FINAL PROJECT REPORT

SECTION 1. ADMINISTRATIVE INFORMATION:

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- **Agency or Institution of the recipient:** USGS SE CASC
- Project title: Examining Diverse Management Objectives and Broadening Stakeholder Engagement for Climate Adaptation Planning of Historic Structures Within the National Park System
- **Agreement number:** G22AC00273
- **Date of the report:** December 16, 2025
- **Period of time covered by the report:** 09/01/22 - 08/31/2025
- **Actual total cost of the project:** $395,771.56

SECTION 2. *PUBLIC* SUMMARY:

This project sought to advance an adaptation planning tool, the Optimal Preservation Model, designed to help National Park Service cultural resource managers make informed choices about preserving historic structures threatened by climate change. The model combines assessments of historic importance with vulnerability data and uses advanced algorithms to evaluate various adaptation strategies over a 30-year planning horizon. Advances to the modeling effort included reevaluating and broadening the inclusion of stakeholder values in the calculations of each structure's historical significance and the selection of adaptation strategies, as well as accounting for risks associated with future storm-related damage to structures. Working in collaboration with project partners at Cape Lookout National Seashore and two National Park Service organizations with missions tied to the national seashore's two historic districts (Cape Lookout Village and Portsmouth Village), several outreach and engagement efforts supported necessary two-way communication to understand local values and explain the complex tradeoffs associated with climate adaptation planning for the historic districts. Ultimately, the project team developed and tested five new model configurations to reflect different decision priorities and generated visualizations of model outputs. The visualizations allow managers to explore cost efficiencies in relation to various future outcomes on cultural landscapes based on the broadening of stakeholder values. Additional visualizations, specifically maps of the villages at 2035, 2045 and 2055, help communicate the potential future composition of the districts. The maps display the structures that are remaining within the historic district, their condition and the types of adaptation actions and post-storm recovery actions applied to each structure. This work advances an evidence-based model that helps cultural resource managers make more informed and transparent decisions about how to best steward historic districts located in climate vulnerable landscapes.

SECTION 3. PROJECT SUMMARY:

This project aimed to (a) expand upon the pilot test of a climate adaptation decision support framework, the Optimal Preservation (OptiPres) Model, to the full complement of structures located in two historic districts at Cape Lookout National Seashore and (b) advance the utility of the decision framework by performing substantial updates to the model. The OptiPres Model was designed using a values-based decision analytic approach and uses a heuristic optimization algorithm (i.e., simulated annealing) to consider climate and budget uncertainties when framing complex tradeoffs. The OptiPres Model was initially developed during a pilot test at Cape Lookout National Seashore, with model updates made during a transferability test at Gulf Islands National Seashore. The model currently considers a single, budget-constrained management objective: maximizing accumulated resource values during a 30-year planning period under numerous budget scenarios. The model's input data include: cultural resource value metrics, vulnerability metrics, storm scenarios, costs for adaptation actions, and annual budget scenarios. Outputs highlight the pattern and sequencing of adaptation actions across a 30-year planning horizon to achieve the maximum accumulated resource value for the structures within each historic district. To advance the model's utility, this project proposed and met four objectives including: (a) identify additional management objectives (e.g., resource vulnerability, cost efficiency, visitor safety, visitor experience quality, potential uses, continuity in heritage values, and place connections), (b) compile historic and use potential values for all structures within 2 historic districts, (c) update the list of pragmatic adaptation actions, costs, and model dynamics based on post-hurricane (Florence and Dorian) recovery efforts, and (d) broaden stakeholder engagement in the weighting of historic and use potential values and adaptation action preferences with members of two partner organizations who hold strong place-based connections to the historic districts.

The project revised the OptiPres Model and expanded the model to include four additional, alternative model parameterizations: (1) Resist-Direct-Accept (R-D-A) model, (2) Building priority model, (3) Action preference model, and (4) Public planning priority model. Visualization of model outputs to enhance decision making included: 30-year adaptation action portfolios, temporal changes following post-storm recovery, and temporal changes in structure conditions. Additionally, geospatial outcome maps of historic districts were created to foster public outreach and engagement.

Results of the projects highlight that without sufficient funding, the resource value of historic structures at Cape Lookout National Seashore face substantial and unavoidable loss, as limited budgets accelerate deterioration and restrict cost-intensive adaptation actions. While the fixed timeline of the R-D-A framework model may delay adaptation actions that enhance structures' resilience to storm impacts, adequate funding enables cost-intensive actions to be applied early to preserve both historic values and cultural landscape integrity. The public planning priority model further illustrates that incorporating community preferences to OptiPres Model can maintain iconic structures and sense of place by applying post-storm retention as a proactive action, but one that comes at the cost of losing physical access into historical structures. Future efforts could enhance the model's transferability by integrating financial benefits from third-party rental programs, advancing research on "letting go" decisions and transformative actions (e.g., high-tech documentation and virtual interpretive experiences to preserve intangible cultural meaning), and refining the model to more explicitly compare adaptation outcomes linked to different stakeholder priorities. Overall, the project combines optimization modeling with a community-engaged approach to develop a climate adaptation planning framework to provide transparent, value-driven, and place-centered decisions for long-term cultural resource management. The implications derived from the model results can support decision-making in other coastal park units with similar cultural resource stewardship challenges.

SECTION 4. REPORT BODY:

Purpose and Objectives:

The purpose of this project was to advance the Optimal Preservation (OptiPres) Model for climate adaptation planning of structures located in climate-vulnerable historic districts. The OptiPres Model's objective function is to maximize the accumulated resource value of the structures within a historic district across a 30-year planning horizon. Each structure in the model is assigned an initial resource value by dividing its vulnerability value (exposure + sensitivity) by its cultural resource value (metrics for historical significance; see: Fatorić and Seekamp, 2018[1]) for year 1. Then, the model applies sequences of actions to each structure in each year of the model, with each action (or inaction) improving or reducing the vulnerability value and the cultural resource value, until the optimal solution is derived under specified budget scenarios (i.e., greatest possible accumulated resource value at year 30; see Seekamp et al., 2019[2] for further details). Budget scenarios are conceptualized as the industry standard budget (the total cost of annual maintenance for all structures), low budget (22.5% of the industry standard), high budget (200% the industry standard), and periodic funding budget (industry standard budget with five-year influxes of industry standard to the base budget).

The project was implemented at Cape Lookout National Seashore, a landscape where two historic districts (Cape Lookout Village and Portsmouth Village) are threatened by sea-level rise, nuisance flooding, and increasingly severe storm events. Both historic districts embody federal maritime and local community significance. National Park Service managers face difficult decisions regarding cultural resource stewardship given the range of cultural connections to places like Cape Lookout Village and Portsmouth Village, the minimal differences between structures' exposure to climate stressors, ongoing fiscal constraints, ongoing storm-related damage and destruction to historic structures and cultural landscapes, and the likelihood of future climatic impacts. In other words, there are complex tradeoffs affiliated with decisions about which structures to preserve, which to adapt, and which to let go.

To address these gaps, the project set out to develop, test, and apply the OptiPres Model, a decision-support framework designed to evaluate long-term trade-offs in cultural resource stewardship under climate stressors. Specifically, the objectives were to: (a) identify additional management objectives (e.g. resource vulnerability, cost efficiency, visitor safety, visitor experience quality, potential uses, continuity in heritage values and place connections), (b) compile historic and use potential values for all structures within two historic districts, (c) update the list of pragmatic adaptation actions, costs, and model dynamics based on post-hurricane (Florence and Dorian) recovery efforts, and (d) broaden stakeholder engagement in the weighting of historic and use potential values and adaptation action preferences with members of two partner organizations who hold strong place-based connections to the historic districts.

All four objectives were met during the project period, with substantial updates to the OptiPres Model. Early in the project period, we used the Analytical Hierarchy Process (AHP) to reorganize and weight the calculations of significance for each historic structure (see output refereed journal article, Kibria et al. 2024). We also operationalized federal adaptation guidance (i.e., the Resist-Accept-Direct framework) into decision rules that can be systematically tested against alternative adaptation planning approaches. Additionally, we integrated stochastic storm impacts and post-storm actions into the OptiPres Model (see output report, Dalyander et al., in review), as well as synthesized community values and perspectives in the OptiPres Model that reflect both structure-level significance and preferences for or

[1] Fatorić, S., & Seekamp, E. (2018). A measurement framework to increase transparency in historic preservation decision-making under changing climate conditions. Journal of Cultural Heritage, 30, 168-179.

[2] Seekamp, E., Post van der Burg, M., Fatorić, S., Eaton, M.J., Xiao, X., and McCreary, A., 2019, Optimizing historical preservation under climate change—An overview of the optimal preservation model and pilot testing at Cape Lookout National Seashore: U.S. Geological Survey Open-File Report 2018–1180, 46 p., https://doi.org/10.3133/ofr20181180.

against particular adaptation strategies. Related to the broadening of stakeholder values, we administered an online survey questionnaire with members of two partner organizations with interests in the stewardship of the historic districts (see refereed journal article Li et al., in review), prepared new outputs (geospatial maps; see data product Xiao et al., in progress) for use in one of our outreach workshops in which we piloted a new participatory planning tool, District Decisions, that uses gamification to convey model dynamics and landscape outcomes to members of associated communities (see refereed journal article Seekamp et al., in review). In summary, the project not only achieved its intended objectives but also advanced climate adaptation and participatory science by demonstrating how climate science, optimization, federal frameworks, and community engagement can be integrated into a practical tool for climate adaptation planning.

Organization and Approach:
The project was organized into a series of interrelated tasks designed to integrate climate science, optimization modeling, and community engagement into a comprehensive decision-support framework for cultural resource adaptation at Cape Lookout National Seashore.

Task 1: Data compilation and structural assessments. We first compiled baseline data on metrics of historic structures in Portsmouth and Cape Lookout Villages, including their structural conditions, historical significance, and use values. Engineering cost estimates for a range of adaptation and preservation actions (e.g., core and shell preservation, elevation, relocation, documentation, active removal) were developed in collaboration with preservation experts. This dataset formed the foundation for subsequent modeling.

Task 2: Development of the OptiPres modeling framework. Using this compiled baseline dataset, the team advanced the OptiPres Model, an optimization-based decision-support tool. The model was designed to evaluate adaptation trade-offs across a 30-year planning horizon. Probabilistic storm events and flooding projections were integrated into the OptiPres model. Optimization was chosen because it enables transparent and comprehensive evaluation of competing factors, such as financial constraints, preservation of structures, and structural integrity, etc., under changing conditions.

Task 3: Participatory engagement workshops. Model outputs were translated into geospatial maps at decadal intervals, visualizing the projected outcomes of structure-specific conditions and their adaptation actions for Cape Lookout Village and Portsmouth Village across the 30-year planning horizon under the objective of maximizing their accumulated resource values. These maps were used in structured workshops with descendant community members, agency managers, and preservation professionals. Scenario-based gamification was employed to elicit values, identify trade-offs, and test the usability of model outputs in collaborative planning. Workshops provided a forum for deliberation under simulated decadal changes, storm events, and budget constraints.

Task 4: Testing alternative decision frameworks. To examine the implications of different planning logics, we operationalized five model parameterizations based on outcomes of participatory engagement workshops, partner organization survey, and baseline OptiPres design: (1) Unconstrained model, (2) Resist-Direct-Accept (R-D-A) model, (3) Building priority model, (4) Action preference model, and (5) Public planning priority model. Each model specification has different adaptation priorities that alter outcomes. This multi-model approach was adopted to ensure both scientific rigor and community relevance.

Task 5: Visualization and communication. Visualization outputs were created that translate complex model outputs into accessible formats for decision-making reference and public engagement. Four types of output types were generated. Output A: 30-year adaptation action portfolios. Visual summaries were produced to illustrate the allocation of adaptation actions across all historic structures over the 30-year planning horizon. These portfolios highlight how different strategies accumulate resource value and alter the historic districts through time under varying model logics and budget constraints. The portfolio approach communicates the cumulative implications of adaptation decisions, allowing managers to compare how alternative approaches lead to different long-term outcomes for Cape Lookout Village and Portsmouth Village. Output B: Temporal patterns of adaptation actions and storm-related actions applied in structures. Time-series visualizations were generated in 10-year intervals to illustrate both adaptation actions and post-storm actions applied to structures across different budget scenarios. These figures highlight how conservation strategies and adaptation pathways shift over time, revealing how financial resource availability shapes the timing and type of actions implemented. Output C: Temporal changes in structure conditions and use values. Time-series visualizations were generated to track both physical structure conditions and associated use values under climate stressors. These figures demonstrate how structures transition from “good” to “fair” to “poor” or “very poor” states, as well as how adaptation actions stabilize or enhance the condition of historic structures. Output D: Geospatial maps. GIS-based maps depict the spatial distribution of structure conditions and adaptation actions across Cape Lookout Village and Portsmouth Village. Color-coded symbology shows baseline conditions of historic structures and model-selected actions at decadal intervals. These maps serve as intuitive decision-support visuals that enable interest-holders to grasp where vulnerabilities cluster, and which structures are preserved, adapted, or transformed across the 30-year planning horizon for five model configurations (Unconstrained, Resist–Direct–Accept, structure Priority, Action Preference, Public Planning Priority) under four budget scenarios.

Project Results, Analysis and Findings:

First, we revised the cultural resource value metrics for historic structures within the OptiPres Model from the pilot study and initial algorithm (Seekamp et al., 2019). These updates were made based on a science co-production workshop (March 2023) with National Park Service staff at Cape Lookout National Seashore, North Carolina State Historic Preservation Office staff, and representatives from the two partner organizations (Core Sound Waterfowl Museum and Heritage Center; Friends of Portsmouth Island). The revisions resulted in three components written as expressed management objectives: (a) maximizing historical conditions, (b) fostering awareness, and (c) maximizing financial benefits (Kibria et al., 2024). Additionally, the weights of three objectives, attributes, and sub-attributes of each objective were revised during these workshop discussions. The revised objective, attributes, sub-attributes, and their weights are presented in Table 1.

Table 1. Revised and original OptiPres Model sub-attributes of cultural resource value and associated weights

Revised Model	**Weights**	**Original Model**	**Weights**
a. Historical character and conditions	0.458	**a. Historical Significance**	0.71
Historical character	0.460	Association with fundamental purpose of the park unit	0.26
Defining character	0.652	Historical character	0.27
Uniqueness	0.348	Defining character	0.475
Condition of the building or structure	0.54	Uniqueness	0.525
b. Fostering Heritage Awareness	0.416	Condition of the building or structure	0.17
Association with fundamental purpose of the park unit	0.283	National Register	0.30
National Register	0.175	Spatial significance and eligibility	0.41
Spatial significance and eligibility	0.45	Eligibility	0.59
Eligibility	0.55	**b. Use potential**	0.29
Visitor Use	0.142	Interpretive use	0.17
Scientific Use	0.12	Third-party use	0.26
Non-profit third-party use	0.105	Operational Use	0.17
c. Financial Benefits	0.126	Visitor use	0.17
For profit third-party use	0.317	Scientific use	0.28
Operational use	0.683		

The revised objectives and weights were integrated to the revised algorithm of OptiPres Model (Figure 1). The algorithm's selectivity can be adjusted through parameters that define the threshold for accepting improvements. With sufficient iterations, the process can approximate a near-optimal solution. Because the outcomes are influenced by the timing and type of action taken, each action (or inaction) has the potential to enhance or reduce a structure's cultural resource value and affect its vulnerability.

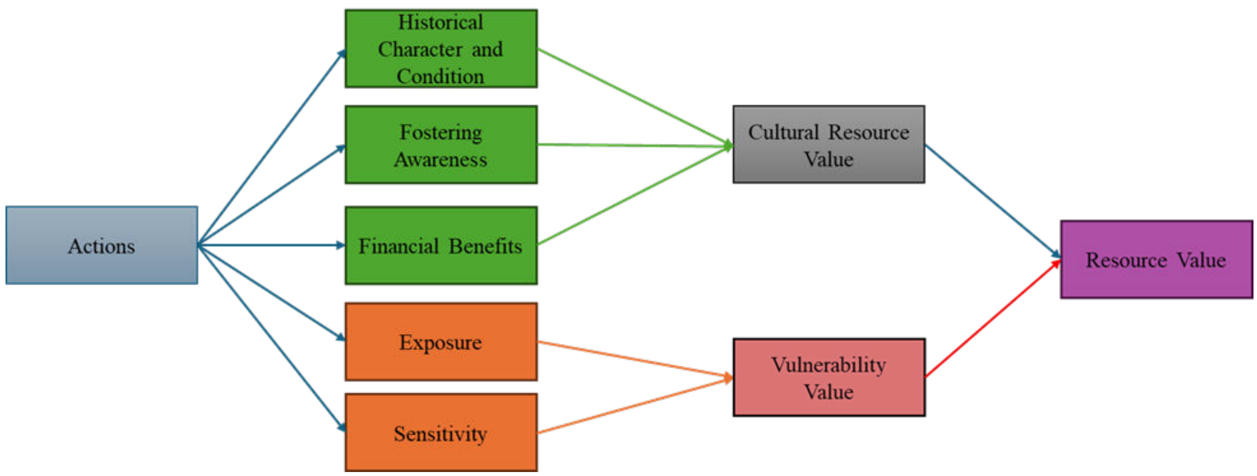

Figure 1. Simple diagram of OptiPres Model calculations and dynamics

A series of OptiPres Model variations were tested with consideration of specific needs for climate adaptation planning at Cape Lookout National Seashore, including: (1) Unconstrained model, (2) Resist-Direct-Accept (R-D-A) model, (3) Building priority model, (4) Action preference model, and (5) Public planning priority model. Visualizations of OptiPres Model outputs include: (a) 30-year adaptation action portfolios; (b): Temporal patterns of adaptation actions and storm-related actions applied in structures; (c): Temporal changes in structure conditions and use values, and (d) Geospatial maps.

Model variations 3-5 were derived following an engagement workshop in which project partners identified a group of individuals with strong place connections to the historic districts (e.g., prior owners or decedents of prior owners of the historic structures). The workshop included an overview of the OptiPres Model and the outputs of model variations 1 and 2. Then, participants were introduced to a public planning tool, District Decisions, a serious game designed by Seekamp, Xiao and Li for this project. District Decisions uses gamification to provide participants with the "power of the purse:" participants are provided with a game board (GIS map of buildings) with color coded house game pieces to represent the current conditions of each structure, as well as a list of the cost for adaptation actions for each structure, an annual budget (game money), and a worksheet to track their decisions and the resulting consequences for each decision (action or inaction) on a structure's condition. The conditions were updated after each round with the color-coded house game pieces. Three rounds of game play for each district occurred simultaneously, with NPS superintendent and NC SHPO staff present to answer questions throughout the serious game. We recorded the conversations to track which structures were of most importance (model variation 3), which adaptation actions were most preferred (model variation 4), and which outcomes resulted from game play (structure priorities and adaptation action preferences; model variation 5). A key stakeholder sentiment shared during the engagement workshop, was *Let's go back to the first step over here… we're trying to make good decisions now, because thirty years from now you can't go back*. This sentiment demonstrates the value of this type of engagement process in conveying the difficult tradeoffs facing NPS managers in a changing climate.

An example of a 30-year adaptation action portfolio for Portsmouth Village (PV) under the low budget scenario ($321,832) from the unconstrained model is displayed in Figure 2. In this example, the preservation and adaptation actions are applied to most structures in Portsmouth Village. However, two iconic structures—PV Church and PV Life Saving Station—were not maintained or adapted during the first decade of the planning horizon. This inaction results in both structures being estimated to collapse in year-8, as each structure's condition cumulatively decays to very poor conditions. All other structures were retained on the landscape, with 70% of them being elevated in the early or middle of the planning horizon. This adaptation strategy (i.e., elevating structures early in the planning horizon) reduces the sensitivity and makes the structure more resistant to climate risks (Figure 3). Additionally, core & shell preservation with historic materials was applied to 45% of structures in PV (Figure 3).

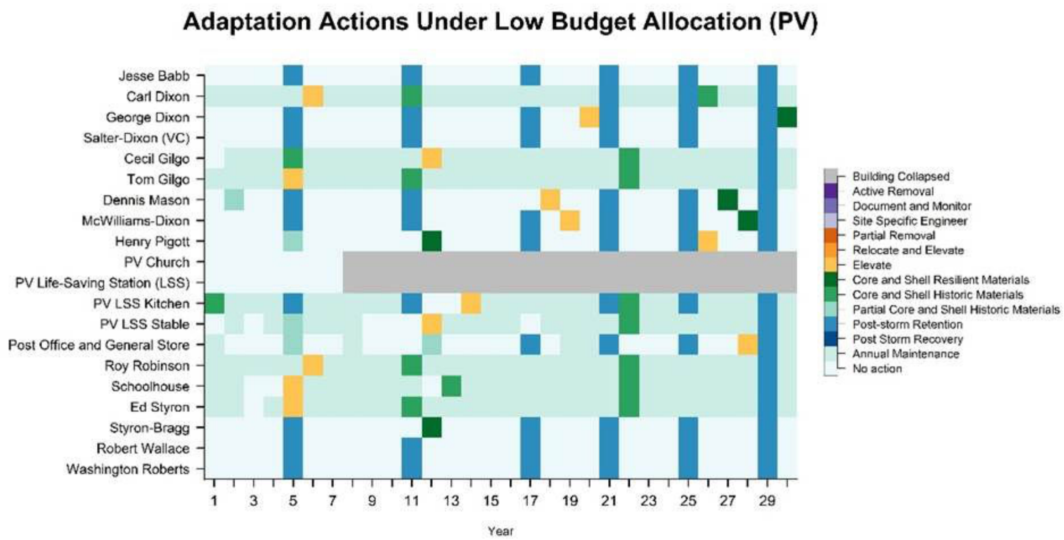

Figure 2. Adaptation portfolio of PV under low budget scenario (Unconstrained Model)

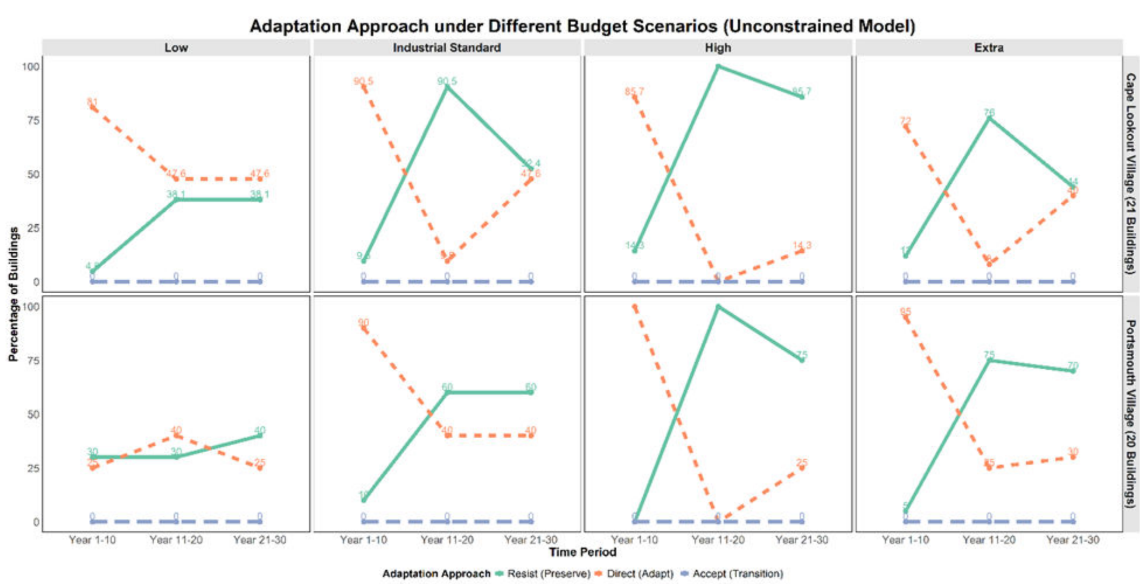

Figure 3. Proportion of structures receiving different adaptation strategy types (Resist-Accept-Direct) during 10-year intervals for four budget scenarios in Cape Lookout Village and Portsmouth Village (Unconstrained Model)

The storminess sequence for PV included storms to occur in the following years: 2024, 2030, 2036, 2042, 2046, 2050, and 2054 (Dalyander et al., in review). This storm sequence represents a reasonable frequency and magnitude (major vs. minor) of storms based on average conditions, and is used to explore the impacts of these events on the model. The storm-related actions (i.e., post-storm recovery; post-storm retention) applied to structures in Portsmouth Village by the 10-year interval under the low budget scenario are summarized in Figure 4. Post-storm retention (i.e., stabilizing and reducing sensitivity to future storms) dominates storm-related actions as the cost of post-storm recovery (i.e., historic preservation restoration) is too expensive and would otherwise leave other structures unmaintained. Following major storms in each decade (years 1-10: 2025-2034; years 11-20: 2035-2044; years 21-30: 2045-2054), the model output indicates that about 45%, 55%, 90% of structures in PV receive post-storm retention actions, respectively (Figure 4). Notably, the post-storm retention actions applied in 2053 (year 29 of the planning horizon) improve the condition of most structures retained on the landscape to good or fair at the end of the planning horizon. This finding (application of actions in year 29) demonstrates that the OptiPres Model is working correctly, as the objective function is to maximize resource value (i.e., the accumulated resource value of all structures) at the end of the 30-year planning horizon.

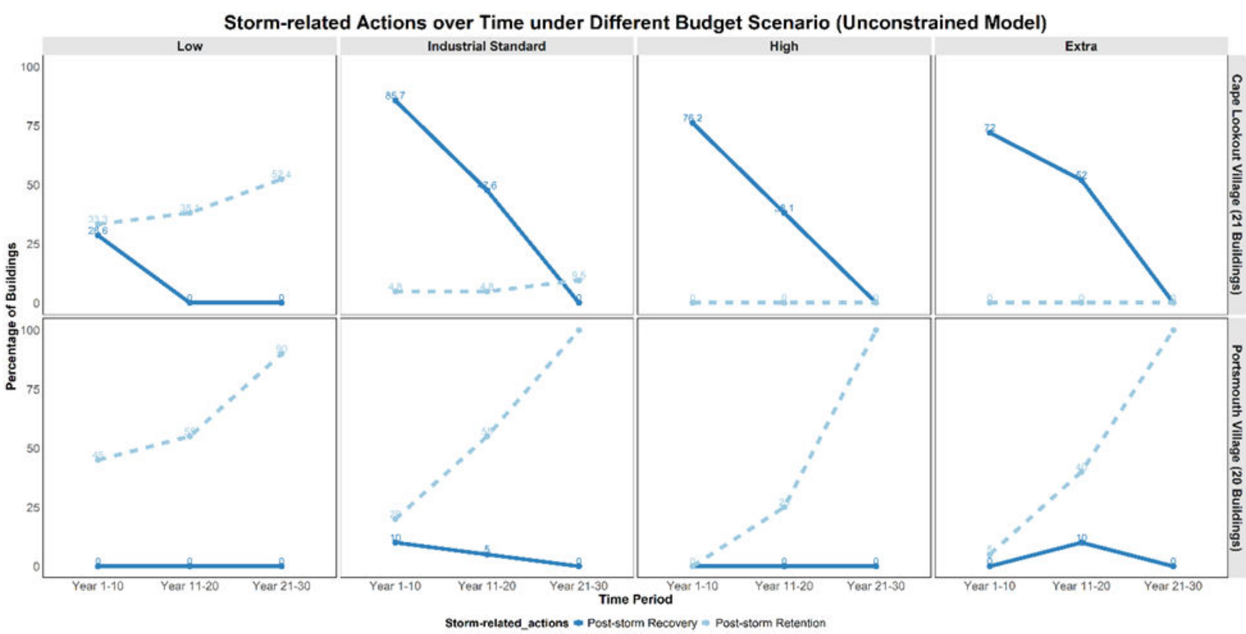

Figure 4. Proportion of structures receiving storm-related actions during 10-year intervals for four budget scenarios in Cape Lookout Village and Portsmouth Village (Unconstrained Model)

Applying or failing to apply adaptation actions across the 30-year horizon can significantly impact the conditions of structures in Portsmouth Village, which are visualized in Figure 5. For example, 7% of structures in Portsmouth Village decay to poor conditions in the first planning decade and nearly 13% of structures decays to poor conditions in the third planning decade.

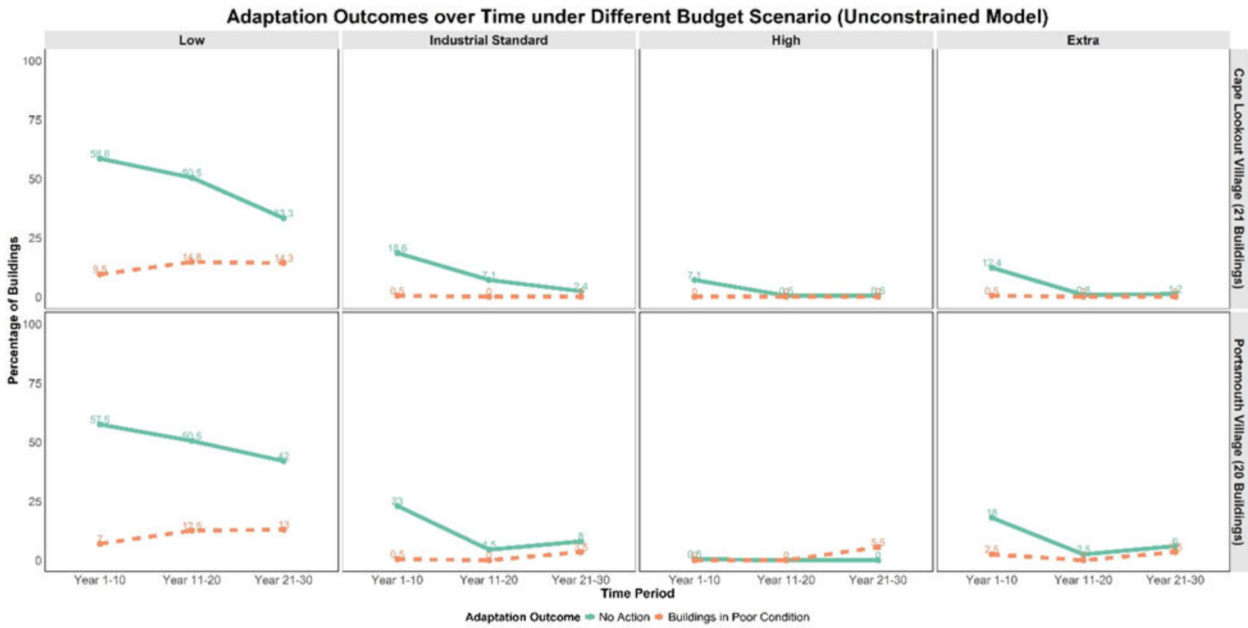

Figure 5. The proportions of structures receiving no action and in poor condition during 10-year intervals for four budget scenarios in Cape Lookout Village and Portsmouth Village (Unconstrained Model)

These sets of visualizations were generated for other four alternative model parameterizations, including Resist-Direct-Accept (R-D-A) model, Building priority model, Action preference model, and Public planning priority mode. To evaluate tradeoffs of adaptation decisions and adaptation outcomes among five models, we compared the accumulated resource value, percentage of structures collapsed and cost effectiveness of budget allocation.

When comparing accumulated resource value across the five models, the unconstrained model and the building priority model yielded higher values under both low and industry standard budget scenarios (Figure 6). Under the low budget scenario, the unconstrained model achieved the highest accumulated resource value (78.0% of the original), while the public planning priority model produced the lowest accumulated resource value (62.0%). The lower accumulated resource value from the public planning priority model is driven by two factors: (1) elevation and relocation actions were not applied to structures, leaving them more vulnerable to storm impacts compared to the unconstrained model; and (2) funding was directed toward several community-preferred structures that are expensive to maintain, leaving insufficient financial resources for other structures. Nevertheless, the public planning priority model aligns with community members' values by prioritizing actions that preserve specific structures in their original locations (i.e., the model selects actions focused on maintaining historic integrity and preserving the most iconic structures when funding is limited). Notably, the building priority model achieves the highest resource value under the industry standard budget scenario.

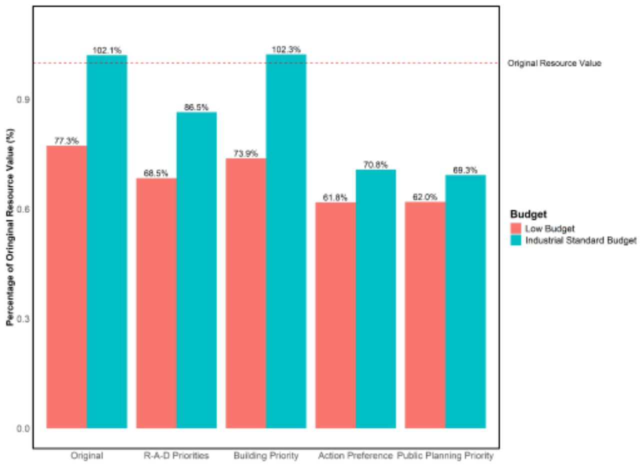

Figure 6. Proportion of accumulated resource values under low and industry standard scenario among five tested models

We also compared structure collapse rates across the five models and found that the building priority model led to the highest percentage of collapsed structures by the end of the planning horizon (36.6%) (Figure 7). In contrast, the action preference model and the public planning priority model maintained a much larger proportion of standing structures with only 2% and 12% collapsing, respectively. This outcome reflected the stakeholders request to include post-storm retention as a relatively low-cost adaptation strategy that maintains the “feeling” of the historic district. When included in the action preference model and the public planning priority model, the application of post-storm retention as an adaptation strategy (a recommended and preferred strategy by associated community stakeholders)—even when no storm occurs—improved a structure’s condition and reduced its sensitivity. As a result, more structures could be retained on the landscape. However, this approach involved important trade-offs: while structures were physically retained, some might no longer be accessible or usable, highlighting the dilemma of balancing the number of preserved structures with the possibility of their continued use.

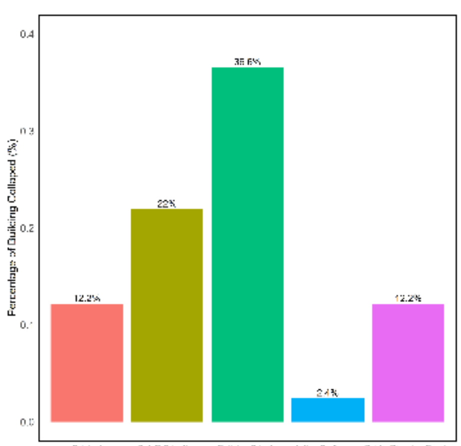

Figure 7. Percentage of structures projected to collapse under low budget scenario among five tested models

We also explored the economic efficiencies of each of the five models tested. The five models used nearly all of their allocated funding under the low budget scenario, with spending ranging from 96.2% to 98.7% of the total budget (Figure 8). In contrast, under the industry standard budget scenario, the action preference model and the public planning priority model used only 54.9% and 46.1% of the allocated funds, respectively (Figure 8).

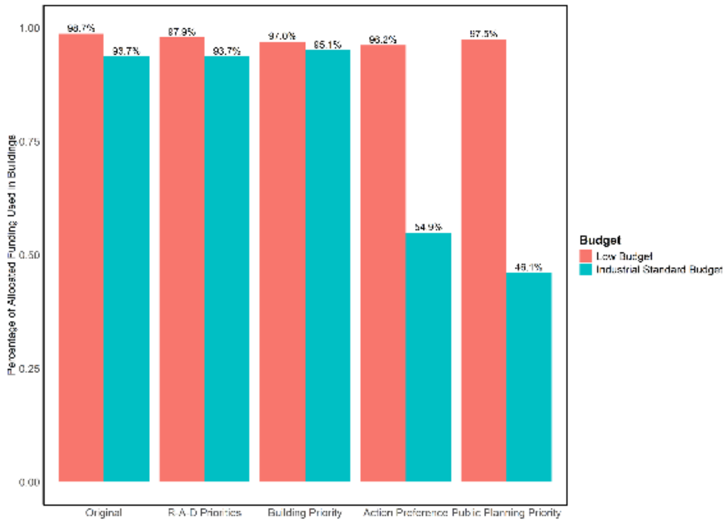

Figure 8. The percentage of allocated funding used under low and industry standard scenario among five tested models

The GIS map outputs enhance communication about how the model results influence the cultural landscapes of the historic districts. To illustrate this output, the unconstrained model at the end of the 30-planning horizon in Portsmouth Village predicted only one structure being in good condition, two structures having collapsed, and the remaining structures having had post-storm retention and being in fair condition (Figure 9).

Adaptation Actions for Portsmouth Village (2045-2055, Unconstrained Model)

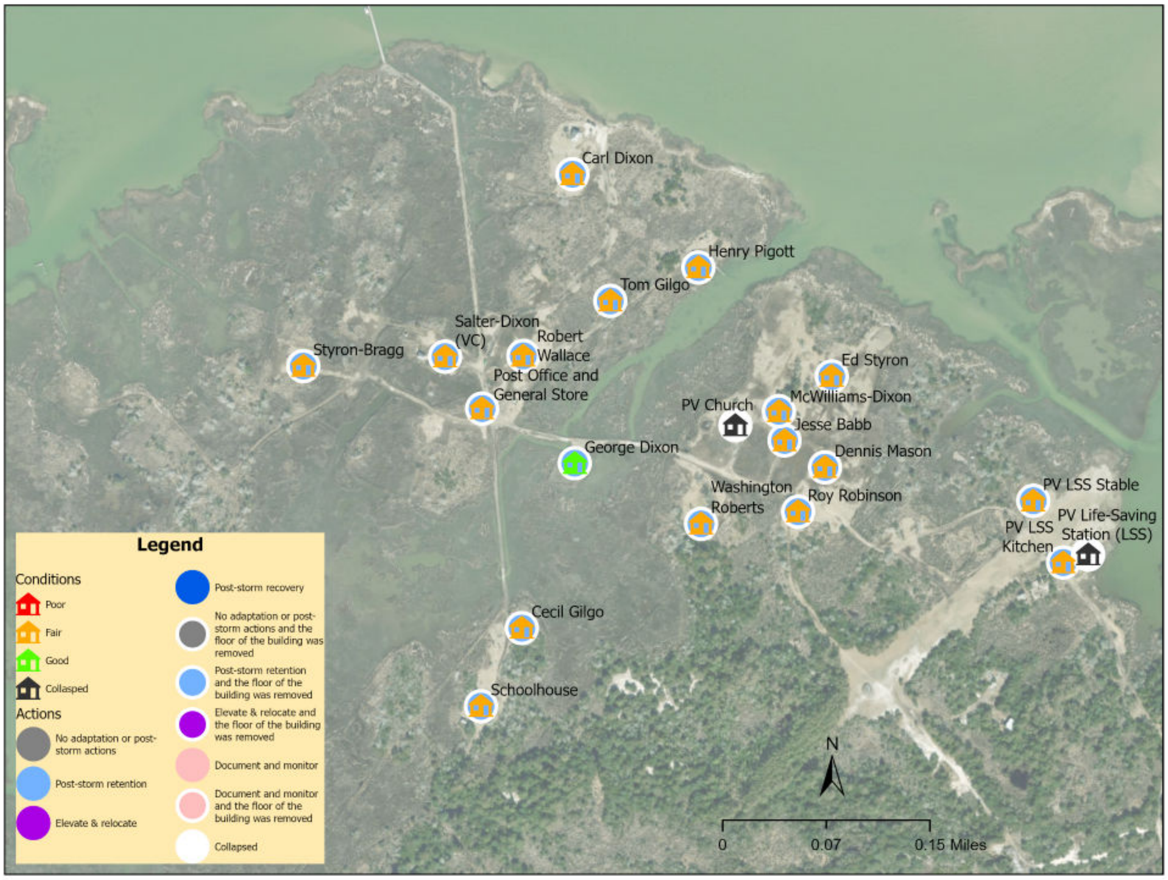

Figure 9. Geospatial map showing the outcome of the third decade (2045-2055) for the unconstrained model in Portsmouth Village.

Conclusions and Recommendations:

The project's updates to and outputs from the OptiPres Model highlight that structures in the two historic districts at Cape Lookout National Seashore face substantial and unavoidable losses without sufficient funding allocation for historical preservation. The low-budget scenario—the most realistic annual funding allocation for historical preservation—retains only about 77% of total accumulated resource value in the unconstrained model, with even lower ratios of total accumulated resource values than for the other four models. Insufficient funding limits the application of costly but necessary adaptation actions, accelerates structure deterioration, reduces public access, and increases the risk of collapse for community-preferred historical structures such as the PV Church and the PV Life-saving station. These projected losses threaten not only individual structures but also the cultural landscape and the sense of place that community members derive from an intact historic district. Findings further show that applying a rigid 10-year timeline for specific types of actions under the R-D-A framework (i.e., actions that resist change in years 1-10; actions that direct change in years 11-20; and actions that accept change in years 21-30) may diminish resource value by delaying essential adaptation actions; more flexible pathways informed by unconstrained model outputs may better support preservation goals under increasing climate stressors. The implications of these results likely can be transferred to other coastal park units with similar vulnerabilities to the stewardship of historic structures.

Our project also demonstrated that increasing funding allocation to the industry standard level fundamentally alters preservation-focused outcomes. With sufficient financial resources, relocation, elevation, and core & shell preservation can be applied early, enhancing long-term resilience to storm impacts and maintaining historical values across both villages. Under these higher budgets, preserving iconic structures and sustaining the broader structure portfolio, as well as enhanced stewardship of community priorities, can occur without compromising overall landscape integrity. The public planning priority model also illustrated that low-cost post-storm retention measures, when used proactively as an adaptation strategy, can keep more structures on the landscape when budgets are insufficient for preservation-focused stewardship. However, as an adaptation-focused strategy, post-storm retention prohibits public access into or any type of use of the structures (e.g., park operations, concessionaire rentals). A key limitation of the study that has not yet been addressed is to explore how access to and within historic districts may be compromised by storm-related damage to docks, shifts in shoals without continued dredging, and persistent nuisance flooding. These impacts could affect management decisions, which raises important questions about changes to community members' place connections and management priorities when future landscape becomes physically inaccessible. Together, these findings underscore that adaptive planning frameworks which balance historical value preservation, community preferences for structures and actions, and value-driven adaptive pathways offer transparent and place-centered decisions to preserve both the physical and cultural integrity of this heritage landscape.

Future model updates may enhance the transferability and utility of the OptiPres Model. First, incorporating financial benefits from the upcoming third-party rental programs could provide additional funding to support preservation across the villages. Second, additional research is needed to assess "letting go" decisions under severe climate stressors and to identify safe, periodic debris-removal practices or transformative actions that help maintain intangible cultural values when structures are no longer physically accessible. Third, refining the model to compare adaptation outcomes associated with different prioritization objectives could highlight where contentious decisions may exist, particularly given that higher resource values are achieved through relocation and elevation strategies in the unconstrained model but community members' expressed extreme reluctance to consider these actions as acceptable. Finally, integrating high-tech documentation and immersive virtual interpretative experiences as a transformative action into the OptiPres Model may offer a way to preserve cultural meaning and support long-term community place connections to historic districts even as climate stressors intensify and structures are lost.

Outreach and Products:

This project has diverse approaches of outreach, including:

1. **Peer-reviewed articles:**

    1) Kibria, A. S., Seekamp, E., Xiao, X., Dalyander, S., & Eaton, M. (2024). Multi-criteria decision approach for climate adaptation of cultural resources along the Atlantic coast of the southeastern United States: Application of AHP method. *Climate Risk Management, 43*, 100587.

2) Seekamp, E., Li, P., & Xiao, X. (in review). Broadening engagement through gamified climate adaptation planning for cultural resources and landscapes. *Landscape and Urban Planning*.
3) Li, P., Seekamp, E., Larson, L., Kibria, A., & Xiao, X. (in review). Community members' place connections shape adaptation preferences for cultural resources and landscapes under climate change. *Land Use Policy*.

2. Graduate student thesis:

1) Li, P. (2025). *Place connections and pathways of adaptation: Community preferences for cultural resource stewardship under climate change* (Order No. 32331513). Available from Dissertations & Theses @ North Carolina State University @ Raleigh; ProQuest Dissertations & Theses Global. (3264173252). https://proxying.lib.ncsu.edu/index.php?url=https://www.proquest.com/dissertations-theses/place-connections-pathways-adaptation-community/docview/3264173252/se-2

3. Non-blind Referred Technical Reports & Fact Sheets

1) Seekamp, E., Li, P., Kibria, A., & Xiao, X. (in press). *Climate adaptation planning of historic structures at Cape Lookout National Seashore: Partner organizations' member survey report*. [Technical report]. NC State Extension Publication, NC State University, Raleigh, NC.
2) Dalyander, P., Xiao, X., Seekamp, E., Li, P., & Eaton, M. (2024). Cape Lookout National Seashore Storm Characterization: Evaluation in Support of Cultural Resource Management. [Technical report]. The Water Institute. Prepared for N.C. State University as part of a project funded by the U.S. Geological Survey Southeast Climate Adaptation Science Center. Baton Rouge, LA. 23 p.

4. Presentations

1) Li, P., Kibria, A., Xiao, X., & Seekamp, E. (2025). Community members' place connection and climate adaptation preferences to cultural resources. Paper presented at the *2025 National Environment and Recreation Research Symposium (NERR)*, Virginia Beach, VA, April, 2025.
2) Li, P., & Seekamp, E. (2025). Investigating community members' place connections and adaptation preferences to cultural resources and landscapes under climate change. Poster presented at the *18th Annual NC State University Graduate Student Research Symposium*, Raleigh, NC, April, 2025.
3) Li, P., & Seekamp, E. (2025). Investigating community members' place connections and adaptation preferences to cultural resources and landscapes under climate change. Poster presented at the *2025 College of Natural Resources Graduate Research Symposium*, NC State University, Raleigh, NC, March, 2025.

4) Seekamp, E. (2025). Recovery-driven learning for the future of cultural landscapes. Panel presentation at the *2025 Southeast CASC Regional Science Symposium*, Asheville, NC, September, 2025.
5) Li. P. (2025). When do we let go? Futures and thresholds for cultural resource adaptation. Lightning talk presented at the *2025 Southeast CASC Regional Science Symposium*, Asheville, NC, September, 2025.
6) Li, P., Seekamp, E., Larson, L., Kibria, A., & Xiao, X. (2025). Community members' place connections shape adaptation preferences for cultural resources and landscapes under climate change. Poster presented at the *2025 Southeast CASC Regional Science Symposium*, Asheville, NC, September, 2025.
7) Li, P., Seekamp, E., Larson, L., Kibria, A., & Xiao, X. (2025). Community members' place connections shape adaptation preferences for cultural resources and landscapes under climate change. Poster presented at the *2025 Share Your Science Symposium*, Raleigh, NC, November, 2025.
8) Kibria, A.S.M.G., Seekamp, E., Xiao, X., Li, P., Dalynader, S., Eaton, M. (2024). Fostering Consensus Among Stakeholders in Multi-Criteria Climate Adaptation Decisions with The AHP Method. The Southeast Environment and Recreation Research (SERR) Conference, March 24- 26, Helen, Georgia, USA.
9) Kibria, A.S.M.G., Seekamp, E., Xiao, X., Li, P., Dalynader, S., Eaton, M. (2024). Driving Consensus Among Stakeholders on Climate Adaptation Decisions for Coastal Resources. 2024 Coastal Resiliency Research Symposium. September 19-20, 2024, Morehead, NC, USA.
10) Dr. Xiao Xiao participated in a panel discussion session at the 2024 Coastal Resiliency Research Symposium. September 19-20, 2024, Morehead, NC, USA.
11) Kibria, A., Seekamp, E., Xiao, X., Li P., Dalyander, S., Eaton, M. 2023. Climate-vulnerable heritage management in the Outer Banks of southeastern United States: Application of analytic hierarchy process. Paper presented at the 2023 International Association of Society & Natural Resources (IASNR) Symposium, June 11-15, Portland ME.

5. Workshops and meetings

1. February 11, 2025: Community Night for Cape Lookout National Seashore. Drs. Seekamp and Xiao, along with graduate student Peizhe Li, partnered with Core Sound Waterfowl Museum and Heritage Center director Karen Amspacher and Cape Lookout National Seashore Superintendent Jeff West to host a community event on Harkers Island. The event featured decade-by-decade photo slides of historic structures that were used to prompt storytelling and reflect on cultural changes across generations.
2. March 8, 2025: Adaptation Planning Activity with Community Members of Cape Lookout National Seashore. Drs. Seekamp and Xiao, Peizhe Li, and project partners Karen Amspacher and Jeff West facilitated an interactive adaptation planning session with descendant community

members. The session employed a scenario-based planning tool, District Decisions, to elicit values, priorities, and preferences under varying environmental conditions.

3. September 21, 2024: Friends of Portsmouth Island Annual Meeting. Drs. Xiao and Kibria, as well as graduate student Peizhe Li, attended the annual meeting of Friends of Portsmouth Island (a partner organization of Cape Lookout National Seashore and this project). Dr. Xiao presented the findings of the survey to the community members who also participated in our survey data collection.
4. Additional multi-stakeholder workshop convenings to meet project objectives:
    a. January 17-20, 2023 (in-person): Frame problem, set objectives, weight objectives; site visits
    b. March 27, 2023 (online): Identify adaptation actions
    c. May 17, 2023: Weight adaptation actions, revise measurement framework (in-person)
    d. June-July, 2-23: Elicit measurement framework weights and metric scores (online)

6. Data products

1) Xiao, X., Seekamp, E., & Li, P. (in process). *Climate adaptation actions for historic structures at Cape Lookout National Seashore: Optimal preservation model maps* [Data set]. ASU Library Research Data Repository. https://doi.org/10.48349/ASU/5XXFLT
2) Dalyander, S. 2023. Cape Lookout National Seashore Storm Characterization: Annual Progress Report, 2022-2023 (in support of: Examining Diverse Management Objectives and Broadening Stakeholder Engagement for Climate Adaptation Planning of Historic Structures Stewarded by the National Park Service). The Water Institute.