal and informal)
- Plans
- Implementation
- Enforcement
- Staffing – number of staff (term vs seasonal) and training
- Transparency
- Accountability
- Meets multiple goals (across NPS program areas)
- Number of viable management options (don't select them, just recognize the variety available)
- Willingness to take effective action
- Willingness to take timely action

Social factor examples:

- Significance (across a variety of sectors/communities)
- Cohesion
- Community organizations and associations
- Trust
- Diversity of livelihoods, culture and language
- Awareness
- Conflicts
- Equity (gender, financial)
- Perceptions
- Culture
- Values and attitudes
- Champions (leaders that support effort)
- National interests
- Constituencies dedicated to an asset

Economic factor examples:

- Base funding
- Competitive funding
- Congressional line items
- Emergency funding
- Administrative system to disburse finances in timely fashion
- Likely scale of economic resources required to do a variety of actions

Since this assessment separated adaptive capacity from the vulnerability formula, we developed a graphic to show the relationship between the two for each resource/asset assessed. This is displayed through a matrix of vulnerability vs adaptive capacity for focal areas or resources/asset groupings. The following four general concepts were assigned to each quadrant of the matrix that captures the general context based on the vulnerability and adaptive capacity scores:

- **Monitor for Change:** For low-vulnerability and low-adaptive capacity situations the term “monitor for change” was applied with the assumption that while these resources appear to be low priority for now, the situation can change.
- **Options Available:** For low-vulnerability and high-adaptive capacity situations the term “options available” was applied with the assumption that these resources may provide opportunities to begin adaptations using existing capacity.
- **Serious but Actionable:** For high-vulnerability and high-adaptive capacity situations the term “serious but actionable” was applied with the assumption that these resources are a priority due to their vulnerability and there is existing capacity to address them individually or preferably in an integrated way with similar resources.
- **High Concern – Reconsider Goals:** For high-vulnerability and low-adaptive capacity situations the term “reconsider goals” was applied with the assumption that there isn’t sufficient existing capacity to address these highly-vulnerable resources and there is the chance that NPS goals will not be met should the vulnerabilities turn into impacts over time. In such circumstances, more realistic and achievable goals should be drafted.

Assessment Process

The assessment process consisted of background work carried out mainly by The University of Rhode Island (URI) staff and the detailed study of facilities conducted by Western Carolina University (WCU) (Peek et al. 2022; Peek et al. 2023). Experts were organized into three workgroups – natural resources, cultural resources, and facilities. Conference calls occurred before and in between two onsite workshops aimed at eliciting qualitative judgments, capturing staff knowledge, and testing efficient approaches for use by park staff. Workgroups at each onsite workshop were tasked with integrating and prioritizing across all park resources. This vulnerability assessment report was prepared after the second workshop.

In advance of the first workshop, workgroups were provided background information and orientations to be able to maximize the efficiency of each face-to-face activity.

The general flow and objective of workgroup activities is listed below:

Project Launch Conference Call: The project was introduced to George Washington Birthplace NM staff via conference call/webinar held in June 2019. Due to COVID-19, the workshops were delayed until it was safe for the workgroups to meet in person at the park.

- **Workshop #1** was held on March 23-24, 2022 at the George Washington Birthplace NM. The objectives were to:
 - Learn about the methods for conducting an integrated climate change vulnerability assessment.
 - Share expert judgement on the exposure and sensitivity of George Washington Birthplace NM's natural and cultural resources and facility assets.
 - Reveal key linkages across the natural, cultural and facility program areas to understand the inter-dependence of resources and assets at George Washington Birthplace NM to achieve management goals.

Workshop #2 was held at George Washington Birthplace NM July 12-13, 2022. The objectives were to:

- Review the overall vulnerability of facility assets and natural and cultural resources (combining exposure and sensitivity) for three time periods.
- Select indicators for adaptive capacity and assign scores.
- Reveal key linkages across the natural, cultural and facility program areas in select focal areas to understand the co-dependence of assets/resources at George Washington Birthplace NM to achieve management goals/objectives.
- Identify recommendations and next steps on how to use the results – such as further data needs and adaptation planning.
- Set out the goals and process for the final report preparation, sharing the results and next steps towards adaptation.
- Evaluate the assessment process to inform the next iteration at a different site.

Full details of the method are available in the methods report (Ricci et al. 2019a).

Climate Projections

Key climate stressors on resources and assets were identified by the workgroups. The stressors focused on priority issues, given the limited scope of the assessment. Stressors included by all three workgroups were: SLR, flooding, storm surge, erosion, and wind. Both Natural and Cultural Resources Workgroups used changes in temperature, changes in precipitation, and fire. Other stressors identified by the Cultural Resources Workgroup included humidity, species shifts, pests &

disease and invasive species. For this assessment, non-climate stressors were not included unless they interacted with climate stressors.

The assessment looked at observed climate change trends and future projections. Three time frames, 2022, 2050, and 2100 were used throughout the assessment. The 2022 time frame represented current conditions to identify existing vulnerabilities and recognized the park is currently seeing impacts. The mid-century projection should be incorporated into the long-term planning horizon of some current and planned projects. The end-of-century projection recognized our responsibility to preserve resources for future generations. Building on the principle of using existing data and knowledge where feasible, the team coordinated with other ongoing studies especially coordinating with the Facilities' SOP/WCU protocol (NPS 2016; Peek et al. 2022).

Sea level rise scenarios are based on the closest long term tide gauge to the park, which was at Solomon's Island, MD. For the 2050 scenario, we used 0.63 m (2.07 ft) to remain consistent with the Facilities' *Coastal Hazards & Climate Change Asset Vulnerability Assessment Protocol* (NPS 2016; Peek et al. 2022) that was in the process of being updated during the assessment. To balance consistency with past use of protocol for comparisons with other parks and updates of NOAA (2017) and interagency SLR scenarios (Sweet et al. 2022), we used a value from *Sea Level Rise and Storm Surge Projections for the National Park Service* (Caffrey et al. 2018) that fell between NOAA's Intermediate and Intermediate-High scenarios for 2050. Explanation of and details on this admittedly confusing workaround that allowed the use of a locally relevant scenario with the tools that were available at the time are available in Appendix A, a summary of the SLR projections that was provided as a workshop handout.

For temperature and precipitation, historical data (NPS 2017b; Gonzalez et al. 2018) and projections based on Multivariate Adaptive Constructed Analogs - downscaled Global Climate Models projections using a hot/wet climate future (CCRP analysis based on Abatzoglou and Brown, 2012) were used. For each time frame, exposure was determined based on when it fell outside of the range of historical variability. While the projections were downscaled to the model cell that included the park, the spatial resolution on the projections was insufficient to determine any spatial differences within the park. To make it more useable for the workshop, Table 1 of quantified climate projection exposure was developed with key metrics, while Table 2 simplified exposure implication for each time frame.

The following current data sources for storm surge and flooding were selected: the NOAA Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model for category 3 hurricane, Federal Emergency Management Agency (FEMA) VE (area with 1% or greater chance of flooding and additional storm wave hazard) and AE (area with 1% annual chance of flooding) flood zones following Peek et al. (2022).

Table 1. Climate projections that are the basis of exposure at George Washington Birthplace National Monument.

Stressor	Metric	Historical	Climate Projections	
			2050	2100
Temperature	Mean annual temperature	58.6 °F	63.3 °F	67.8 °F
	Daily highs	69.2 °F	73.9 °F	78.4 °F
	Daily lows	48.1 °F	52.6 °F	57.1 °F
	Hot days (> 95°F)	14	44	84
	Cold nights (< 32°F)	77	44	24
Precipitation	Mean annual total	44.4"	47.9"	49.0"
	Frequency heavy precipitation events	Yes	Yes	Yes
	Peak daily precipitation (days >1")	7.9	9.9	10.5
	Drought severity *	-0.89	-1.35	-5.59

* Based on Standardized Precipitation Evapotranspiration Index

Table 2. Exposure projections across three-time frames at George Washington Birthplace National Monument.

Stressor	Metric	Exposure Projections *		
		2022	2050	2100
Temperature	Mean annual temperature	Yes	Yes	Yes
	Daily highs	No Data	Yes	Yes
	Daily lows	No Data	Yes	Yes
	Hot days (> 95°F)	No Data	Yes	Yes
	Cold nights (< 32°F)	No Data	Yes	Yes
Precipitation	Mean annual total	No	Yes	Yes
	Frequency heavy precipitation events	Yes	Yes	Yes
	Peak daily precipitation	No Data	Yes	Yes
	Drought severity	No Data	Maybe	Yes

* Defined as whether “yes” or “no” the 20-year mean, centered on the year (2020, 2040, or 2080), is greater than the historical (1950–2005) mean plus one standard deviation. For purposes of consistency with other projections, we refer to the 2040 centered projection as 2050 and the 2080 centered one as the 2100 or end-of-century projection.

The future scenarios included continued warming trend with a relatively constant change across all months, and maximum temperature increase is greater than annual average and is strongest in the winter. Days above 95°F increase four-fold while days with below-freezing drop almost by half. Precipitation increases moderately, except for stronger increases in late summer. The combination of SLR, increased heavy precipitation events, continuing regional trends towards more frequent and extreme storms, leads to significant increases in flooding. On the other hand, rapidly warming temperatures lead to soil moisture stress when rainfall is below average and drought severity may increase.

Caveats

This assessment used existing information, but a more detailed analysis may be needed for particular resources or assets. Storm surge and flooding from SLOSH and VE zones do not include SLR or the potential for increased frequency of storms in the future. This limitation explains why much of the exposure does not change between 2050 and 2100 time frames. It should be noted that we used a mix of available projections that varied on alignment with these time frames; temperature and precipitation projections for mid-century are based on available analysis centered on 2040 and end of century are based on available analysis centered on 2080 (Analyses: NPS CCRP).

The results of the assessment are presented in the following sections highlighting in-depth analysis for each of the workgroups: Cultural Resources, Natural Resources, and Facilities followed by the two key focal areas selected through the workshops – Shoreline, and the Memorial Core. The general organization for each section is to describe the value and importance of the resources, present the overall vulnerability and the adaptive capacity, and finally offer recommendations for next steps or management actions. The body of the report has summary tables and examples of outputs for the natural resources, cultural resources and facilities program areas (sometimes referred to as divisions, hereafter often referred to as “the program areas”). The full dataset and supporting materials for all the resources have been provided to the park in a spreadsheet that a version of which will be posted to the Integrated Resource Management Applications (IRMA) portal accompanying this report.

Results

Results of the assessment are provided by first reviewing the three resource groups followed by the two integrated focal areas.

Cultural Resources

Key Messages

At George Washington Birthplace NM, the cultural landscapes, historic features and archeological sites that comprise the core values of the park are already being impacted by ongoing erosion, SLR, and storms, which are all accelerated by climate change.

- Urgent action needs to be taken along the shoreline to determine the best treatment for coastal archeological resources. In particular, priorities for action must be determined through tribal consultations.
- While individual elements of the cultural landscape, including cedar groves, are not highly vulnerable, the cumulative effect on cultural landscape could be substantial and should be monitored and planned for. The workgroup identified the stressor of wind which drives tree falls as one of the most threatening climate change impacts on the cultural resources of the park.
- The Memorial House Museum is moderately vulnerable because of its museum collections; however, it does have adaptive capacity because the items could be relocated.

Vulnerability

The two components of vulnerability in this study are exposure and sensitivity. To address exposure and sensitivity, the Cultural Resources Workgroup dealt with cultural resources within the main categories – archeological sites, historic structures, museum collections, cultural landscapes, and ethnographic resources. For ethnographic resources there were assessed individually except for the archeological sites which were divided into three different categories based on their exposure. They were categorized based on their distance from the shore as mapped in flood zones – over the three time frames considered. Polygons were developed to cover all individual archeological sites according to three categories;

- Coastal archeological sites
- Near-coastal archeological sites
- Inland archeological sites

Archeological resources were identified from the CRIS-Archeological Module. Although roads were included in CRIS for the site, because of the large number of cultural resources to assess, the Facilities Workgroup scores for the roads were used.

The Cultural Resources Workgroup determined that coastal erosion and wind events resulting in tree damage were the primary stressors to cultural resources across the site.

Once a list of resources was developed, the Cultural Resources Workgroup assessed the exposure and sensitivity of each resource to 11 separate stressors of climate change. These stressors are: flooding (river and creek), erosion, SLR, storm surge, temperature, precipitation, species shift, pests and disease, wind, humidity, and fire.

The exposure and sensitivity of each resource to these 11 factors were assessed in two ways. For sites that had specific geographic locations, exposure to these factors was determined by data overlays in a GIS map. For resources without identified or with a broad geographic footprint, a binary Yes/No response for exposure to each stressor was provided by subject matter experts. For sensitivity, the Cultural Resources Workgroup used a scale from 1-4 to represent sensitivity of each resource. In this system, a score of '4' meant the resource warranted significant concern given the sensitivity to the climate stressor and corresponded with the qualitative score of high sensitivity, a score of '3' for moderate concern and a score of '2' for low concern. A score of '1' indicated that the resource did not warrant additional concern beyond the normal level of care and maintenance. Each of the five types of cultural resources had different considerations for exposure and sensitivity, discussed below. Vulnerability was calculated by normalizing (through binning) the raw exposure and sensitivity scores and then adding them together. These scores were binned first since sensitivity had a larger scoring range than exposure. The results of the cultural resources vulnerability are shown in Figure 3 and tallied in Table 3.

Table 3. Cultural resources vulnerability results summary for 2050 at George Washington Birthplace National Monument.

Resources	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total # Analyzed
	#	%	#	%	#	%	#	%	
Archeological Sites	2	67%	0	0%	1	33%	0	0%	3 *
Historic Structures	0	0%	1	8%	5	42%	6	50%	12
Cultural Landscape	0	0%	2	15%	7	54%	4	31%	13
Museum Collections	0	0%	0	0%	2	100%	0	0%	2
Facilities (roads and trails of cultural value)	1	6%	1	6%	6	38%	9	56%	17
All Cultural Resources	3	7%	4	9%	21	46%	19	41%	47

* The 38 identified archeological sites were grouped into 3 categories according to their distance from the shore for purposes of analysis and discussion.

The exposure, sensitivity, and vulnerability scores by each stressor for each time frame have been provided to the park in a spreadsheet that a version of which will be posted to the IRMA portal accompanying this report. A data viewer for internal park use to protect cultural resource data shares all the data layers and final scores for resources with geographic information.

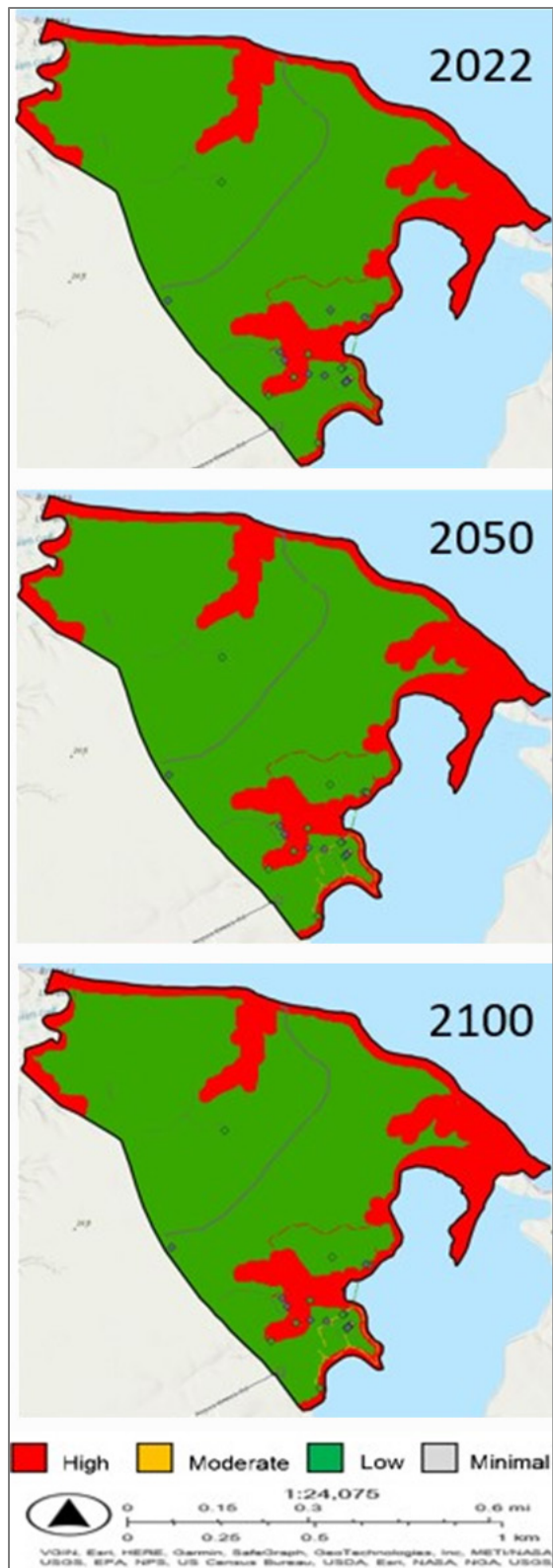


Figure 3. Vulnerability of cultural resources in 2022, 2050, and 2100 at George Washington Birthplace National Monument.

Archaeological Sites

The archeological resources of George Washington Birthplace NM are being impacted by ongoing erosion and SLR. The combination of erosion and SLR can damage sites, disperse artifacts, and make sites inaccessible. Erosion from storm events along the Potomac has already destroyed archeological resources. The archeological sites at George Washington Birthplace NM were grouped according to their distance from the coast as mapped in the flood zones for 2022, 2050 and 2100, hence their exposure. These flood zones thus defined the ‘coastal archeological sites’ (8 archeological sites covering a total area of 380,129 m²), the ‘near-coastal archeological sites’ (1 archeological site covering an area of 15,017 m²) and the ‘inland archeological sites’ (29 archeological sites covering a total area of 163,050 m²) for the current assessment. The coastal archeological sites are highly vulnerable from 2022, the near-coastal sites are highly vulnerable by 2050 and the inland sites are moderately vulnerable from 2100. These archeological sites include both pre-contact resources as well as resources that date from the original Washington family occupation of the site.

Historic Structures

Most of the historic structures in George Washington Birthplace NM are located in the Memorial Core of the park (Figure 4). These structures all date from the early 20th century and are colonial revivalist reconstructions of the buildings that may have existed during the Washington era. These include the following structures:

- Memorial House Museum
- Colonial Revival Kitchen
- Rockefeller Barn
- Farm Workshop
- Spinning and Weaving Room
- Log House
- Log House Storage Shed
- Historic Pump House & Bathrooms
- Colonial Revival Kitchen Gazebo
- Ice Pond Pump House

Most of these resources have a minimal to low vulnerability across the time frames, except for the Memorial House Museum which had a moderate vulnerability across the periods, on account of the unreliable climate control for the museum collections it houses.

The granite obelisk monument in the center of the traffic circle that greets visitors arriving on site was rated as minimal vulnerability and low adaptive capacity by the Cultural Resources Workgroup, although the Facilities Workgroup identified higher adaptive capacity. The Washington family burial ground, which dates to the Washington family habitation, with associated brick wall, pillars,

ornamental iron gate and pathway is along the road to the beach. It rated as having low vulnerability across time frames. The adaptive capacity of this site is high.

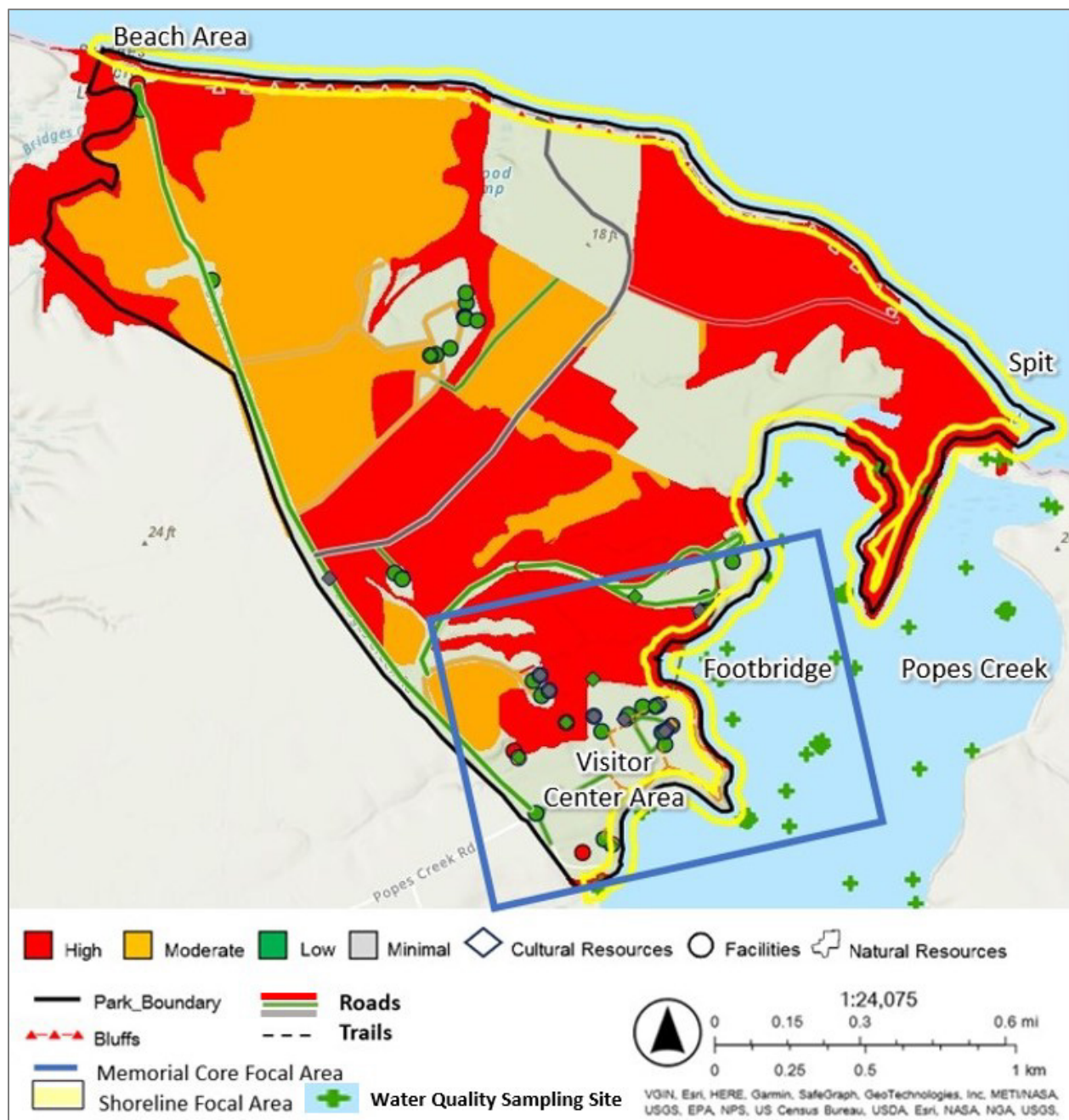


Figure 4. Vulnerability scores for facility assets, cultural and natural resources for George Washington Birthplace National Monument by 2050.

Museum Collections

Concerns about the exposure and sensitivity of collections from George Washington Birthplace NM were twofold. First, direct impacts of climate change may affect the foundation of buildings or

increase the amount of electricity needed to maintain the temperature and humidity of the historic structures and the storage facility, both on a regular basis and during storms when power is lost. Second, any excavation and retrieval of artifacts conducted in the park as a mitigation measure (in terms of loss of cultural resources to erosion, rather than referring to reduction of emissions which is another common climate mitigation) could increase the required museum storage space, potentially leading to budgetary and management challenges.

The presence of museum collections on display in the Memorial House Museum substantially raised the vulnerability rating given by the Cultural Resource Workgroup as compared to the Facilities Workgroup. No substantial museum collections are stored in the visitor center.

Cultural Landscapes

The two identified cultural landscapes at George Washington Birthplace NM are the *George Washington Birthplace Landscape* and the *George Washington Memorial Core*, which together cover the entire George Washington Birthplace NM landscape (NPS, 2018). The site prioritized the preservation of the colonial revivalist reconstruction of the Washington era, and the landscape that attracted the Washington family to settle there. Cultural landscape elements include fig shrubs, the Colonial Revival Garden and sundial, the stone and brick walkways, the woodland between Bridges Creek Road and Duck Hall, the views to Pope's Creek and the Potomac River, the Ice Pond Dam, and the agricultural ditches.

The many interlinked elements of the cultural landscapes are critical in their coherence: while the loss of a single cedar tree doesn't damage the cultural landscape, the loss of the Cedar Tree Grove would have a major deleterious impact to the cultural landscape. In this way, the collective elements of the cultural landscape provided resilience to the group. At the same time, protecting the elements of the cultural landscape would curtail some of the adaptive efforts identified by the Facilities Workgroup such as removing or heavily pruning trees.

Most elements of the cultural landscape have minimal to low vulnerability except for the two groves of eastern red cedar which have moderate vulnerability across all time frames. Agricultural ditches across the NM are a component of the cultural landscape and are minimal vulnerability in 2022 increasing to low vulnerability by 2050. These ditches were divided into two groups: those maintained for drainage along the road and at the maintenance building and all others.

Ethnographic Resources

The cultural resources are not well understood for their ethnographic value or vulnerability. The Ethnographic Overview and Assessment from 2009 does identify ethnographic resources, and the Cultural Resources Workgroup felt planned consultations were required to understand these resources and their vulnerability better.

Adaptive Capacity

Cultural resources represent a diverse collection of materials, structures and sites with diverse preservation requirements and limited adaptation strategies in the face of climate change. While natural resources may have intrinsic adaptive capacity, man-made sites and memorialized views

may not have the same flexibility. NPS guidance recognizes that resource adaptation may include a range of options from document and accept loss to improve resilience/resistance or relocate. The ability of site managers and partners to aid in the protection of cultural resources from the impacts of climate change represents one type of adaptive capacity. The decision to handle adaptive capacity separately was informed by the work supporting the NPS Cultural Resources Climate Strategy (Rockman et al. 2016) though the method was developed at a pilot workshop prior to that publication (Ricci et al. 2019b).

Adaptive capacity of the **archeological resources** was rated as moderate but depends on considerations discussed extensively above in the Memorial Area Focal Core section (Table 4). These resources are of high concern to the park and require management planning and potentially revisiting goals and treatment. Details of the adaptive capacity scores for cultural resources are included in a spreadsheet that has been provided to the park, a version of which will be posted to the IRMA portal accompanying this report.

Table 4. Cultural resources adaptive capacity results summary at George Washington Birthplace National Monument. The percentages represent a percentage of high, moderate, and low adaptive capacity for each type of cultural resources (adding to 100% across the line). The *All Cultural Resources* row represents an average of the individual types of cultural resources.

Resources	High Adaptive Capacity		Moderate Adaptive Capacity		Low Adaptive Capacity		Total # Analyzed
	#	%	#	%	#	%	
Archeological Sites	0	0%	3	100%	0	0%	3*
Historic Structures	2	17%	10	83%	0	0%	12
Cultural Landscape	1	8%	10	77%	2	15%	13
Museum Collections	1	50%	1	50%	0	0%	2
Facilities (roads and trails of cultural value)	8	50%	8	50%	0	0%	16
All Cultural Resources	12	26%	32	70%	2	4%	46

*The 38 identified archeological sites were grouped into 3 categories according to their distance from the shore for purposes of analysis and discussion.

Most **historic structures** have a moderate adaptive capacity and should be monitored for change. The Memorial House Museum and Historic Pump House and Bwere identified as having high adaptive capacity. It may be necessary to use modern materials on buildings for improved adaptive capacity moving forward.

The adaptive capacity for the **cultural landscape** elements was moderate for all resource except for the sundial which was low and the views which were high. The Cedar Grove of red cedar trees, which were the most vulnerable elements of the cultural landscape, have a moderate adaptive capacity.

Future adaptation activities of **ethnographic resources** will be informed by tribal consultations, which are planned in the near future, with affiliated tribes. The goal is to understand key sites,

characteristics, and species of significance in the tidewater lifestyles. It was also recognized that there may be ancestral ties in local African American families to the plantation culture of the Washington family farming practice who should be engaged in discussions on access, value, and use of the park. In addition, many underserved groups actively use the site for recreation – for picnicking and fishing in particular. Their use and ascribed value of the site will need to be understood and valued for future management planning.

Relationship of Vulnerability to Adaptive Capacity

Comparing the vulnerability of cultural resources to adaptive capacity provides additional insights into the areas of concern and how they could be linked to other resources when considering actions (Figure 5).

The *Serious but Actionable* cultural resources include the following:

- Archeological Sites:
 - Over time with erosion and SLR, archeological sites become more vulnerable, however only the most vulnerable sites attract interest and investment. Inland sites have lower adaptive capacity than coastal sites. Despite having more time to learn approaches and trial on the coastal sites, there is less interest and attention paid to the inland sites, and the emergency funding cycle won't benefit these inland sites on a 50-year timeframe. The coastal sites have an urgent need for intervention - Archeological sites are falling off the bluff, but with time, more sites will require attention.
 - Our understanding of adaptation options for archeological sites includes mitigation (constructing retaining walls) or excavation.
 - Appropriate mitigation actions for the coastal archeological sites will be determined following planned tribal consultations.
- Nature Trail:
 - Planning needs to begin to either relocate or reinforce the Nature Trail.

All other cultural resources should be monitored for change and hold adaptation potential:

- Memorial House Museum:
 - Moderately vulnerable because of collections held in facility with the current HVAC system. If the HVAC system were replaced, the vulnerability could be reduced to low.
- Cedar Trees:
 - Hold high-level discussions about the priorities of the Cedar Grove (archeological sites protected, buffer services provided to historic core)
 - While individual elements of the cultural landscape, including cedar groves, are not highly vulnerable the cumulative effect on cultural landscape could be substantial and should be monitored and planned for.
- Ice Pond Dam:

- Critical role played by Ice Pond Dam. Need for studies and infrastructure investments (implications of failure are huge – would shut down the park)

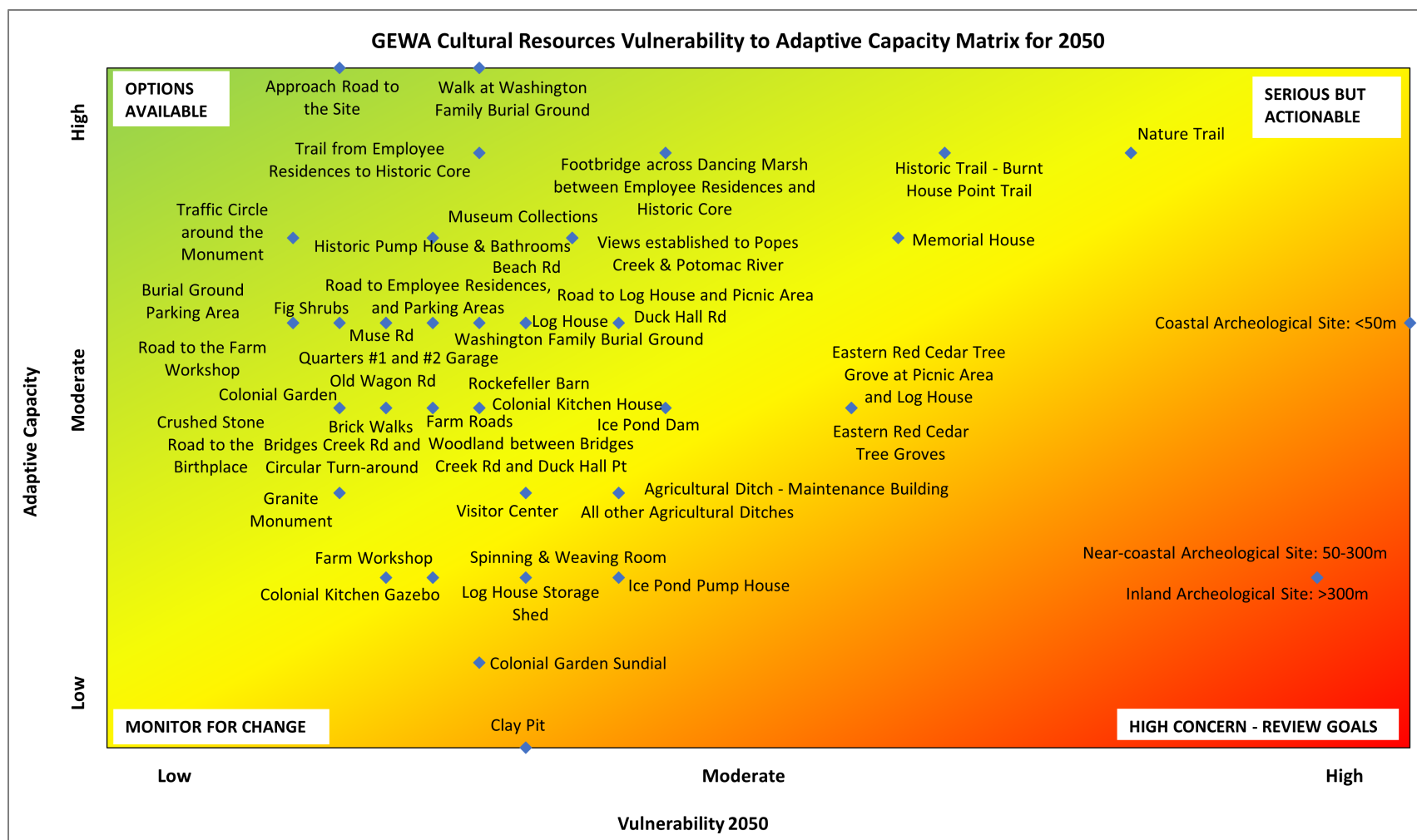


Figure 5 Comparison of vulnerability to adaptive capacity for cultural resources at George Washington Birthplace National Monument in 2050.

Recommendations

The Cultural Resources Workgroup observed that sites are already being lost to erosion and climate change factors. As such, the workgroup's overall recommendation is that adaptation actions need to be implemented alongside ongoing planning processes. Recommendations from the workgroup at the conclusion of this process fall into two categories: planning and action. The following planning recommendations focus on documentation of existing resources and applying for funding:

- Vulnerability and adaptive capacity information from this study need to inform planning and funding moving forward. An integrated approach should be strongly considered for prioritizing action and identifying options, based on the experience of George Washington Birthplace NM during this process.
- Manage the climate impacts in a proactive way by defining goals and strategies that include climate change education in multiple languages appropriate for the current visitors to the park.
- Be proactive in planning efforts and have plans in place for cultural resources before resources in bluffs are lost to erosion and creek dynamics change.
- Prioritize tribal consultations on ethnographic resource priorities and appropriate treatment of resources in planning adaptive measures.

The following action-oriented recommendations focus on developing collaborative plans with partner organizations:

- Document what will be lost and recover and archive limited artifacts as museum space and budgets allow, potentially offsite.
- Interpret the alterations that climate change causes on the park, as well as the management actions taken in the face of these changes. Recognize that the coastal changes are part of the cultural landscape processes that define the tidewater lifestyle at the core of the park's goals.

Continue to prioritize appropriate routine maintenance to minimize deterioration and maintain resistance to weather. Consider enhanced maintenance – such as mold and decay-resistant treatments – as an adaptation method.

Natural Resources

Key Messages

- Several shoreline natural resources are already highly vulnerable. Those natural resources that are projected to increase in vulnerability are all projected to do so by mid-century, with no further change between the 2050 and 2100 time frames.
- None of the natural resources have high adaptive capacity. The workgroup made this determination on account of the comparatively lower significance of natural resources to the park's purpose, and hence the unlikelihood of attracting additional focused funding to protect these resources.

- The connections in the sediment system between the Beaches, Bluffs, Freshwater Ponds, and Tidal Wetlands are complex, and additional research is necessary to understand the potential for threshold changes that can affect other resources. The potential for threshold changes, such as the loss of the spit or a breach that changes a freshwater pond to brackish in a storm event was of particular concern and the likelihood of such events is beyond currently available projections.

Vulnerability

The natural resources that were assessed were a combination of habitats, species, and other features such as water quality (Table 5). Habitats were chosen based on those in the vegetation classification and mapping report (Patterson 2008), informed by the Natural Resource Condition Assessment (Nelson et al. 2012), and simplified based on workgroup discussion. Vegetation classes were combined into a smaller number of habitat categories. Those resources where geospatial data is available are mapped in Figure 6.

Table 5. Summary of natural resources examined in the vulnerability assessment for George Washington Birthplace National Monument.

Natural Feature	Summary Characteristics *
Bats	At-risk bat species that may roost at the park but lacking a park inventory. Includes federally listed northern-long eared bat and state-endangered tricolored bat (and federally proposed), and little brown bat.
Beaches	Beaches are sand based habitats along shorelines, perhaps with some shrubby vegetation. There are two areas of beach in the park, the recreational beach east of the mouth of Bridge's Creek and the spit at the mouth of Pope's Creek.
Birds	Inventory of bird species show wide diversity, both those that breed here and others that use the park during other life stages. Bald eagles are included, which merit special protection status.
Bluffs	The steep shoreline slope along the banks of the Potomac River and Popes Creek are geologic features that result from a complex system of geomorphic and hydrological processes that are constantly changing. The high bluffs are composed of Miocene-aged shallow marine deposits from the Calvert Formation beneath younger Quaternary sediments.
Coastal Plain Dry Calcareous Forest	Globally rare natural community found only in scattered locations in Virginia and Maryland known from steep, usually south-facing, erosive ravine slopes that have cut down into deposits of shells and limesands. <i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> / <i>Dichanthelium boscii</i> – <i>Bromus pubescens</i> – <i>Erigeron pulchellus</i> var. <i>pulchellus</i> – <i>Aquilegia canadensis</i> .
Cultural Meadow	Open fields and grasslands, some of which were created by past agricultural forest clearing. Hay fields and pasture areas are maintained as part of the cultural landscape.
Freshwater Ponds	Two of the freshwater ponds that are subject to episodic breaching with concern that could convert to brackish.
Herps	Reptiles and amphibians: based on 2002 inventory documented 8 frog species, 4 salamander species, 7 turtle species, 3 lizard species, and 6 snake species (Mitchell 2008).

* Summary Characteristics are primarily from Patterson (2008).

Table 5 (continued). Summary of natural resources examined in the vulnerability assessment for George Washington Birthplace National Monument.

Natural Feature	Summary Characteristics *
Insect Pollinators	Insects that help carry pollen from the male part of the flower (stamen) to the female part of the same or another flower (stigma).
Non-globally Rare Forest	Combined remainder of forest types including: Loblolly Pine – Hardwood Forest, Loblolly Pine Plantation / Early-Successional Loblolly Pine Forest, Disturbed Acidic Slope Forest, Disturbed Calcareous Forest, Successional Black Locust Forest, Successional Red-cedar Forest, Successional Sweetgum Forest.
Non-riverine Saturated Forest	Globally rare forest community restricted to extensive, flat terraces and very wide, ancient floodplains that are no longer subject to alluvial processes. <i>Quercus (phellos, pagoda, michauxii) / Ilex opaca</i> var. <i>opaca</i> / <i>Clethra alnifolia</i> / <i>Woodwardia areolata</i> .
Paleontological Resources	The Calvert Formation, which consists of silty sand deposits along the park's shoreline, consists of abundant shallow marine fossils dating between 22 and 14 million years old during the early and middle Miocene.
Tidal Wetlands	Wetlands along Bridges Creek, Longwood Swamp, Digwood Swamp, Duck Hall Point, Pope's Creek, and Dancing Marsh, and including vegetation classes of Tidal Oligohaline Marsh, Tidal Mesohaline and Polyhaline Marsh (low salt marsh), and Tidal Shrub Swamp (Iva type).
Vernal Pools	Seasonal depressional wetlands.
Water Quality	Water quality in Popes Creek (monitored through Northeast Coastal and Barrier Network) and Potomac River. Note that George Washington Birthplace National Monument does not own or have authority over these waters, but that water quality affects park resources.

* Summary Characteristics are primarily from Patterson (2008).

Each resource was assessed based on exposure to eight climate change related stressors: SLR, severe storms/surge, erosion, flooding (freshwater), temperature change, precipitation change, invasive species, and fire. Note bats and insect pollinators have non-climate stressors that are not accounted for in this climate change assessment. Vulnerability was based on the workgroup's scores (scoring of minimal, low, moderate, high) of exposure and sensitivity of the resource to each climate stressor. The vulnerability to each stressor was then combined for the total score. Each stressor was treated equally and not weighted differently, with the exception of a method change from Ricci et al. (2019a) to follow Facilities' Workgroup to use an auto-high option. The auto-high option, where if a specific exposure stressor would have an overwhelming influence on the overall vulnerability for a resource, then if it is high for that stressor, it is automatically raised to high vulnerability overall, was used for severe storms/surge. The combined vulnerability across all stressors then determined a resource's score (minimal, low, moderate, high) for each time frame. The exposure, sensitivity, and vulnerability scores by each stressor for each time frame including notes on sensitivity indicators have been provided to the park in a spreadsheet. A version of this spreadsheet will be posted to the IRMA portal accompanying this report.

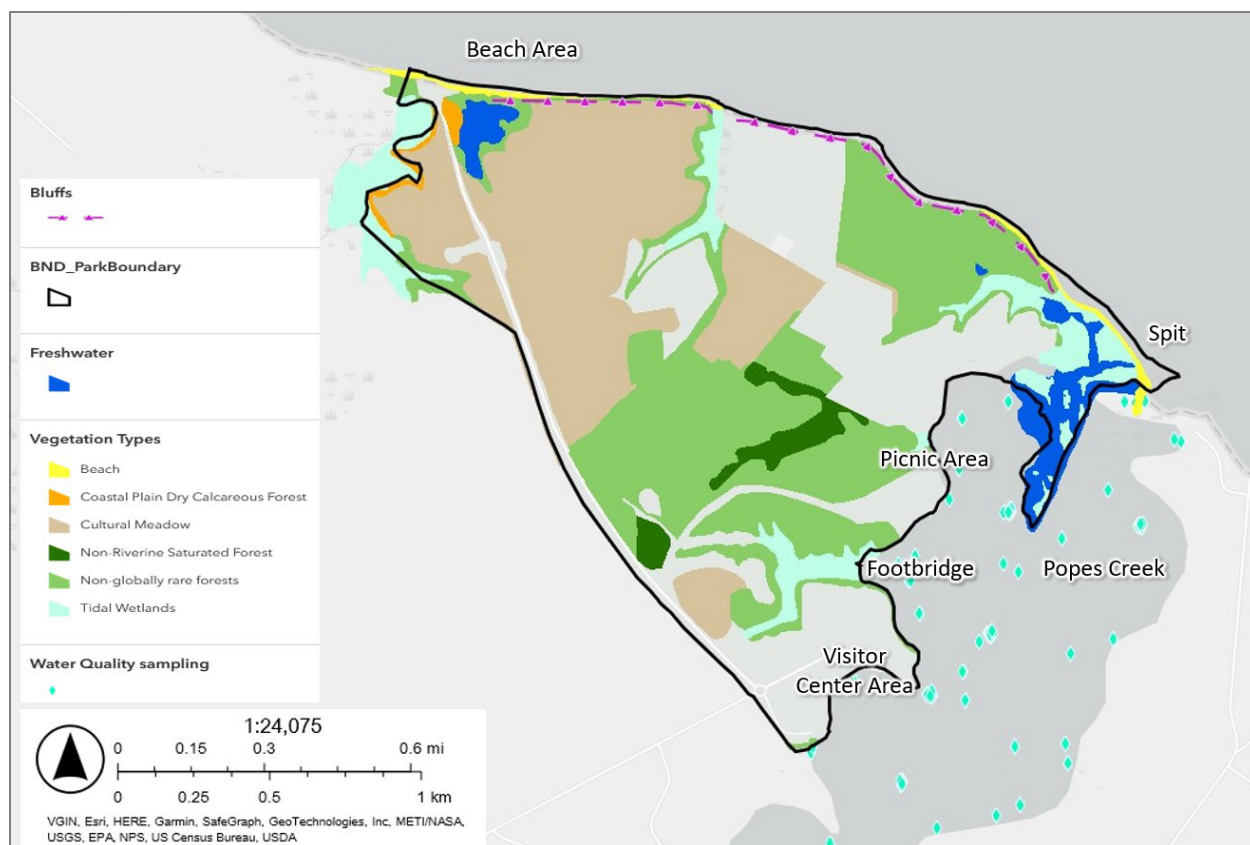


Figure 6. Land cover features of George Washington Birthplace National Monument from Nelson et al. (2012), generalized by habitat types.

The SLR and storm surge analysis was simplified to represent SLR as a change in contour level of the shore. It did not incorporate dynamic geomorphology nor the increased impact of storm surge as sea level rises. The discussions did include historic bluff erosion rates and factors affecting how that may change in the future, as well as the uncertainty in how the beaches, and the spit in particular, will respond. Since this framework sensitivity is simplified to not change over time, for resources that are expected to have changing sensitivity to future exposure, the guidance was to score based on the 2100 time frame.

There was a mix between high, moderate, and low vulnerability of natural resources in 2022, but more resources were high and moderate vulnerability than low. Several resources increase in vulnerability by 2050, but there weren't additional increases by 2100 (Table 6). Everything that was highly exposed was high by 2050, so there is no room to go higher. Figure 7 shows a map of natural resources vulnerability for those resources with geospatial data, with the top panel for 2022 and the bottom panel 2050 and 2100 (no difference between the time frames). Many of the species' scores are closely dependent on their habitats, e.g., insect pollinators are dependent on cultural meadow habitat.

The high vulnerability resources identified were the beach, tidal wetlands, bluffs, paleontological resources, freshwater ponds, and herps (reptiles and amphibians). These were all high in 2022, and

most were categorized via the auto-high method due to storm surge exposure and high sensitivity to that. Note that tidal wetlands vary spatially and by wetland type, but they were assessed as auto-high based on potential for loss if the spit at the mouth of Pope’s Creek was lost. By 2050, the moderately vulnerable Coastal Plain Dry Calcareous Forest and the combined non-globally rare forest become highly vulnerable. The Non-riverine Saturated Forest which was low vulnerability in 2022 increased to moderate by 2050 and remains so through 2100. Birds similarly increase from low to moderate vulnerability by 2050.

Table 6. Natural resources vulnerability scores by time frame at George Washington Birthplace National Monument.

Resource	2022	2050	2100
Bats	Moderate	Moderate	Moderate
Beaches	High	High	High
Birds	Low	Moderate	Moderate
Bluffs	High	High	High
Coastal Plain Dry Calcareous Forest	Moderate	High	High
Cultural Meadow	Moderate	Moderate	Moderate
Freshwater Ponds	High	High	High
Herps	High	High	High
Insect Pollinators	Moderate	Moderate	Moderate
Non-globally Rare Forest	Moderate	High	High
Non-riverine Saturated Forest	Low	Moderate	Moderate
Paleontological Resources	High	High	High
Tidal Wetlands	High	High	High
Vernal Pools	Moderate	Moderate	Moderate
Water Quality	Low	Low	Low

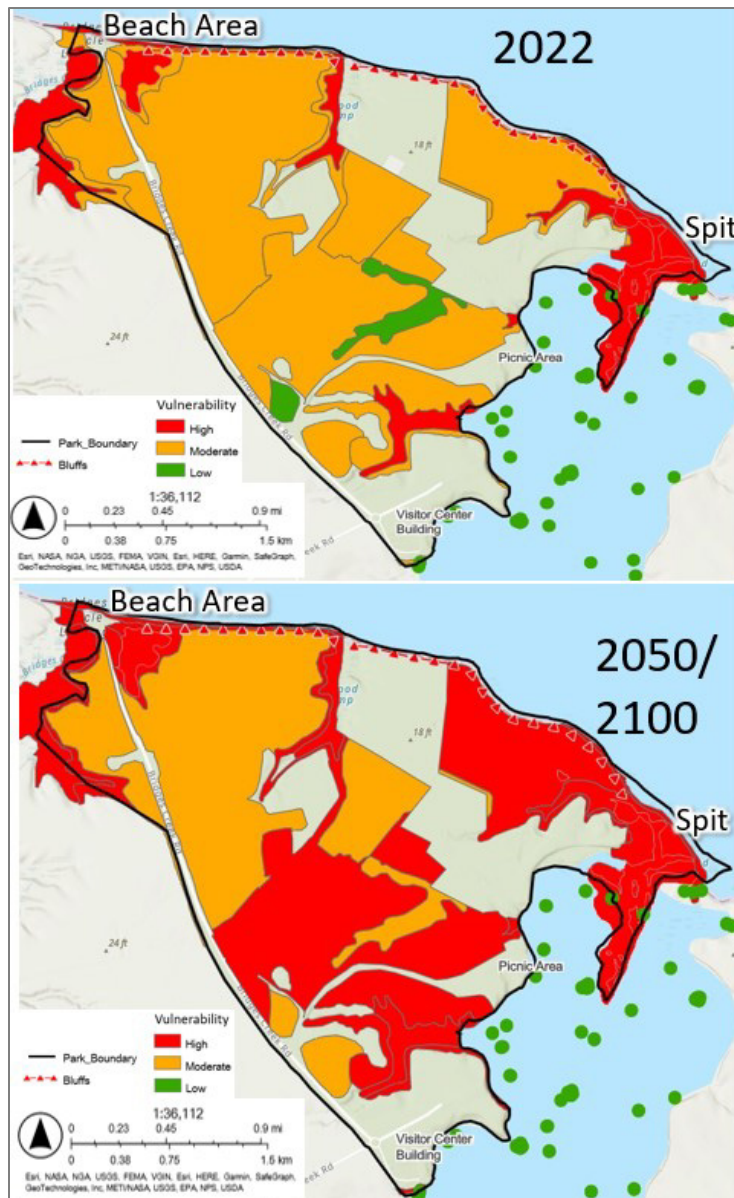


Figure 7. Vulnerability of natural resources in 2022 (top), 2050, and 2100 (bottom) at George Washington Birthplace National Monument. Water quality is mapped for locations of sampling stations but was considered parkwide. Note that there were no changes between 2050 and 2100 so the map is the same for these time frames.

Adaptive Capacity

None of the natural resources were scored as high adaptive capacity, with 2/3 of the resources scored as moderate adaptive capacity and 1/3 as low. The workgroup discussed if the method should be adjusted, such as where the binning intervals were set, to have a spread between high, moderate, and low, but determined that parkwide, relative to cultural resources and facilities, consistency was more important than a full range of scores, and that this result was representative of relative adaptive capacity. Given the park's historical purpose, many of the natural resources do not score highly for Social and Organizational components of adaptive capacity, and the couple that do have low Physical

or Economic components. Many resources that have high significance, such as Bluffs and Paleontological Resources have few available, effective adaptation options other than monitor and document loss. Natural resources differ from most other resources in adaptive capacity by having potential intrinsic ability to adapt, such as Beach which scored high for this component. Within the Physical category of the POSE framework, intrinsic adaptive capacity was captured separately from the physical-technology component under the physical category in case it was to be handled separately in future analyses, though we did not separate it to be consistent with previous methods (Ricci et al. 2019a). For several resources, this intrinsic component was moderate, and was matched by either moderate (Tidal Wetlands, Bats, Birds) or high (Cultural Meadow, Non-globally Rare Forest, Insect Pollinators) Physical-technology component.

Table 7 shows adaptive capacity scores for natural resources. Following the group discussion of whether some cultural resources have intrinsic adaptive capacity, the Natural Resources Workgroup discussed whether some of the natural resources do not. Those that they determined it was not a meaningful category were marked as not applicable.

Table 7. Adaptive capacity scores for natural resources at George Washington Birthplace National Monument.

Resource	Physical-Intrinsic	Physical-Technology	Organizational	Social	Economic	Adaptive Capacity
Bats	Moderate	Moderate	Moderate	Low	Low	Moderate
Beaches	High	Moderate	Low	High	Moderate	Moderate
Birds	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Bluffs	n/a *	Low	Low	Low	Low	Low
Coastal Plain Dry Calcareous Forest	Low	Low	Low	Low	Low	Low
Cultural Meadow	Moderate	High	Moderate	Moderate	Moderate	Moderate
Freshwater Ponds	n/a	Moderate	Low	Low	Moderate	Moderate
Herps	Low	Moderate	Low	Low	Low	Low
Insect Pollinators	Moderate	High	Moderate	Moderate	Moderate	Moderate
Non-globally Rare Forest	Moderate	High	Moderate	Low	Moderate	Moderate
Non-Riverine Saturated Forest	Low	Low	Low	Low	Low	Low
Paleontological Resources	n/a	Low	Moderate	High	Moderate	Moderate
Tidal Wetlands	Moderate	Moderate	Low	Moderate	Low	Moderate
Vernal Pools	n/a	Moderate	Moderate	Low	Moderate	Moderate
Water Quality	n/a	High	Low	High	Low	Moderate

*n/a is not applicable.

Relationship of Vulnerability to Adaptive Capacity

The natural resources vulnerability versus adaptive capacity matrix (Figure 8) shows a cluster of resources that fall in the High Concern-Review Goals (high vulnerability and low to moderate adaptive capacity) quadrant. For Coastal Plain Dry Calcareous Forest and Bluffs, effective adaptation strategies are not available. For Tidal Wetlands, there are available strategies, but they are expensive, and they lack both funding options and strong organizational support. For Freshwater Ponds, they may be reliant on decisions made for Beaches. The resources that fall in the Monitor for Change (low to moderate vulnerability and low to moderate adaptive capacity) quadrant include Bats, Vernal Pools, and Non-riverine Saturated Forests. The lack of baseline inventory for Bats and Vernal Pools is a challenge yet is key for the Monitor for Change quadrant. For Bats, discussion raised whether the park could rely on the annual monitoring at the Navy base, but subsequent explanation indicated that would not be a reasonable proxy given the distance and the potential for maternity colonies. Getting baseline data for Vernal Pools of water levels and dissolved oxygen could be relatively straightforward and inexpensive.

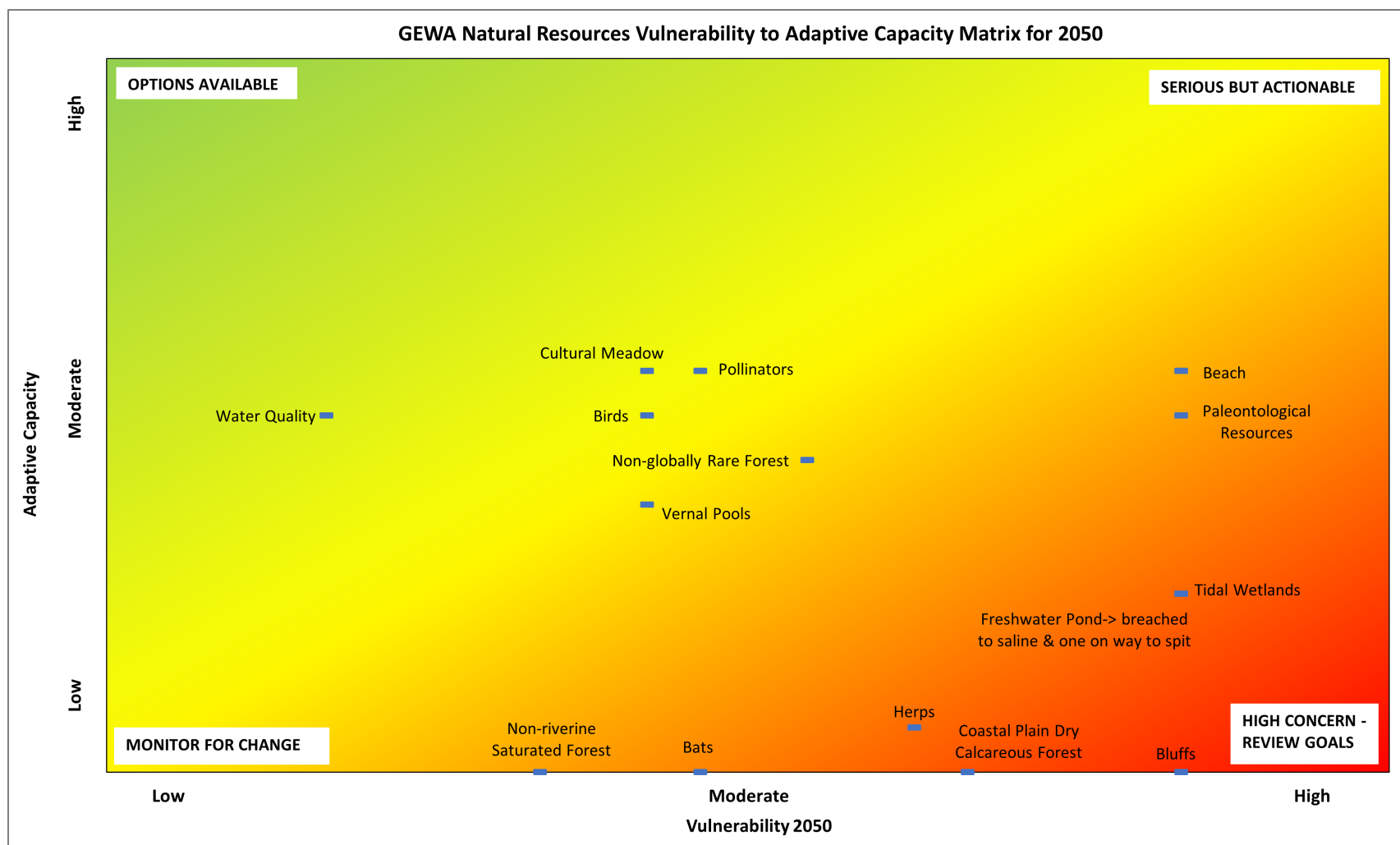


Figure 8. Comparison of vulnerability to adaptive capacity for natural resources at George Washington Birthplace National Monument by 2050.

Without any natural resources with high adaptive capacity, none fall clearly in the Options Available quadrant (low to moderate vulnerability and moderate to high adaptive capacity) or Serious But Actionable quadrants, but there are a few that are borderline with moderate adaptive capacity. Water Quality, Cultural Meadow, Birds and Pollinators could be considered Options Available. The options for Water Quality are limited because the bodies of water are not owned by the park, thus we are reliant on partnering, though there are a variety of partners throughout the Chesapeake Bay working to improve water quality and with an understanding of the challenges climate change brings. Combined options for Cultural Meadow, Birds and Pollinators could be developed in conjunction with the cultural landscape treatment. Paleontological Resources and Beach could be considered Serious but Actionable; they are the resources most actively monitored. The strategies currently used for monitoring and documenting Paleontological Resources are likely to be continued and could be strengthened as connections with archeological sites monitoring and documentation strategies. The Beach may rise as a priority more for its recreational value than as a natural resource, and that may affect whether its naturally functioning processes are included in adaptation strategies. Birds, Non-globally Rare Forests, and Vernal Pools are not expected to be park priorities for active adaptation actions, but better baseline data or monitoring could position them to be part of larger regional efforts.

Recommendations

- Continue monitoring beach, bluffs and associated resources according to protocols. Implement paleo monitoring plan. Northeast Coastal and Barrier Inventory & Monitoring Network (NCBN) will continue beach and bluff monitoring but protocol is at neap tide so they can no longer access a large portion of the paleo resources simultaneously as intended. With SLR, there is a need to monitor on low tide during the lower parts of the tidal cycle during a spring tide in order for the exposed paleontological resources to be above the water line. A challenge of paleontological monitoring is that visits are planned well in advance but then access can be limited due to temporary surge/higher water levels surrounding storms. Explore options for volunteer, student, or intern monitoring programs that could be more responsive to local weather and water level conditions.
- A baseline bat inventory is needed, with an acoustic survey as a minimum. Any adaptation actions for the forests need to show that federally listed species are not using those habitats. It would have the added benefit for knowing if bats are using any structures ahead of any work on them.
- Baseline studies of birds, pollinators, herps, and vernal pools might be suited to a Scientists in Parks intern or student thesis. While separate specialties, scope could be manageable for one intern for multiple categories if suitable mentorship available.
- To better understand the two rare forest types, a Focused Condition Assessment might be a suitable funding source. An update to the vegetation inventory requires new data, so the Inventories program could be a better funding source. While this could potentially combine all forests, the priority should be on the Coastal Plain Dry Calcareous Forest and the Non-riverine Saturated Forest.

- Beware of unintended consequences, such as hardscapes, that can be detrimental to shoreline or favoring tidal wetlands over freshwater wetlands.

Facilities

Key Messages

- Facilities (consisting of building and transportation assets) in George Washington Birthplace NM play a critical role in protecting and providing public access to the valued cultural and natural resources at the park. Most of the buildings have low vulnerability (88%) to climate change due to the topography of the park on a bluff over the Potomac River. Transportation assets located closer to the shoreline or in low lying areas are more vulnerable. Over 65% of transportation assets were moderate or high vulnerability. These assets have a combined current replacement value over \$9M (from the NPS Facilities Management Software System (FMSS) database).
- Of the 57 facility assets assessed, only the Beach Parking Lot saw a shift in vulnerability scores over the three time frames of the assessment – shifting from moderate to high vulnerability by 2050. Most of the historic buildings have low vulnerability, including those in the Memorial Core, due to their location at a higher elevation and sufficiently far from large trees. The Visitor Center, Ice Pond House, and Log House were the only buildings with moderate vulnerability. All the facility assets have moderate to high adaptive capacity due to the qualities of these assets, though action is contingent upon timely funding and decisions on long-term strategies to provide safe access to the park.
- Areas of concern for facilities include the Ice Pond Dam which is vulnerable to flash flooding and serves as a weak link for critical systems of communications, electricity, and access. The Visitor Center’s basement, which houses its mechanical systems, is vulnerable to flooding. Transportation assets like roads and trails are vulnerable to flooding and erosion along the shoreline. This vulnerability is most pronounced in the Beach Parking Lot and on sections of the Nature and Historic Trails along the shoreline. Adaptation options are viable for resolving many of these key vulnerabilities while maintaining cultural, natural and visitor use values.

Vulnerability

To assess vulnerability of facility assets, the following indicators were used based on the SOP/WCU protocol (NPS 2016; Peek et al. 2022; Peek et al. 2023).

Exposure Indicators:

- Flooding potential
- Extreme Event Flooding
- SLR Inundation
- Shoreline Change
- Reported Coastal Hazards
- Wind

Sensitivity Indicators:

- Flood Damage Potential (Elevated)
- Storm Resistance and Condition
- Historical Damage
- Protective Engineering
- Additional Sensitivity Indicators for Bridges (From National Bridge Inventory)
 - Bridge Clearance
 - Scour Rating
 - Bridge Condition
 - Bridge Age

Most facility assets have minimal to low exposure to climate change (86%). The Beach Parking area was the only asset to increase in exposure (from moderate to high by 2050). There were no changes in exposure between 2050 and 2100. The Nature Trail, Spit Road (only the segment at the end close to the water), and the Footbridge scored high exposure. The following were scored moderate exposure – Visitor Center and Access Road, Beach Parking, Ice Pond Dam and Culverts, and the Historic Trail. All other assets were low exposure with six of the roads not being exposed and receiving a rank of minimal. Following the SOP/WCU protocol, this assessment categorizes those assets that did not score exposed for any of the exposure indicators as minimal.

The majority of assets scored zero for all sensitivity factors and received a rank of minimal sensitivity (38 out of 57 or 66%) (Table 8). The Memorial House Museum was the only asset to score low sensitivity. The Ice Pond Pump House was the only building asset to score high sensitivity. The Log House and Visitor Center were moderate sensitivity. Transportation assets were more sensitive. The Beach Road and Parking Lot, Picnic Area Access Road, Ice Pond Dam, Historic and Nature Trails, Footbridge, and Ice Pond Culverts were some of the high sensitivity assets. Transportation assets that were minimal or low sensitivity were all located at higher elevation and away from flood prone areas.

Table 8. Facility assets' sensitivity results summary at George Washington Birthplace National Monument. Sum of percentages may not be equal to 100 due to rounding.

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Minimal Sensitivity	
	#	%	#	%	#	%	#	%
Structures	1	3%	3	9%	1	3%	29	85%
Transportation	12	52%	2	8%	0	0%	9	39%
All Facility Assets	13	23%	5	9%	1	2%	38	66%

Combining the exposure and sensitivity scores for each of the three time frames, George Washington Birthplace NM has a majority of facility assets scored as minimal or low vulnerability – 68% by 2050 (Table 9). Almost all of the building assets have low vulnerability (88%). Similarly, to the exposure analysis, almost all of the facility assets near the shoreline are moderate or highly vulnerable. The exposure, sensitivity, and vulnerability scores for each asset by each stressor for each time frame have been provided to the park in a spreadsheet that a version of which will be posted to the IRMA portal accompanying this report, as well as one provided to the park based on the SOP/WCU protocol (Peek et al. 2023) for 2050, in the NPS Coastal Vulnerability Data Viewer (internal to NPS).

Table 9. Facility assets vulnerability results summary for 2050 at George Washington Birthplace National Monument.

Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total # Analyzed
	#	%	#	%	#	%	#	%	
Structures	0	0%	4	12%	30	88%	0	0%	34
Transportation	8	35%	6	26%	8	35%	1	4%	23
All Facility Assets	8	14%	10	18%	38	66%	1	2%	57

The distribution of vulnerability for facility assets can be seen in Figure 9. Segments of roads and trails that go close to the shoreline have moderate or high vulnerability. Those near the higher elevated Memorial Core are low vulnerability for the most part except for a few roads.

The combined current replacement values (from the NPS FMSS database) for assets that are highly or moderately vulnerable by 2050 is over \$9M. Most of this value is in the assets in proximity to the shoreline due to low elevation and exposure to flooding and erosion. The highest value transportation assets that are highly vulnerable include beach and visitor center access roads, Ice Pond Dam, Historic Trail, and the footbridge. The Visitor Center and Log House Conference Center are the two highest value buildings in moderate vulnerability.

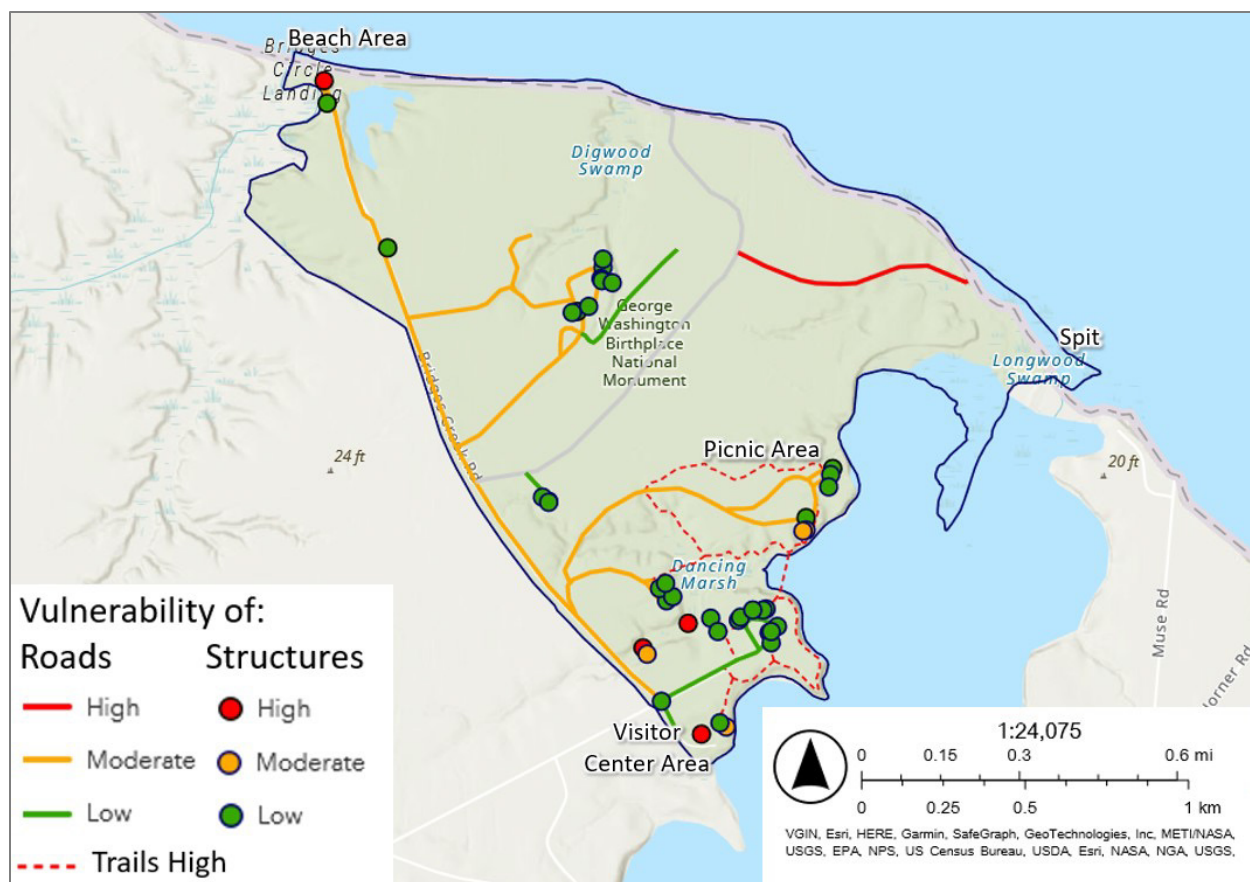


Figure 9. Vulnerability of facilities by 2050 based on climate projections at George Washington Birthplace National Monument.

Adaptive Capacity

All the assets were assessed for adaptive capacity. In general, a great majority (79%) of the assets exposed to climate stressors have moderate adaptive capacity to reduce vulnerability (Table 10). The remainder of assets have high adaptive capacity. Most of the facility assets have a realistic protection or adaptation option for the climate scenarios projected in this assessment. This is due to a combination of high physical (able to build or move assets), organizational (NPS ownership of the assets), and social (the importance of these assets to meeting cultural and natural resource mandates) capacities. A few low scores for adaptive capacity arose in relation to economic factors and or social conflicts such as over what to do about the limited beach parking. Otherwise, social and organizational capacities seemed to be moderate or high for addressing most issues. This can be seen in relation to the vulnerability of the visitor center and Ice Pond Dam flooding issues. These are critical assets at the park and therefore likely to get the support and resources required to adapt.

Table 10. Facility assets adaptive capacity results summary at George Washington Birthplace National Monument. Sum of percentages may not be equal to 100 due to rounding.

Assets	High Adaptive Capacity		Moderate Adaptive Capacity		Low Adaptive Capacity		Total # Analyzed
	#	%	#	%	#	%	
Structures	11	32%	23	68%	0	0%	34
Transportation	1	4%	22	96%	0	0%	23
All Facility Assets	12	21%	45	79%	0	0%	57

In general, the economic adaptive capacity was scored low for a few items where the roads were going to be abandoned closest to the water or ancillary assets not central to the parks mandate would struggle to find funding such as the fueling station and collection storage facility. On the economic component of adaptive capacity, it is unclear as to whether the NPS will be able to raise the funding over the coming decades for incremental maintenance and adaptation when other coastal areas are facing similar challenges. This larger regional and national perspective was not used to score adaptive capacity but certainly will be a factor. Additionally, this assessment did not do a thorough review and analysis of assets' respective criticality or cost estimates, nor revised management goals and objectives should there be any considering climate assessments. Details of the adaptive capacity scores for facility assets are included in a spreadsheet that has been provided to the park, a version of which will be posted to the IRMA portal accompanying this report.

Relationship of Vulnerability to Adaptive Capacity

Looking at the vulnerability and adaptive capacity in combination provides another perspective on some of the key facility issues at George Washington Birthplace NM. The assets located in the Memorial Core except for the Historic and Nature Trails are all within the quadrants of monitor for change or options available (Figure 10). The log house assets are slightly more vulnerable due to their proximity to a rapidly eroding shoreline and large trees. Next the Ice Pond complex with the associated dam, culverts, pump house and critical systems that run through the area are all in the serious but actionable quadrant. There is straightforward engineering work that can be done to address cultural and critical systems priorities.

The matrix highlights the vulnerability and limited adaptive capacity for the trails in the park and some of the natural road segments that end near the shoreline. The park can do a controlled retreat with respect to the vulnerable roads over time and is not a major concern. That is not the case with the trails where they are a major visitor resource and have limited low-cost options along the eroding shoreline.

The Beach Parking Lot and Road which have been mentioned several times in this report are the most challenging facility assets in the matrix. This quadrant encourages the park to review their management goals and objectives in light of the climate assessment to determine the most advantageous adaptation options moving forward.

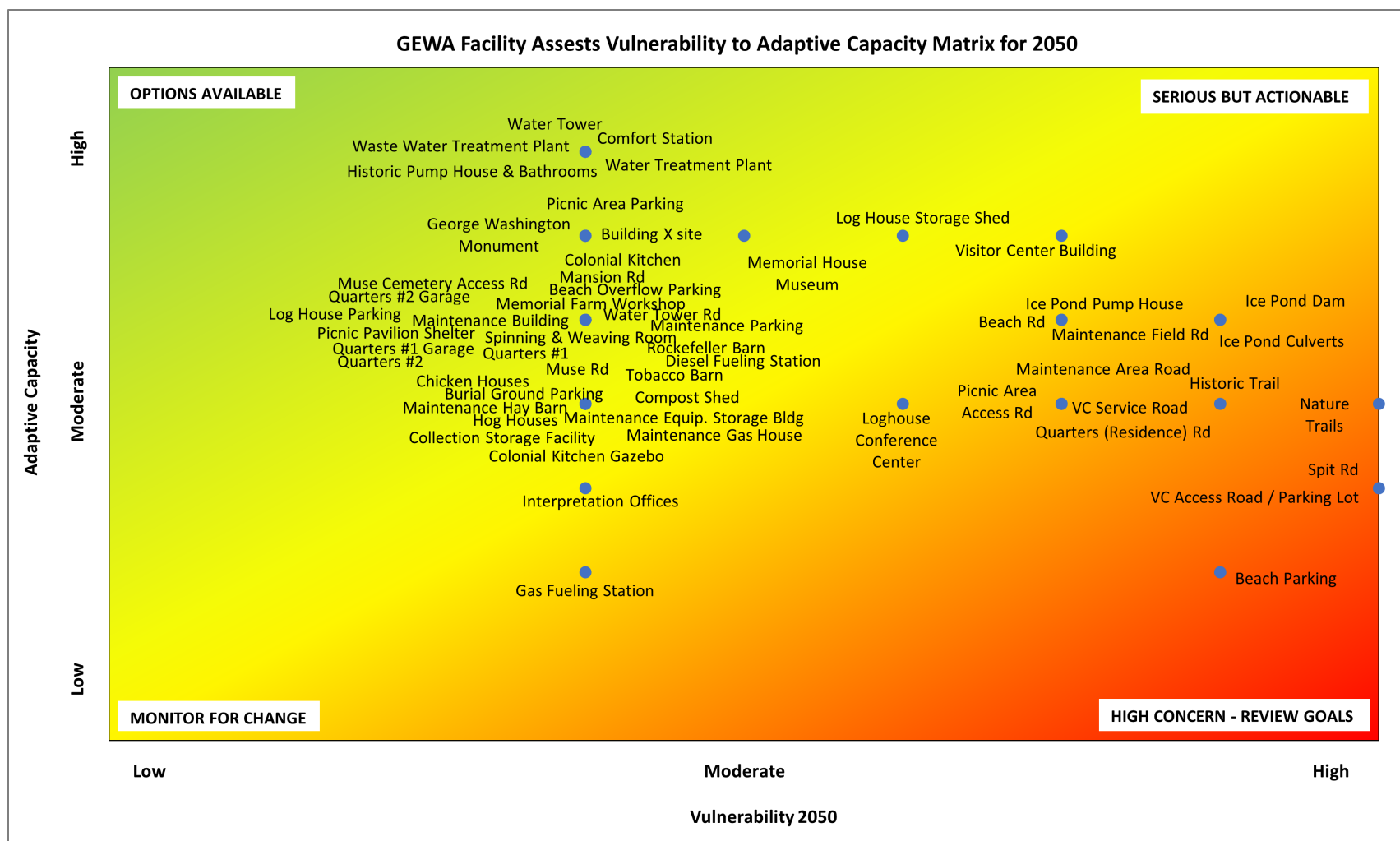


Figure 10. Comparison of vulnerability to adaptive capacity for facility assets by 2050 at George Washington Birthplace National Monument.

Recommendations

- Take highly vulnerable assets through a resiliency/adaptation pre-planning exercise to incorporate criticality and systems. Specifically include the Ice Pond Dam, Beach Parking, and Popes Creek erosion.
- Collect data needed by management on key issues such as:
 - Erosion of shoreline in Popes Creek.
 - Visitor use data on beach parking.
 - Study visitor circulation around the park on trails and shoreline- such as popular spots, routes, and amenities.
 - Parking lot strategies for the beach and Visitor Center.
- Coordination between other parts of the George Washington Birthplace NM staff and local governments e.g.:
 - Integrate the vulnerability assessment results into larger park wide planning and revised goal setting.
 - Coordinate with Local Government on the main access road to George Washington Birthplace NM for assessing condition and maintenance plans.
 - Coordinate with State and local government on shoreline plans, dynamic modeling and facility upgrades.
 - Incorporate vulnerability results into the George Washington Birthplace NM Interpretation Plans and Activities – focus on facilities construction and adaptations.
- Seek win-win situations to increase the odds of action and success. This could include the Ice Pond Dam complex to meet the cultural values, visitor access to the beach area, and critical systems including assessing adaptations for the ranger station.
- Explore potential tradeoffs such as maintaining shoreline trails versus shoreline hardening, beach parking retreat plans, and removing trees near structures versus maintaining cultural landscapes.
- Assess alternatives for protecting critical systems such as utilities and communications in vulnerable areas such as the visitor center and Log House basements. Also explore improved storm water management around structures or adding gutters to the Memorial House Museum.

Integration of Scoring across Program Areas

This assessment focused on the integration across three major program areas – cultural resources, natural resources and facilities. Integration was achieved using a variety of techniques. First, the three workgroups shared their analysis and scoring throughout the process so they could understand how each workgroup assessed the exposure and sensitivity of the resources. Second, interactive workshop sessions for each focal area allowed the group to go deeper in the analysis of how exposure and sensitivity will play out and interact with other associated resources for a place. Finally, as the workgroups scored their respective resources, they noted those which overlapped with another

workgroup due to shared responsibility or direct dependence. The Focal Areas sections that follow highlight how integration occurred for the top two focal areas of shared interest amongst the three workgroups.

Focal Areas for Integration

The three workgroups compared their vulnerability analysis results to identify focal areas for integration that would benefit from coordinated planning and action. The focal areas chosen for integrated discussion were the Shoreline, which includes the Picnic Area, and the Memorial Core (Figure 11). The Picnic Area was initially considered as a third focal area because of the high visitation by local communities and resulting recreational value. These focal areas share a common feature of containing priority resources related to the mandate of the park. By being identified in the enabling legislation, these cultural and natural resources receive the highest priority for preservation and protection. Additionally, the current use patterns show a priority to provide recreational use for the local communities that enjoy the Beach and Picnic Areas. However, they differ in how climate change impacts will play out over time and the options available for management responses. By acting together, the program areas see opportunities for reducing vulnerability and/or redefining management objectives to provide clarity for joint action and combine resources to increase the likelihood of timely, efficient, and effective action.

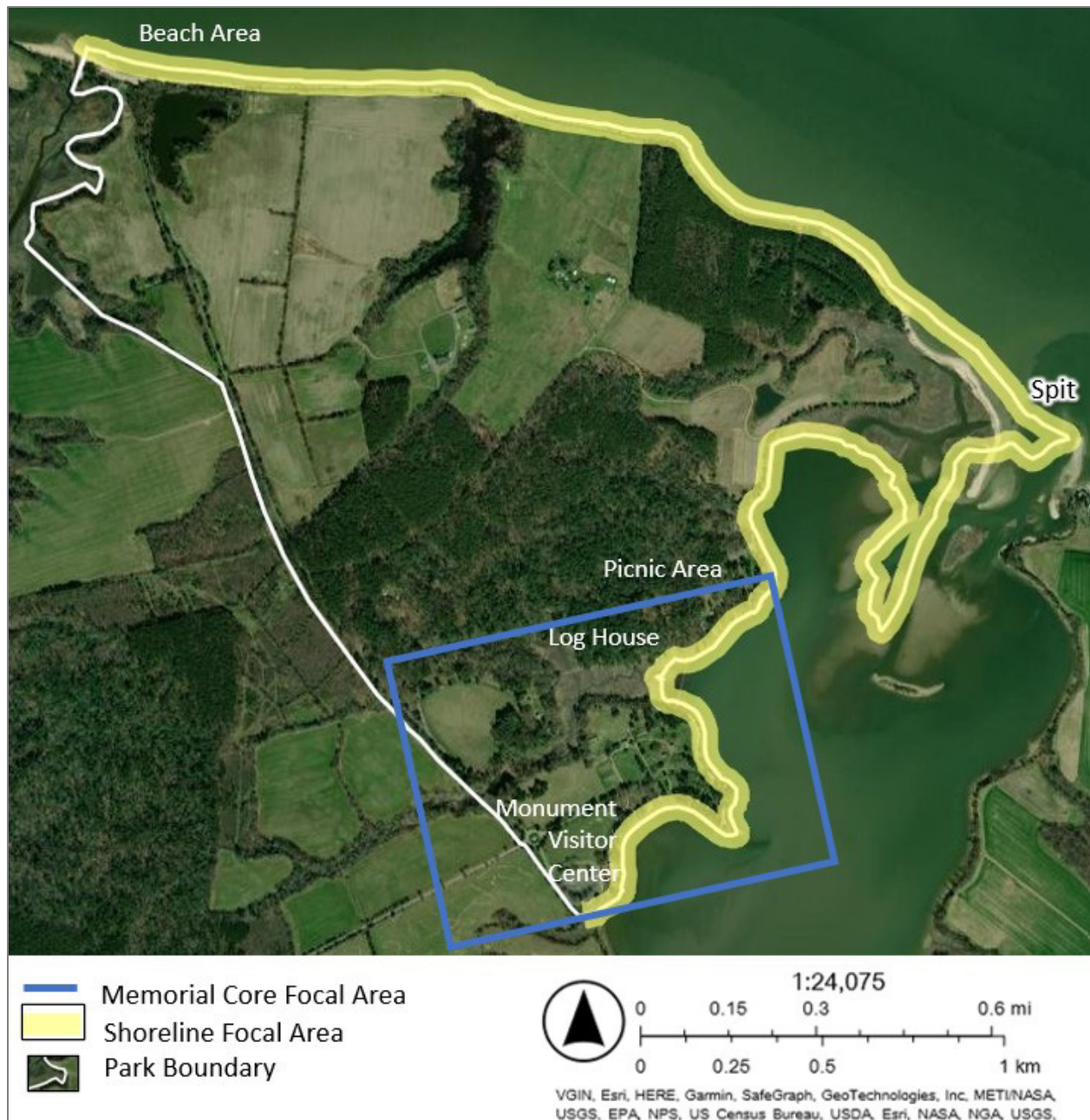


Figure 11. Location of focal areas at George Washington Birthplace National Monument.

Shoreline Focal Area

Description of Resource and Value

The shoreline along the Potomac River as well as along Popes Creek was considered as a combined focal area. The resources are connected as part of a geomorphic system and share vulnerabilities related to storm surge, flooding and erosion. In addition to stewarding the resources, goals for this focal area include community use of the Beach and Picnic Areas. The Beaches (including the spit), and Bluffs along the Potomac River are part of natural processes that erode the bluffs to provide sediment to the coastal system; the erosion results in exposure and loss of archeological and

paleontological resources. This focal area included archeological sites <50 m from the shoreline, those categorized as coastal. The Coastal Plain Dry Calcareous Forest, a globally rare natural community (see description in Natural Resources section), was considered a shoreline habitat because dependent on calcareous/shell substrate that primarily exists in proximity to the coast. In addition to the Tidal Wetlands, Beaches and Bluffs that are distinctly coastal ecosystems, parts of the Cultural Meadow and Forests, and the species that depend on them have sections near to the shoreline.

The Spit at the mouth of Popes Creek (part of the Beach resource category) reduces the energy entering Popes Creek allowing the conditions for tidal wetlands, shoreline cultural landscape features, public access and infrastructure in close proximity to the shoreline. The cultural landscape along Popes Creek includes parts of the Memorial Core, groves of cedar trees and established views of Popes Creek and the Potomac from the shore. Portions of the Nature Trail are along the shoreline and are considered both part of the cultural landscape and a transportation asset. Facilities such as the Footbridge, Beach Parking, and the stairs to the fishing area from the Picnic Area are purposely built along the shoreline to provide visitor access. Other facilities are close to the shoreline though set back, such as the Visitors Center, its parking lot and some historic structures.

Vulnerability

The natural resources most associated with the shoreline (Beach, Bluffs, Paleontological Resources) have high vulnerability from current conditions (Figure 4), primarily due to combined exposure and sensitivity to severe storms and surge. The Coastal Plain Dry Calcareous Forest is moderate vulnerability currently and increases to high by 2050. Species that use but aren't dependent on the shoreline, like Birds, Bats, and Insect Pollinators, are a mix of moderate and low vulnerability in current conditions and Birds increase to moderate vulnerability by mid-century. Water Quality remains low vulnerability for all time frames. The coastal archeological sites are high vulnerability from the current time frame onwards. The Eastern Red Cedar Tree Groves are moderately vulnerability from the current time and remain so. The thinking was that while some individual trees at the edge of bluffs may be lost, collectively the grove was not especially vulnerable. Established views remain low vulnerability for all time frames.

For facility assets close to and along the shoreline, the Beach Parking is moderate vulnerability in current time frame and changes to high by 2050. Note that the Beach Overflow Parking is not considered close to the shoreline and is low vulnerability, but that the option to expand the size of it in response to loss of Beach Parking needs to plan around cultural values in the vicinity, such as potential impacts to archeological sites. The Nature Trails have sections along the shoreline and this is one example of different workgroup scoring differently. The Facilities Workgroup scored the Nature Trail as high vulnerability from the current period forward, but the Cultural Resources Workgroup considered the Nature Trail as moderate by the 2022 time frame and becoming high by 2050. Both workgroups score the Footbridge as low vulnerability for all three time-frames. For facilities in proximity to the shoreline, the Visitors Center Access Road & Parking are currently high vulnerability because of the shoreline proximity. The structures further inland such as the Visitor Center and Log House were scored as low vulnerability for all time frames because the rates of

erosion along Popes Creek are low. The group discussed the possibility for a threshold shift in rates of erosion along Popes Creek if the spit at the mouth of the creek were to completely erode. This possibility increased the vulnerability of the tidal wetlands but there was not sufficient understanding of likelihood and time frame of such an event and how that would play out to influence how the historic structures currently set back enough from the shoreline might be affected.

Adaptive Capacity

For facility assets Nature Trails, Footbridge, Beach Parking and Visitors Center Parking are all medium adaptive capacity. Note that the Cultural Resources Workgroup assessed both the Nature Trail and Footbridge as having high adaptive capacity since they can be rebuilt and repositioned. None of the natural resources are high adaptive capacity. The Bluffs themselves have low adaptive capacity, yet the Archeological and Paleontological Resources within them are moderate because there are adaptation options to extract the associated information while accepting loss of the resources and context as the bluff that holds them erodes. While discussion of shoreline armoring options to collectively protect the bluffs, archeological and paleontological resources had interest, the lack of long-term effectiveness, high cost and tradeoffs meant that these didn't translate into actual adaptive capacity. While archeological and paleontological resources can be excavated for their protection, this solution removes the resources from the landscape and from their original context. The removal of archaeological and paleontological resources then requires management through museum collections. There were questions about how the vegetation and trees affect bluff erosion, whether there could be benefits to tree removal, or if this would be damaging because the trees provide stabilization until they come down. There are differences between trees and shrubs in whether they are protective; the different root systems offer different degrees of stabilization, but shrubs don't have the same risks of root ball erosion if a tree falls. Options to use existing data to do analysis comparing the sections of bluff with forest up to the bluff edge to those with cultural meadow and how that might affect erosion rates were identified as a need. The Coastal Plain Dry Calcareous Forest has low adaptive capacity, but there is a need to understand any relationship with shell mound archeological sites; there is the potential to increase its social component, which with its rare status might raise its profile, though there are still limited management options. The other cultural resources along the shoreline have a moderate (Cedar Groves) to high (Views) adaptive capacity.

Relationship of Vulnerability to Adaptive Capacity

Figure 12 shows a matrix comparing the vulnerability and adaptive capacity of the Shoreline focal area resources and assets. There are some clusters in relationship between its vulnerability and adaptive capacity that could be considered together. A number of the Facilities are in the Serious But Actionable (moderate to high vulnerability and moderate to high adaptive capacity) quadrant including the Visitor Center Service Road, Footbridge, Nature Trails, Historic Trail, Log House and Log House Storage Shed. The Coastal Archeological sites are also in this category. Note that the Facilities Workgroup assessed the Visitor Center as Serious but Actionable, but the Cultural Resources Workgroup assessed it as in Monitor For Change (low to moderate Vulnerability and low to moderate adaptive capacity).

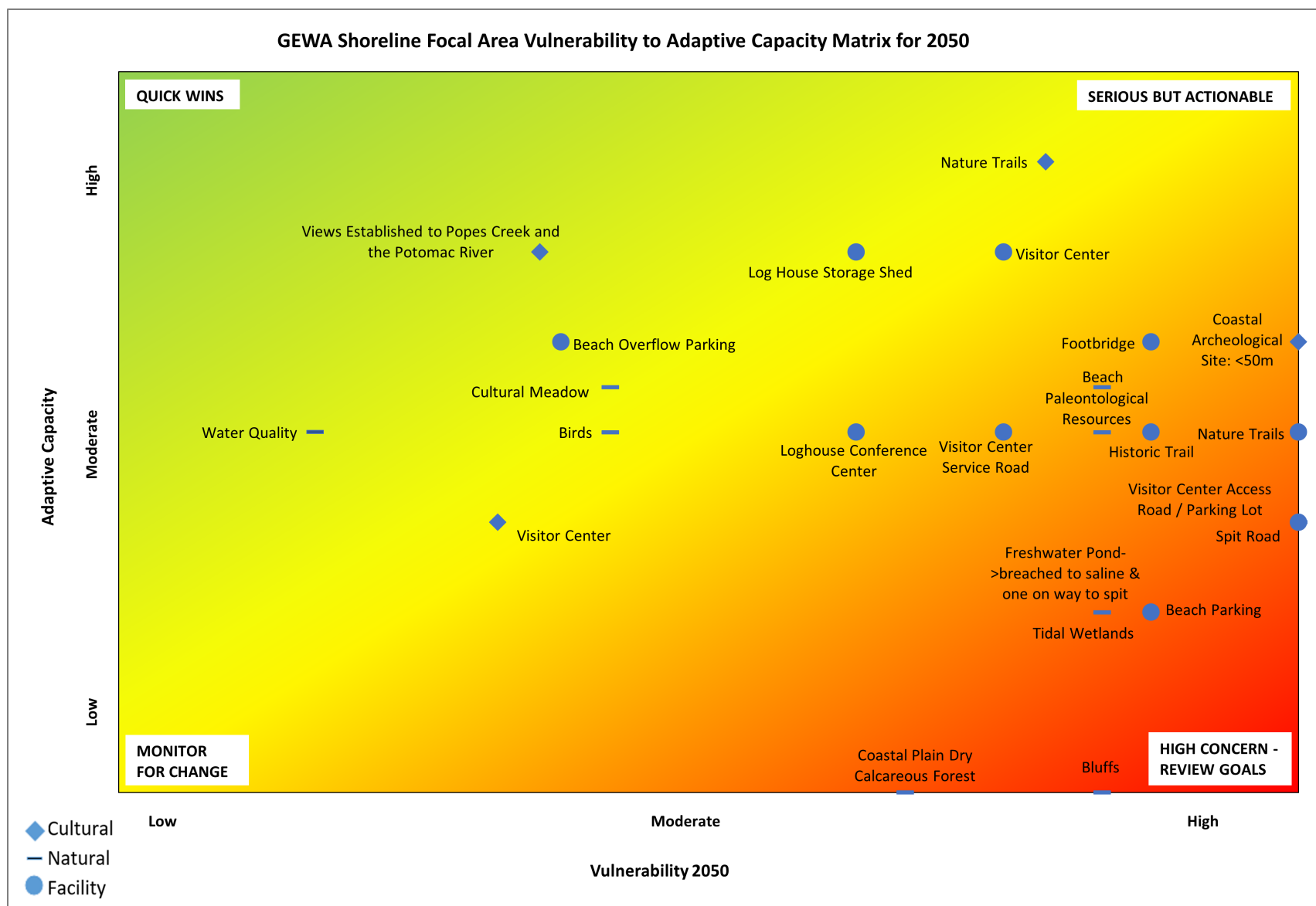


Figure 12. Relationship of vulnerability to adaptive capacity for George Washington Birthplace National Monuments Shoreline focal area.

The resources in the High Concern – Review Goals (moderate to high Vulnerability and low to moderate adaptive capacity) quadrant include several natural resources: Bluffs, Coastal Plain Dry Calcareous Forest, and Freshwater Ponds, as well as the Visitor Center Parking Lot and Beach Parking Lot. The park should review the long-term goals and strategies for these in relation to the other resources and the focal area to for long term planning for a different future. The Options Available (low to moderate Vulnerability and moderate to high adaptive capacity) quadrant include Views, Beach Overflow Parking, Cultural Meadow, Birds, and Water Quality.

Recommendations

Recommendations for addressing climate change vulnerability in the Shoreline focal area were identified based on the analysis and discussions of the focal group.

- Coordinate paleontological monitoring plan with archeological monitoring and NCBN shoreline change monitoring. Bluff monitoring designed for paleontological resources can benefit archeological resources, at least to monitor bluff condition even if not seeing the archeological resources which are higher up.
- Further, the NPS should consider how potential shoreline stabilization techniques would impact the viewshed and cultural landscape.
- Update the Ethnographic Resources Inventory and entering the information into the NPS CRIS. Multiple topics could be informed by this.
 - It is unknown if human remains are part of the archeological sites.
 - There is a need to understand the connection between the importance of the Coastal Dry Plain Calcareous Forest, which is a rare habitat, dependent on calcareous substrate, and shell mound archeological sites. The discussion included the idea that this forest only occurs over these shell mounds, but the calcareous substrate dates from Tertiary period shell deposits, so before human occupation. The priority for protecting these forests, as reflected in the currently low adaptive capacity could be informed but a better understanding of any association with archeological sites and would need to consider the views of associated Tribal Nations.
 - There were questions from the Natural Resources Workgroup if there are tidal wetlands that should be scored as higher adaptive capacity due to their importance as ethnographic resources. It was noted that for the Colonial National Historical Park vulnerability assessment (Ricci et al. 2019b), consultation with the Pamunkey Tribal Historic Preservation Officer indicated that Tidal and Non-tidal Wetlands were of cultural importance.
- Explore piloting USGS' Coastal Change Likelihood tool (Sterne et al. 2022) as a case study in the Beach areas, especially for the spit.

Memorial Core Focal Area

Description of Resource and Value

The Memorial Core focal area includes the Memorial Core Cultural Landscape in addition to the Visitor Center, Ice Pond System, adjacent Wetlands and crossing Trails, as well as the Log House.

This focal area is primarily comprised of historic structures within maintained landscapes and some natural sites (mainly the Tidal Wetlands). Shoreline erosion issues have been addressed by the shoreline focal group, so vulnerability along the bluff of the Memorial Core was not dealt with by this focal area group.

The George Washington Birthplace NM management goals related to the Memorial Core Cultural Landscape include the following:

- Maintain visitor access and circulation.
- Maintain the cultural landscape and cultural resources.
 - The George Washington Birthplace NM Foundation Document (NPS 2021) places the cultural resources at the center of the park goals – they are the reason the park was founded.
 - These cultural resource management goals include: preserving the commemorative landscape, the below-ground Washington resources, and pre-contact archeological resources.
- Moving forward, the NPS hopes to increase access to Washington-era resources and the natural resources interpretation.
- Planned tribal consultations will inform management goals and approaches related to pre-contact resources, as well as increasing understanding of the ethnographic resources of the park.
- Obtain funding for climate change adaptation – building specific projects around this adaptation process including a 5-year plan for the use and maintenance of structures.

In discussions with the interdisciplinary group of experts, a number of strategic resources were identified for the Memorial Core Focal Area: the Ice Pond Dam, the Visitor Center, and Coastal Archeology resources may be facing imminent damage from climate change impacts.

Vulnerability

Built in 1976, the Visitor Center is a well-maintained entry point for interpretation of the site. It is predicted to remain moderately vulnerable to flooding and erosion (Figure 13). The core vulnerability aspect of the Center is the location of all electronic and mechanical utilities in the basement. Erosion is unlikely to impact the Visitor Center in the short term due to the calm waters of the creek and setback from the shoreline. Early adaptation measures should consider whether elevating these systems is an appropriate first step, then consider additional efforts such as seawalls, elevating part of the building or rebuilding the wooden deck.

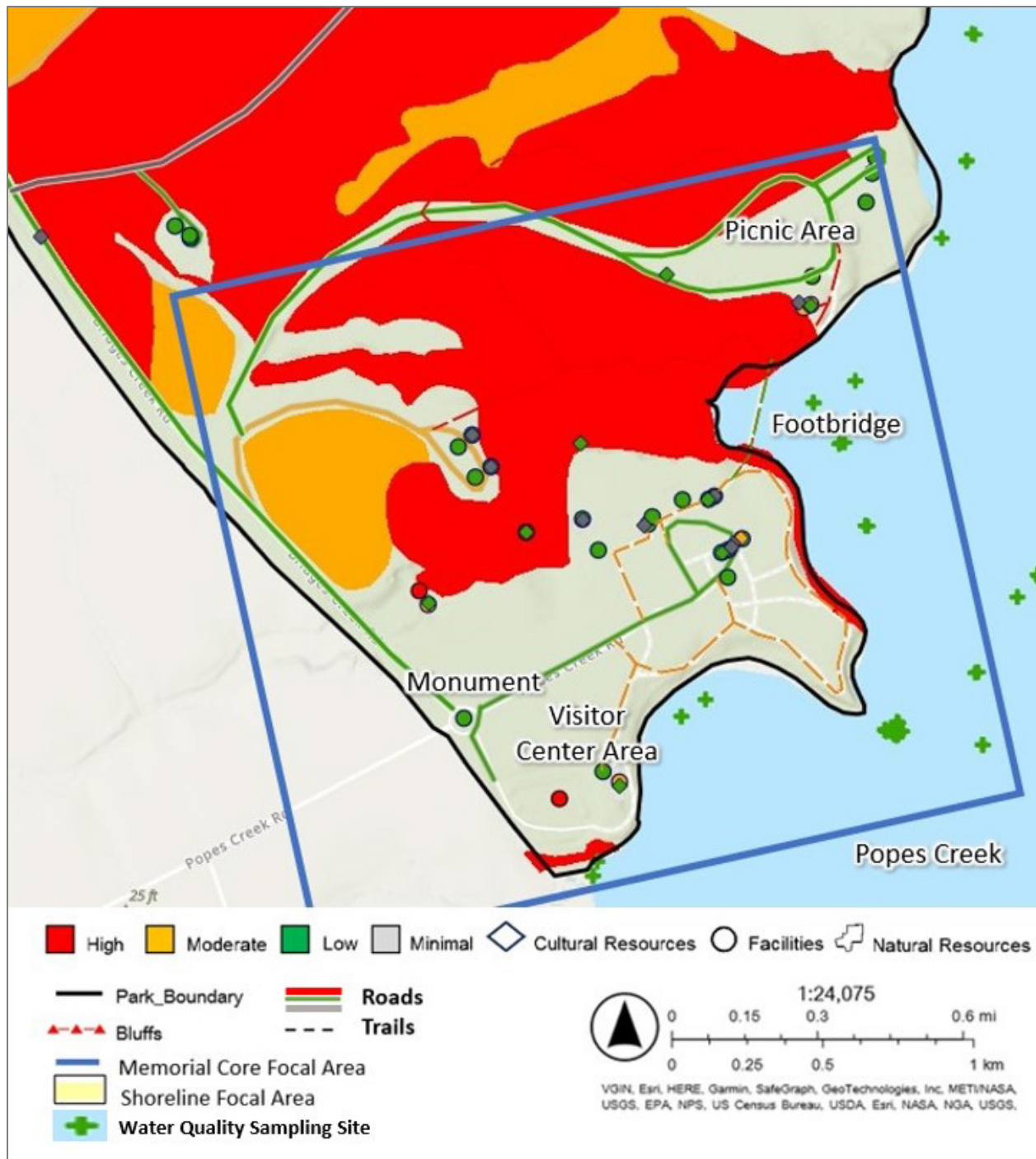


Figure 13. Vulnerability of Memorial Core Focal area for George Washington Birthplace National Monument by 2050.

The Visitor Center and parking area, which forms a topographic low inland of the Center, is highly vulnerable to extreme flooding from rainfall – at times, the flooding has risen to waist deep – and an improved drainage system is urgently needed. The Visitor Center and parking area provide a gateway to visitors to the Memorial Core Cultural Landscape.

Should the Visitor Center be destroyed by floods, or other disasters, the expert group advised it would be unlikely to be rebuilt as part of the NPS trend towards visitor center-free parks.

The Memorial House Museum, while out of flood zones, is highly vulnerable to wind and tree damage as well as mold as a result of the temperature differential between the climate-controlled interior and the exterior conditions. The principal source of vulnerability of the Memorial House Museum is damage to the collections on exhibit within due to rising moisture levels.

The future management of Memorial House Museum will need to deal with rising moisture levels and the resultant mold. Rain comes under the door facing the kitchen to the south, and although gutters would change the historic appearance of the house, they would be better for maintenance. Based on climate change projections considered, the Memorial House Museum will probably not be destroyed by 2100 but there may be a need for adaptive reuse. The collections on display may need to be displayed elsewhere by 2100. A new HVAC system expected to be installed in the Memorial House Museum would reduce vulnerability of artifacts. Tree maintenance is underway although a plan for maintenance to prevent wind-driven treefall damage while maintaining the cultural landscape is necessary. In addition, this cultural landscape plan should consider a future where insect pests have longer active seasons.

The Log House is moderately vulnerable. Erosion at the base of the cliffs makes archeological resources vulnerable on the bluffs above. Tree falls could impact buildings and uprooting trees would disturb archeological sites. While high exposure, the low vulnerability of gardens is due to low sensitivity.

The Ice Pond Dam is highly vulnerable to storm surge and has been shored-up twice in last 8 years. It blew out in Tropical Storm Lee in 2011. More substantial re-enforcement may be required to make this Dam resilient to future storm and flooding events, as it is a critical conduit to the functioning of the site as it exists today.

Although the Ice Pond Dam itself may not be a critical historic structure for the park, loss of its facility functions would restrict the visitor recreation opportunities to a concentrated area in the Memorial Core and remove access to the picnic areas and coastal areas on the northern coastal side of the park. In addition to the vehicular access the Ice Pond Dam provides to much of the site, important utilities also pass through the dam. Water, electricity and the septic lines all pass through the Ice Pond Dam, assuring a connection from the Memorial Core to its septic field, to the north of the Ice Pond Dam, and providing water and electricity to the Log House, and housing on the north side of the Ice Pond Dam.

Adaptive Capacity

The adaptive capacity of resource elements across the Memorial Core varies widely. Many of the structural facilities including the Visitor Center, Log House, Memorial House Museum and footbridge have moderate to high adaptive capacity. The maintenance of views from the site out to Pope's Creek and the Potomac has high adaptive capacity. Other elements of the cultural landscape including cedar groves, fig shrubs and features of the formal gardens have moderate to low adaptive

capacity. The historic farm buildings also have low adaptive capacity. The archeological sites have moderate to low adaptive capacity, although the acceptability of various forms of adaptation, including excavation and removal of resources, varies in value and feasibility. Acceptability of these techniques remains to be determined.

Relationship of Vulnerability to Adaptive Capacity

For resources in the Memorial Core focal area, comparing vulnerability to adaptive capacity (Figure 14), resources span the range of quadrants (Options available, Serious but actionable, Monitor for change, and High Concern/ Review Goals). Following the planned tribal consultations, park management will have more information on how to manage the archeological sites which fall in the lower right quadrant of High Concern and will be able to review goals for the management of these resources directly with the Tribal Nations concerned. The Cultural Resources Workgroup considered the nature trail to be a more actionable opportunity (high adaptive capacity) than the facilities group, as the Cultural Resources Workgroup deemed that the exact location of the nature trail could change with the changing shorelines, and structural solutions have already been sought. In addition, the Cultural Resources Workgroup considered both the Log House and the Memorial House Museum to be less vulnerable than the Facilities Workgroup. The main vulnerability of the Memorial House Museum rests in the protection of the collections it houses whose integrity depend on the building's climate control which is constantly vulnerable to power outages and rising mold. A planned new HVAC system would reduce vulnerability of collections housed within the Memorial House Museum. This system should be designed with future climate conditions in mind. These two sites should be considered carefully by site managers to maintain their use and value to George Washington Birthplace NM.

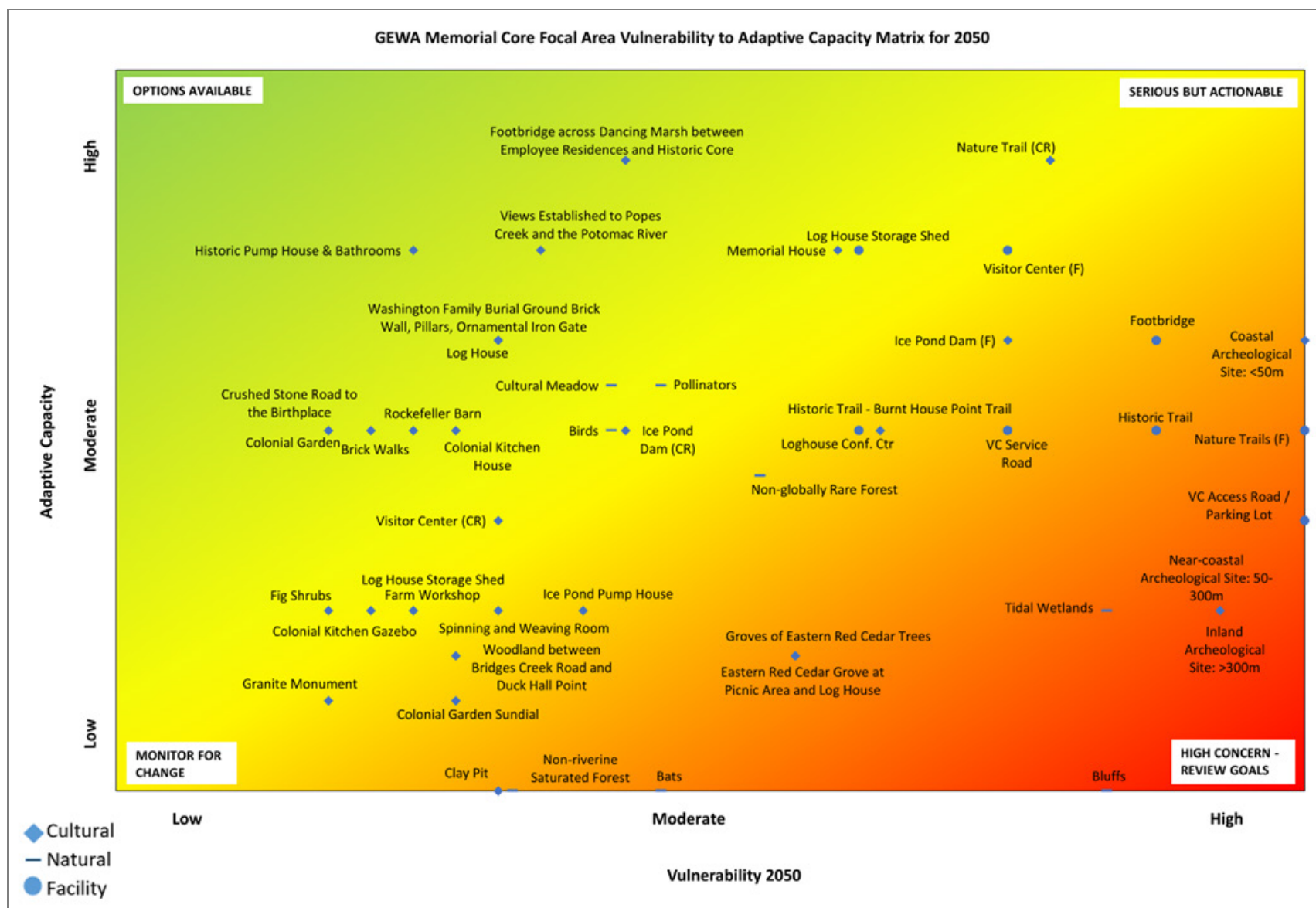


Figure 14. Relationship of vulnerability to adaptive capacity for George Washington Birthplace Memorial Core Focal Area.

Recommendations

The discussion of the interacting vulnerability and adaptation options of resources underscored the ability to adapt without losing the resource value, as perceived from a natural, facilities or cultural value and function. Recommendations for addressing climate change vulnerability in the Memorial Core are primarily prioritizing routine maintenance that responds to current and future conditions. It would be strategic to apply for funding for projects around the following themes into this adaptation process:

- Critical facilities of cultural value including the Memorial House Museum and outbuilding, and the Log House require routine, maintenance in order to maintain the adaptive capacity the expert group identified.
- While the Visitor Center is usually treated separately from the Memorial Core, the workgroup felt the interpretations, facility and access provided by the Visitor Center to the Memorial Core cultural landscape made it a critical resource in this discussion. A timeline needs to be established to determine planning and funding including whether or not utilities should be moved out of the basement and accomplishing that work if necessary and managing dangerous flooding of storm water in the parking lot.
- Conduct a structural study of the Ice Pond Dam to shore up the dam in a more permanent way before future storm events take it out again. Improvements have been made twice in the past 8 years after flooding from Tropical Storm Lee took out the Ice Pond Dam completely in 2011. These were urgent rapid repairs to get functionality back.
- Conduct an updated cultural landscape plan for the Memorial Core to consider tree management, including replacement in consideration of wind damage potential and for the likelihood of pests to be active longer in the seasons.
- The walking trails are a popular and important resource to access many other resources within the park. Consider relocation of trails or accept that trails will not always be accessible.
- Archeological resources eroding out of the bluffs would justify excavation. Undercutting of the bluff makes any excavation or information reconnaissance on the archeological sites more difficult or dangerous due to the possibility of bluff edge sloughing or collapse. There is a recognized need to make tribal partnerships stronger to understand the tribal priorities for management of these resources as many Tribes prefer not to disturb culturally significant sites that may contain human remains. Tribal consultations initiated by the park are now underway and the Virginia Department of Historic Resources will hire a Tribal Outreach Coordinator. In addition, any excavation will result in some loss of context and requires storage collection facilities to keep collections. Similar data recovery archeology is underway on Jamestown Island for Colonial National Historic Park and experiences should be shared.

Reflections and Next Steps

Conducting a climate change vulnerability assessment is just the beginning of a long-term process for adapting to changes originating from climate and non-climate sources. At the last workshop participants reflected on the assessment experience then outlined some potential next steps for moving forward.

Reflections

The following summarizes the reflections on the process, tools and outputs of this assessment.

Results

- There are a limited number of resources that change vulnerability across the three time frames for all the park resources examined. This could be due to most resources at the park are elevated from the river and creek shoreline, though dynamic erosion along many of the bluffs could accelerate over time. Additionally, this assessment used conservative projections and static SLR and erosion models, among others, to determine vulnerability over time.
- There is a need to revisit the vulnerability process at the site level as part of developing an adaptation strategy. There also needs to be a comprehensive and dynamic sediment transport model to fully understand the likely future projections.

Benefits of Integrated Vulnerability Assessment

- The assessment provides a generalized screening tool that assesses vulnerability in a consistent framework across program areas to spur discussions of how to use vulnerability and adaptive capacity to adapt to climate change parkwide. The park may need to revisit an issue highlighted through this process in a more detailed vulnerability process at site level as part of developing an adaptation strategy.
- Park staff recognizes the need to prepare for addressing climate change in the near to medium-term. There are significant gaps in management knowledge including a lack of a dynamic sediment transport model and links to shoreline infrastructure in some areas and this process highlighted areas to prioritize filling gaps.

Integration

- The assessment can be used to provide input to various planning processes used by park staff for today's programming and future planning. These include:
 - Mainstream climate and vulnerability information into other planning processes
 - Resource Stewardship Strategy implementation
 - Annual and 5-year work plans for program areas
 - Environmental Impact Statements
 - Capital Investment Strategy
 - Baseline and existing conditions report (Natural Resource Condition Assessment, Cultural Resource Stewardship Assessment (NPS 2017a))

- The importance of discussing facility assets, cultural and natural resources within the same process became obvious to all: they are interdependent. It was apparent that all resources and assets (across resource program areas or even within) are not necessarily valued in the same way or for the same reasons. One person said ‘this was a good first step and we should highlight that neither priorities nor critical systems analysis was done in our scoring and should be considered in going forward.’
- The process reveals differences among the three program areas (and even within the program areas) illustrating the varying stages of awareness, methods of assessment, and adaptation approaches. This provides opportunities for lessons to be learned across program areas and within a park staff.
- Engaging across disciplines in focal areas lends itself to interpretation, which can help articulate the integration and tell a story of the past, present and future.

Framework

- Most participants rated the framework as very effective, though there is room for improvement to meet the varying needs across the NPS. Formulating and applying a common framework across program areas is a challenge, given the different issues and opportunities. Employing the POSE adaptive capacity framework brought to the fore the realities of how society and economics could impact efforts to develop adaptation plans.
- There was some debate among the Cultural Resources Workgroup regarding whether cultural resources have any intrinsic adaptive capacity. For this reason the group didn’t consider this aspect of adaptive capacity in their analysis.

Process

- All the participants agreed or strongly agreed that the process was effective for facilitating worthwhile discussions and providing valuable outputs. Thus most of the participants also thought the assessment increased their ability to incorporate vulnerability into park planning and implementation.
- Workgroups bring in expert judgement directly related to the park, broader expertise from partners and is complemented by national and regional NPS perspectives. The effectiveness is improved with strong local leadership, such as by having park staff lead each workgroup. There are significant benefits from conducting the assessment internally with the staff and partners that can’t be matched by contracting consultants to do the analysis, though it was a substantial time commitment.
- Conducting much of the assessment over the course of two face-to-face workshops builds trust and buy-in among and within the program areas. It also reduces fears of the process, allowing equal footing and better understanding of perspectives and priorities among program areas.
- Identifying stressors (for each program area) enables each workgroup to deal with multiple facets of the climate change issue that are affecting their resources, not just SLR. This makes the process more relevant for coastal and inland parks alike. One limitation of this process is

it treats all stressors equally, as there was not a simple way to weight the most important stressors differently than the secondary ones. Natural Resources and Facilities Workgroups selected specific stressors that they weighted through an auto-high function which elevated the overall exposure scores to high irrespective of the other stressor related exposure scores.

Projections

- Given that this is a rapid assessment, we used bathtub models for SLR scenarios which do not capture the sediment transport dynamics of the Potomac River around the park. However, the workshop discussions included experts that have used their knowledge and experience in local studies, therefore we were able to adjust the findings and recommendations based on the reality of how the dynamic system works (Wilson et al 2019).
- The NPS has changed some of their guidance on use of climate projections since the pilot assessment methodology was written (Ricci et al. 2019a). This assessment was able to use SLR projections that more accurately follow the recent trends. This enabled the assessment to be better received by the park staff and experts in the workgroups.

Communication

- The park was in the process of hiring a new Chief of Interpretation and Education and therefore asked to hold off on developing messages in the workshops. The project will work with the new hire once the report is finalized to assist in communicating the vulnerability assessment results. Educating field staff, especially interpretive staff, will be critical; they have been thinking a lot about climate change and when provided the vulnerability information, they will be able to communicate it to visitors and communities.

Partnerships

Local partners will be key in implementing adaptation strategies for parks. In conducting an integrated assessment, each park determines which partners need to be involved in the assessment and at what stage. This can include other key stakeholders (i.e., local organizations, community planners, Sea Grant extension agents) who can benefit from diverse information gathering, honest discussion about issues and opportunities to build partnerships, and get buy-in for taking next steps.

- There were no stakeholders from local communities participating in the two workshop process. A few partners from academic institutions and sister agencies were able to commit to the two workshop format and their input was invaluable. In particular, participation by park staff from other parks who had already gone through this integrated vulnerability assessment was invaluable.
- **Incorporate into other NPS documents/processes:** Park staff envision the results of the vulnerability assessment being incorporated into other existing planning documents and processes of the park. This will increase organizational acceptance of the results and knowledge of how to apply the actions into ongoing short-term and long-term management planning.
- **Disseminate with NPS Staff and Partners:** A core principle of this vulnerability assessment is that understanding and acting on the results depend as much on NPS and park staff

organizational capacity as it does on the specific technical findings. Thus, all park staff should be informed and engaged in application of these vulnerability results. The assessment began with the three program areas of cultural resources, natural resources, and facilities. As mentioned above, educating field staff and interpretive staff will be important. Because it is a small park with overlapping staff roles there are other program areas, including interpretation, law enforcement, and administration, that were involved that should be updated and involved in navigating strategies for adaptation planning.

- **Tribal consultations** will be conducted in the near future to bring the Tribes up to date on the assessment process and results to invite their interpretation and potential partnerships for moving forward in protecting the park resources.

In conclusion, key to moving forward is engaging partnerships with local governments, and neighboring associations that share an interest. George Washington Birthplace NM has a strong foundation to build from in these areas that should help accelerate the adaptation planning process. The vulnerability assessment data and maps can be a valuable resource for jumpstarting the adaptation planning process and integrating into existing planning processes. They can be used to bring onboard new partners and help them appreciate the underlying vulnerability issues and changes over time.

Literature Cited

- Amberg, S., K. Kilkus, S. Gardner, J. E. Gross, M. Wood, and B. Drazkowski. 2012. Badlands National Park: Climate change vulnerability assessment. Natural Resource Report NPS/BADL/NRR—2012/505. National Park Service, Fort Collins, Colorado.
- Abatzoglou, J. T., and T. J. Brown. 2012. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology* 32:772–780. Available at: <https://doi.org/10.1002/joc.2312> (accessed 15 December 2023).
- Beavers, R. L., A. L. Babson, and C. A. Schupp (eds.). 2016. Coastal adaptation strategies handbook. NPS 999/134090. National Park Service. Washington, DC.
- Blank, G. B., M. S. Martin, C. Swaim, and H. A. Devine. 2007. A synthesis of natural resource information for George Washington Birthplace National Monument. Technical Report NPS/NER/NRTR—2007/077. National Park Service. Philadelphia, Pennsylvania.
- Bruneau, M., S. Chang, T. Eguchi, G. Lee, T. O'Rourke, A. Reinhorn, M. Shinozuka, K. Tierney, W. Wallace, and D. von Winterfeldt. 2003. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra* 19(4):733–752. Available at: <https://doi.org/10.1193/1.1623497> (accessed 15 December 2023).
- Caffrey, M. A., R. L. Beavers, and C. H. Hoffman. 2018. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report NPS/NRSS/NRR—2018/1648. National Park Service, Fort Collins, Colorado.
- EA Engineering, Science, and Technology, Inc., PBC. 2023. Coastal Engineering Review George Washington Birthplace National Monument (GEWA) – Shoreline Erosion Strategy. Geologic Resources Division (GRD). EA Inc., Hunt Valley, Maryland.
- Glick, P., B. A. Stein, and N. A. Edelson (eds.). 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. National Wildlife Federation, Washington, D.C.
- Gonzalez, P., F. Wang, M. Notaro, D. J. Vimont, and J. W. Williams. 2018. Disproportionate magnitude of climate change in United States national parks. *Environmental Research Letters* 13: 104001. Available at: <https://doi.org/10.1088/1748-9326/aade09> (accessed 15 December 2023).
- Hardaway, C. S., Jr., D. A. Milligan, K. P. O'Brien, and C. A. Wilcox. 2009. Shore status, evolution, and storm vulnerability assessments. Technical Report. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.
- Mitchell, J. C. 2008. Inventory of amphibians and reptiles of George Washington Birthplace National Monument. National Park Service, Northeast Region. Philadelphia, PA. Natural Resources Report NPS/NER/NRTR-2008/110. Available at: <http://www.nps.gov/nero/science> (accessed 15 December 2023).

- Nelson, S. A. C., H. A. Devine, B. M. Hartis, E. F. Hain, and W. S. Slocumb. 2012. Natural resource condition assessments for George Washington Birthplace National Monument and Thomas Stone National Historic Site. Natural Resource Report NPS/NER/NRR—2012/576. National Park Service. Fort Collins, Colorado.
- National Oceanic and Atmospheric Administration (NOAA). 2017. Global and regional sea level rise scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. Silver Spring, MD. Available at: https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf (accessed 15 December 2023).
- National Oceanic and Atmospheric Administration (NOAA). 2016. Tides and currents. Available at: <https://tidesandcurrents.noaa.gov/> (accessed 21 December 2022).
- National Oceanic and Atmospheric Administration (NOAA). 2018. National centers for environmental information, climate at a glance: U.S. Time Series. Available at: <http://www.ncdc.noaa.gov/cag/> (accessed 30 January, 2018).
- National Park Service (NPS). 2021. Coming to terms with climate change: Working definitions. National Park Service, Climate Change Response Program, Fort Collins, Colorado.
- National Park Service (NPS). 2018. Resource stewardship strategy summary: George Washington Birthplace National Monument, Virginia.
- National Park Service (NPS). 2017a. Cultural resource stewardship assessment. George Washington Birthplace National Monument, Virginia.
- National Park Service (NPS). 2017b. Climate change trends and vulnerabilities, George Washington Birthplace National Monument. National Park Service, Natural Resource Stewardship and Science. Berkeley, California.
- National Park Service (NPS). 2016. Coastal hazards and climate change asset vulnerability protocol: Project description and methodology. NPS 999/132623. National Park Service, Washington, D. C.
- Patterson, K. 2008. Vegetation classification and mapping at Colonial National Historical Park, Virginia. Technical Report NPS/NER/NRTR—2008/129. National Park Service. Philadelphia, Pennsylvania.
- Peek, K. M., H. L. Thompson, B. R. Tormey, and R. S. Young. 2023. Coastal hazards & sea-level rise asset vulnerability assessment for George Washington Birthplace National Monument: Summary of results. NPS 332/187362. Program for the Study of Developed Shorelines, Western Carolina University. Cullowhee, North Carolina.

- Peek, K. M., B. R. Tormey, H. L. Thompson, and R. S. Young. 2022. Coastal hazards & sea-level rise asset vulnerability assessment protocol: Updated project description & methodology. Natural Resource Report NPS/NRSS/CCRP/NRR—2022/2427. National Park Service, Fort Collins, Colorado. Available at: <https://doi.org/10.36967/2293653> (accessed 15 December 2023).
- Psuty, N. P., K. Butler, K. Ames, A. Habeck, and G. Liu. 2019. Shoreline position (1D) monitoring at George Washington Birthplace National Monument: 2010–2017 trend report. Natural Resource Report NPS/NCBN/NRR—2019/1879. National Park Service, Fort Collins, Colorado.
- Ricci, G., S. Gaines, and A. Babson. 2024. Integrated coastal climate change vulnerability assessment data: George Washington Birthplace National Monument. National Park Service. General dataset available at: <https://irma.nps.gov/DataStore/Reference/Profile/2301939> (accessed 03 January 2024).
- Ricci, G., D. Robadue, Jr., P. Rubinoff, and A. L. Babson. 2019a. Method for integrated coastal climate change vulnerability assessment. Natural Resource Report NPS/NER/NRR. National Park Service, Fort Collins, Colorado.
- Ricci, G., D. Robadue, Jr., P. Rubinoff, A. Casey and A. L. Babson. 2019b. Integrated coastal climate change vulnerability assessment: Colonial National Historical Park. Natural Resource Report NPS/NER/NRR—2019/1945. National Park Service, Fort Collins, Colorado.
- Ricci, G., D. Robadue, Jr., and A. L. Babson. 2017. Designing and scoping climate change vulnerability assessments for coastal national parks in the northeast region: Guidance and lessons learned. Natural Resource Report NPS/NER/NRR—2017/1426. National Park Service, Fort Collins, Colorado.
- Rockman, M., M. Morgan, S. Ziaja, G. Hambrecht, and A. Meadow. 2016. Cultural resources climate change strategy. Washington, DC: Cultural Resources, Partnerships, and Science and Climate Change Response Program, National Park Service.
- Schmelz, W., and N. Psuty. 2019. Quantification of airborne lidar accuracy in coastal dunes (Fire Island, New York). Photogrammetric Engineering and Remote Sensing 85:133–44. Available at: <https://doi.org/10.14358/PERS.85.2.133> (accessed 15 December 2023).
- Sterne, T. K., E. A. Pendleton, E. E. Lentz, and R. E. Henderson. 2022. Coastal change likelihood in the U.S. northeast region: Maine to Virginia: U.S. Geological Survey data release. Available at: <https://doi.org/10.5066/P96A2Q5X> (accessed 15 December 2023).

- Sweet, W. V., B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak. 2022. Global and regional sea level rise scenarios for the United States: updated mean projections and extreme water level probabilities along U.S. coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, Maryland, 111 pp. Available at: <https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf> (accessed 15 December 2023).
- Wilson, K., E. E. Lentz, J. L. Miselis, I. Safak, and O. T. Brenner. 2019. A Bayesian approach to predict sub-annual beach change and recovery. *Estuaries and Coasts* 42(1):112.

Appendix A. Sea Level Rise Projections Summary

According to historical tide gauge data from the Solomon's Island, MD, tide gauge, sea level around George Washington Birthplace National Monument (GEWA) is rising at a rate of approximately 3.96 mm/yr, which is equivalent to 0.15 in/yr (NOAA 2016; Figure 15; Table 11). This rate is equivalent to an increase of 1.30 ft over 100 years.

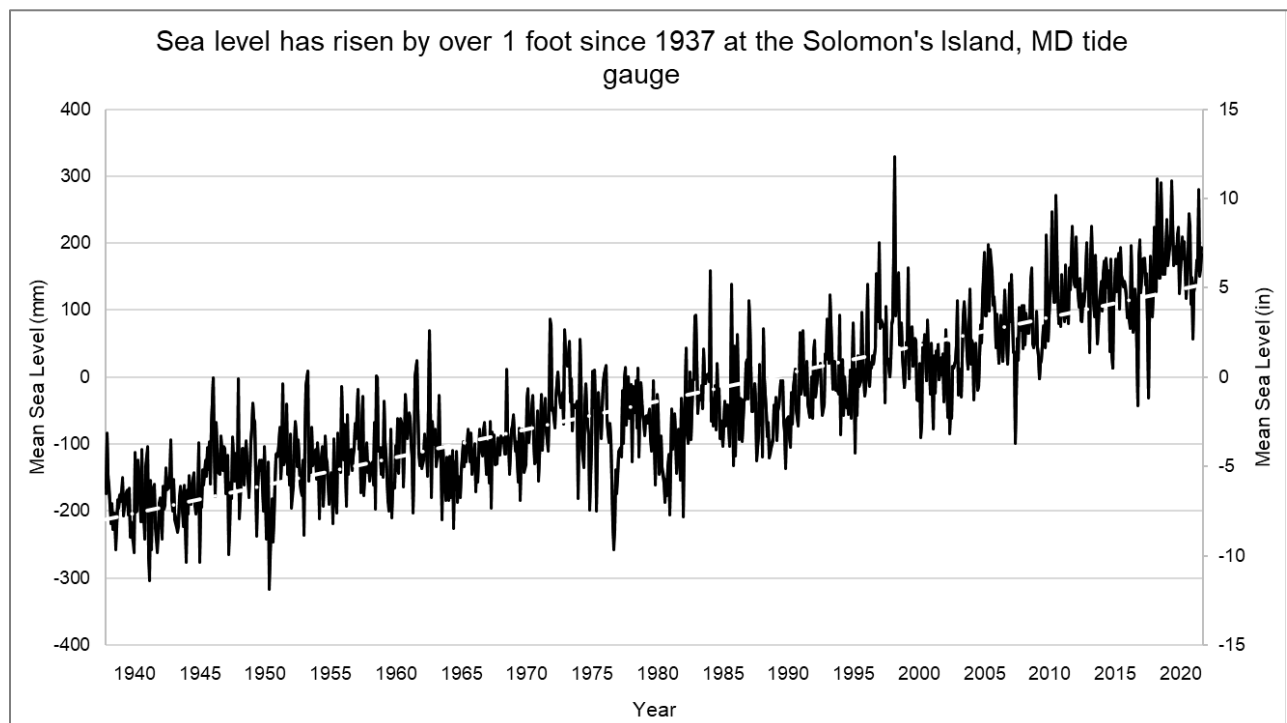


Figure 15. Historic sea level trends at the Solomon's Island, Maryland, tide gauge from 1937-2022 show that sea level has risen by over 1 foot at a rate of 0.15 in/yr (NOAA).

Table 11. Historic and projected sea level trends for George Washington Birthplace National Monument. Sea levels are reported relative to Mean Higher High Water (MHHW) for the 1983-2001 National Tidal Datum Epoch.

Sea Level Trends	Historical	2050	2100
Historic sea level trend, 1937-2022, Solomon's Island tide gauge	+0.15 in/yr	n/a	n/a
Intermediate Scenario (NOAA, 2022)	n/a	+1.41 ft	+4.07 ft
Caffrey et al. (2018) RCP 4.5 scenario	n/a	+2.07 ft	n/a

Under the Intermediate Sea Level Rise (SLR) Scenario (NOAA 2022), sea level is predicted to rise by 4.07 ft by 2100 at the Solomon's Island, MD, tide gauge (Table 11). Figure 16 displays the Intermediate SLR curve along with curves for the other NOAA scenarios: Intermediate Low, Intermediate High, and High. For the 2100 scenario in this climate change vulnerability assessment,

the NOAA Intermediate scenario is used because developing NPS guidance is likely to recommend this scenario for applications such as this.

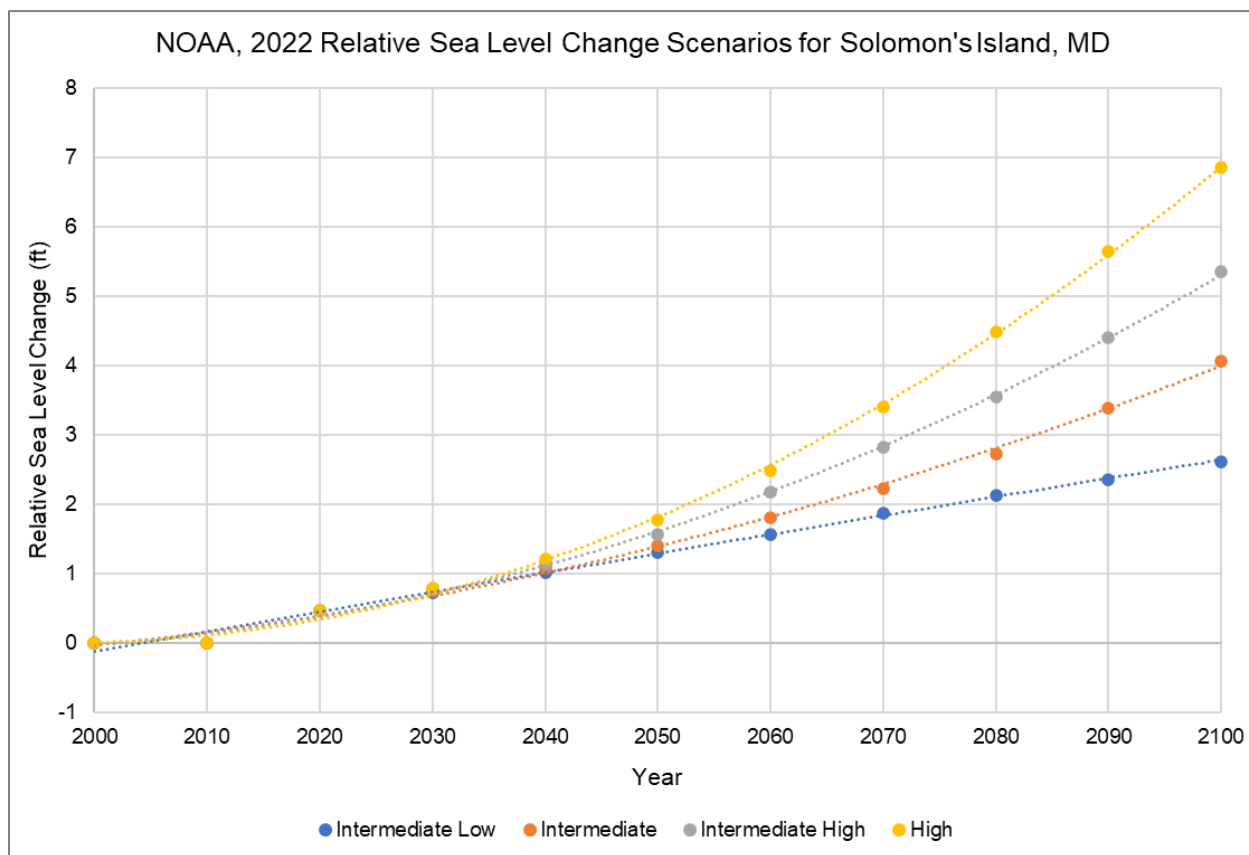


Figure 16. NOAA (2022) relative sea level rise projections for the Solomon's Island, Maryland, tide gauge.

For the 2050 scenario, we are using 0.63 m (2.07 ft) to remain consistent with the 2016 Western Carolina University (WCU) *Coastal Hazards & Climate Change Asset Vulnerability Assessment Protocol*. This scenario is available for GEWA from *Sea Level Rise and Storm Surge Projections for the National Park Service* (Caffrey et al. 2018). However, during the WCU asset vulnerability assessment, instead of using the 2050 value for RCP 8.5 in the standard protocol, the 2100 value for RCP 4.5 was used because it is an NPS scenario that fell between to NOAA's Intermediate and Intermediate-High scenarios (NOAA 2017) for 2050. This was a workaround that allowed the use of a locally relevant scenario with the tools that were available at the time.

The maps used in this assessment were developed using the NOAA SLR viewer data download. The NOAA scenarios are not available as GIS layers; however, NOAA SLR layers are available in one-foot increments. For the 2100 scenario (NOAA Intermediate) used in this assessment, the 4 ft increment is used because it is closest to the value of the NOAA Intermediate scenario for 2100 (4.07 ft; Table 11).

Storms Summary

12 tropical storms, depressions, extratropical, and subtropical storms have passed within 10 miles of GEWA since 1867, which include five extratropical storms, four tropical depressions, one tropical storm, one category 1 hurricane (unnamed storm, August 23, 1993), and one category 2 hurricane (unnamed storm, October 23, 1878) (Table 12). Storms are expected to intensify over the next century.

Table 12. Historic and projected storm trends for George Washington Birthplace National Monument.

Storm Trends	Storm Trend Metrics
Number of tropical storms, depressions, extratropical, and subtropical storm paths within 10 miles of GEWA, 1867-2021 ¹	12
Estimated storm surge height (Category 1, mean tide) ²	2.9 ft
Estimated storm surge height (Category 4, mean tide) ²	12.8 ft

¹ [NOAA, 2021, Historical Hurricane Tracks](#)

² [Shaw and Bradley, 2014, SLOSH Category 1-4 Storm Surge Points](#)

Sea Level Rise and Storm Surge Vulnerability

- The GEWA shoreline is eroding and vulnerable to storms. Even when storms do not pass within 10 miles of the park, they can impact the shoreline. For example, between 2002 and 2007, during which Hurricane Isabel (2003) and Tropical Storm Ernesto (2006) passed the park, some sections of the shoreline eroded up to 30 feet (Hardaway et al. 2009, Psuty et al. 2019). Storms are expected to intensify over the next century, so more hurricanes will likely impact the park.
- The marsh in Popes Creek used to be mostly contiguous, but it has since turned into marsh islands as much of the space has been converted to open water.
- Cultural resources of the park, including archeological sites, historic landscapes, and structures, are vulnerable. For example, archeological resources at the Pond are facing high rates of erosion and structures can be damaged by flooding or storm surge.

Paleontological resources are also threatened. The Calvert Formation, which consists of silty sand deposits along the park's shoreline, consists of abundant shallow marine fossils dating between 22 and 14 million years old during the early and middle Miocene. Fossils include abundant microfossils such as foraminifera and diatoms; plant pollen, spores, seeds, wood, and logs; shells and other invertebrates such as worm trace fossils; and marine vertebrates, like sharks, rays, bony fish, and marine turtles and mammals. The Calvert Formation is exposed along the water's edge at GEWA and is being eroded by rising tides and strong storms, which threaten the preservation of these unique fossils.

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