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Testing the Transferability of the Optimal Preservation Model at Gulf Islands National Seashore

Natural Resource Report NPS/GUIS/NRR—2021/2303





ON THIS PAGE
Interpretive sign outside Building 5 (Post Administration Building/ Discovery Center) within The Pensacola Harbor Defense Project Historic District displaying impacts from Hurricane Ivan in 2004 at Gulf Islands National Seashore. Photo credit: E. Seekamp (2018).

ON THE COVER
Sandbags protecting structural columns from erosion during storm events inside Fort Pickens within The Pensacola Harbor Defense Project Historic District at Gulf Islands National Seashore. Photo credit: E. Seekamp (2018).

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Natural Resource Report NPS/GUIS/NRR—2021/2303

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Contents

Page

Figures v

Tables x

Appendices xi

Executive Summary xii

Acknowledgements: xviii

Introduction 1

Study Area 3

Methodology 4

The Optimal Preservation Model 4

Climate Adaptation Actions Considered 6

Model Algorithm 7

Annual Budget Scenarios 8

Model Improvements 9

Model Results and Interpretations 11

Original Model 11

Scenario 1—No Budget 11

Scenario 2—An Uncertain Budget 13

Scenario 3—Sufficient Annual Maintenance Budget 25

Scenario 4—Accounting for Periodic Funding 28

Updated Model A – Fort Pickens Maintenance and Use Potential Dynamics 32

Scenario 1—No Budget (Updated Model A) 33

Scenario 2—An Uncertain Budget (Updated Model A) 34

Scenario 3—Sufficient Annual Maintenance Budget (Updated Model A) 43

Scenario 4—Accounting for Periodic Funding (Updated Model A) 46

Updated Model B – Fort Pickens Maintenance and Core and Shell Preservation 48

Scenario 1—No Budget (Updated Model B) 49

Contents (continued)

Page

Scenario 2—An Uncertain Budget (Updated Model B) 50

Scenario 3—Sufficient Annual Maintenance Budget (Updated Model B) 59

Scenario 4—Accounting for Periodic Funding (Updated Model B) 62

Discussion 65

Insights from the Transferability Study 65

Insights from Model Enhancements 66

Considerations for Future Applications of the OptiPres Model 67

Conclusions 70

References 72

Figures

Page

Figure 1. OptiPres Model dynamics (Seekamp and others 2019b). 8

Figure 2. Accumulated resource values of all structures at the beginning and end of the 30-year planning horizon under a "no budget" scenario. 12

Figure 3. Percentages of total resource value for each structure under "no budget" scenario 13

Figure 4. Expected total resource value of the optimal management portfolio at the end of the 30-year period, as a function of annual budget (black line) and compared to the original total resource value (red line). 14

Figure 5. Actions applied under a $50,000 annual budget allocation. 15

Figure 6. Percentage of accumulated resource value for each structure under a $50,000 annual budget allocation and total cost for each structure receiving some type of action. 16

Figure 7. Actions applied under a $300,000 annual budget allocation. 17

Figure 8. Percentage of accumulated resource value for each structure under a $300,000 annual budget allocation and total cost for each structure receiving some type of action. 19

Figure 9. Actions applied under a $400,000 annual budget allocation. 20

Figure 10. Percentage of accumulated resource value for each structure under a $400,000 annual budget allocation and total cost for each structure receiving some type of action. 21

Figure 11. Actions applied under a $500,000 annual budget allocation. 22

Figure 12. Percentage of accumulated resource value for each structure under a $500,000 annual budget allocation and total cost for each structure receiving some type of action. 23

Figure 13. Actions applied under a $750,000 annual budget allocation. 24

Figure 14. Percentage of accumulated resource value for each structure under a $750,000 annual budget allocation and total cost for each structure receiving some type of action. 25

Figure 15. Actions applied under a $57,232,370 annual budget allocation. 26

Figure 16. Percentage of accumulated resource value for each structure under a $57,232,370 annual budget allocation and total cost for each structure receiving some type of action 27

Figure 17. Actions applied under a $400,000 annual budget allocation with additional $400,000 allocation every five years. 29

Figures (continued)

Page

Figure 18. Percentage of accumulated resource value for each structure under a $400,000 annual budget allocation with an additional $400,000 allocation every five years and total cost for each structure receiving some type of action. 30

Figure 19. Actions applied under a $57,232,370 annual budget allocation with additional $400,000 allocation every five years. 31

Figure 20. Percentage of accumulated resource value for each structure under a $57,232,370 annual budget allocation with an additional $400,000 allocation every five years and total cost for each structure receiving some type of action. 32

Figure 21. Accumulated resource values of all structures at the beginning and end of the 30-year planning horizon under a "no budget" scenario (Updated Model A). 33

Figure 22. Percentages of total resource value for each structure under "no budget" scenario (Updated Model A) 34

Figure 23. Expected total resource value of the optimal management portfolio at the end of the 30-year period, as a function of annual budget (black line) and compared to original total resource value (red line) (Updated Model A) 35

Figure 24. Actions applied under a $50,000 annual budget allocation (Updated Model A). 36

Figure 25. Percentage of value of each structure under the budget of $50,000 every year (Updated Model A). 37

Figure 26. Actions applied under a $300,000 annual budget allocation (Updated Model A). 38

Figure 27. Percentage of value of each structure under the budget of $300,000 every year (Updated Model A). 39

Figure 28. Actions applied under a $400,000 annual budget allocation (Updated Model A). 40

Figure 29. Percentage of value of each structure under the budget of $400,000 every year (Updated Model A). 41

Figure 30. Actions applied under a $500,000 annual budget allocation (Updated Model A). 42

Figure 31. Percentage of value of each structure under the budget of $500,000 every year (Updated Model A). 43

Figures (continued)

Page

Figure 32. Actions applied under a $57,232,370 annual budget allocation (Updated Model A). 44

Figure 33. Percentage of value of each structure under the budget of $57,232,370 every year (Updated Model A). 45

Figure 34. Actions applied under a $400,000 annual budget allocation with additional 400,000 budget allocation every five years (Updated Model A). 47

Figure 35. Percentage of value of each building under a $400,000 annual budget allocation with additional 400,000 budget allocation every five years (Updated Model A). 48

Figure 36. Accumulated resource values of all structures at the beginning and end of the 30-year planning horizon under a “no budget” scenario (Updated Model B). 49

Figure 37. Percentages of total resource value for each structure under “no budget” scenario (Updated Model B) 50

Figure 38. Expected total resource value of the optimal management portfolio at the end of the 30-year period, as a function of annual budget (black line) and compared to the beginning total resource (red line) (Updated Model B). 51

Figure 39. Actions applied under a $50,000 annual budget allocation (Updated Model B) 52

Figure 40. Percentage of value of each structure under the budget of $50,000 every year (Updated Model B). 53

Figure 41. Actions applied under a $300,000 annual budget allocation (Updated Model B) 54

Figure 42. Percentage of accumulated resource value for each structure under a $300,000 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B). 55

Figure 43. Actions applied under a $400,000 annual budget allocation (Updated Model B) 56

Figure 44. Percentage of accumulated resource value for each structure under a $400,000 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B). 57

Figure 45. Actions applied under a $500,000 annual budget allocation (Updated Model B) 58

Figures (continued)

Page

Figure 46. Percentage of accumulated resource value for each structure under a $500,000 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B). 59

Figure 47. Actions applied under a $57,232,370 annual budget allocation (Updated Model B). 60

Figure 48. Percentage of accumulated resource value for each structure under a $57,232,370 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B). 62

Figure 49. Actions applied under a $400,000 annual budget allocation with additional $400,000 allocation every five years (Updated Model B). 63

Figure 50. Percentage of value of each building under a $400,000 annual budget allocation with additional $400,000 allocation every five years (Updated Model B). 64

Figure 51. Components of resource value under annual allocation of $50,000. 93

Figure 52. Components of resource value under annual allocation of $300,000. 94

Figure 53. Components of resource value under annual allocation of $400,000. 95

Figure 54. Components of resource value under annual allocation of $500,000. 96

Figure 55. Components of resource value under annual allocation of $750,000. 97

Figure 56. Components of resource value under annual allocation of $57,232,370. 98

Figure 57. Components of resource value under annual allocation of $400,000 with an additional $400,000 every five years. 99

Figure 58. Components of resource value under annual allocation of $57,232,370 with an additional $400,000 every five years. 100

Figure 59. Components of resource value under annual allocation of $50,000 (Updated Model A). 101

Figure 60. Components of resource value under annual allocation of $300,000 (Updated Model A). 102

Figure 61. Components of resource value under annual allocation of $400,000 (Updated Model A). 103

Figure 62. Components of resource value under annual allocation of $500,000 (Updated Model A). 104

Figures (continued)

Page

Figure 63. Components of resource value under annual allocation of $57,232,370 (Updated Model A). 105

Figure 64. Components of resource value under annual allocation of $400,000 with additional 400,000 allocation every five years (Updated Model A). 106

Figure 65. Components of resource value under annual allocation of $50,000 (Updated Model B). 107

Figure 66. Components of resource value under annual allocation of $300,000 (Updated Model B). 108

Figure 67. Components of resource value under annual allocation of $400,000 (Updated Model B). 109

Figure 68. Components of resource value under annual allocation of $500,000 (Updated Model B). 110

Figure 69. Components of resource value under annual allocation of $57,232,370 (Updated Model B). 111

Figure 70. Components of resource value under annual allocation of $400,000 with an additional allocation of 400,000 every five years (Updated Model B). 112

Tables

Page

Table 1. Information about the structures within The Pensacola Harbor Defense Project Historic District. 76

Table 2. Comparison of weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO). 78

Table 3. Resource value of structures in the Pensacola Harbor Defense Project Historic District by weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO). 79

Table 4. Optimal Preservation (OptiPres) Model dynamics associated with each action. 81

Table 5. Adaptation actions and maintenance costs for the 28 historic structures. 87

Table 6. Updated Optimal Preservation (OptiPres) Model dynamics for Use Potential associated with each action (Updated Model A). 88

Table 7. Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Original Model. 114

Table 8. Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Modified Model A. 116

Table 9. Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Modified Model B. 118

Table 10. Percentage of total cost contributions for each structure under varying annual allocations: Original Model. 120

Table 11. Percentage of total cost contributions for each structure under varying annual allocations: Modified Model A. 122

Table 12. Percentage of total cost contributions for each structure under varying annual allocations: Modified Model B. 124

Appendices

Page

Appendix 1. Study site information. 74

Appendix 2. Weights, resource values and adaptation actions applied in the Optimal Preservation (OptiPres) Model. 78

Appendix 3. Value of condition, remaining significance, and use potential for 28 structures associated with each scenario 92

Appendix 4. Percentage contribution of each structure to the accumulated resource value and total costs at the end of the 30-year planning horizon under each scenario 113

Executive Summary

Project Rationale

This is an exploratory study that can inform decisions, but does not prescribe specific actions, nor does it take the place of other required decision-making steps or processes. The impacts predicted in a changing climate pose challenges to cultural resource management. In coastal environments, cultural resources are particularly vulnerable to ground-related flooding and erosion from storm-related events and sea level rise. The extent of impacts from these weather and climatic events are dependent upon the sensitivity of the materials that comprise the cultural resources, as well as the exposure of the cultural resources on the landscape. Moreover, fiscal constraints limit the extent to which cultural resources can be maintained (as evidenced by ongoing deferred maintenance issues) and adapted. Current policy guidance for the National Park Service (NPS) states that the agency "will prioritize cultural resource funding and management actions on projects that integrate vulnerability and resource significance" (NPS 2014).

Study Purpose

In this report, we present an application of the Optimal Preservation (OptiPres) Model, a climate adaptation planning and decision support framework for historic structures, at Gulf Islands National Seashore (GUIS). The purpose of the study was to test the transferability of the OptiPres Model to another coastal site managed by the NPS, following a successful pilot test at Cape Lookout National Seashore (CALO) (see: Seekamp and others 2019). Additionally, the application of the OptiPres Model at GUIS allows the assessment of how well the model functions for multiple types of structures: wooden buildings, and masonry buildings, forts and batteries.

Study Location

This study included 28 structures located within the historical context of the Pensacola Harbor Defense Project Historic District, Fort Pickens unit, at GUIS. These structures have experienced considerable and repeated historical flooding, many of which have sustained considerable damage during storm events. These sensitivities and their location on Santa Rosa Island (exposure) make them particularly vulnerable to the impacts associated with the accelerating climate variability (Peek et al. 2015). As such, park managers are challenged to meet historic preservation planning goals not only by fiscal constraints but surmounting vulnerabilities, making prioritization of adaptation actions a critical need.

Methodology

Model Overview

The OptiPres Model examines funding allocation decisions for maximizing the resource value (i.e., historical significance and use potential) of historic structures across a 30-year planning horizon, while considering climate change vulnerabilities, costs of adaptation actions, and fiscal constraints. Additionally, the OptiPres Model incorporates dynamics that mimic how management decisions, including no action and adaptation actions, affect the resource value and vulnerability of a historic structure.

It is important to note that the OptiPres Model is not designed to be a prescriptive planning and decision support framework. Rather, the OptiPres Model enables insights regarding the tradeoffs that would be necessary to maximize the accumulated resource value of all historic structures within a specified landscape under different fiscal allocation scenarios. Using an optimization algorithm, the OptiPres Model evaluates trade-offs between:

- Investing in actions that maintain or preserve resources in situ,
- Investing in actions that preserve a structure by elevating it higher than its original location,
- Making triage decisions to free-up resources for more costly actions, or
- Making triage decisions that shift management attention from one type of historical resource to other types of historical resources.

Model Updates

This application of the OptiPres Model also included GUIS staff perceptions of the relative importance of the resource value (significance and use potential) attributes to test the ability for park-level priorities to be made explicit. Additionally, we included tests of several model updates:

- Dynamics associated with a structure's use potential when annual maintenance is withheld or reinstated,
- Changing the constraint of the core and shell preservation action to more typical cycles (once every 10 years rather than once every 30 years), and
- Fractional annual maintenance costs for large, high-cost structures (i.e., Fort Pickens).

Scenarios Tested

The optimization process results in the selection of the combination of annual investments that provides the highest resource value to the decision-maker over a 30-year planning horizon given a specified annual budget allocation. In the transferability test, the annual budget allocations were:

- $300,000 ("low" budget scenario),
- $400,000 ("typical" budget scenario), and
- $500,000 ("high" budget scenario).

These scenarios reflect the range of costs for planned projects (2018-2022) under the Park's comprehensive fee plan, which is funded from visitor fees collected under the Federal Recreation Enhancement Act. We also examined budget uncertainty by running the model in:

- $50,000 increments from $0 to $500,000, and at $750,000 and $1,000,000 ("uncertain" budget scenario).
- As the "high" budget scenario was less than 1% of the total annual maintenance cost estimates for the 28 structures, we included several other planning scenarios in the model runs to better explore the possibility of the triage decision tradeoffs. These model runs set the annual budget allocations at:
- $57,450,000 ("sufficient annual maintenance" budget scenario),

- $400,000 ("typical" budget) + an additional $400,000 allocation every 5 years ("periodic funding increase" budget scenario), and,
- $57,232,370 ("sufficient annual maintenance" budget) + an additional $400,000 allocation every 5 years ("periodic funding increase" budget scenario).

These periodic funding increase model runs, which were also included in the CALO pilot test, allowed us to examine how pulses of funding (e.g., through competitive grants or donation funding) may enhance the maximization of resource values across the 30-year planning horizon.

Key Findings

Transferability Test

The study results support that the OptiPres Model is:

- **Transferable** for use in **other coastal NPS units** with structures vulnerable to sea level rise and storm-related flooding and erosion.
- **Transferable** to evaluate adaptation strategies to preserve **diverse types of historic structures.**
- **Locally adaptable** to integrate park-level value judgments about the relative importance of resource value (significance and use potential) attributes.

Scenario Results

The findings of the OptiPres Model at GUIS suggest:

- **Spending any money to manage even a subset of structures is better than doing nothing.**
    - No action ($0 budget) results in nearly ~55% loss in accumulated resource value.
- **Spending more money leads to improved management performance.**
    - Similar trends were found for the "low", "typical" and "high" budget scenarios, with increasing accumulated resource values as annual budget allocations increased, in which ~76%, 78%, and 79%, respectively, of the original accumulated resource value was retained.
- **Insufficient budget allocations can drastically lower the accumulated resource value within a historic district.**
    - The "low", "typical" and "high" budget scenarios were never sufficient for even the annual maintenance of Fort Pickens or any of the batteries.
    - The "sufficient annual maintenance" budget scenario retained ~94% of the original accumulated resource value.

- **Surges in budget allocations (+ "periodic funding increase" budget scenarios) may reduce a structure's sensitivity.**
    - The timing of core and shell preservation actions tended to occur earlier for more structures when "periodic funding" is available, which enhances the condition of structures and, likely, their ability to sustain less damage if a storm-event were to occur during the 30-year planning cycle.
- **Triage decisions for lower-valued structures may be necessary to maintain higher-valued structures.**
    - When budgets are insufficient, structures with the lowest resource values received no action to enable maintenance or preservation actions for structures with the highest resource values.
- **Avoiding deterioration of historic structures to poor condition class is optimal**
    - Decay in a structure's resource value was minimized by selecting core and shell preservation at optimal times in the planning period to avoid the penalties associated with the 'poor' condition class. Simultaneously, allowing a structure to deteriorate to 'near poor' conditions was another type of triage decision that allowed for the management of other structures.
- **Undesirable management outcomes are possible when budgets are insufficient.**
    - The "low", "typical" and "high" budget scenarios could only maintain wooden and masonry buildings, not the fort or batteries, with the annual maintenance and core and shell preservation actions.
    - Given the prominence of Fort Pickens with the historic context of the district, the reliance on fee-generated income for preservation and adaptation actions may result in an undesirable management situation.
    - A critical risk facing park managers is the inefficiencies of current budget allocations for maintenance, preservation treatments, and adaptation actions.
- **Some coastal NPS units may not be suitable for adaptation**
    - There was no specific threshold in annual budget allocations in which adaptation was the optimal action for any of the structures.
    - Raising the elevation of a structure was not selected for any of the wooden and masonry buildings due to the protections offered by the existing sea wall, siting (the highest elevation within the historic district), current floor elevations, or some combination thereof. We verified with the researchers who conducted the vulnerability assessment (Peek and others 2015) that these characteristics would

result in no change in the vulnerable scores if investments were made to further *elevate* wooden and masonry buildings.

- The decay in resource values associated with *elevating* wooden and masonry buildings, and the costs associated with elevating without reducing vulnerability, make annual maintenance and core and shell preservation the optimal actions.

- The decay in resource values associated with *document and monitor* and *active removal*, despite being of lower cost than *elevate*, made them nonoptimal actions, particularly as inaction is not associated with a "point of no return" penalty (in which there would be human health and safety concerns that would require a forced choice of either *document and monitor* or *active removal*).

Model Enhancement Results

The enhancements to the OptiPres Model enabled more realistic management conditions to be reflected. Specifically, we found that:

- **Use potential dynamics**, which account for human safety, **enhance budgetary effectiveness in the model.** However, use potential dynamics result in lower accumulated resource values at the end of the 30-year planning horizon, as declines in condition are also affiliated with declines in the potential for operation, third-party and visitor use.

- **Enabling core and shell preservation to be selected within 10-year cycles during the planning period**, which reflects more typical timing of preservation treatments, **results in higher accumulated resource values at the end of the 30-year planning horizon.** It seems that decay associated with not applying annual maintenance periodically on some buildings to accommodate the benefits of cyclic maintenance might be an appropriate tradeoff in the stewardship of historic structures given extreme fiscal constraints.

- **Partial funding for the maintenance of Fort Pickens did not minimize losses to its historic value.** Yet, this partial funding approach to annual maintenance may be worthy of future exploration as a new category of actions that could be applied in future modeling efforts. However, the algorithm may need to be updated in such a way that if partial annual maintenance was selected in one year, it must be selected in each subsequent year until the structure is fully maintained.

Future modifications to improve the decision model include:

- Enhancing and standardizing cost estimates for adaptation actions,
- Integrating probabilistic events such as hurricanes and post-storm recovery dynamics,
- Testing more complex objective functions, and
- Refining the ability to elicit and include stakeholder input.

Concluding Remarks

This project focuses on a decision support framework, the OptiPres Model, that is intended for climate adaptation planning of historic structures. Key contributions of this work are in the OptiPres Model's ability to provide a multi-decadal approach to facilities management for historic structures while also considering climate change risks and vulnerabilities. While many historic structures are contributing features of historic districts and cultural landscapes, our project scope does not seek to assess the effects of adaptation on the historic setting or historic context(s). Rather, the scope of our project seeks to investigate a range of budgetary scenarios and analyze the effectiveness of each scenario in safeguarding accumulated resource value of all structures included in the modeling effort. It is our hope that by providing a framework for prioritizing adaptation actions, appropriate subject matter experts will have a foundation for assessing the cumulative effect on historic districts and cultural landscapes.

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Introduction

Tangible cultural resources are the physical remains of what is considered to be significant about heritage; however, they are non-renewable resources that, once lost, cannot be recovered. The U.S. Department of the Interior National Park Service (NPS) is charged with cultural resource stewardship, which includes the planning and management of resources that hold important societal meanings regarding historic and prehistoric heritage (NPS, 1995). Yet, stewardship of cultural resources is challenged not only by limited fiscal resources but also by natural hazards and climate-change effects, such as rising seas and increased storm-related flooding and erosion in coastal zones (Rockman and others, 2016). In particular, the sensitivity of materials to typical decay patterns and rates can be increased by declining conditions associated with deferred maintenance, by increased exposure to natural hazards and climate-change effects, or both. As the vulnerability of materials increases, the integrity of cultural resources can decline, negatively affecting important historical, cultural, and scientific associations and, thus, the significance of the resources (Seekamp and others 2019b; Xiao and others 2019). In response, managers are faced with difficult tradeoffs to achieve desired management outcomes related to maximizing the resource values of historic structures (for example, significance and use potential) within cultural landscapes.

Managers recognize that adaptation actions can themselves compromise the integrity of (and associations embedded within) cultural resources. Determining which specific resources to prioritize for adaptation (e.g., elevating or moving) further complicates heritage stewardship, as decisions are value-laden and budgets are rarely sufficient to respond to all resource needs. Prioritization of adaptation actions provides incomplete guidance to decision makers, who are then left to face the critical decision of how to allocate a finite budget across the prioritized resources to achieve a desired management benefit. A more effective approach to provide decision-relevant guidance is to address allocation decisions as portfolio problems. Rather than evaluating the relative priority of one resource over another, a portfolio approach assesses the expected management benefit of allocating decisions across a collection of resources or investments. The decision then is to select the portfolio which maximizes the overall resource value.

The purpose of this study was to assess the transferability of the decision framework, the Optimal Preservation (OptiPres) Model, to a wider range of allocation planning decisions. The OptiPres Model was originally developed to inform planning decisions for adapting specific types of cultural resources, historic structures, to climate change. The OptiPres Model uses numerical optimization algorithms to integrate multiple considerations, including budget constraints, cultural resource vulnerabilities to climate-change effects, cultural resource conditions, heritage values, and the use potential of cultural resources (Seekamp and others 2019b; Xiao and others 2019). The OptiPres Model was designed to help mangers consider difficult tradeoffs to achieve desired management outcomes related to maximizing the resource values (that is, historical significance and use potential) of historic structures. In particular, the outputs of the OptiPres Model help inform priorities for maintenance and adaptation of historic structures given specified budget scenarios. More specifically, the OptiPres Model outputs enable assessments of the timing and application of a portfolio of maintenance and adaptation actions to most effectively preserve an assortment of structures

associated with different histories, intended uses, current conditions, and construction materials over a 30-year planning horizon given a specified annual budget allocation. Initial runs of the OptiPres Model were pilot tested on a subset of buildings located within two historic districts at Cape Lookout National Seashore, North Carolina (Seekamp and others 2019b), which were refined to account for changes to the vulnerability of buildings in the years in which adaptation actions were applied (Xiao and others 2019).

The modelling effort described in this report applies and adapts the OptiPres Model's original algorithm to the structures associated with the Pensacola Harbor Defense Project Historic District, Fort Pickens unit, at Gulf Islands National Seashore. First, we applied the original algorithm to provide the NPS with an assessment of whether or not the OptiPres Model is transferable to other coastal parks that have additional types of historic structures (for example, masonry forts and buildings, concrete batteries and concrete buildings) beyond the types of historic structures included in the pilot test at Cape Lookout National Seashore (that is, wooden buildings and a masonry lighthouse). Then, we adapted the original algorithm to provide the National Park Service with a more robust modelling effort: (a) more accurately accounting for the loss of a structure's current or potential use when no action occurs, (b) accounting for the likelihood that cyclic maintenance (that is, core and shell preservation treatments) would be needed more than once in a 30-year planning cycle, and (c) accounting for cost and capacity constraints associated with the annual maintenance of Fort Pickens.

It is important to note that the OptiPres Model provides one source of information that can be considered during climate adaptation planning efforts. Specifically, the values included in the model predominately reflect those of National Park Service personnel and State Historic Preservation Office personnel (see Fatorić and Seekamp 2017, 2018). Managers should also consider additional stakeholder values, such as local community members and visiting publics, when making allocation decisions that affect the integrity of and meanings associated with structures listed on the National Register of Historic Places. For example, see Seekamp and others (2019a) for a stakeholder studies synthesis report that demonstrates diverse stakeholder groups' preferences for climate adaptation of historic structures.

Study Area

Gulf Islands National Seashore was designated in 1971 and includes 2 administrative units, one in Florida and one in Mississippi. In the 2014 General Management Plan, the NPS stated that managers are challenged by the increase in "intensity and frequency of storms in the Gulf of Mexico," which "has accelerated the rate of needed repairs on national seashore infrastructure resulting from storm damage" and that "climate change forecasts reinforce the likelihood that this trend will continue into the foreseeable future" (NPS 2014, p. ii). Gulf Islands National Seashore's Foundation Document indicates that the purpose is to preserve and interpret "an interconnected system of coastal defense fortifications, barrier islands, wilderness, and coastal and marine ecosystems in Mississippi and northwest Florida, while providing for public use and enjoyment" (NPS 2016, p. 4). The coastal fortifications are considered one of the fundamental resources but that "due to insufficient level of maintenance, the condition of coastal fortifications is continually deteriorating" (NPS 2016, p. 17).

One area of particular historic importance is Pensacola Harbor Defense Project Historic District, located on Santa Rosa Island. Fort Pickens is the largest of the 19th century fortifications built as part of the "Third System" of national defense, and "many of the extant cultural resources on Santa Rosa Island were part of the 13th Coast Artillery Regiment of the U.S. Army Coast Artillery Corps. In addition to the coastal defense forts, numerous artillery batteries can be found that span the time from the Civil War to the end of World War II" (NPS 2016, p. 3). Fort Pickens was listed on the National Register of Historic Places in 1972, while the Pensacola Harbor Defense Project Historic District was entered into the National Register of Historic Places on May 15, 2017. According to the Historic District's nomination form, the District is listed as "nationally significant under National Register Criteria A and C in the areas of Architecture, Engineering, and Military History, for its association with the design and engineering of coastal defense systems and their evolution to meet the emerging capabilities of military armaments between 1893 and 1947" (Slaton and others 2016, Section 7, p. 6). The full historical description from the summary paragraph of the Nomination Form can be found in Appendix 1.

A total of 28 structures were selected for inclusion in this study with the guidance of park managers. It is important to note that two non-contributing structures, the Ranger Station and Ranger Station Garage (former Coast Guard Station/Life Saving Station and Garage) were included, as park managers are considering investing in restoration that could improve their historic integrity. For a list of building and structure information, including circa dates, materials, and condition class, uses and vulnerability level at the time of data collection (June – August 2018), see Appendix 1, Table 1. See chapter 4 from Casey (2018) for additional information about the historic structures at Gulf Islands National Seashore in relation to changing barrier island dynamics, prior storm events, and climatic change.

Methodology

The Optimal Preservation Model

The OptiPres Model is a decision support framework developed for the National Park Service to provide decision-makers with guidance on how to best manage multiple types of historic structures by applying actions over time. More specifically, the model uses an optimization algorithm to evaluate trade-offs between (a) investing in actions that maintain or preserve resources in situ, (b) investing in actions that preserve a structure by elevating it higher than its original location, (c) making triage decisions to free-up resources for more costly actions (e.g., foregoing expensive maintenance for a structure to perform lower cost actions on another structure), or (d) making triage decisions that shift management attention from one type of structure for other types of structures (e.g., focusing on the added value particular types of structures may convey to total accumulated resources). The model selects the combination of investments that provides the highest resource value to the decision-maker over a specified time period and budget constraint.

We have provided visual descriptions of optimal investment portfolios (sequences of actions applied to a set of structures; hereafter "portfolio" or "portfolios") to aid with data interpretation. It is important to note that the model outputs (i.e., visualizations) are not prescriptive (i.e., do not provide a specific path for implementing adaptation actions) but rather are descriptive (i.e., demonstrate the patterns of, or strategic approaches for, optimal actions given specific budget constraints) and could be used as one of several possible considerations to inform decision-making. In this report, we test the transferability of this model assuming **the objective is to maximize total resource value of structures within Pensacola Harbor Defense Project Historic District over a 30-year planning horizon**.

We developed an objective function, or a numerical expression of the statement above, which integrates resource value attributes related to two subobjectives: maximizing historical significance and maximizing use potential. Attributes of Historical Significance were: association with fundamental purpose of the park unit, condition of the building or structure, historic character (a weighted average of two sub-attributes: defining character and uniqueness to the park), and national register (a weighted average of two sub-attributes: spatial significance and eligibility). Attributes of Use Potential were: operational use, visitor use, interpretive use, third-party use, and scientific use.

Each of the subobjectives and their attributes are associated with a specified weight that reflects specific value judgment about the relative importance of each attribute. The weights of the historical significance and use potential attributes were derived by averaging responses to an online-survey of current and retired park staff at GUIS (for the comparison of weights of the historical significance and use potential between this study and the CALO pilot study, see Appendix 2, Table 2). Each attribute has a set of metrics (descriptive levels) with values (numerical scores) that were assigned by National Park Service staff and North Carolina State Historic Preservation staff who participated in the pilot study at Cape Lookout National Seashore (for specific details, see Fatorić and Seekamp, 2017, 2018). The metric levels (but not the metric level values) applied to each structure in the present study were provided by Gulf Island National Seashore staff. As not all metrics have the same

number of levels, the metrics were normalized prior to calculating the weighted averages. The resource values for each structure were quantified by first calculating the weighted averages of the metric level values applied for each subobjective (historical significance and, separately, use potential) and, then, multiplying each subobjective with its associated weight, and adding the two subobjective values together. A comparison of resource values for each structure using the GUIS and CALO pilot study weights are provided in Appendix 2, Table 3 (we use the GUIS resource values in this study). We also provide a comparison of the CALO and GUIS weighting schemes for the purposes of testing the transferability of the model. Specifically, we are demonstrating that localized values differ, though only slightly, between the two case studies.

The objective function integrates the weighted resource value attributes and non-weighted **vulnerability attributes** (i.e., exposure and sensitivity data; Box 2) for flooding-related coastal climate change threats (for specific details, see NPS 2016; Peek and others 2015). Attributes of **Exposure** were: flooding exposure (based on FEMA flood maps), storm surge estimates (mean high tide during category 3 hurricanes), sea level rise projections for 2050 (under a high, RCP 8.5 emission scenario), erosion and coastal proximity, and evidence of historical flooding. Attributes of **Sensitivity** were: flood damage potential, storm resistance, prior storm damage, and presence of protective engineering.

It is important to note specific limitations related to the use of a 30-year planning horizon. For example, climate change scenarios and land cover change projections adjust following major disturbances, such as hurricanes, and as forecasting science improves. The forecasting scenario used to develop the vulnerability metrics (RPC 8.5) for the vulnerability attributes highlight that drastic sea level rise impacts may not be actualized in 30 years. However, the storm surge models used to develop the vulnerability metrics do not account for flood-related damage from Pensacola Bay storm surge or from intense rainfall. Moreover, most of the historic structures located within the Pensacola Harbor Defense Project Historic District are located behind a seawall that currently provides protection from some storm-related flooding and erosion, and many of the structures are already located at the highest elevation points within the district. Therefore, managers may find that inundation will occur at increased or decreased rates compared to the forecast used in this study (RPC 8.5), which will enhance or limit the effectiveness of some adaptation strategies over a 30-year planning horizon.

Climate Adaptation Actions Considered

The climate adaptation actions in the GUIS OptiPres Model were considered under the following factors: a) the availability of adaptation actions for the park; and b) the feasibility of estimating the costs of adaptation actions. Unlike the CALO pilot test, two adaptation actions (i.e., relocation, and relocation with elevation) were removed in this application of the OptiPres Model at GUIS because no relocation zone could be identified. Four available adaptation actions include: core and shell preservation using historic materials, elevating the structure in situ, document and monitor, and active removal. It is important to note that: (a) the seawall has been breached in prior storms, (b) the seawall can actually inhibit draining of storm event water (both from breaching and from rain events), and (c) that the elevations of the seawall are still relatively low, ranging from 1.081 meters to 3.564 meters above sea level. Although the NPS seeks to retain the historic fabric of a structure to the greatest extent possible, preservation treatments often include the use of new materials. The distinction here is that the materials are the best suited to maintain the fabric, rather than using materials that are best suited to reduce the sensitivity of a structure to future climate change impacts. It was assumed that structures must be in good condition prior to elevation; therefore, core and shell preservation is embedded within the elevation action. It is also important to note that: (a) the seawall has been breached in prior storms, (b) the seawall can actually inhibit draining of storm event water (both from breaching and from rain events), and (c) that the elevations of the seawall are still relatively low, ranging from 1.081 meters to 3.564 meters above sea level.

Under specific budget allocations, the model searches for optimal combinations of **adaptation actions** applied to each structure over a 30-year time horizon. Adaptation actions were developed based on those listed in the NPS Cultural Resource Climate Change Strategy (Rockman and others 2016). The cost of each action is structure-specific, and the total annual cost of these actions is constrained by the annual budget. All of the adaptation action cost estimates include those affiliated with documenting the alterations to the structure (and for a historic structures report if one has yet to be written), as well as interpreting (minimally or extensively) the way the park has adapted the structure to minimize climate change impacts. Additional actions that can be applied within the model include **no action** and **annual maintenance**.

We did not include annual inflation rates for cost estimates or for annual budget allocations. In addition, we assumed that core and shell preservation (and elevation) would include treatments associated with upgrading the conditions of structures to the good condition class, with the costs of improving a structure from a fair to good condition class being less expensive than the cost of improving a structure from a poor to good condition class. To accommodate this assumption, we integrated a penalty index into the model for the condition improvement of core and shell preservation (and elevation). Specifically, assuming the stable core and shell preservation (and elevation) costs for a structure, the penalty index operated as follows: (1) if the condition of a structure is higher or equal to the fair condition class, applying the core and shell preservation (or elevation) action will improve the structure to the good condition and achieve 100% of the value for the good condition class; (2) if the condition of a structure is lower than fair condition but higher or equal to poor condition, applying the core and shell preservation (or elevation) action will achieve

80% of the value for the good condition class; and, (3) if the condition of a structure is lower than the poor condition class (from decay rates associated with inaction and annual maintenance), applying the core and shell preservation (or elevation actions) will achieve 66% of the value for the good condition class.

A full description of the actions is provided in Appendix 2, Table 4 and the estimated structure-specific costs of each action are provided in Appendix 2, Table 5. The costs were calculating based on square footage estimates for primary structure materials (i.e., masonry, concrete, wooden). It is important to note that the costs associated with maintaining and adapting Fort Pickens and the batteries are exceptionally high and exceed typical annual budget allocations for managing all of the historic structures within the Pensacola Harbor Defense Project Historic District. More research is needed to enhance the accuracy of these costs when the OptiPres Model is transferred to other park units. Square footage estimates were provided by staff at the Interior Region 2 Office of the National Park Service. To compute these estimates, the square foot cost of adaptation was extrapolated based on previously estimated costs for comparable adaptation applied to comparable structures at Cape Lookout National Seashore. Costs were escalated 8% to account for differences in construction costs between 2016 and 2018. Costs were escalated 1% to account for city cost index differences between the two locations. The costs provided with this adaptation summary can be understood as order of magnitude costs variable up to 40%, similar to an NPS class C estimate, which are considered to be comparable estimates sufficient for optimization of adaptation action categories based on multiple factors such as cost, vulnerability, and use potential. Interpretation and documenting estimates were provided by Gulf Islands National Seashore staff on a building by building basis.

Model Algorithm

The model uses a stochastic search algorithm (i.e., simulated annealing) that randomly picks one year and one structure and then randomly selects an action. It then projects the impact of that single change on each of the metrics, beginning with the initial conditions, over all 30 years. If the total resource value improves as a result of the change, then the change is retained until a better one is found. If the resource value does not improve, then the change is rejected and another one is selected. Additional model parameters are used to control how selective the algorithm is about how large an improvement is required for acceptance. If run many millions of times, the algorithm should converge on a near-optimal solution. The dynamics of the projection over time are specific to the actions applied. As such, each action can influence the relative resource value of any given structure (positively or negatively), as well as reduce the vulnerability of a specific structure (Figure 1). More specific details on the model dynamics can be found in Appendix 2, Table 4.

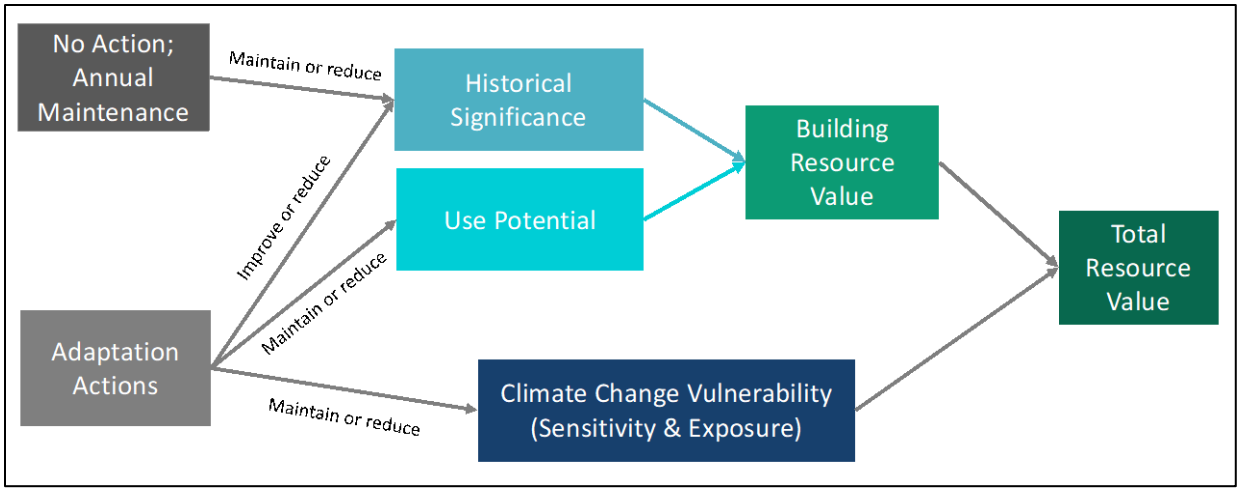


Figure 1. OptiPres Model dynamics (Seekamp and others 2019b).

Annual Budget Scenarios

We developed the range of annual budgets included in this study to align as closely as possible with the budget allocations of the CALO study (Seekamp and others 2019b), including a "no budget" scenario. Based on the estimations of the annual budget allocations for the park from the GUIS staff, the typical annual budget scenario was set to be $400,000. In the CALO study (Seekamp and others 2019b), this scenario was called the industry scenario and was the estimate of what should be provided annually if all buildings were to be maintained. No such estimate was available for GUIS and the park staff opted to provide a 5-year average of annual allocations.

We set the "low" range of budget allocations at $300,000 (25% less than the typical annual budget scenario) and the "high" range of budget allocations at $500,000 (25% higher than the typical annual budget). This is the same value that was used in the CALO study (Seekamp and others 2019b) but in that study that value was based on the ideal amount of annual appropriations that would allow for some adaptation actions to be implemented. In addition, we set the first model run at a baseline budget allocation of $0 (no budget scenario). Then, we set the second model run at a budget allocation of $50,000 to make it comparable with the "low" budget scenarios of the CALO study. To explore the uncertainty related to budgets, we then iteratively ran the model in increments of $50,000 increases in the budget allocation to the high budget allocation ($500,000 intervals), and with two additional budget scenarios of $750,000 allocation and $1,000,000 allocation, respectively. These additional model runs were necessary to examine for efficiency trends, as they could possibly allow for some adaptation actions to be selected by the OptiPres Model. We name this series of model runs from $50,000 to $1,000,000 as the "uncertain budget" scenario. It is important to note that the term "annual budget allocation" is used in this report to replicate the terminology used in the CALO study report (Seekamp and others 2019b). However, the estimates ("low," "typical," and "high") were generated based on information provided by GUIS and SERO staff that reflects planned projects (2018-2022) under the Park's comprehensive fee plan, which is funded from visitor fees collected under the Federal Recreation Enhancement Act.

Additionally, we included several other planning scenarios in the model runs. Because the low, typical, and high budget scenarios were less than 1% of the total cost of performing annual maintenance on each structure in a given year, we set a scenario of "sufficient annual maintenance budget" that was determined by adding the annual maintenance costs associated with each structure ($57,450,000). Moreover, to test the transferability of the OptiPres model, we include a "periodic funding increase" scenario, including: 1) an annual allocation of 400,000 (typical annual budget) with an additional $400,000 allocation every five years; and 2) an annual allocation of $57,232,370 (sufficient annual maintenance budget) with additional $400,000 allocation every five years. These periodic funding increase model runs allowed us to explore the outcome if annual budgets were significantly increased (e.g., through competitive grants or donation funding) every 5 years (years 5, 10, 15, 20, 25, and 30).

Model Improvements

We have made a series of updates to model constraints for the original OptiPres Model, with consideration of specific needs for climate adaptation planning at GUIS. The primary improvements for the OptiPres model include: a) integrating dynamics for use potential attributes (i.e., operational use, third-party use and visitor use). Specifically, if no action is taken, then any structure currently being used for park operations, by a third party, or open to the public would essentially need to be closed to the public. However, if following this inaction and use closure, core and shell preservation could enable the structure to be reopened to its original use(s). The model updates enable these dynamics (see Appendix 2, Table 6 for more details). Specifically, if no action is taken, then any structure currently being used for park operations, by a third party, or open to the public would essentially need to be closed to the public. However, if following this inaction and use closure, core and shell preservation could enable the structure to be reopened to its original use(s). The model updates enable these dynamics (see Appendix 2, Table 6 for more details). b) changing the time constraint for core and shell preservation from one to three instances across the 30-year planning horizon (allowing one core and shell preservation action every ten years) Essentially, we are no longer treating this action as an adaptation action but rather considering it reoccurring maintenance, which more accurately reflects its application in practice. c) introducing a more realistic annual maintenance action for Fort Pickens due to its size and high cost of annual maintenance (i.e., to apply annual maintenance of 10% of the area of Fort Pickens each year). We developed two separate algorithms for the model improvements: Model A Updates (Fort Pickens fractional annual maintenance and the use potential dynamics) and Model B Updates (Fort Pickens fractional annual maintenance and the 10-year cycles of core and shell preservation). 1 Our intention was to determine if reducing the cost of annual maintenance to Fort Pickens, assuming 1/10th of the structure could receive maintenance annually (cost and capacity constraints), would increase the likelihood of the model selecting this structure. Our rationale for trying to force its selection is related to its prominence within the landscape and that its presence led to the construction of the other structures in the historic district.

We tested the updated OptiPres Model under the same scenarios used for the transferability test and compared the model improvement outputs with the transferability test outputs. Noteworthy is that the examination of the "sufficient annual maintenance budget" scenarios enable a full interpretation of

the performance of the model improvements. We present the scenario results for both Updated Model A and Updated Model B in comparison to the "original model" to highlight the differences that the model improvements make upon the algorithm developed in the Cape Lookout pilot study.

Model Results and Interpretations

We tested the behavior and summarized the output of the OptiPres Model under four different planning scenarios: 1) a "no budget" scenario of expected dynamics if no actions are implemented to maintain or adapt the structures in the historic district, 2) an uncertain budget scenario, 3) a sufficient annual maintenance budget scenario, 4) periodic funding increases. These four planning scenarios were selected to replicate runs from the CALO pilot test (Seekamp and others 2019b) that NPS personnel and the project researchers wanted to explore. Limited and uncertain budgets are status quo for many cultural resource managers, and periodic budget allocations enable special projects. To assist in the interpretation of the results, we have included the costs of each action for the 28 structures in Appendix 1, Table 5. Throughout this report, we often reference a subset of these structures as "wooden and masonry buildings" to distinguish them from the larger masonry and concrete structures found within the historic district (i.e., Fort Pickens, the 9 batteries, and Tower 234). We also include tables that display the relative value changes for each structure across the 30-year planning horizon in Appendix 4 (Tables 7 – 9), as well as tables that present the proportion of total nonmonetary resource value and proportion of total monetary costs for each building within each model run in Appendix 4 (Tables 10 – 12).

Original Model

Scenario 1—No Budget

To illustrate the changes in resource values of structures under different planning scenarios, a baseline "no budget" scenario was created. Under this scenario, no actions were applied to any structures over the 30-year period. We estimated the accumulated resource values of all structures at the beginning of the 30-year period ("beginning values" = 174), and the accumulated values of all structures at the end of 30-year period ("ending values" = 96) (Figure 2). Accumulated resource value of the historic structures decreased rapidly when no maintenance or adaptation actions are taken, resulting in a roughly 55% loss of the original resource value remaining at the end of 30-year period. The significant decline of resource value was caused by continuous decay of the structures' condition and the lack of improvement in vulnerability scores under the "no budget" scenario.

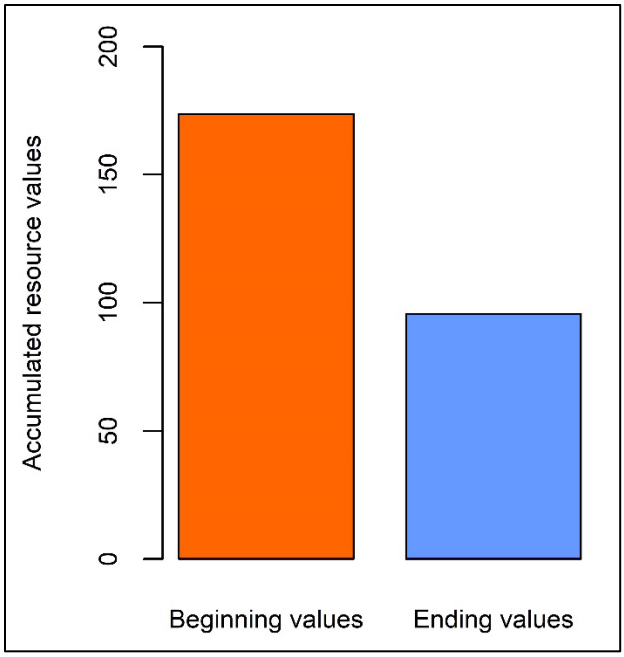


Figure 2. Accumulated resource values of all structures at the beginning and end of the 30-year planning horizon under a "no budget" scenario.

We also estimated the percentage of current and future resource value for each structure under the "no budget" scenario (Figure 3; Appendix 4, Table 7, $0 column). The individual resource values of structures at the beginning of the 30-year period were approximately equivalent to the resource values of structures at the end of the 30-year period when no actions were taken. It is important to note that dynamics of vulnerability and structures' condition operated asymmetrically across the study area. Some structures are less exposed than others, while wooden structures are associated with a faster decay rate than masonry or cement structures. The few wooden structures [e.g., Coast Guard Garage, Santa Rosa Life Saving Station, Officer Quarters (Fort Pickens)] in the historic district accounted for relatively small percentage of resource values (less than 3%), whereas Fort Pickens, and a few masonry structures (e.g., Pump House, Mine Loading Room and Mine Storage Room) accounted for larger percentage of resource values (about 5%). The Pump House accounted for a slightly higher percentage of resource value than other masonry structures due to its lower vulnerability to climate change.

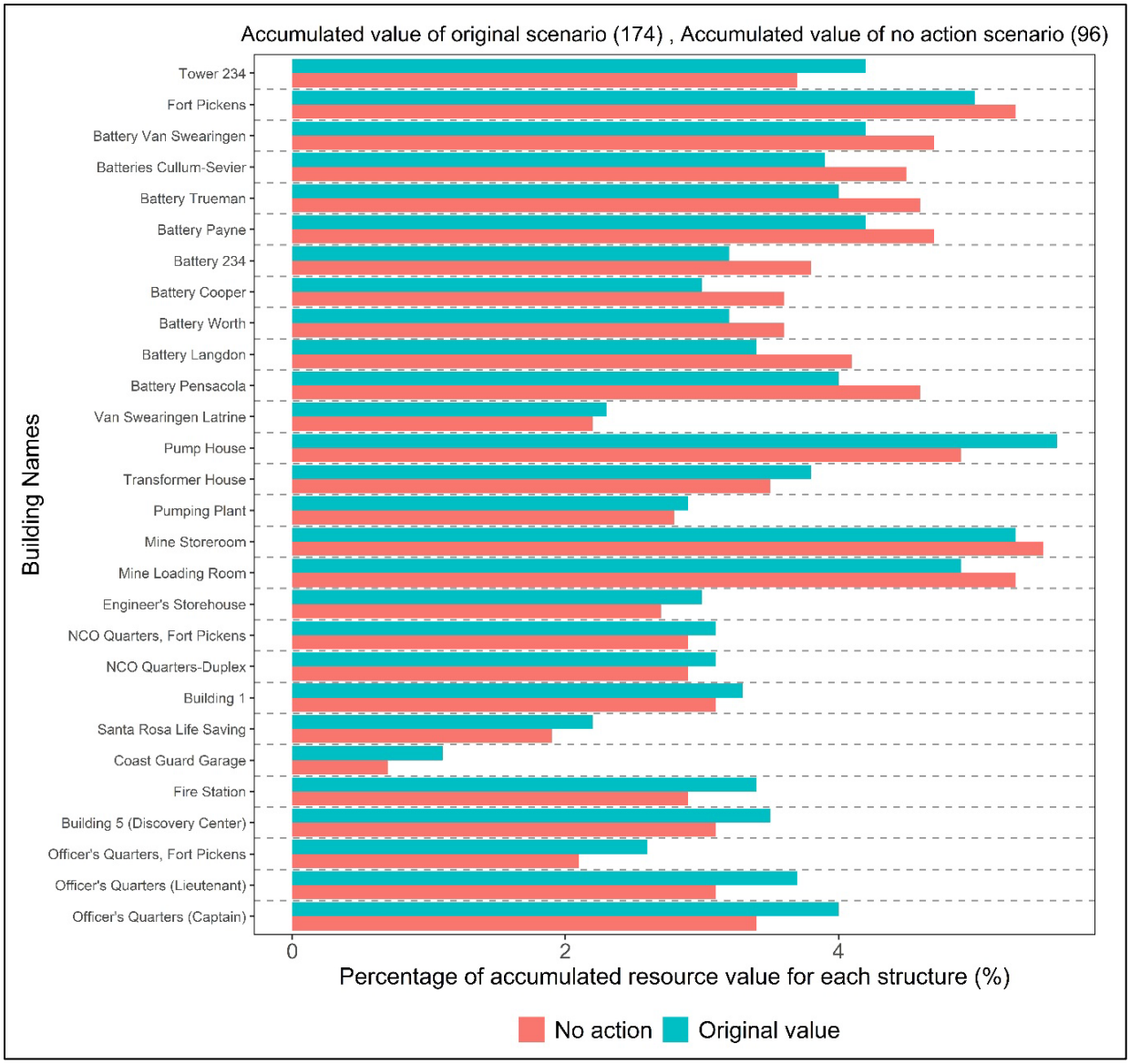


Figure 3. Percentages of total resource value for each structure under “no budget” scenario. Units of accumulated value at the beginning and end of the 30-year time horizon (174 and 96, respectively) are on a constructed, composite scale and, as such, are only relative to each other.

Scenario 2—An Uncertain Budget

We simulated the effect of an uncertain budget by running the model under a range of budget levels, from $50,000 USD to $500,000 USD in steps of $50,000, and two additional levels: $750,000 and $1,000,000. We do not run the $750,000 and $1,000,000 budget levels in the model modification scenarios, as the efficiency curve flattened prior to $500,000. The expected total resource value of the optimal portfolio of actions applied across the 28 historic structures for the budget levels is displayed in Figure 4. These results suggested at least three things: (a) that spending any money to manage even a subset of structures is better than doing nothing; (b) that spending more money leads to improved management performance; (c) that for the range of budgets examined, the total resource

values are substantially lower than the original resource value (174); (d) that $750,000 is identified as an obvious asymptotic threshold. Below we present the management portfolios used to generate Figure 4. To be comparable with the CALO pilot test (Seekamp and others 2019b) and test the transferability of the OptiPres model, we present results for the $50,000, $300,000, $400,000, $500,000 budget levels. As the additional $750,000 budget level was identified as a threshold, we also present the results from this model run.

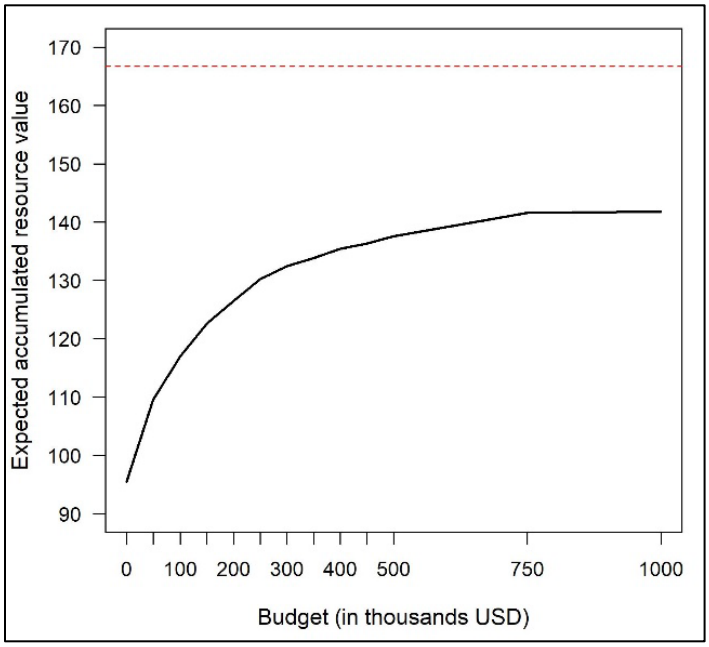


Figure 4. Expected total resource value of the optimal management portfolio at the end of the 30-year period, as a function of annual budget (black line) and compared to the original total resource value (red line).

Portfolio for a Budget of $50,000

The optimal set of actions under $50,000 budget suggested that only 10 out of 28 structures were eligible to receive either annual maintenance or core and shell preservation actions (Figure 5). Because the total cost of annual maintenance for all structures is much higher than $50,000, many structures—especially Fort Pickens and the batteries with relatively high annual maintenance costs—were not affordable to be maintained. The percentage of total resource value (110) and relative total cost of each structure ($1,346,562) is provided in Figure 6 and Appendix 4 (Tables 7 and 10). The percentages of resource value for the 10 structures selected for annual maintenance or core and shell preservation improved compared to the beginning of 30-year planning horizon, especially for Van Swearingen Latrine, Pump House, and Fire Station, which received both annual maintenance and core and shell preservation. However, the total resource values of the unmanaged 18 structures declined substantially. Despite the stable use potential, the decline in both the condition and historical values of 18 unmanaged structures resulted in an estimated 63% decline in total resource value during the 30-year planning period. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 51.

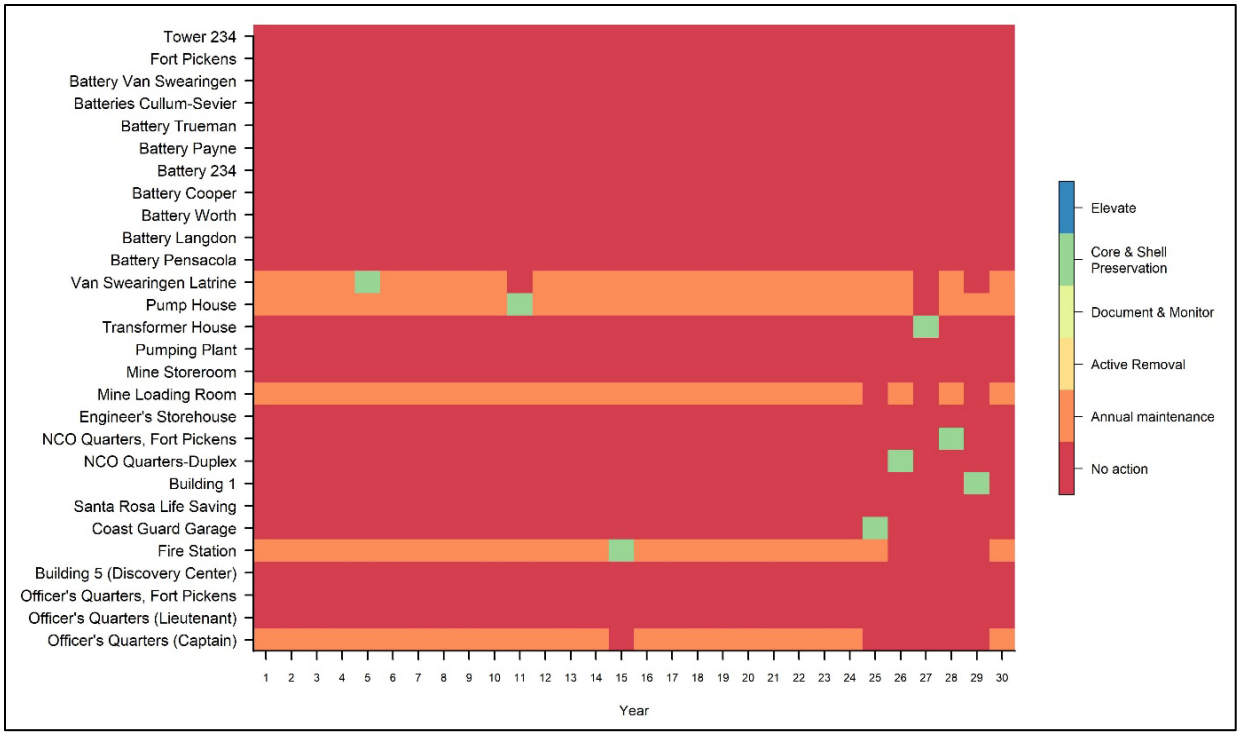


Figure 5. Actions applied under a $50,000 annual budget allocation.

The optimal solution suggested that the timing of core and shell preservation is likely to be determined by both historical value and conditions. In the OptiPres model, the weight of historical value is much higher than the weight of condition. Because the annual budget allocation is very low and the model must free up other resources (that is, apply no action to structures that had been receiving annual maintenance) to make the core and shell affordable in most cases. As such, tradeoffs often have to be made between the time of annual maintenance and core and shell preservation. Core and shell preservation was applied to four wooden structures (NCO Quarters, Fort Pickens, NCO Quarters-Duplex, Building 1, and Coast Guard Garage) and the concrete Transformer House at the end of 30-year period (Figure 5), which was likely to be driven by their relatively low historical value. The structures with higher historical value were selected to be improved as early as possible, while the ones with lower historical values were upgraded at the end of planning horizon to create the largest boosts to those structures' conditions.

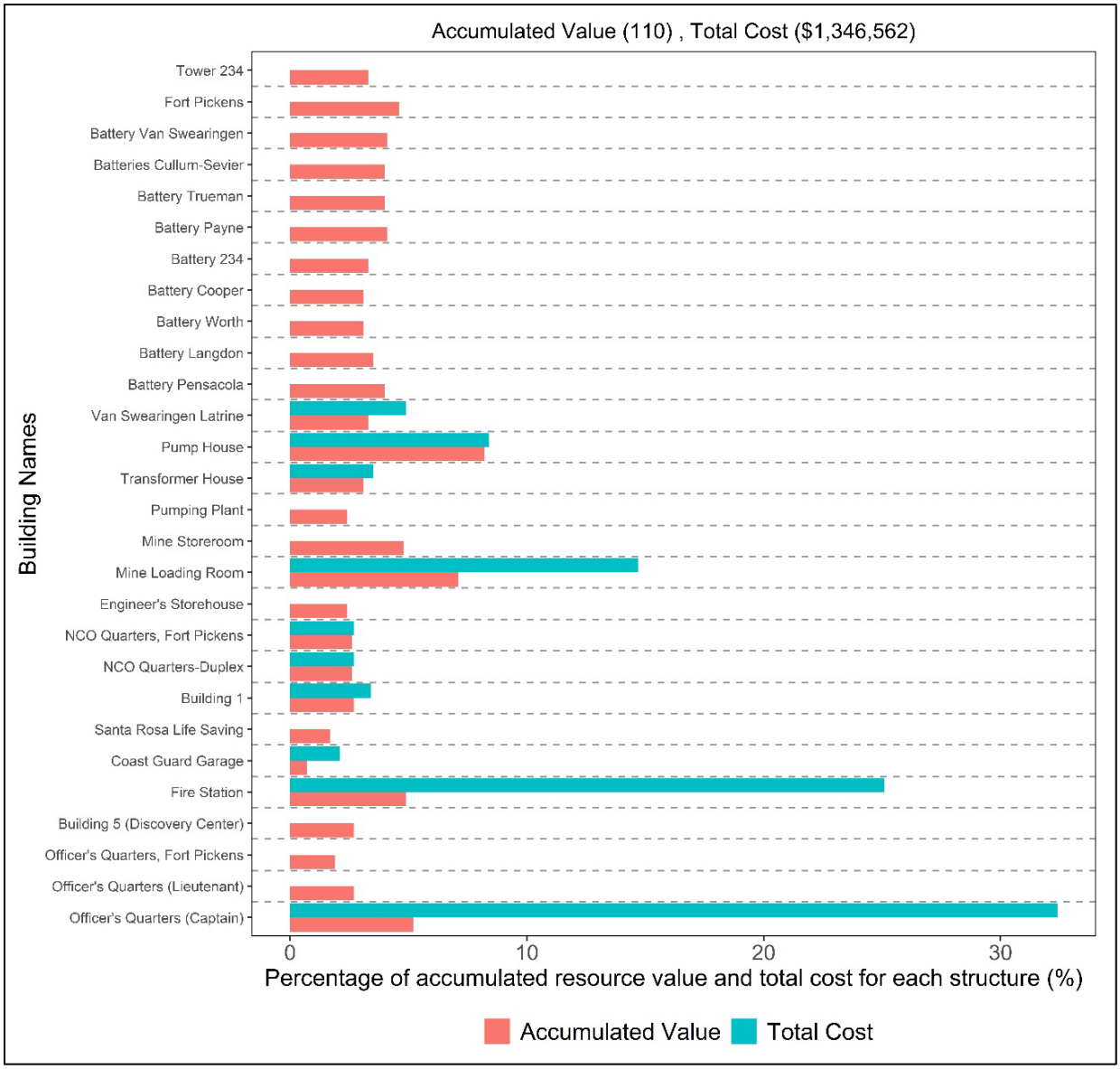


Figure 6. Percentage of accumulated resource value for each structure under a $50,000 annual budget allocation and total cost for each structure receiving some type of action.

Portfolio for a Budget of $300,000

The optimal strategy under this budget allocation suggested applying annual maintenance and core and shell preservation to most of the wooden and masonry buildings, as well as Tower 234, while Fort Pickens and all of the batteries remained "unmanaged" (Figure 7). Under this scenario, the budget was insufficient to perform annual maintenance for any battery or Fort Pickens, making them ineligible to receive any actions during the planning horizon. It is also important to note the budget was insufficient to perform annual maintenance for all of the other structures (the total cost of annual maintenance for structures, excluding Fort Pickens and the batteries, is $670,000); therefore, the three structures with the highest costs of annual maintenance (Pumping Plant, Mine Storeroom, and Engineer's Storehouse) were unmanaged in all but three years (when each receives core and shell

preservation) and funds were allocated to core and shell preservation actions for the other structures. This strategy included periodically stopping annual maintenance on 7 other structures to support the costs associated with core and shell preservation actions.

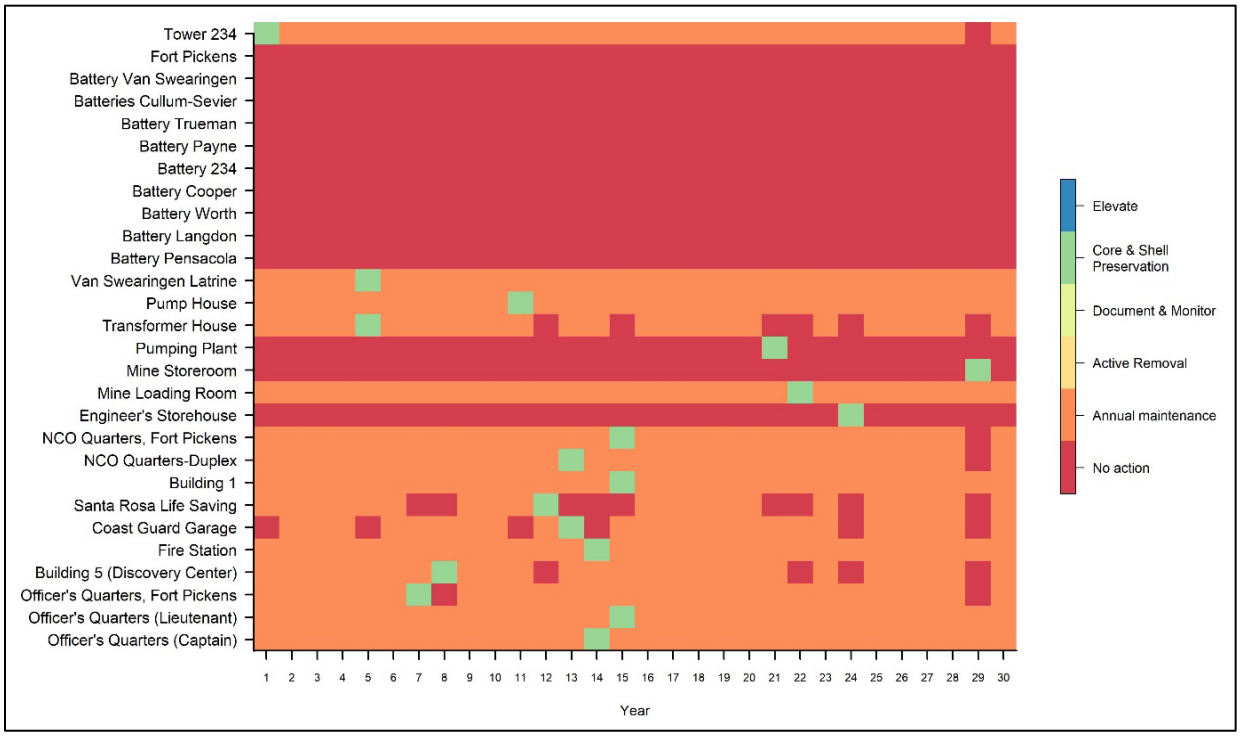


Figure 7. Actions applied under a $300,000 annual budget allocation.

The core and shell preservation actions were distributed widely across the planning horizon (Figure 7). The three structures with the highest costs of core and shell preservation (Pumping Plant, Mine Storeroom, and Engineer's Storehouse) were pushed to the end of the planning horizon to minimize the decline of conditions and historical values for other structures (Appendix 3, Figure 52). For other structures, the timing of core and shell preservation was highly dependent on the conditions, which is related to the penalty index for structures with condition classes between fair and poor and lower than poor. As described in the Methods section, we assumed the cost of core and shell preservation will be higher if the condition of the structure is in fair or poor condition classes than in good condition class; therefore, we integrated a penalty index into the model for the improvement of the condition class from core and shell preservation (and elevation) if the structure condition is below fair (only improved to 80% of the value associated with the good condition class) or poor (only improved to 66% of the value associated with the good condition class) condition class. The findings indicate that the OptiPres model applied annual maintenance at the beginning until the condition of the structure decays to nearly the lower class, and then applied core and shell preservation so that the maximum marginal improvement of condition is achieved for the structure.

To further explain the timing of core and shell preservation, we provide the following example. The model applied annual maintenance to the Officer's Quarters (Captain), which maintained its

historical value but the condition of the structure continued to decay. The model applied core and shell preservation to the Officer's Quarters (Captain) at year 14, which is the year before the condition of structure would decay to the fair condition class. During the year in which the core and shell preservation action is applied, the structure received a one-time improvement of condition to the good condition class. However, if the model does not apply the core and shell preservation at year 14, then the structure condition will decay to the fair condition class, and the model then would apply a penalty to the condition improvement resulting from a later-applied core and shell preservation action, where the value of the condition could only be improved to 80% of the good condition value.

The total resource value under this scenario (132) increased by nearly 20% of the value under the previous scenario of a $50,000 annual budget (Figure 8). The relative proportion of accumulated value of each structure under this budget differed from the previous scenario. The percent contribution from Fort Pickens and all of the batteries declined about 1% compared to previous scenario, due to the consistent decline in condition and historical value from receiving no action. The tradeoff for these declines was the improvements in conditions and historical values that were applied to more of the other structures. However, Fort Pickens (and possibly some or all of the batteries) is likely a high priority for park managers. Thus, the loss of significance could represent an undesired management situation, as Fort Pickens serves as an important landmark for Pensacola Harbor Defense Project Historic District. It may be important to identify alternative funding sources to make Fort Pickens eligible to receive maintenance. In fact, we created the $1/10^{th}$ of annual maintenance cost for Fort Pickens in the OptiPres Model updates to provide one possible alternative approach to funding important, but costly, landmarks.

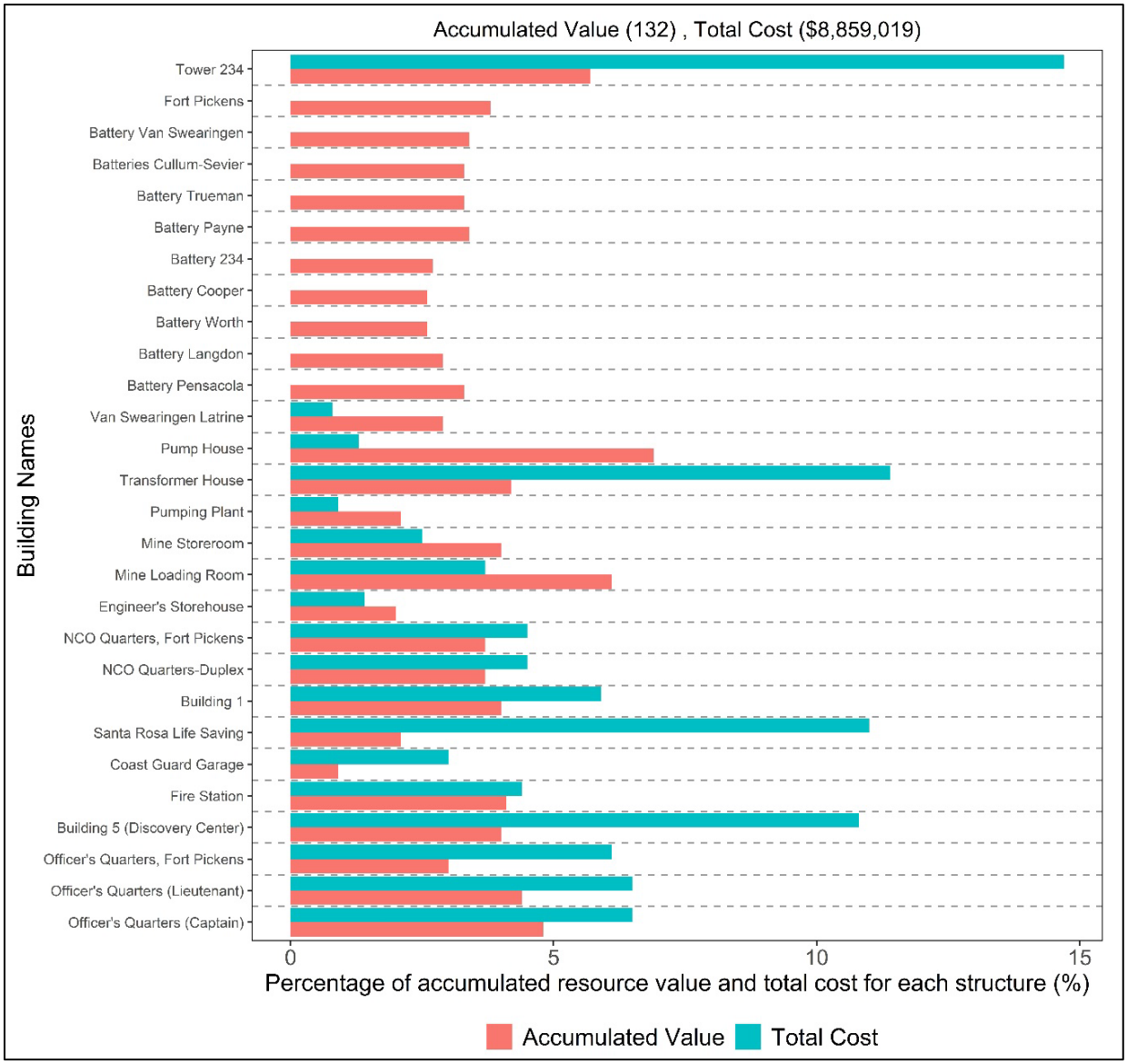


Figure 8. Percentage of accumulated resource value for each structure under a $300,000 annual budget allocation and total cost for each structure receiving some type of action.

The pattern of percentage accumulated value and total cost were asymmetric under this scenario (Figure 8; Appendix 4, Tables 7 and 10). A few structures with lower percentage of accumulated value have used relatively higher proportions of the total budget. For example, the Santa Rosa Life Saving/Coast Guard Station accounts for 2% of accumulated value at the end of planning horizon by spending 11% of budget. However, the Pump House, which accounted for a relatively high percentage of accumulated value (7%), only used 1% of budget.

Portfolio for a Budget of $400,000

The optimal strategy under this budget allocation was very similar to the strategy of previous scenario. Under this budget scenario, annual maintenance was still the dominant action selected for

most wooden and masonry buildings and Tower 234, and core and shell preservation actions were applied to all of the structures typically receiving annual maintenance across the planning horizon (Figure 9). Fort Pickens and all of the batteries were not eligible for any adaptation actions across the planning horizon. Perhaps the biggest difference of optimal strategies between this budget scenario and previous budget scenario was that one masonry structure (Pumping Plant) received annual maintenance for more than 80% of planning period. In addition, due to increased funding allocation in this scenario (60% of total cost of annual maintenance for all wooden structures, masonry structures, and Tower 234), the number of structures that had to receive no action to free up funds to apply core and shell preservation actions was reduced from 7 to 5 (with the exceptions of the Mine Storeroom and the Engineer's Storehouse). This additional funding also enabled the timing of core and shell preservation treatments for a few structures (e.g., Pumping Plant, Mine Loading Room, and Mine Storeroom) to occur a little earlier in the planning horizon compared to the previous scenario. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 53.

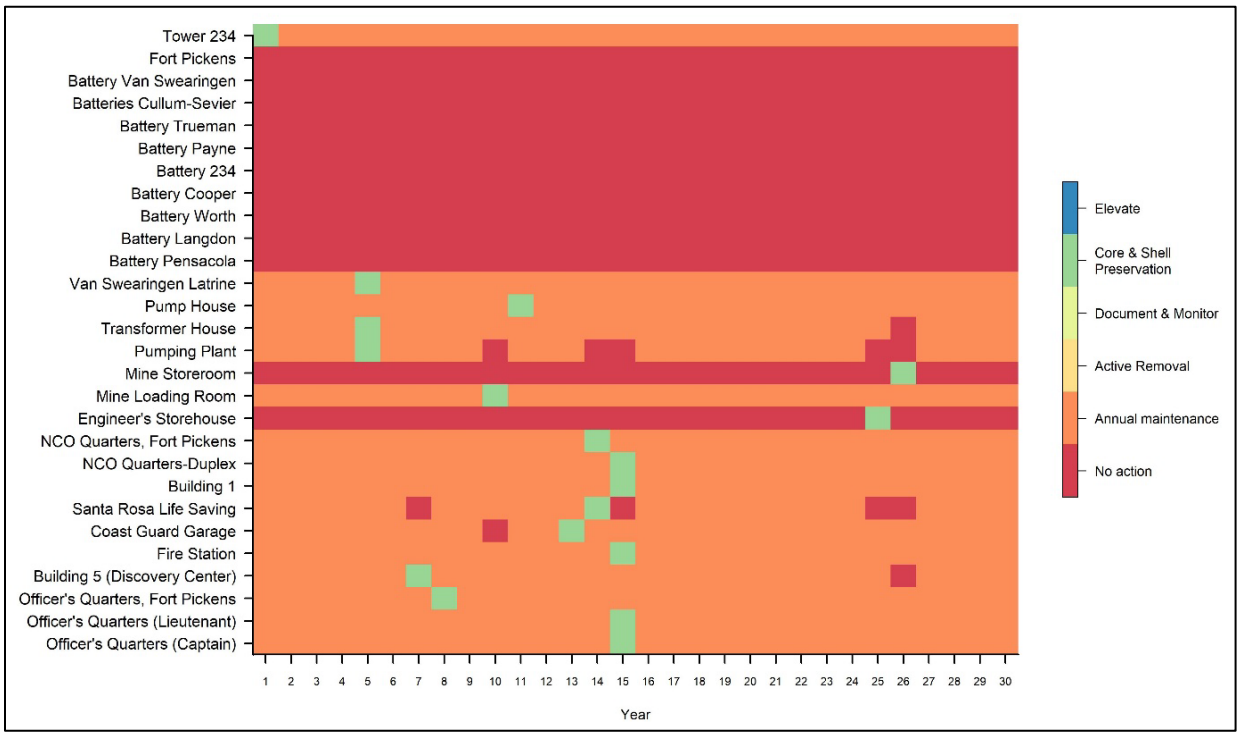


Figure 9. Actions applied under a $400,000 annual budget allocation.

The total resource value (135) under this scenario only increased 2% of the accumulated value under the previous $300,000 annual budget scenario (Figure 10). The percentage contribution of each structure was very similar to that of pervious scenario, except for the Pumping Plant, which increased by 1% compared to previous scenario. Similar to the previous scenario, the patterns of percentage contributions of accumulated value and total cost ($11,256,531) were greatly asymmetric under this scenario (Appendix 4, Tables 7 and 10). It is important to note that the total resource value under this scenario (typical annual budget) was 22% less than the original resource value, and the landmark of

the district (Fort Pickens) received no actions for all years, suggesting that this scenario may also result in an undesired management situation.

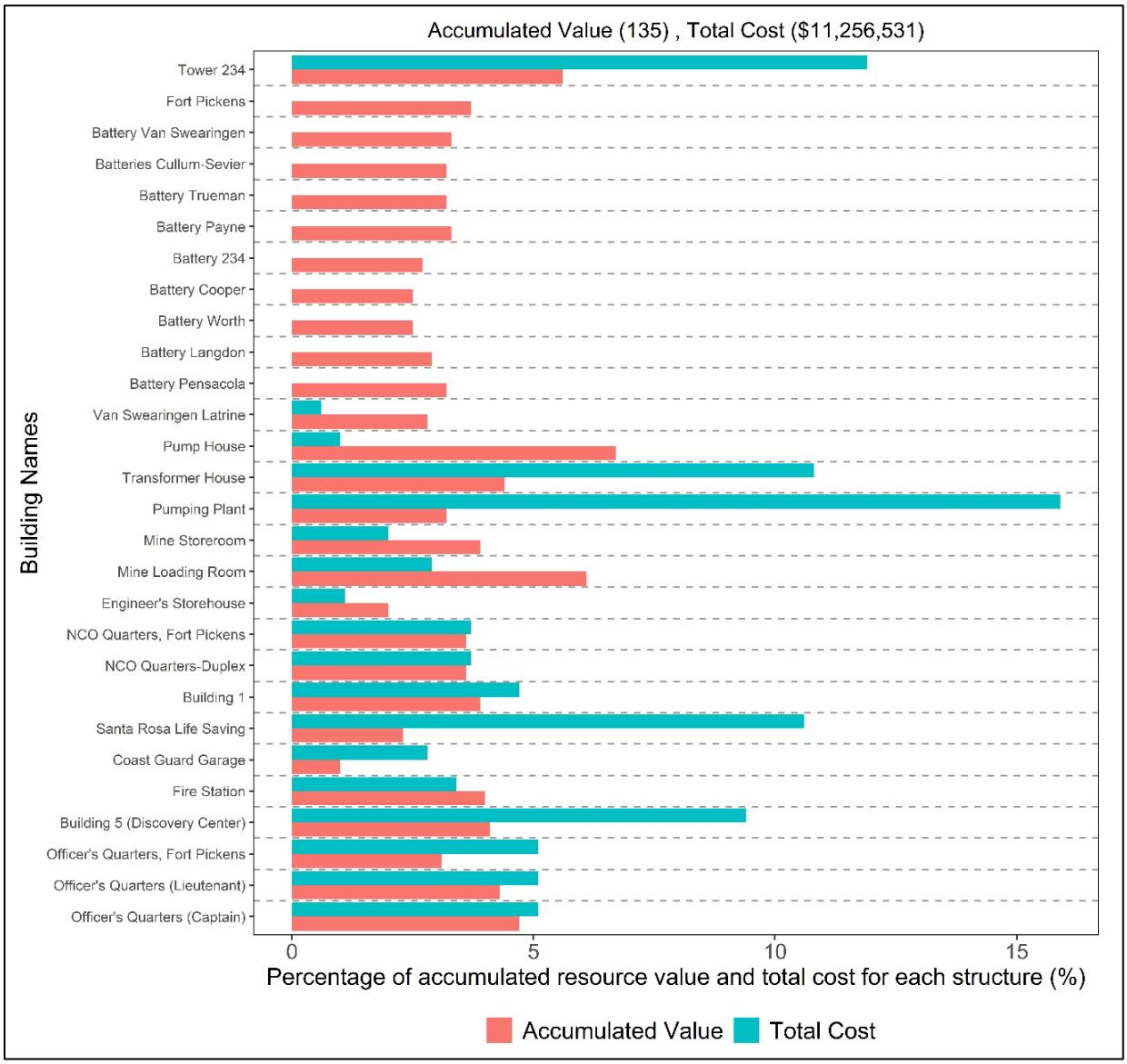


Figure 10. Percentage of accumulated resource value for each structure under a $400,000 annual budget allocation and total cost for each structure receiving some type of action.

Portfolio for a Budget of $500,000

The optimal strategy under this budget allocation ($500,000) was very similar to the strategy of typical annual budget allocation ($400,000). Under this budget scenario, annual maintenance was still the dominant action for most wooden and masonry buildings and Tower 234, and core and shell preservation actions were applied to these structures across the planning horizon (Figure 11). Fort Pickens and all batteries remained ineligible for any adaptation actions across the planning horizon. The increase in annual funds made one more masonry structure (Engineer's Storehouse) affordable

for annual maintenance for most years during the planning period compared to typical annual budget scenario. Similar to previous scenarios, the structure with the highest costs of core and shell preservation (Mine Storeroom) was pushed to the end of the planning horizon to minimize the decline of its condition and historical value. In addition, the increased funding allocation reduced the number of times no action was selected for the wooden and masonry buildings (with the exception of the Mine Storeroom) from 5 to 3 when compared to the typical annual budget scenario. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 54.

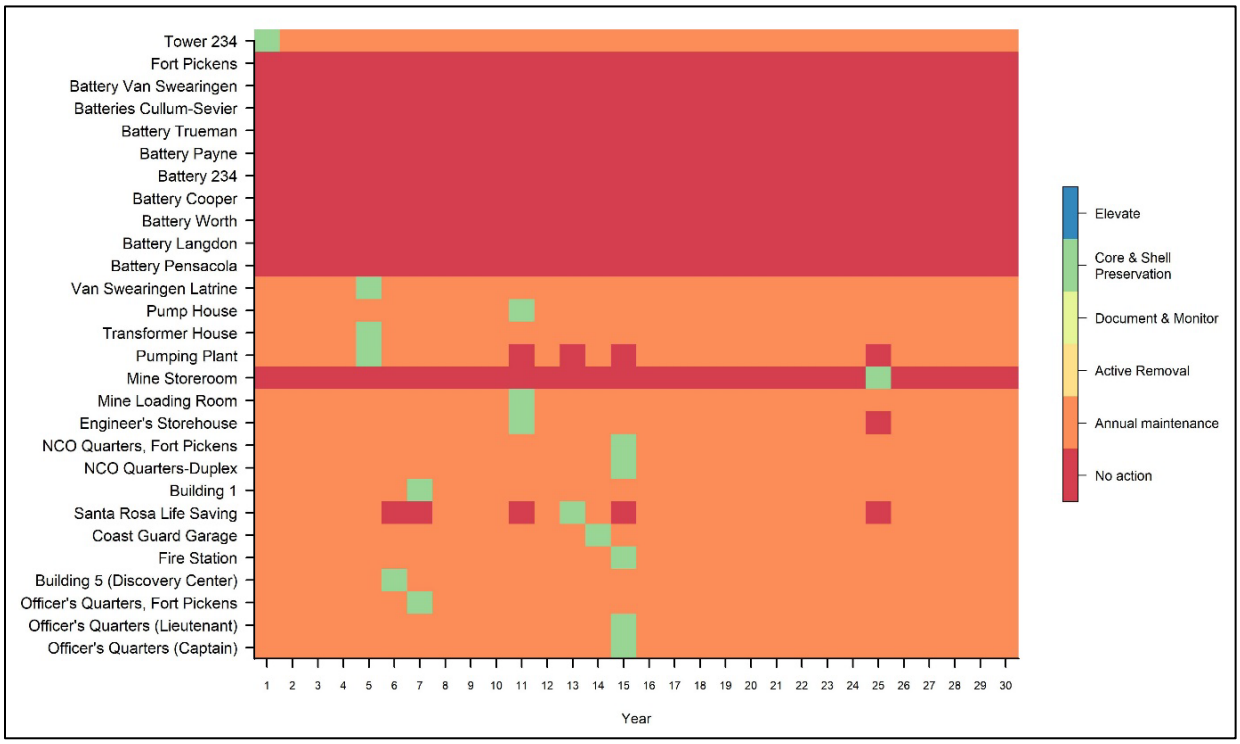


Figure 11. Actions applied under a $500,000 annual budget allocation.

The total resource value (138) under this scenario only increased 2% of the value under the typical annual budget scenario (Figure 12). The percentage contribution of each structure was very similar to that of typical annual budget scenario, except for Engineer's Storehouse, which increased to 2% compared to the typical annual budget scenario. Similar to the previous scenario, the patterns of percentage contributions of accumulated value and total cost ($14,469,297) were greatly asymmetric under this scenario (Appendix 4, Tables 7 and 10). The cost of actions for masonry structures accounted for nearly 50% of the total cost of all structures.

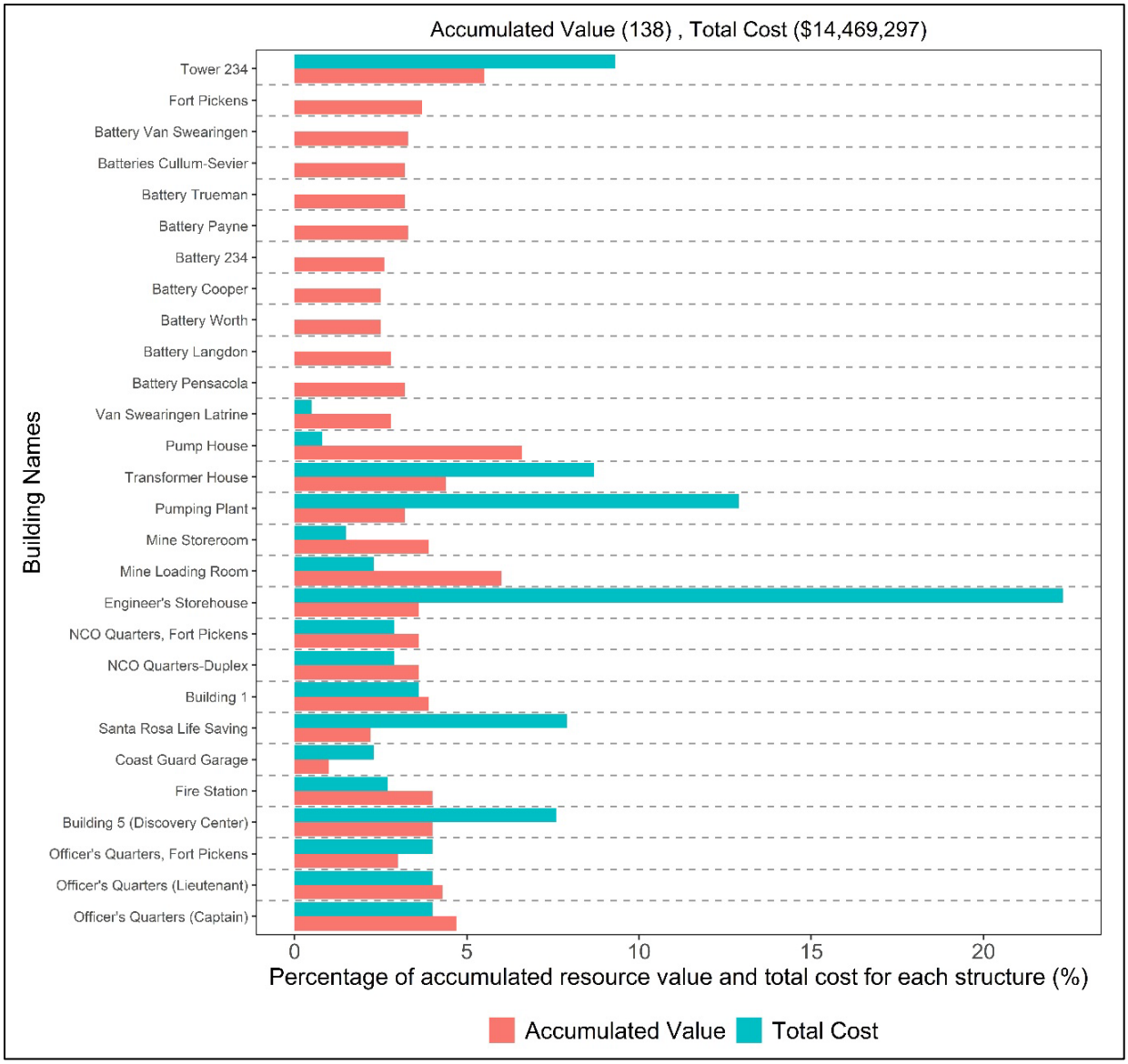


Figure 12. Percentage of accumulated resource value for each structure under a $500,000 annual budget allocation and total cost for each structure receiving some type of action.

Portfolio for a Budget of $750,000

The optimal strategy under this budget allocation ($750,000) was very similar to the strategy of the $500,000 annual budget allocation. Under this budget scenario, annual maintenance was still the dominant action for most wooden and masonry buildings and Tower 234, and core and shell preservation actions were applied to these structures across the planning horizon (Figure 13). Fort Pickens and all batteries remained ineligible for any adaptation actions across the planning horizon. The increase in annual funds made one more masonry structure (Mine Storeroom) affordable for annual maintenance for most years during the planning period compared to the $500,00 annual budget allocation. Additionally, the Mine Storeroom received the core and shell preservation action earlier in the planning cycle (unlike the $500,000 allocation in which this action was applied in the

second half of the planning cycle). In addition, the increased funding allocation reduced the number of years in which no action was applied to the wooden and masonry buildings, and the Santa Rosa Life Saving/Coast Guard Station only received no action in 2 (as compared to 5) years. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 53.

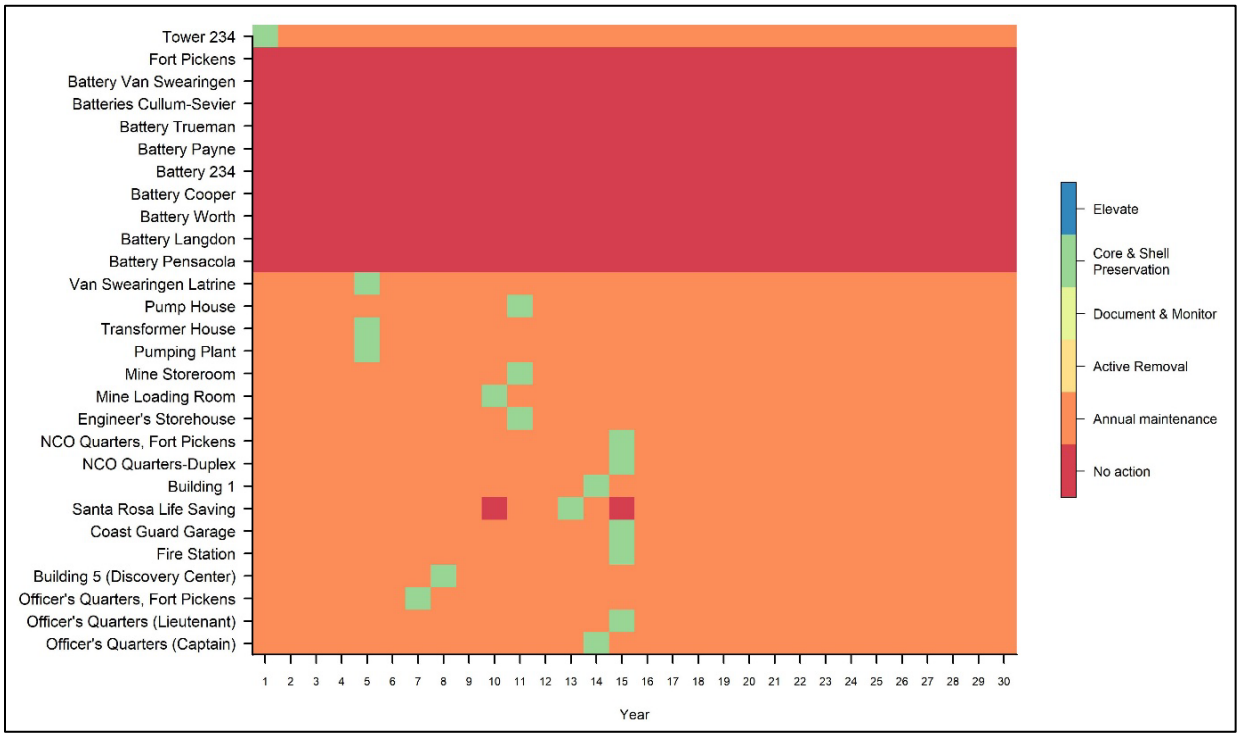


Figure 13. Actions applied under a $750,000 annual budget allocation.

The total resource value (139) under this scenario increased by 3% from the total resource value under the typical annual budget scenario (Figure 14). The percentage contribution of each structure to the total resource value was different than the percentage contribution of the scenario of $500,000 annual allocation. In particular, the percentage contribution increased substantially for the Mine Storeroom (28% compared to 2% in the previous scenario). Similar to the previous scenario, the patterns of percentage contributions of accumulated value and total cost ($20,582,613) were greatly asymmetric under this scenario (Appendix 4, Tables 7 and 10). The cost of actions for masonry structures accounted for nearly 64% of the total cost of all structures.

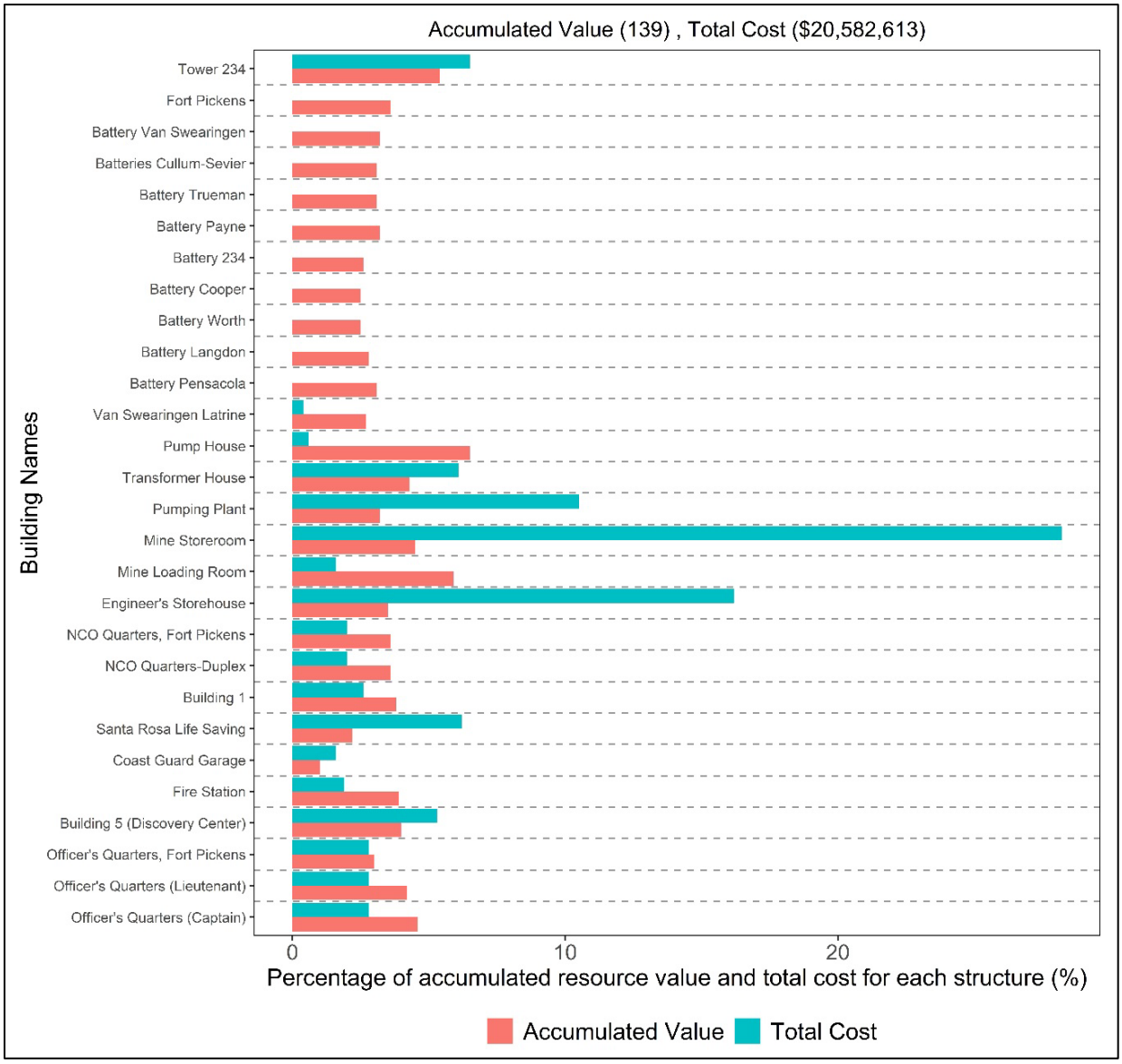


Figure 14. Percentage of accumulated resource value for each structure under a $750,000 annual budget allocation and total cost for each structure receiving some type of action.

Scenario 3—Sufficient Annual Maintenance Budget

The optimal strategy under this $57,232,370 budget allocation suggested (1) applying annual maintenance for all structures as many years as possible and (2) applying core and shell preservation actions before year 16 would achieve the highest resource value (Figure 15). Because the funding allocation for this scenario was sufficient for the annual maintenance costs of all structures, Fort Pickens and all batteries were eligible for adaptation actions, which maintained the historical values of Fort Pickens and batteries during the planning period (Appendix 3, Figure 53). Note that applying core and shell preservation actions resulted in Batteries Langdon and 234 being ineligible to receive management action for a few years, which was likely related to their high cost of annual maintenance. The optimal strategy suggested that when the annual budget was sufficient, the core

and shell preservation action (at the cost of not performing annual maintenance on Battery Langdon or Battery 234) achieved a net higher resource value than only applying annual maintenance to all structures. Because core and shell preservation can improve both condition and historical value of all structures, the timing of applying core and shell preservation was the result of tradeoffs between accumulated historical value and one-time improvement of conditions. More specifically, applying core and shell earlier can increase the accumulated historical value but the one-time improvement of condition will be lower; however, applying core and shell later can reduce the accumulated historical value but the one-time improvement of the condition will be higher. Therefore, the model applied core and shell preservation earlier to those structures that have relatively high historical resource values (for example, Fort Pickens, Tower 234, Pump House, or Mine Storeroom) at the time when the condition of the structure decayed to nearly the lowest (poor) condition class.

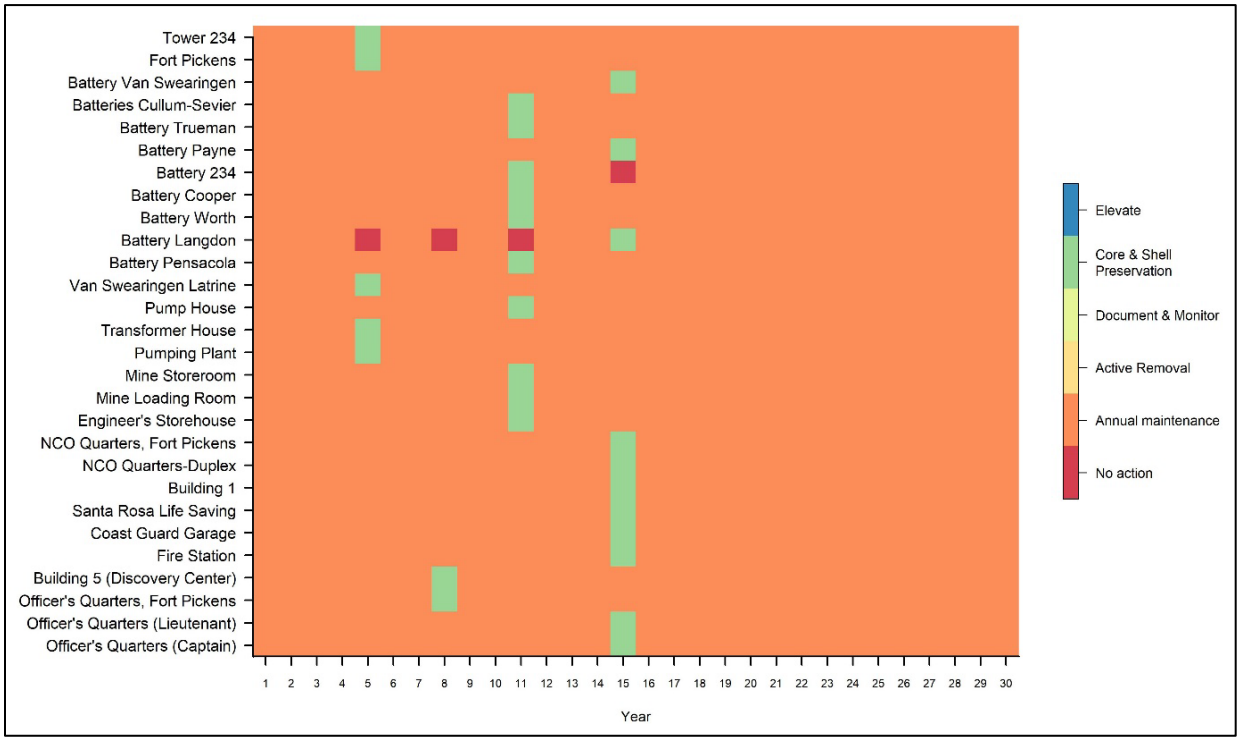


Figure 15. Actions applied under a $57,232,370 annual budget allocation.

The total resource value (163) under this sufficient budget scenario (Figure 16) increased the value of the typical ($400,000) annual budget scenario by 21%, and from the high budget ($500,000) scenario by 18%. It's important to note that even under this sufficient annual maintenance budget scenario, the total resource value was lower than the original resource value of the historical structures because the sufficient annual maintenance funds can only maintain the historical value of the structure, but cannot prevent the decay of conditions. The percentage contribution of each structure was very similar as that of the beginning scenario because each structure received similar types of actions (annual maintenance and core and shell preservation) for most years. As no adaptation actions were selected, the vulnerability scores were not reduced, which would have created an improvement in the

total resource value. It is our assumption that no adaptation actions are being selected due to (a) the limited ways in which the adaptation actions would affect the vulnerability scores based on the attributes associated with the exposure and sensitivity measures and (b) the inability to apply the adaptation actions to many of the structures. It is important to note that there was discussion to add beach nourishment as a possible adaptation action (see Beavers, Babson & Schupp, 2016) to all of the structures simultaneously; however, there was insufficient information about how such nourishment would change the exposure measures. The research team intends to update the model in the future to enable the integration of episodic storm events and impacts to the condition of structures, along with costs associated with post-storm recovery actions.

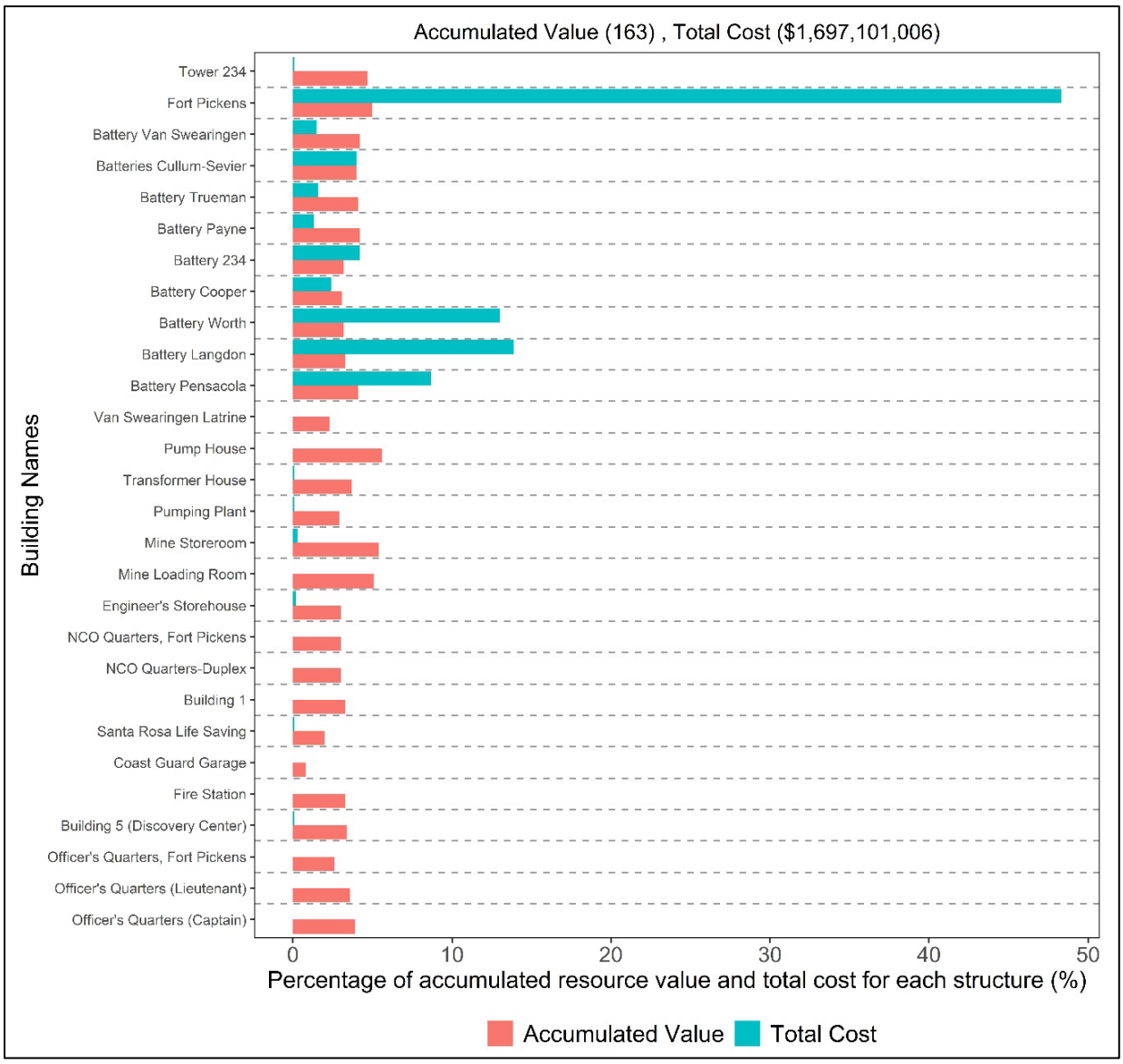


Figure 16. Percentage of accumulated resource value for each structure under a $57,232,370 annual budget allocation and total cost for each structure receiving some type of action.

The patterns of percentage contributions of accumulated value and total cost ($1,697,101,006) were greatly asymmetric under this scenario (Figure 14; Appendix 4, Tables 7 and 10). Fort Pickens accounted for 5% of accumulated resource value by spending 48% of total cost due to the size of the structure. However, the adaptation costs of all wooden and masonry buildings accounted for less than 1% of total costs. These results suggested an updated model that integrated a feasible and balanced approach to the annual maintenance of Fort Pickens and the other structures was needed for further optimization of historical preservation.

Scenario 4—Accounting for Periodic Funding

Portfolio for a Budget of $400,000 with a Surge of $400,000 Every 5 Years

The optimal portfolio for this scenario suggested some structures could be eligible for core and shell preservation earlier when a surge of funds was provided (Figure 17). Two of masonry structures with relatively high cost of annual maintenance received no action for most years except when the additional funding was allocated at the 5-year interval. Because the budget of the typical annual budget scenario could not afford the cost of annual maintenance for all wooden and masonry buildings and Tower 234, the surge of funding made it possible to maintain all of these structures every five years. Moreover, to minimize the number of times no action was selected to afford core and shell preservation actions, the model tended to apply core and shell preservation when additional funding was periodically available. For example, core and shell preservation was selected to be applied to 5 structures at year 5, and 7 structures received core and shell preservation at year 15. As a result, the overall condition of structures improved greatly at year 5 and year 15. Similar to the typical annual budget scenario, the conditions and historical values of Fort Pickens and all batteries decayed dramatically, as there was insufficient budget for any type of action in all years (Appendix 3, Figure 57).

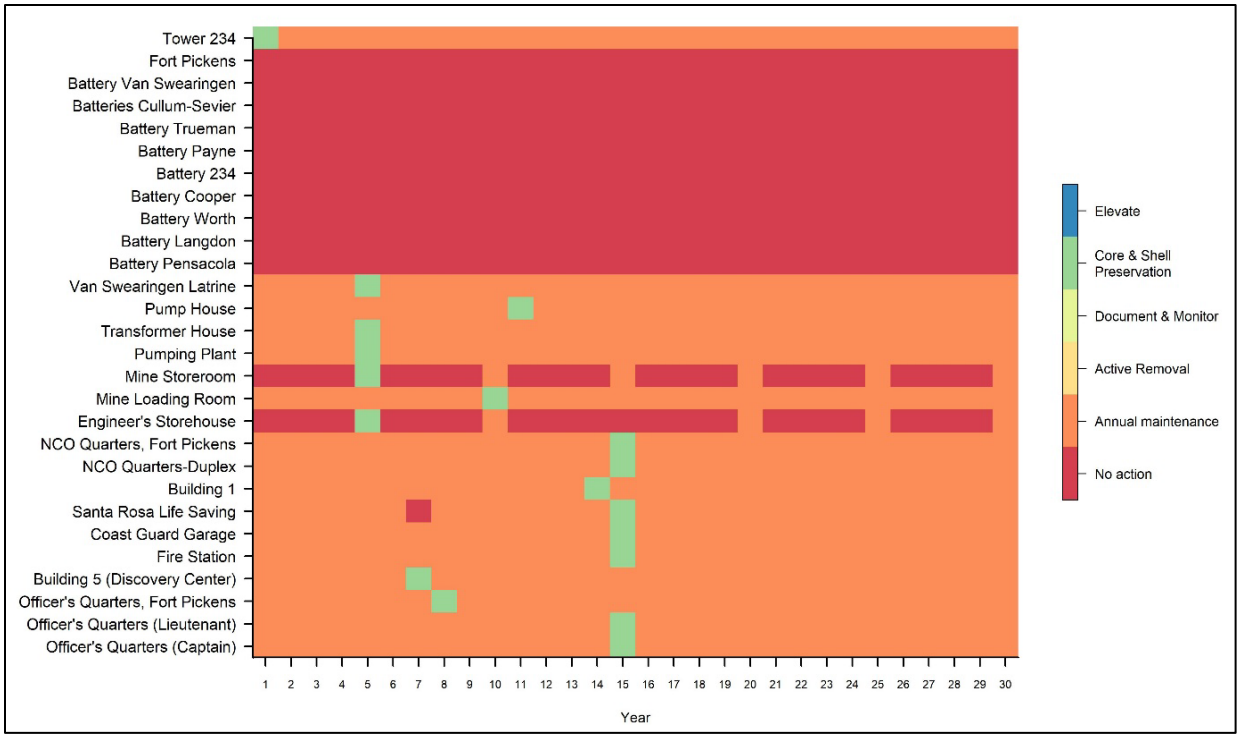


Figure 17. Actions applied under a $400,000 annual budget allocation with additional $400,000 allocation every five years.

The total resource value (137) under this scenario ($400,000 annually with an additional $400,000 every 5 years) was higher than the value of typical ($400,000) annual budget scenario but slightly lower than the value of the high ($500,000) budget scenario (Figure 18). The patterns of percentage contribution of accumulated value and total cost ($13,234,468) were greatly asymmetric (Appendix 4, Tables 7 and 10). The cost of masonry structures accounted for about 43% of the total cost of all structures, while the accumulated resource value of masonry structures accounted for about 30% of accumulated total resource value. Moreover, a few wooden structures also used a relatively high percentage of the budget but accounted for a relatively low percentage of the accumulated resource value. For instance, Santa Rosa Life Saving Station and Building 5 (Discover Center) used 10% and 8% of total cost but only accounted for 2% and 3% of accumulated value, respectively.

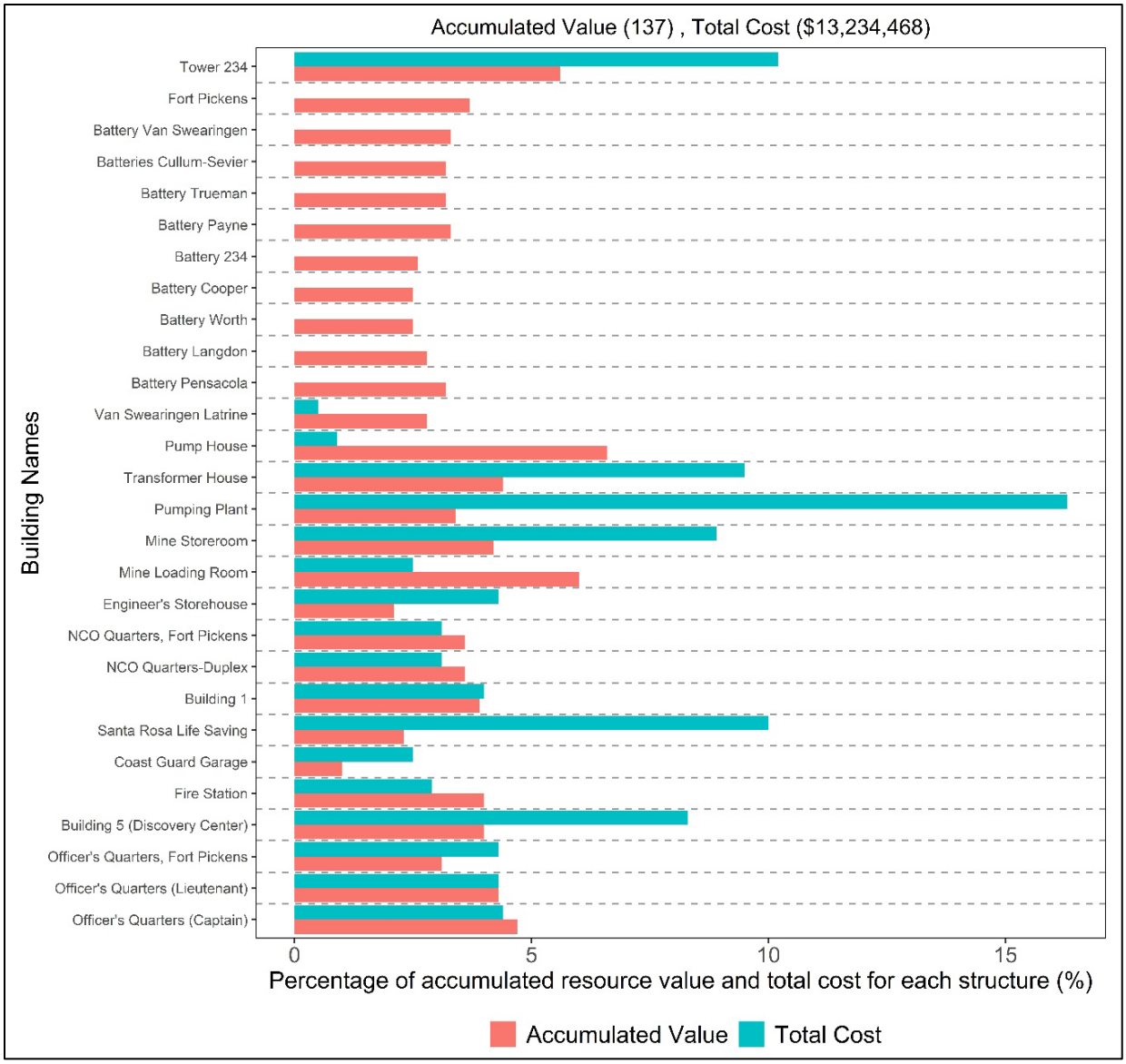


Figure 18. Percentage of accumulated resource value for each structure under a $400,000 annual budget allocation with an additional $400,000 allocation every five years and total cost for each structure receiving some type of action.

Portfolio for a Sufficient Annual Maintenance budget with a Surge of $400,000 Every 5 Years

The optimal portfolio for this scenario (Figure 19) was nearly identical to proposal actions of sufficient annual maintenance budget scenario (Figure 15) because the surge of funding accounted for less than 1% of annual allocated funding. Annual maintenance continued to be the dominant action applied across the planning horizon, and core and shell preservation was applied to all structures before year 17. Perhaps the biggest difference between this scenario and the sufficient annual maintenance scenario (without periodic funding) was that the number of times Battery Langdon receives no action was reduced from 3 to 2. Again, no adaptation actions were selected in this scenario, despite the availability of periodic funding, which appeared to be driven by (a) the

costs associated with adaptation relative to that of core and shell preservation, (b) the greater negative impacts to historic value from many adaptation actions relative to core and shell preservation, (c) the similar improvements or declines in the condition of structures from adaptation actions relative to core and shell preservation, and (d) the limited reduction in vulnerability scores from the adaptation actions. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 55.

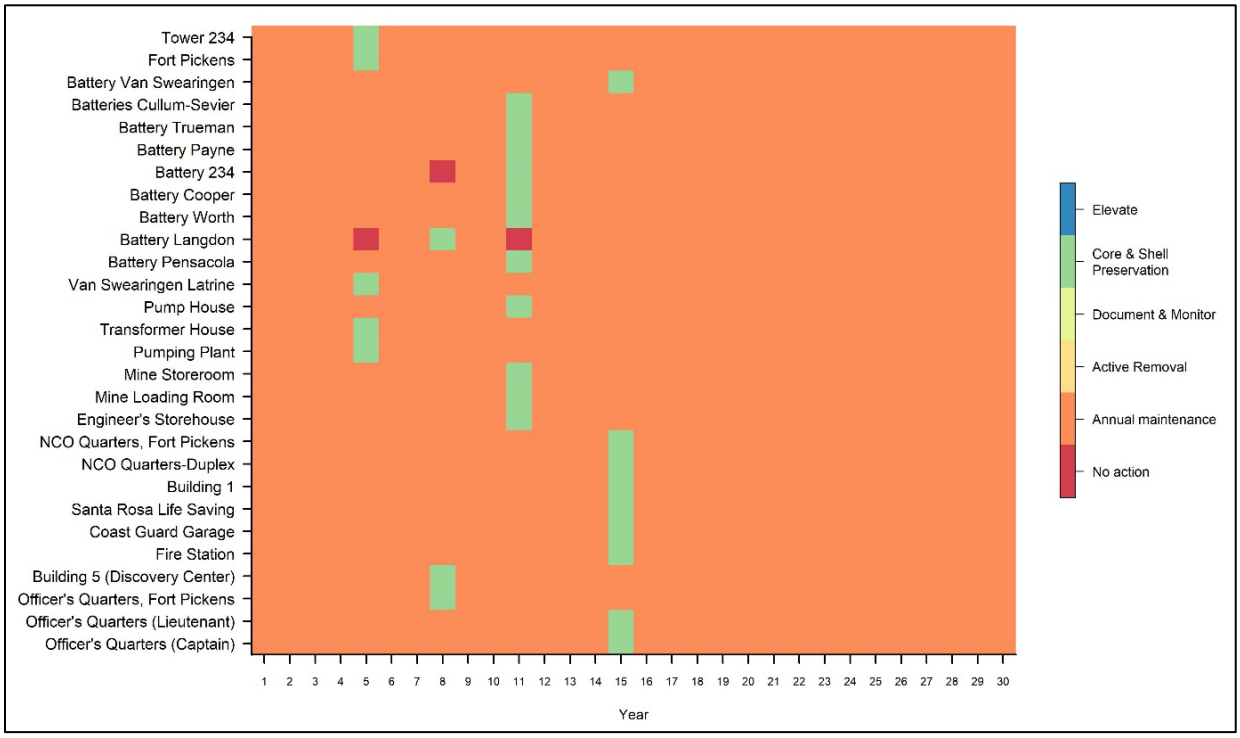


Figure 19. Actions applied under a $57,232,370 annual budget allocation with additional $400,000 allocation every five years.

The total resource value (163) under this scenario (Figure 20) was slightly higher than the value of the sufficient annual maintenance budget. Similar to the sufficient annual maintenance budget scenario, the patterns of percentage contributions of accumulated value and total cost ($1,705,822,261) were greatly asymmetric under this scenario (Appendix 4, Tables 7 and 10). The adaptation costs of Fort Pickens and all batteries accounted for more than 99% of the total cost, whereas the wooden and masonry buildings accounted for less than 1% of the total cost.

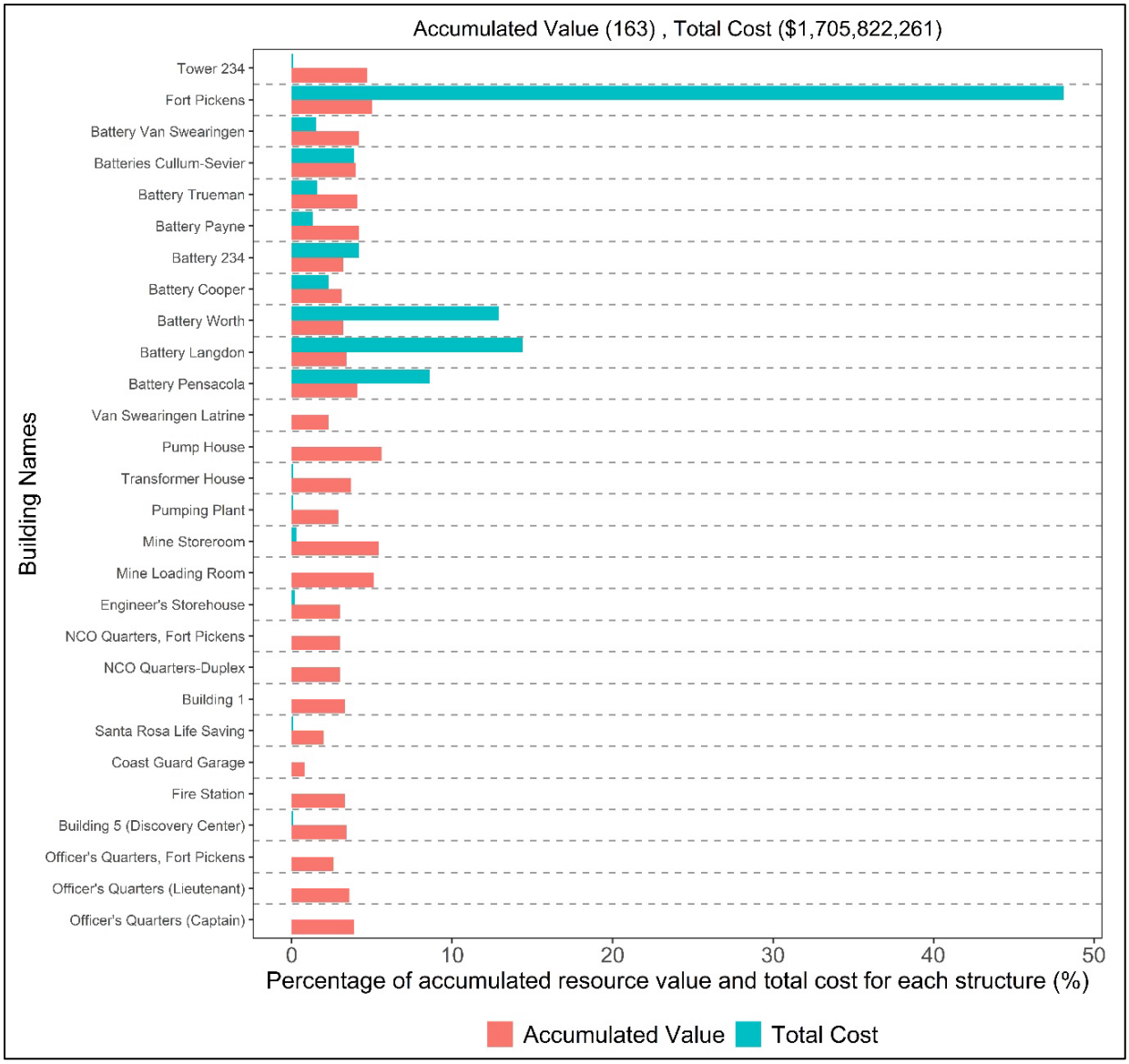


Figure 20. Percentage of accumulated resource value for each structure under a $57,232,370 annual budget allocation with an additional $400,000 allocation every five years and total cost for each structure receiving some type of action.

Updated Model A – Fort Pickens Maintenance and Use Potential Dynamics

To improve the transferability and provide alternative approaches of historical preservation, we made a series of changes to the OptiPres Model. We revised the annual maintenance constraint of Fort Pickens so that the model applies annual maintenance to 1/10 of its area if selected (1/10 of annual maintenance cost). As previously mentioned, we assumed that this might introduce a more realistic annual maintenance action for Fort Pickens due to its size and high cost of annual maintenance. Moreover, dynamics for use potential were integrated into the OptiPres Model to better reflect the constraints for use (operational, third-party, and visitor) when the condition of structures decline. We tested the same four scenarios as the original model for the updated OptiPres model, which makes the

outputs comparable to the original model outputs. To assist in the interpretation of the results, the updated use potential dynamics are described in Appendix 2, Table 6.

Scenario 1—No Budget (Updated Model A)

Under this scenario, no actions were applied to any structures over the 30-year period. The accumulated resource value (174) dropped substantially by the end of the planning horizon (89.2; Figure 21). The accumulated resource value of the historic structures decreased more rapidly than that of the original model due to the new use potential dynamics, in addition to the continuous decay of the structures' conditions and the lack of improvement in vulnerability scores under the "no budget" scenario in the original model. Specifically, the "unmanaged" status for structures over the planning period downgraded the operational use, third-party use, and visitor use to the lowest levels, resulting a higher level of decay of accumulated resource value at the end of planning horizon compared to the original model.

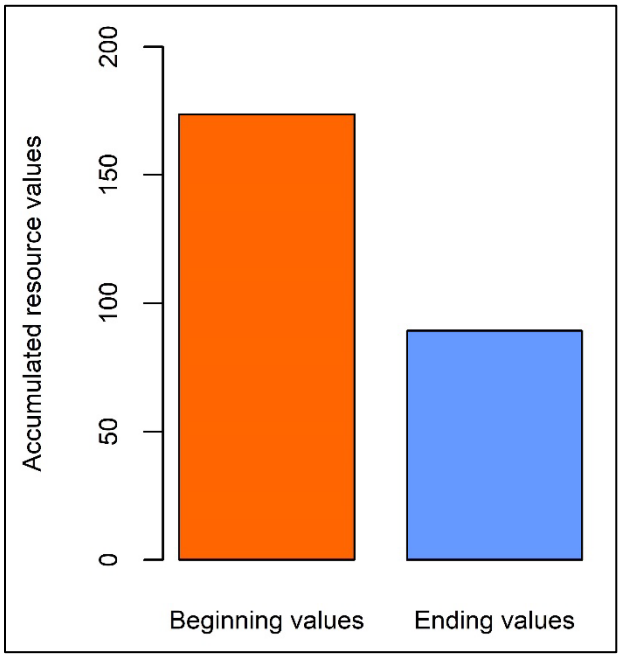


Figure 21. Accumulated resource values of all structures at the beginning and end of the 30-year planning horizon under a "no budget" scenario (Updated Model A).

We also estimated the percentage of current and future resource value for each structure under the "no budget" scenario (Figure 22; Appendix 4, Table 8). The individual resource value of structures at the beginning of 30-year was approximately equivalent to the resource values of structures at the end of 30-year when no action applied. Similar to the original model results, the dynamics of vulnerability, historical value, and use potential were operating asymmetrically across the study area. A few wooden structures [e.g., Coast Guard Garage, Santa Rosa Life Saving Station, Officer's Quarters (Fort Pickens)] accounted for relatively small percentage of resource values (less than 3%), whereas Fort Pickens and a few masonry structures (e.g., Mine Loading Room and Mine Storeroom) accounted for larger percentage of resource values (about 5%).

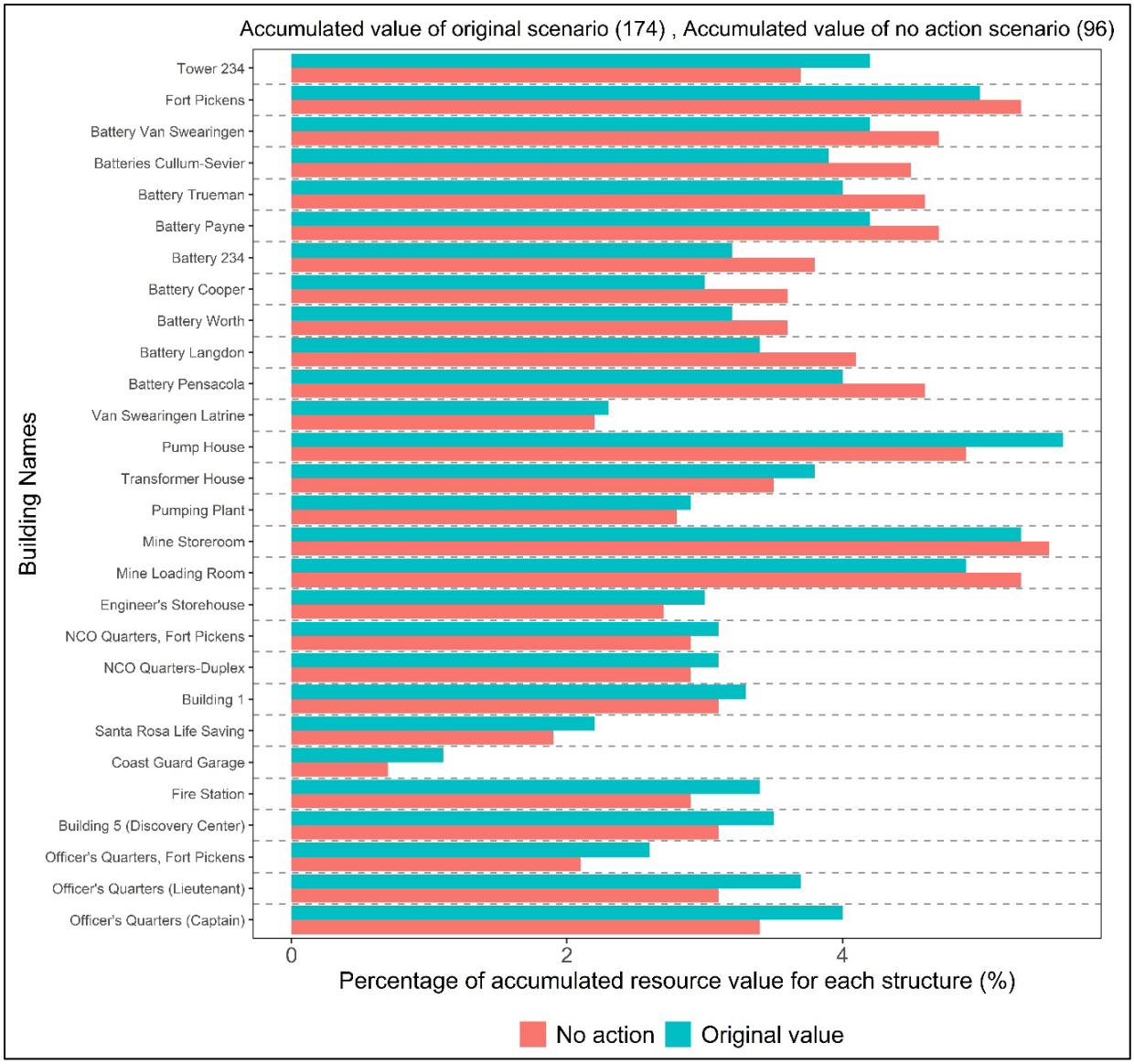


Figure 22. Percentages of total resource value for each structure under “no budget” scenario (Updated Model A). Units of accumulated value at the beginning and end of 30-year time horizon (174 and 89, respectively) are on a constructed, composite scale and, as such, are only relative to each other.

Scenario 2—An Uncertain Budget (Updated Model A)

We simulated the effect of an uncertain budget by running the model under a range of budget levels, from $50,000 USD to $500,000 USD in steps of $50,000. Key findings from the model updates under Scenario 2 included: (a) spending any money to manage even a subset of structures was better than doing nothing; (b) spending more money leads to improved management performance; (c) for this range of budgets examined, the total resource values were lower than the original resource value (174); (d) unlike the original OptiPres model where the budget ranging from $50,000 to $250,000 yielded a relatively high increase of total resource value, the growth rate of total resource value for the updated model declined after $50,000 budget allocation; (e) for this range of budget examined, $250,000 was identified as an obvious threshold in curve, where the total resource value tended to be

static when increasing budgets were allocated (Figure 23). Below we present the management portfolios of $50,000, $300,000, $400,000, and $500,000 budget levels. It is important to note that the landmark structure of the district (Fort Pickens) received no action in all years for each of these scenarios, even under the updated constraint (applying annual maintenance to 1/10 of Fort Pickens). The unmanaged status for Fort Pickens not only made the historical value and condition decay across the planning horizon, but also negatively affected the use potential of Fort Pickens when its condition deteriorated to the point when it had to be closed for visitor use. These results suggested that all of the scenarios could result in an undesired management situation.

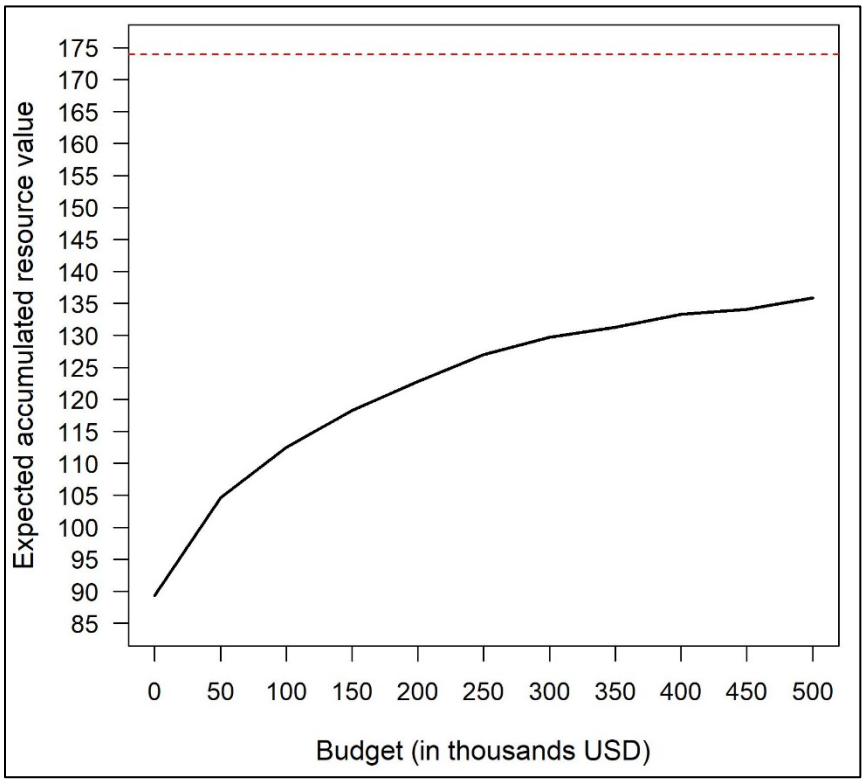


Figure 23. Expected total resource value of the optimal management portfolio at the end of the 30-year period, as a function of annual budget (black line) and compared to original total resource value (red line) (Updated Model A).

Portfolio for a Budget of $50,000 (Updated Model A)

The optimal set of actions under $50,000 budget suggested that only 9 out of 28 structures were eligible to be maintained or receive core and shell preservation treatments (Figure 24). Because the total cost of annual maintenance for all structures was much higher than $50,000, many structures—especially Fort Pickens and batteries with relatively high annual maintenance costs—were not affordable for annual maintenance (Appendix 3, Figure 59). The optimal solution suggested that there were trade-offs between applying core and shell preservation at the cost of applying no action to more structures and applying annual maintenance at the cost of applying no action to fewer structures. Because applying no action in the updated model will decrease the use potential dramatically for the first time, the model did not apply core and shell preservation for Building 1 at

the cost of applying no action to Mine Loading Room, which was different than the portfolio of the baseline scenario in the original model. In addition, the model tended to push the no action later in the planning horizon comparing to the original OptiPres Model to delay the downgrade of use potential resulting from no action.

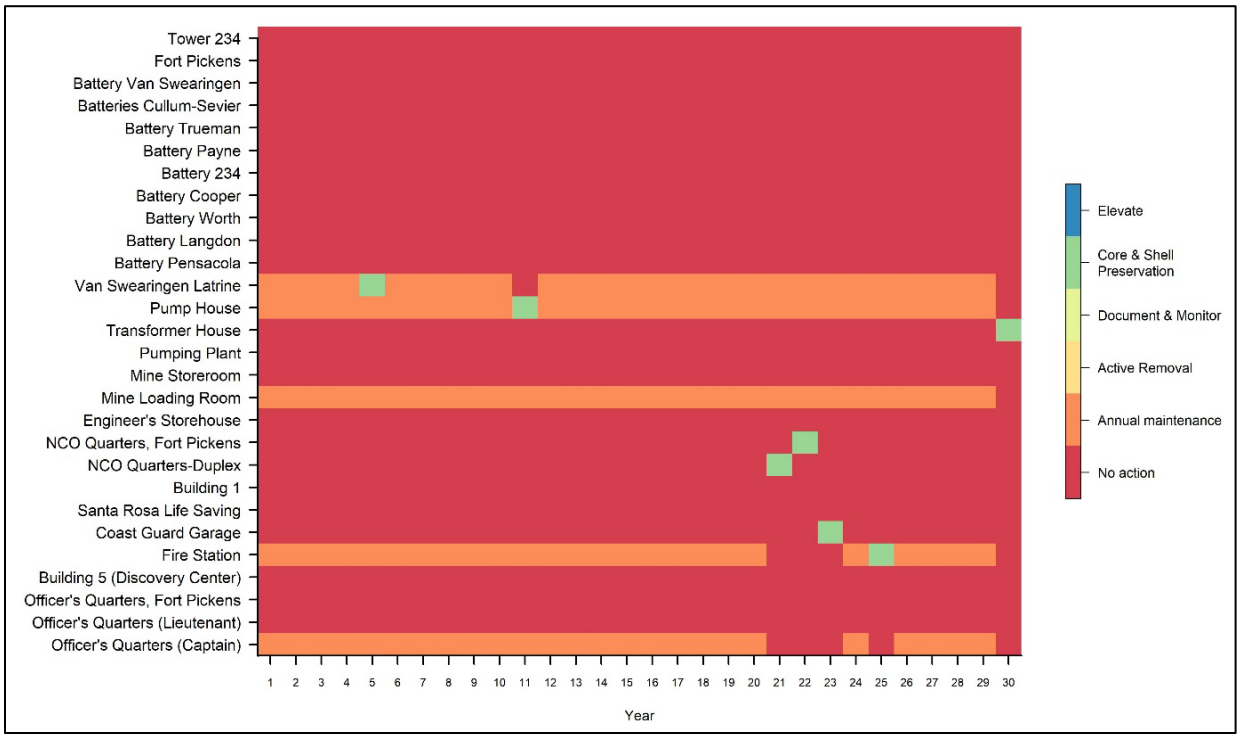


Figure 24. Actions applied under a $50,000 annual budget allocation (Updated Model A).

The percentage of total resource value and relative total cost of each structure is provided in Figure 25 and Appendix 4, Tables 8 and 11, respectively. The percentages of resource value for 9 structures selected for annual maintenance or core and shell preservation were improved after 30-year planning horizon, especially for Van Swearingen Latrine, Pump House, and Fire Station, which received both annual maintenance and core and shell preservation. However, the total resource values of the unmanaged 19 structures declined significantly. The total resource value of this scenario (105) was lower than the value of the baseline scenario ($50,000 annual allocation) in the original OptiPres model. The lower accumulated resource value was primarily caused by the decline of use potential by applying no actions to structures (compared to the relatively stable use potential in the original OptiPres model). The declines in conditions, historical values, and use potential of 19 unmanaged structures suggested that an annual budget of $50,000 was insufficient to maintain 60% of original resource value of historical structures.

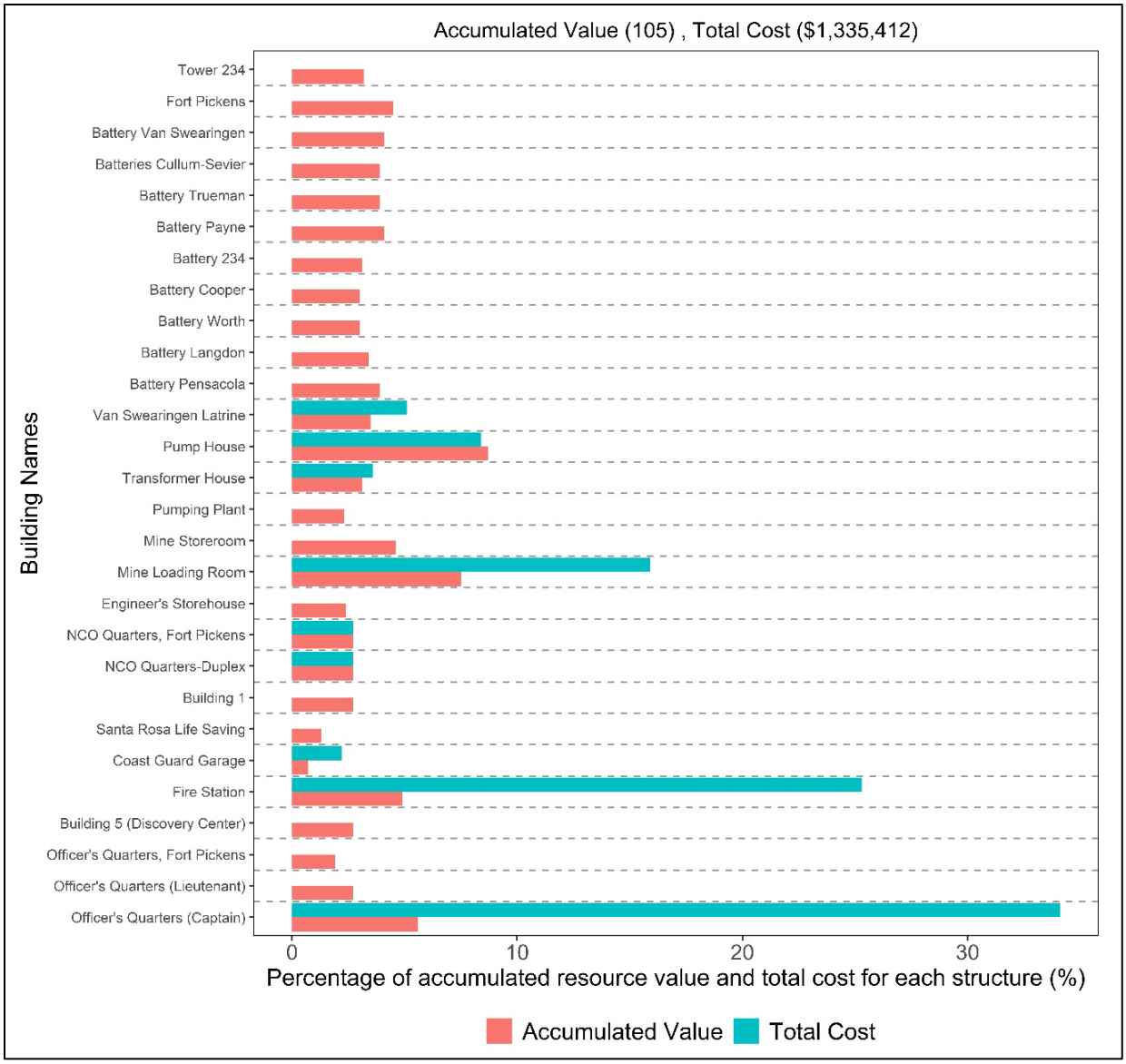


Figure 25. Percentage of value of each structure under the budget of $50,000 every year (Updated Model A).

Portfolio for a Budget of $300,000 (Updated Model A)

The optimal strategy under this budget allocation suggested applying annual maintenance and core and shell preservation to all wooden and masonry buildings, as well as Tower 234, while Fort Pickens and all batteries remained "unmanaged" (Figure 26). Under this scenario, the budget was insufficient to perform annual maintenance for any battery or Fort Pickens, making them ineligible to receive any actions during the planning horizon. It's also important to note the budget was insufficient to perform annual maintenance for all wooden structures, masonry structures, and Tower 234 (the total cost of annual maintenance for these structures is $670,000); therefore, the three structures with the highest costs of annual maintenance (Pumping Plant, Mine Storeroom, and Engineer's Storehouse) were freed up to allocate the funds for core and shell preservation actions to

other structures. The core and shell preservation actions were distributed widely across the planning horizon: the two structures with the highest costs of core and shell preservation (Mine Storeroom and Engineer's Storehouse) were pushed to the end of the planning horizon to minimize the decline of conditions, historical values, and use potential for other structures. The portfolio under this scenario was similar to that of the original OptiPres model (Figure 7). However, the timing of applying no action was different. Because the updated use potential dynamics downgraded the operational use, third-party use, and visitor use metrics to a lower level if the structure was currently in use at the time no action was first applied, the model pushed the timing of the first application of no action as far into the planning horizon as possible. For example, the Coast Guard Garage received no action for the first time at year 5 in the updated model, compared to it receiving no action in year 1 within the original model. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 57.

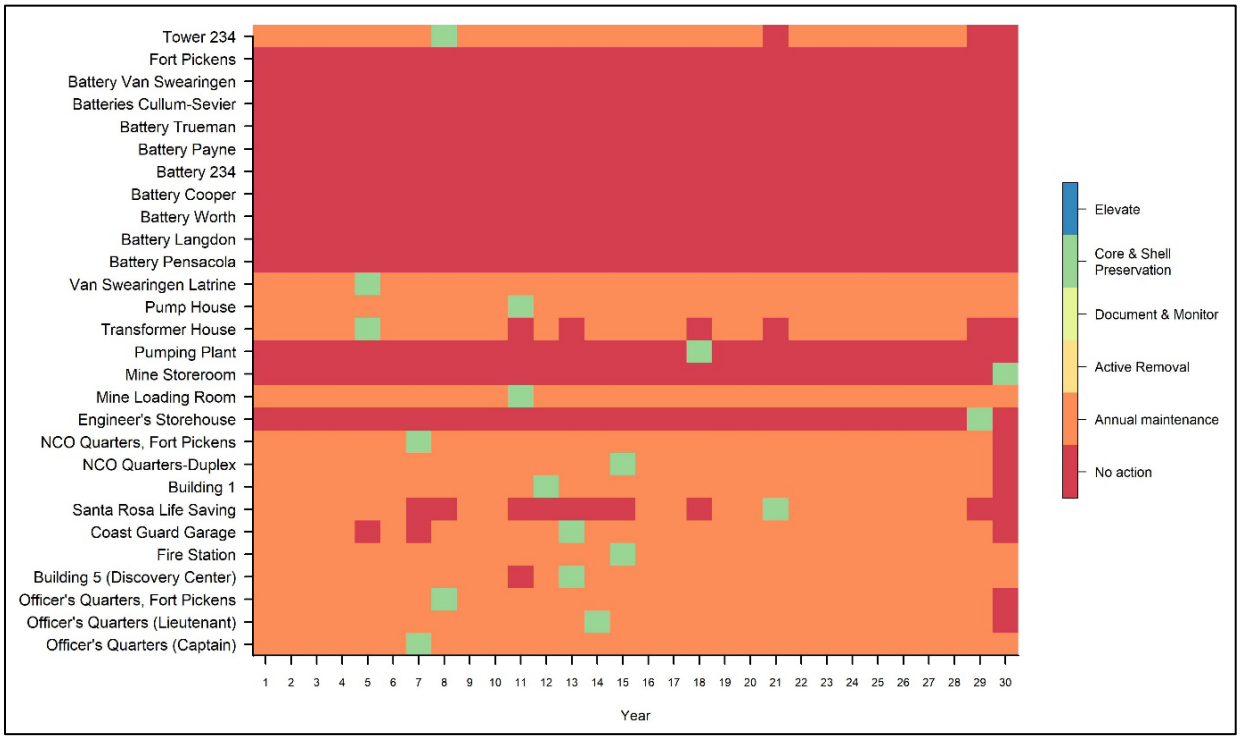


Figure 26. Actions applied under a $300,000 annual budget allocation (Updated Model A).

The accumulated resource value (130) under this scenario (Figure 27) increased by nearly 24% of the value under the baseline allocation ($50,000 annual allocation). The relative proportion of the accumulated value of each structure under this budget differed from the same allocation ($300,000) under the original OptiPres Model (Figure 8). The percent contribution of Fort Pickens and all batteries to the accumulated value declined about 1% compared to the same allocation under the original OptiPres Model, due to the consistent declines in conditions, historical values, and use potential associated with no action.

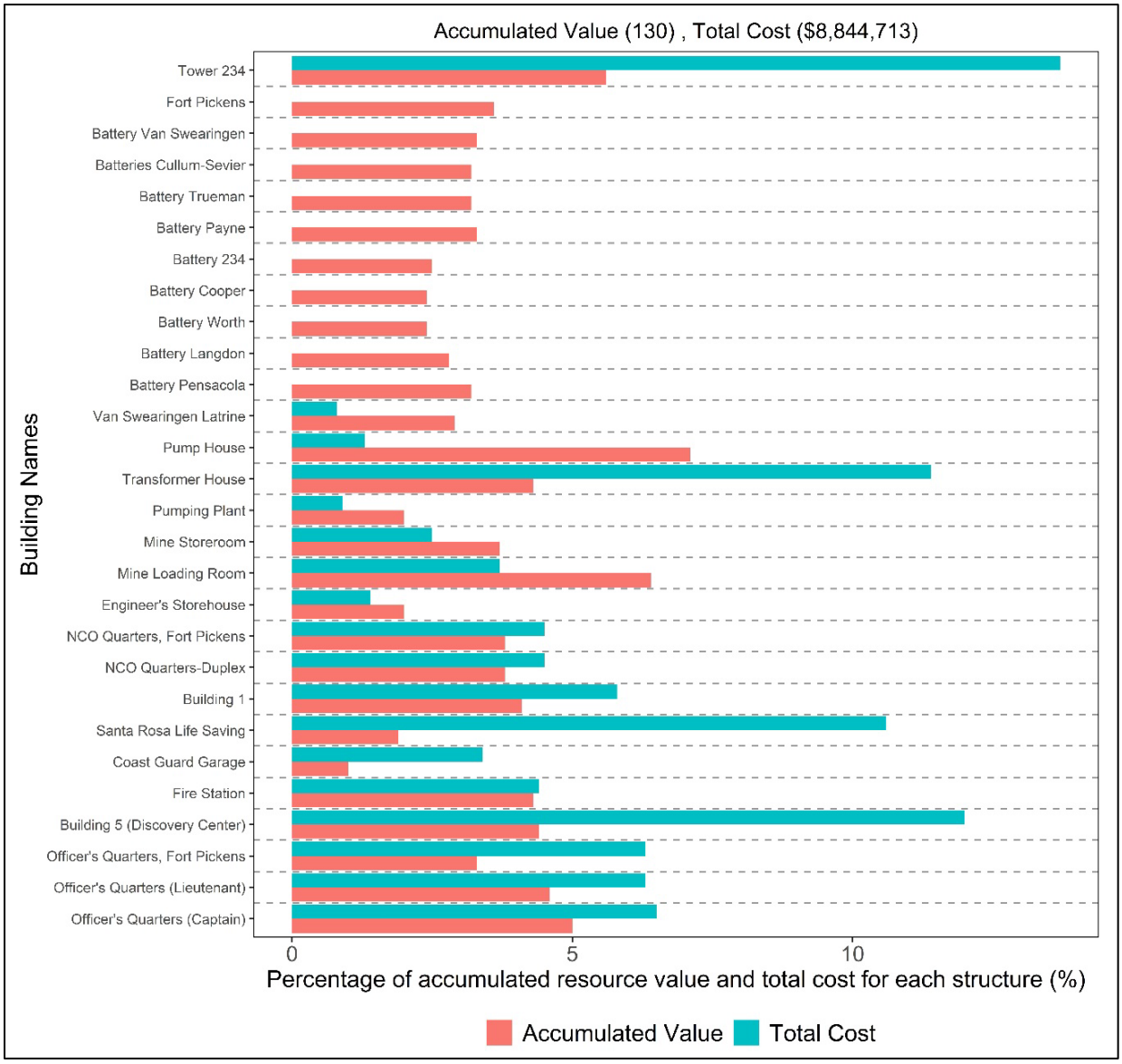


Figure 27. Percentage of value of each structure under the budget of $300,000 every year (Updated Model A).

The patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario (Figure 27; Appendix 4, Tables 8 and 11). A few structures with lower percentage of accumulated value used a relatively higher percentage of the budget. For example, the Santa Rosa Life Saving accounted for 2% of accumulated value at the end of planning horizon by using 11% of budget. However, the Pump House, which accounted for relatively high percentage of accumulated value (7%), only used 1% of budget.

Portfolio for a Budget of $400,000 (Updated Model A)

The optimal strategy under this budget allocation (Figure 28) was very similar to the strategy of previous scenario ($300,000 annual budget allocation; Figure 26). Under this budget scenario, annual

maintenance was still the dominant action for most wooden and masonry buildings and Tower 234, and core and shell preservation actions were applied to all of these structures across the planning horizon. Fort Pickens and all of the batteries were not eligible for any adaptation actions across the planning horizon. Perhaps the biggest difference of optimal strategies between this budget scenario and previous budget scenario was that one masonry structure (Pumping Plant) received annual maintenance for more than 80% of planning period. When comparing to the portfolio of the typical annual budget scenario in the original OptiPres Model, the timing of core and shell preservation actions was a little earlier because core and shell preservation not only improved the condition of the structure but also made the use potential returns to the original value for the structure. Moreover, to minimize the decline of use potential resulting from no action (in the year the action is first applied), the model pushed the no action to the end of planning horizon for a few buildings, including Officer's Quarters (Fort Pickens), Van Swearingen Latrine, Transformer House, and Tower 234. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 58.

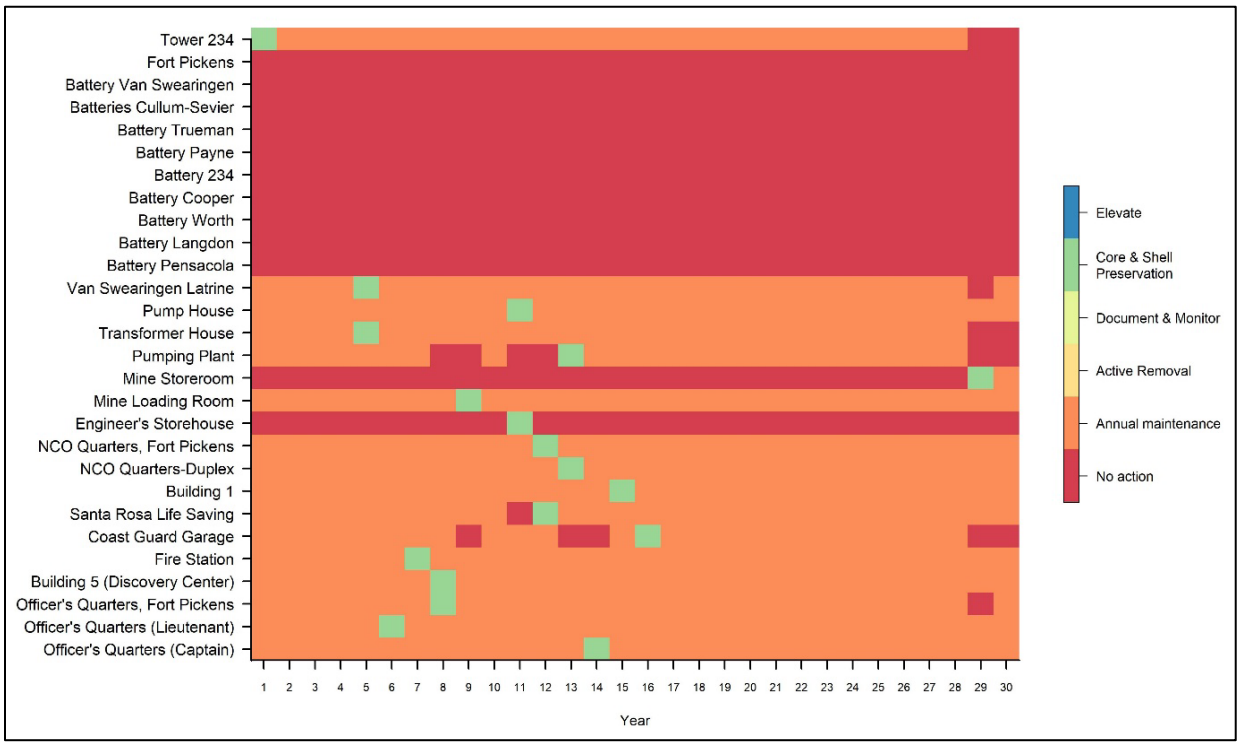


Figure 28. Actions applied under a $400,000 annual budget allocation (Updated Model A).

The total accumulated resource value (133) under this scenario (Figure 29) increased 2% of the value under the previous $300,000 annual budget scenario (Figure 27). The percentage contribution of each structure was very similar to that of previous scenario, except for the Pumping Plant, which increased in its proportion of accumulated value by 1% to previous scenario. Similar to the previous scenario, the patterns of percentage contributions of accumulated value and total cost ($11,348,121) were greatly asymmetric under this scenario (Appendix 4, Tables 8 and 11). It is important to note that the

final accumulated resource value under this scenario (typical annual budget) was 24% lower than the starting accumulated resource value.

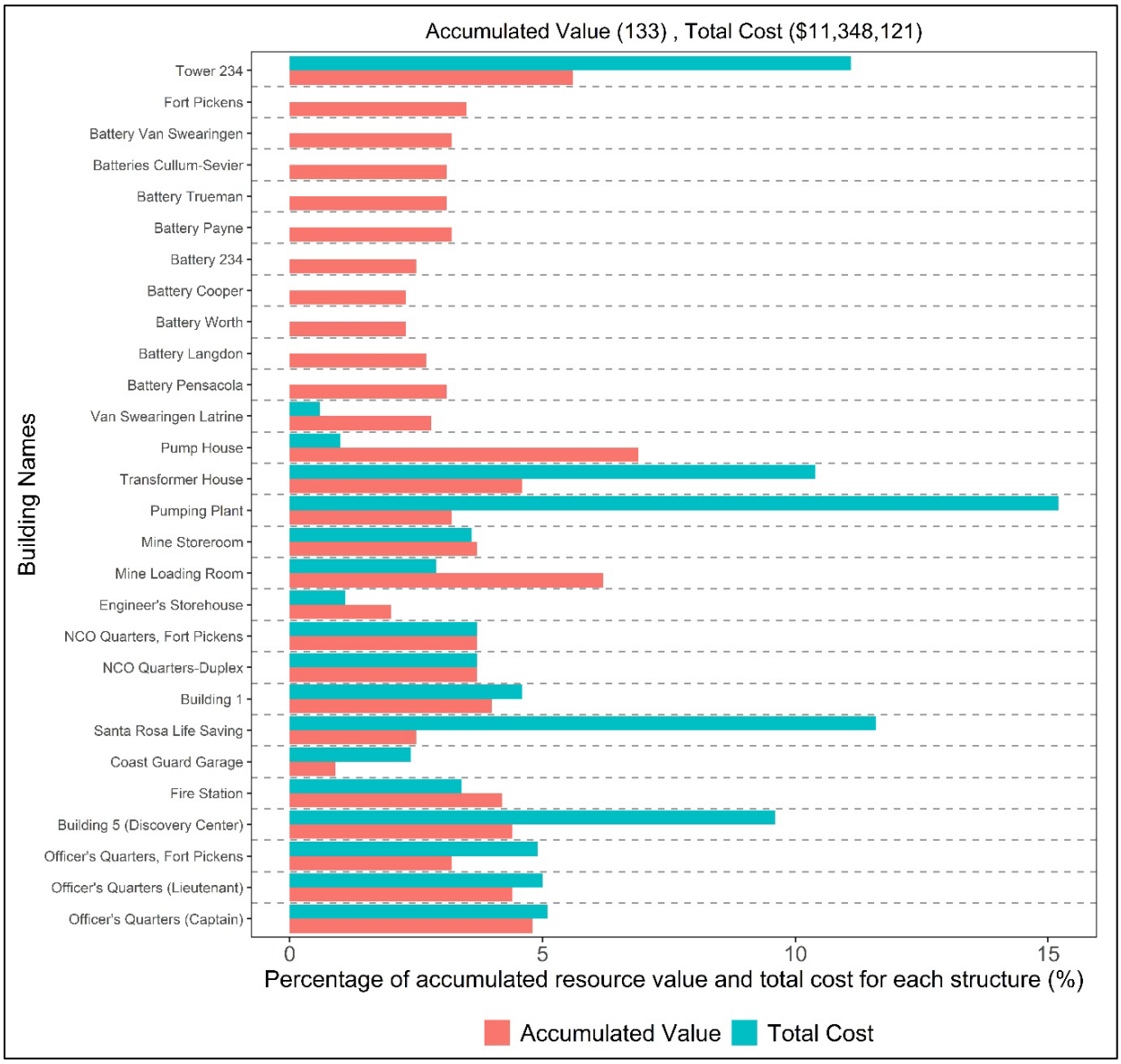


Figure 29. Percentage of value of each structure under the budget of $400,000 every year (Updated Model A).

Portfolio for a Budget of $500,000 (Updated Model A)

The optimal strategy under this budget allocation (Figure 30) was very similar to the strategy of the typical annual budget scenario ($400,000; Figure 28). Under this budget scenario, annual maintenance was still the dominant action for most wooden and masonry buildings and Tower 234, and core and shell preservation actions were applied to all of these structures across the planning horizon. Fort Pickens and all of the batteries were not eligible for any adaptation actions across the planning horizon. The increase in annual funds resulted in one more masonry building (Engineer's

Storehouse) being affordable for annual maintenance for most years during the planning period (compared to the typical annual budget scenario). The structure with the highest costs of core and shell preservation (Mine Storeroom) was pushed to the end of the planning horizon to minimize the declines in conditions, historical values and use potential for other structures. In addition, the increased funding allocation reduced the number of times no action was selected for wooden and masonry buildings when compared to the typical annual budget scenario. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 62.

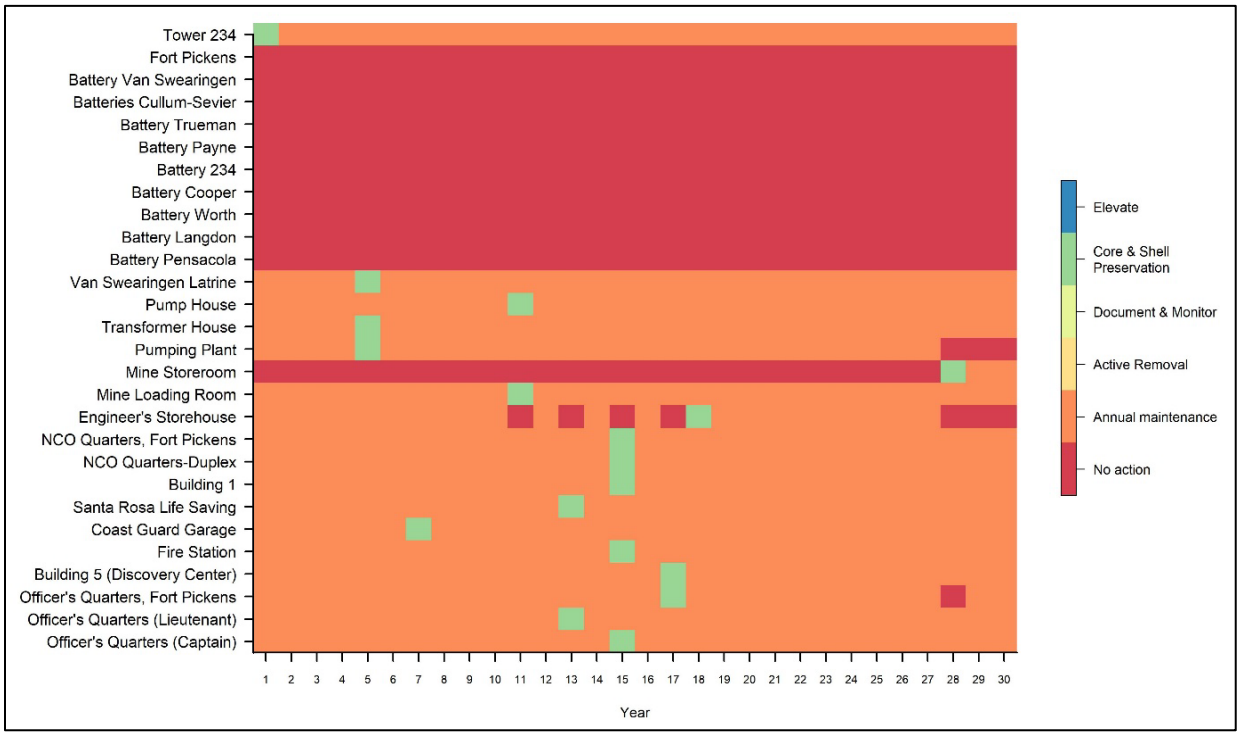


Figure 30. Actions applied under a $500,000 annual budget allocation (Updated Model A).

The total resource value (136) under this scenario (Figure 31) increased 2% of the value under the typical annual budget scenario ($400,000 annual allocation; Figure 29). The percentage contribution of each structure was very similar to that of the typical annual budget scenario, except for Engineer's Storehouse, which increased by 1% compared to the typical annual budget scenario. Similar to previous scenario, the patterns of percentage contributions of accumulated value and total cost (14,458,375) were greatly asymmetric under this scenario (Appendix 4, Tables 8 and 11). The cost of actions for masonry structures accounted for nearly 48% of the total cost of all structures, but only contributed to 31% of total accumulated resource value. When comparing to the total accumulated resource value of the same budget scenario in the original model (Figure 12), the total resource value of the updated model was about 2% lower due to the declining use potential for structures receiving no action.

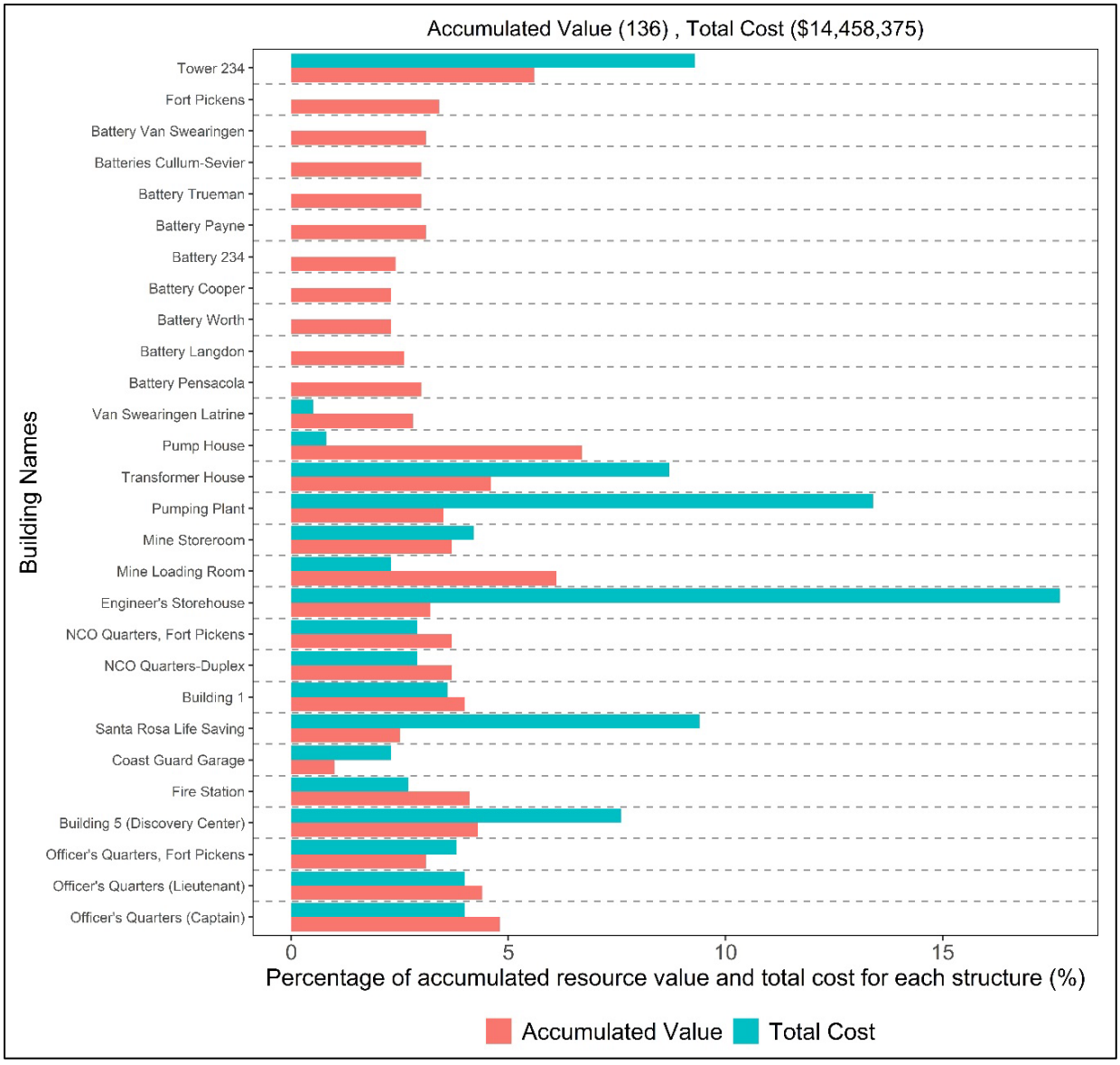


Figure 31. Percentage of value of each structure under the budget of $500,000 every year (Updated Model A).

Scenario 3—Sufficient Annual Maintenance Budget (Updated Model A)

The optimal strategy under this $57,232,370 budget allocation suggested applying annual maintenance for all structures in as many years as possible and applying core and shell preservation actions before year 16 to achieve the highest resource value (Figure 32). Because the funding allocation for this scenario was affordable for the costs of annual maintenance for all structures, Fort Pickens and all batteries were eligible for adaptation actions, which maintains the historical values, condition, and use potential of Fort Pickens and the batteries during the planning period (Appendix 3, Figure 63). When comparing to the management portfolio of the same budget scenario in the original model (Figure 15), one of the biggest differences was that the number of structures receiving no action has been reduced from 4 to 1. This finding was caused by the 1/10 annual maintenance

constraint for Fort Pickens in the updated model, making the budget more affordable for Fort Pickens and allocating 9/10 of annual maintenance cost of Fort Pickens to other structures (for example, Battery London) for annual maintenance in more years. Because core and shell preservation improved condition, historical value, and use potential for all structures in the updated model, the timing of applying core and shell preservation appeared a little earlier in the planning horizon for a few structures (comparing to the original model), especially for wooden buildings.

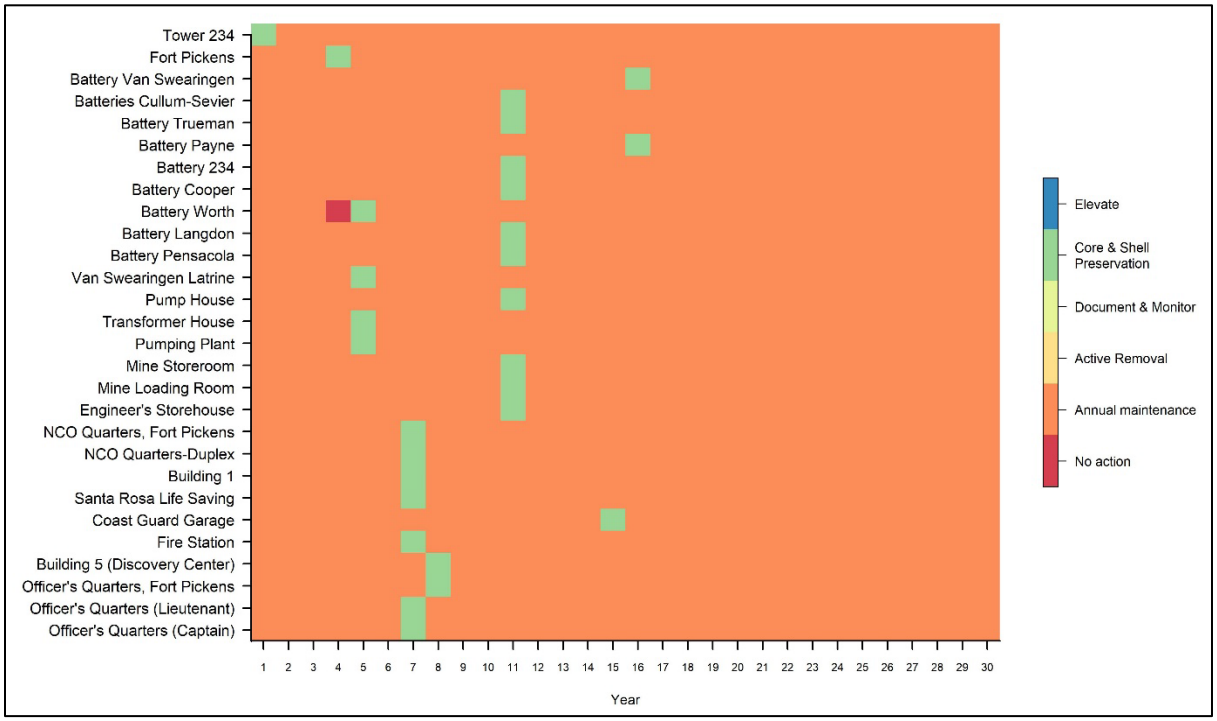


Figure 32. Actions applied under a $57,232,370 annual budget allocation (Updated Model A).

The total resource value (163) under this scenario (Figure 33) increased by 25% from the typical annual budget scenario ($400,000 annual allocation; Figure 29), and 20% from the high budget scenario ($500,000 annual allocation; Figure 31). It is important to note that even under this sufficient annual maintenance budget scenario, the total resource value was lower than the original resource value of the historical structures because the sufficient annual maintenance funds can only maintain the historical value of the structure, but do not prevent the decaying conditions. The percentage contribution of each structure was very similar as that of the beginning time period because each structure received similar types of adaptation actions (annual maintenance and core and shell preservation) for most years. As no adaptation actions were selected, the vulnerability scores have not been reduced, which would have created an improvement in the total resource value.

It is our assumption that no adaptation actions are being selected due to (a) the limited ways in which the adaptation actions would affect the vulnerability scores based on the attributes associated with the exposure and sensitivity measures and (b) the inability to apply the adaptation actions to many of the structures. It is important to note that there was discussion to add beach nourishment as a possible

adaptation action to all of the structures simultaneously; however, there was insufficient information about how such nourishment would change the exposure measures. The research team intends to update the model in the future to enable the integration of episodic storm events and impacts to the condition of structures, along with costs associated with post-storm recovery actions.

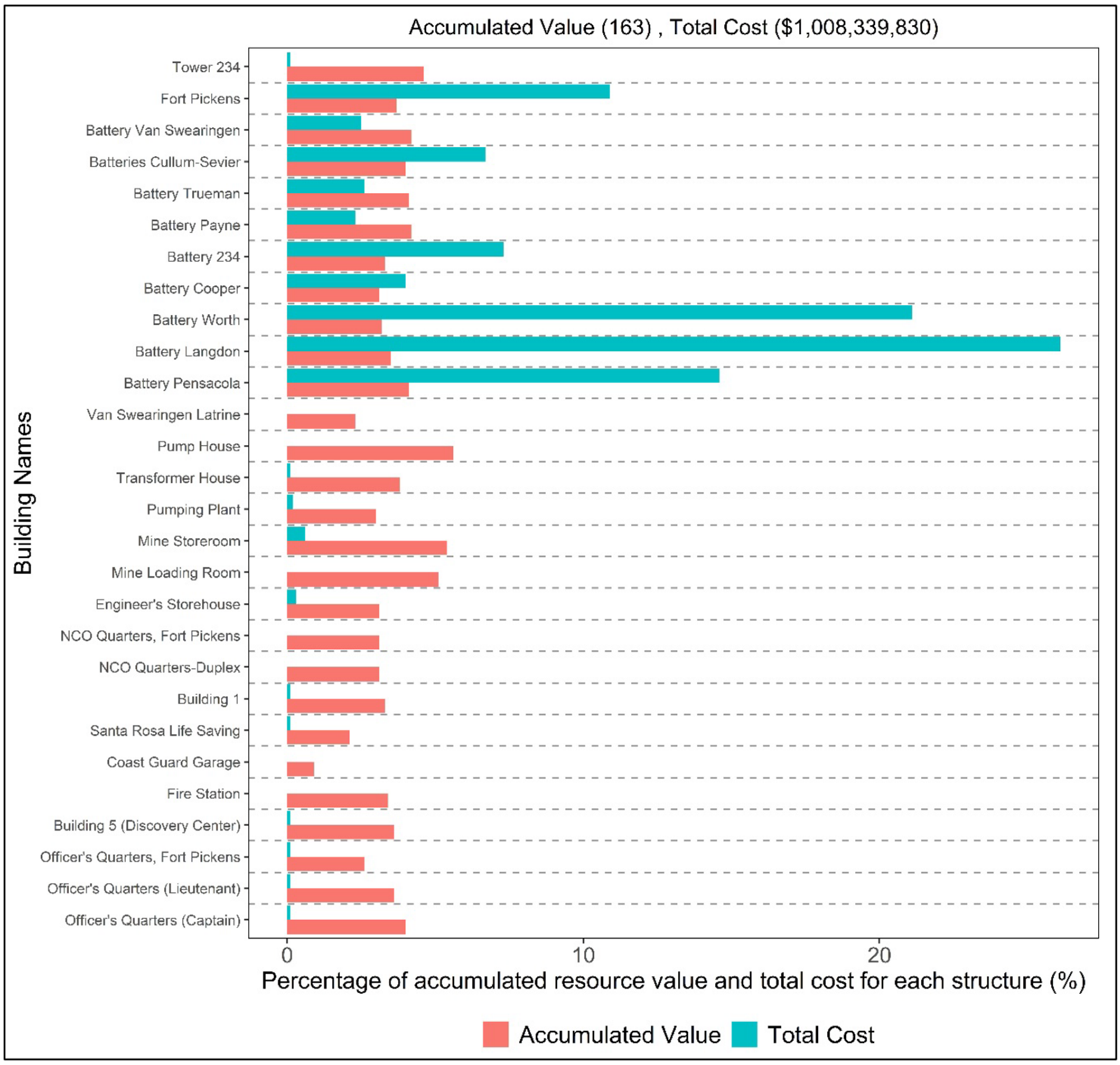


Figure 33. Percentage of value of each structure under the budget of $57,232,370 every year (Updated Model A).

The patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario (Figure 33; Appendix 4, Tables 8 and 11). Although the total resource value under this budget scenario in the updated model was almost equal to the value in the original model under the same budget allocation (Figure 16), the percentage contributions of each structure of total cost were greatly different than those in the original model. The total cost ($1,008,339,830) in the

updated model was about 40% lower than the cost in the original model. Fort Pickens accounted for 11% of total cost in the updated model (compared to 48% in the original model). In the updated model, the batteries used a very high percentage of the budget (87%), and masonry and wooden structures used less than 2% of the budget. Overall, comparing to the original model, the updated model achieved higher budget efficiency for maintaining the total resource value of historical structures (both the original model and the updated model had final accumulated resource values of 163).

Scenario 4—Accounting for Periodic Funding (Updated Model A)

Portfolio for a Budget of $400,000 with a Surge of $400,000 Every 5 Years (Updated Model A)

The optimal portfolio for this scenario suggests some structures were eligible for core and shell preservation earlier when a surge of funds is provided (Figure 34). Two of masonry buildings with relatively high cost of annual maintenance received no action for most years except when the additional funding was allocated at the 5-year interval. Because the budget of the typical annual budget scenario ($400,000 annual allocation) cannot afford the cost of annual maintenance for all wooden and masonry buildings and Tower 234, the surge of funding made it possible to maintain all of these structures every five years. Moreover, to minimize the number of times no action was selected, the model tended to apply core and shell preservation when additional funding was available. For example, 7 buildings received core and shell preservation at year 15, and 4 buildings received core and shell preservation at year 5. As a result, the conditions of buildings improved greatly at year 5 and year 15. Similar to the typical annual budget scenario, the conditions, historical values, and use potential of Fort Pickens and all batteries decayed dramatically, as they did not receive any actions across the 30-year time period (Appendix 3, Figure 64). When comparing to the portfolio under the same budget scenario in the original OptiPres Model, the portfolio of updated model was very similar to the original model, with slight differences in timing of core and shell preservation actions being applied to a few buildings [e.g. Building 1 and Building 5 (Discovery Center)].

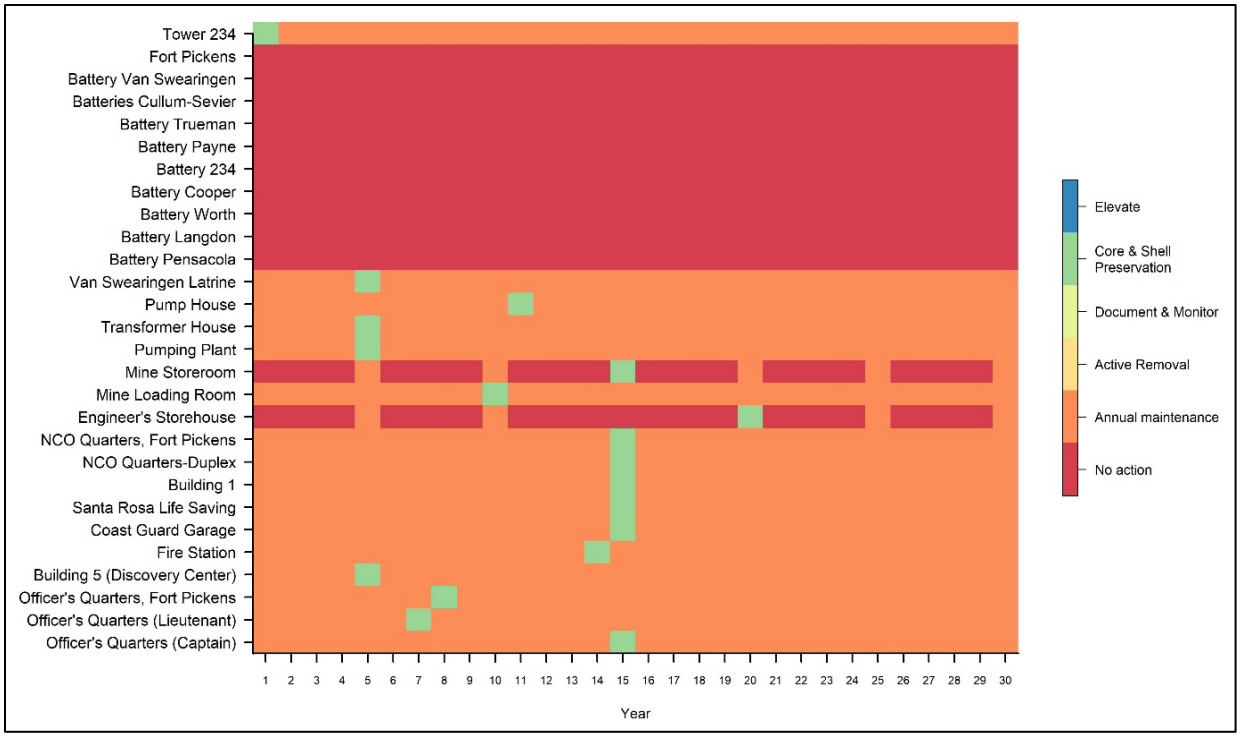


Figure 34. Actions applied under a $400,000 annual budget allocation with additional 400,000 budget allocation every five years (Updated Model A).

The total resource value (135) under this scenario (Figure 35) was higher than the value of the typical annual budget scenario ($400,000 annual allocation; Figure 29) but slightly lower than the value of the high budget scenario ($500,000 annual allocation; Figure 31). The pattern of percentage contribution of each structure to the total accumulated resource value and total cost was very similar to that of high budget allocation (Appendix 4, Tables 8 and 11). The cost of actions for masonry structures accounted for nearly 43% of the total cost of all structures (compared to 30% of the total accumulated resource value). When comparing to the total resource value of the same budget scenario in the original model (Figure 18), the total resource value of the updated model was about 1.5% lower due to the declines in the use potential of Fort Pickens and all of the batteries.

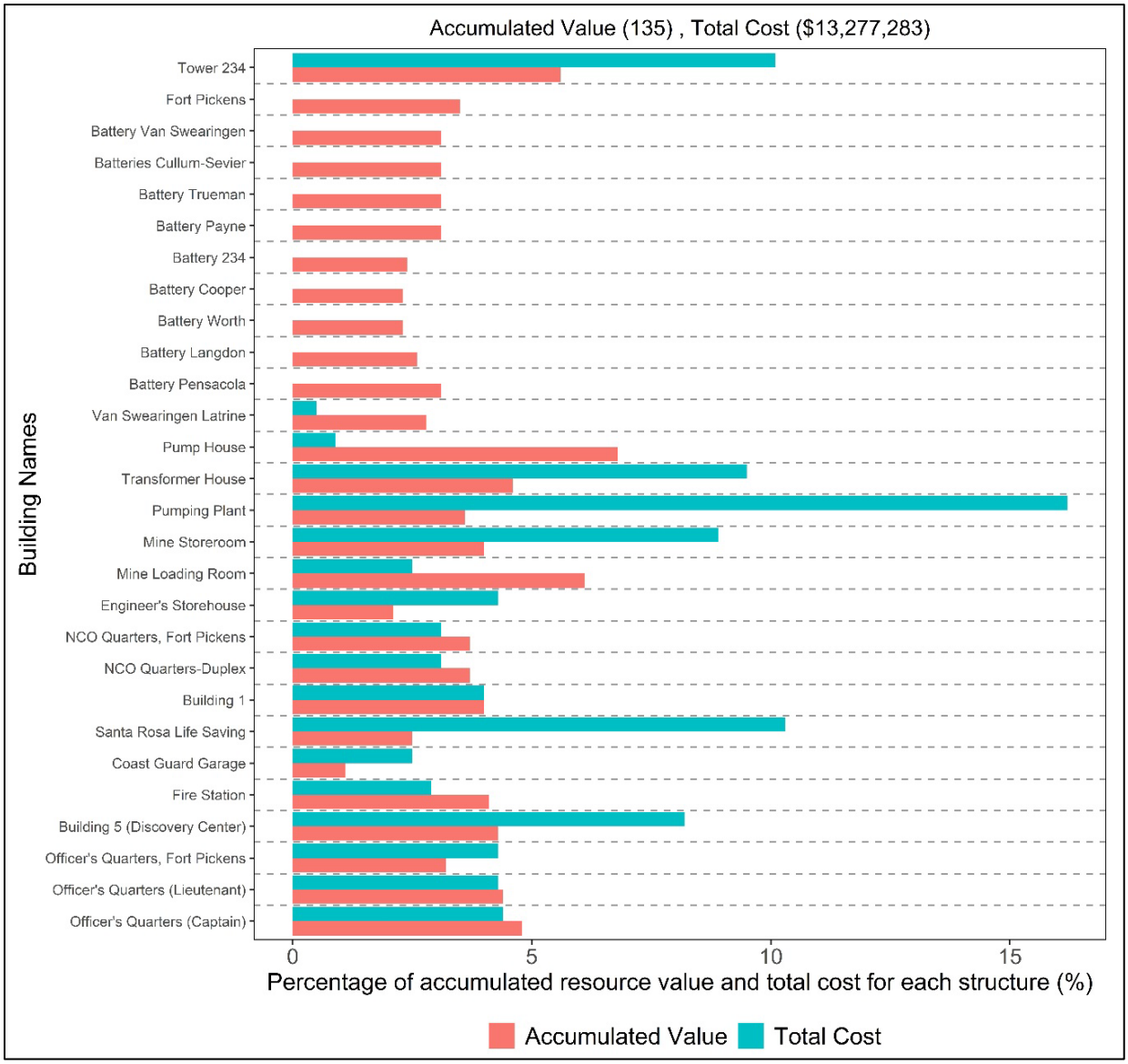


Figure 35. Percentage of value of each building under a $400,000 annual budget allocation with additional 400,000 budget allocation every five years (Updated Model A).

Updated Model B – Fort Pickens Maintenance and Core and Shell Preservation

To enhance the transferability of GUIS model and reflect more realistic time horizons for periodic (cyclic) maintenance, we removed the time limit of core and shell preservation from one-time every 30 years to one-time every 10 years. This means that core and shell preservation could be applied to any structure at any given year between year 1-10, year 11-20, and year 21 to 30. It is important to note the intervals between two different core and shell preservation actions for a structure may not be 10 years. We realize the ideal constraint for core and shell preservation would be having applied every 10 years (e.g., if applying core and shell preservation to Fort Pickens at year 3, then the next core and shell preservation would be on or after year 13). However, due to complexity of the OptiPres model, we set the 10-year interval for the whole model but not to the individual structures.

We hope to enhance this constraint by applying it to individual structures (based on average cyclic maintenance needs for different types of structures) in future investigations. We also retained the fractional annual maintenance costs for Fort Pickens to try to integrate more realistic cost and capacity estimates. We did not include the use potential dynamics so that we could examine its influences separately from the changes in core and shell preservation constraints.

Scenario 1—No Budget (Updated Model B)

Under this scenario, the model outputs (Figure 36, 37) were the same with the original OptiPres Model no budget scenario (Figure 2, 3). The replication in outputs was due to the Updated Model B only having changes to the actions and not the model dynamics, unlike Updated Model A (Figure 19, 20).

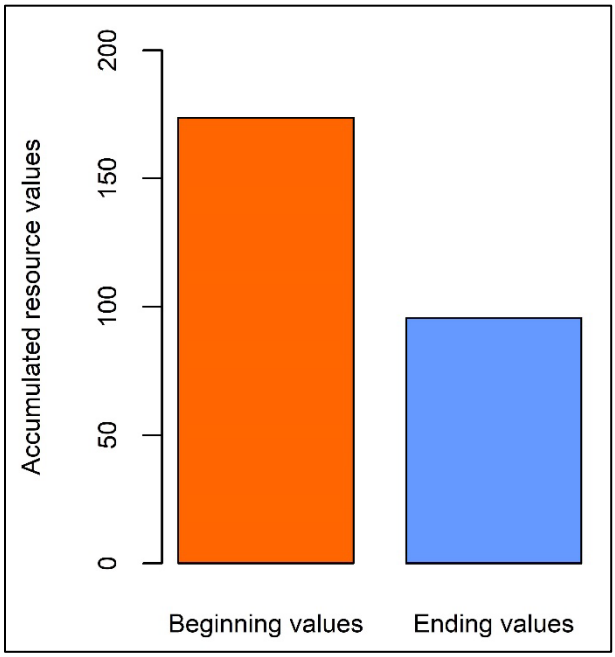


Figure 36. Accumulated resource values of all structures at the beginning and end of the 30-year planning horizon under a “no budget” scenario (Updated Model B).

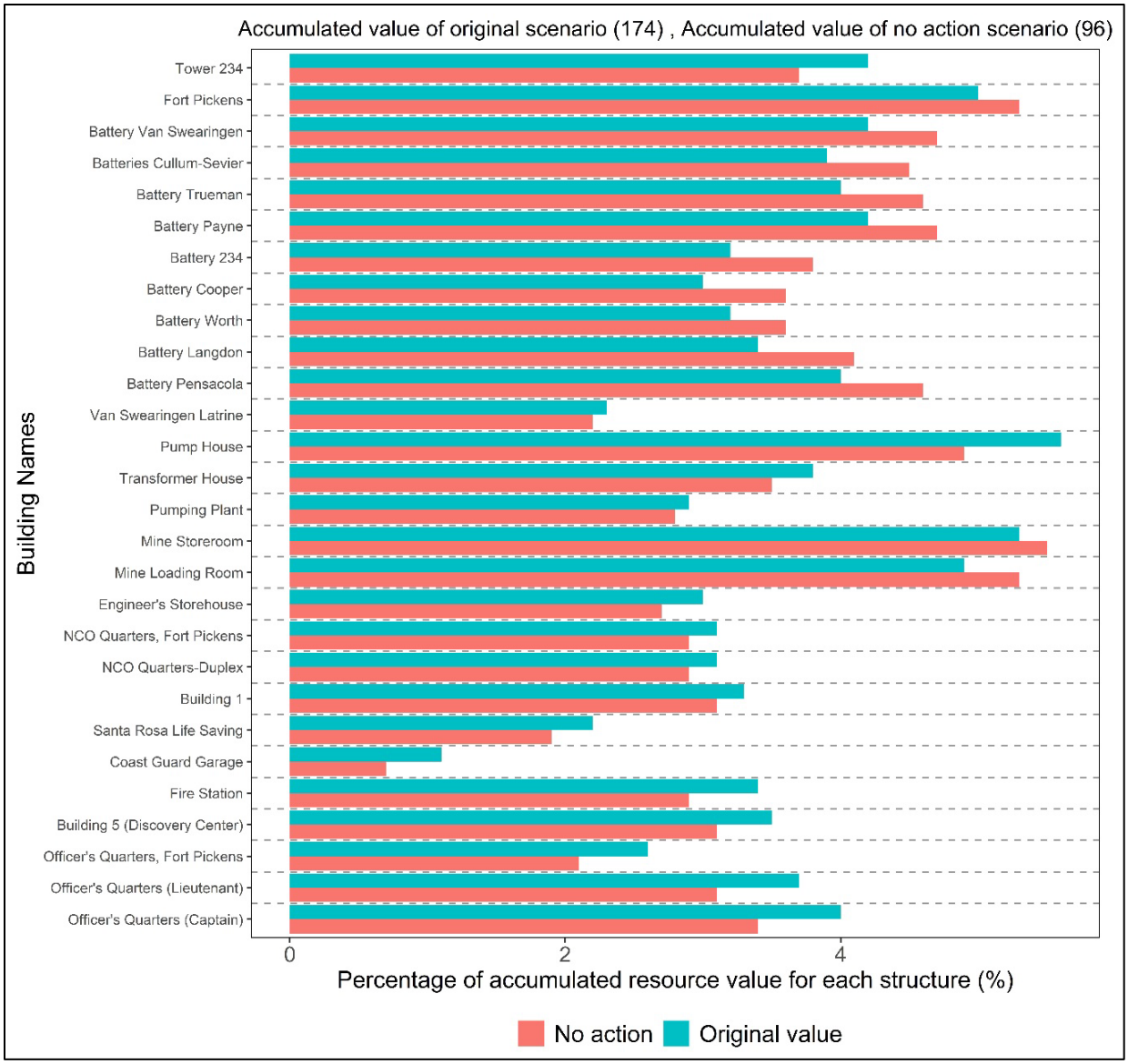


Figure 37. Percentages of total resource value for each structure under "no budget" scenario (Updated Model B). Units of accumulated value at the beginning and end of 30-year time horizon (174 and 96, respectively) are on a constructed, composite scale and, as such, are only relative to each other.

Scenario 2—An Uncertain Budget (Updated Model B)

We simulated the effect of an uncertain budget by running the model under a range of budget levels, from $50,000 USD to $500,000 USD in steps of $50,000 (Figure 38). These results suggested that: (a) spending any money to manage even a subset of structures was better than doing nothing; (b) spending more money led to improved management performance; (c) for this range of budgets examined, the total resource values were lower than the original resource value (174); (d) the total resource values in the updated OptiPres model were improved due to multiple applications of core and shell preservation; (e) for this range of budget examined, $200,000 is identified as an obvious threshold in curve, where the total resource value tended to be static when increasing funds were

allocated. Below we present the management portfolios of $50,000, $300,000, $400,000, and $500,000 budget levels.

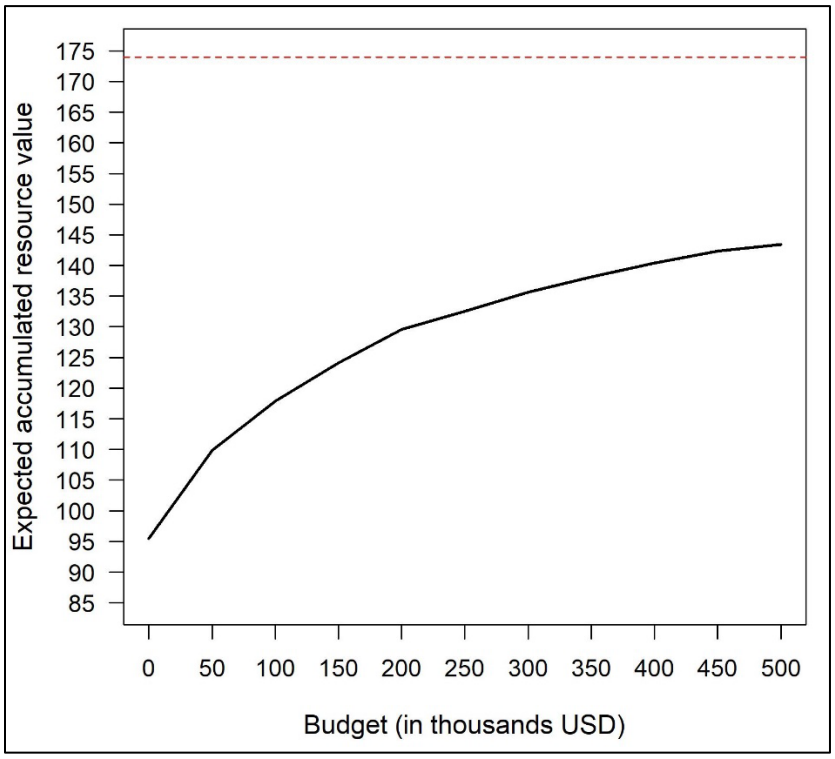


Figure 38. Expected total resource value of the optimal management portfolio at the end of the 30-year period, as a function of annual budget (black line) and compared to the beginning total resource (red line) (Updated Model B).

Portfolio for a Budget of $50,000 (Updated Model B)

The optimal set of actions under a $50,000 annual budget allocation identified that 10 out 28 structures were eligible to be maintained or receive core and shell preservation actions (Figure 39). Because the total cost of annual maintenance for all structures was much higher than $50,000, many structures—especially Fort Pickens and the batteries with relatively high annual maintenance costs—were not affordable to be maintained. However, the management portfolio was greatly different than the same budget scenario in original model, given the cyclic application of core and shell preservation actions (Figure 5).

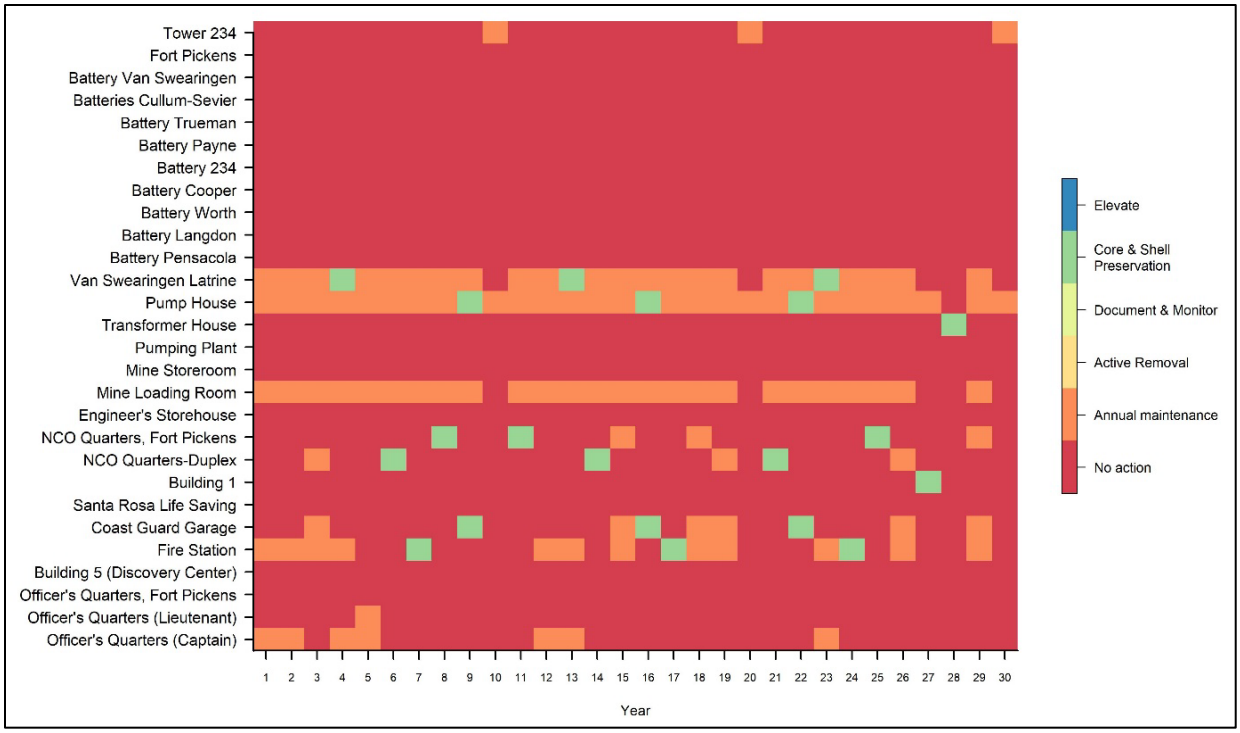


Figure 39. Actions applied under a $50,000 annual budget allocation (Updated Model B).

The percentage of total resource value (110) and relative total cost ($1,445,551) of each structure is provided in Figure 40 and Appendix 4, Tables 9 and 12, respectively. The percentages of resource value for the 10 structured selected for annual maintenance or core and shell preservation were improved (compared to the beginning of 30-year planning horizon), especially for Van Swearingen Latrine and the Pump House, which received core and shell preservation 3 times and annual maintenance for most years across the planning horizon. Also, the updated model applied core and shell preservation 3 times to four wooden structures: NCO Quarters-Duplex, NCO Quarters (Fort Pickens), Coast Guard Garage, and Fire Station. The Transformer House received core and shell preservation only once (the relatively high cost of core and shell preservation made it unaffordable for a few structures to receive any management actions in that year). Additionally, the patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario. A few wooden structures (that received both annual maintenance and core and shell preservation) used relatively high percentages of the total budget, while accounting for a relatively low percentage of accumulated resource value. For instance, the Fire Station and the Coast Guard Garage accounted for 4% and 1% of accumulated resource value by using 17% and 10% of total cost, respectively. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 65.

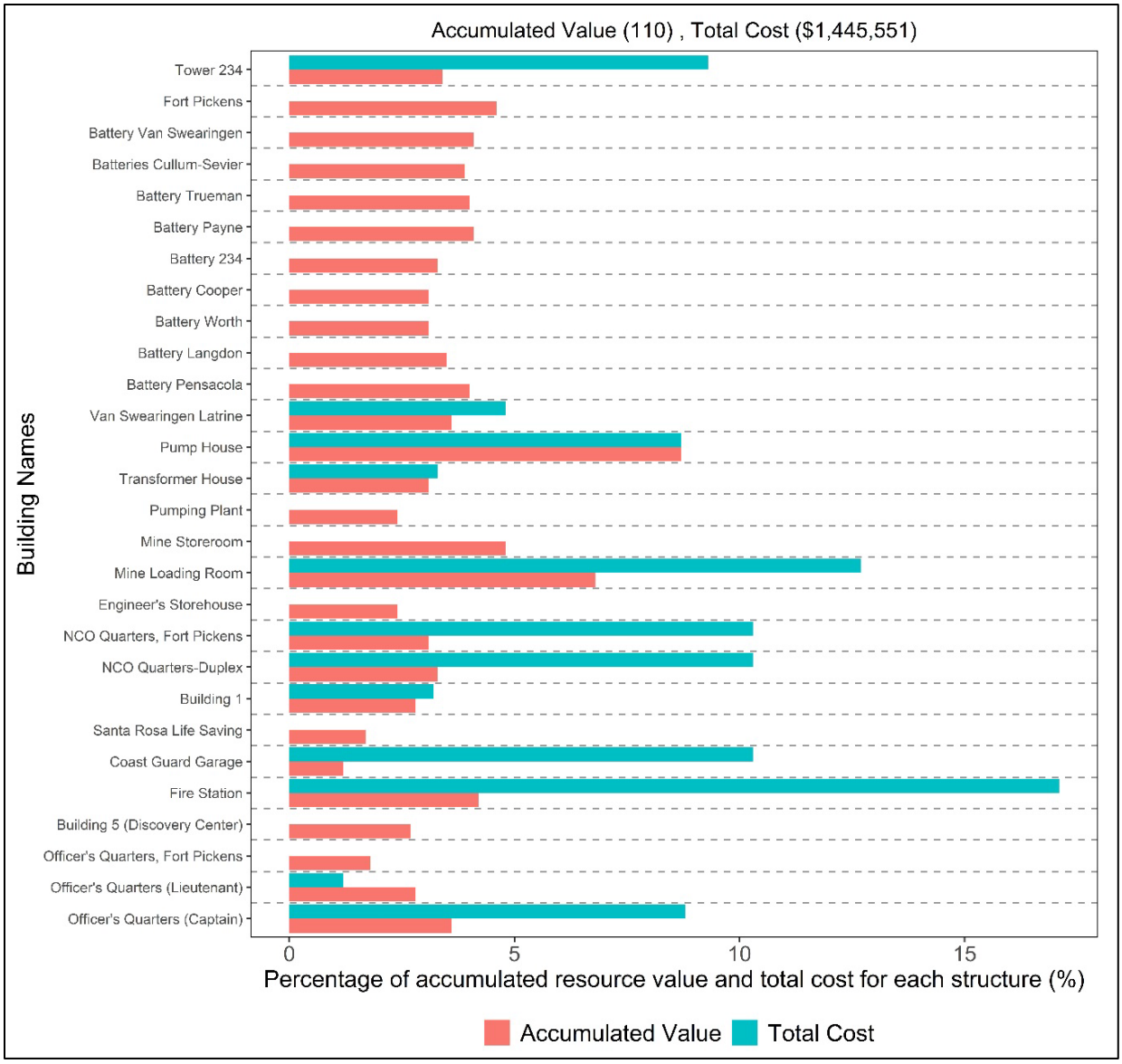


Figure 40. Percentage of value of each structure under the budget of $50,000 every year (Updated Model B).

The total resource value in the updated model (Figure 40) was slightly higher than that of the same scenario in the original model (Figure 6) due to multiple times of core and shell preservation for a few wooden and masonry buildings. However, the total resource values of the unmanaged 18 structures declined significantly. Despite the stable use potential scores, the decline in both the conditions and historical values of 18 unmanaged structures suggested that an annual budget of 50,000 was insufficient. Only 65% of the original resource value of historical structures was maintained, even with the core and shell preservation modifications (that is, core and shell preservation can be applied to structures 3 times during the planning horizon).

Portfolio for a Budget of $300,000 (Updated Model B)

The optimal strategy under this budget allocation (Figure 41) suggested applying annual maintenance and core and shell preservation multiple times to most of the wooden and masonry buildings, as well as Tower 234, while Fort Pickens and all batteries remain "unmanaged." Under this scenario, the budget was insufficient to perform annual maintenance for any battery or Fort Pickens, making them ineligible to receive any actions during the planning horizon. It is also important to note the budget was insufficient to perform annual maintenance for all wooden structures, masonry structures, and Tower 234 (the total cost of annual maintenance for these structures are $670,000); as such, the 3 structures with the highest costs of annual maintenance (that is, Pumping Plant, Mine Storeroom, and Engineer's Storehouse) were "freed up" to allocate the funds for core and shell preservation actions to other structures in most years. The application of core and shell preservation was similar to that found in the original model (Figure 7), but the updated model enabled more applications of the core and shell preservation across the 30-year planning horizon. The relative value changes for each structure across the 30-year planning horizon are displayed in Appendix 3, Figure 66.

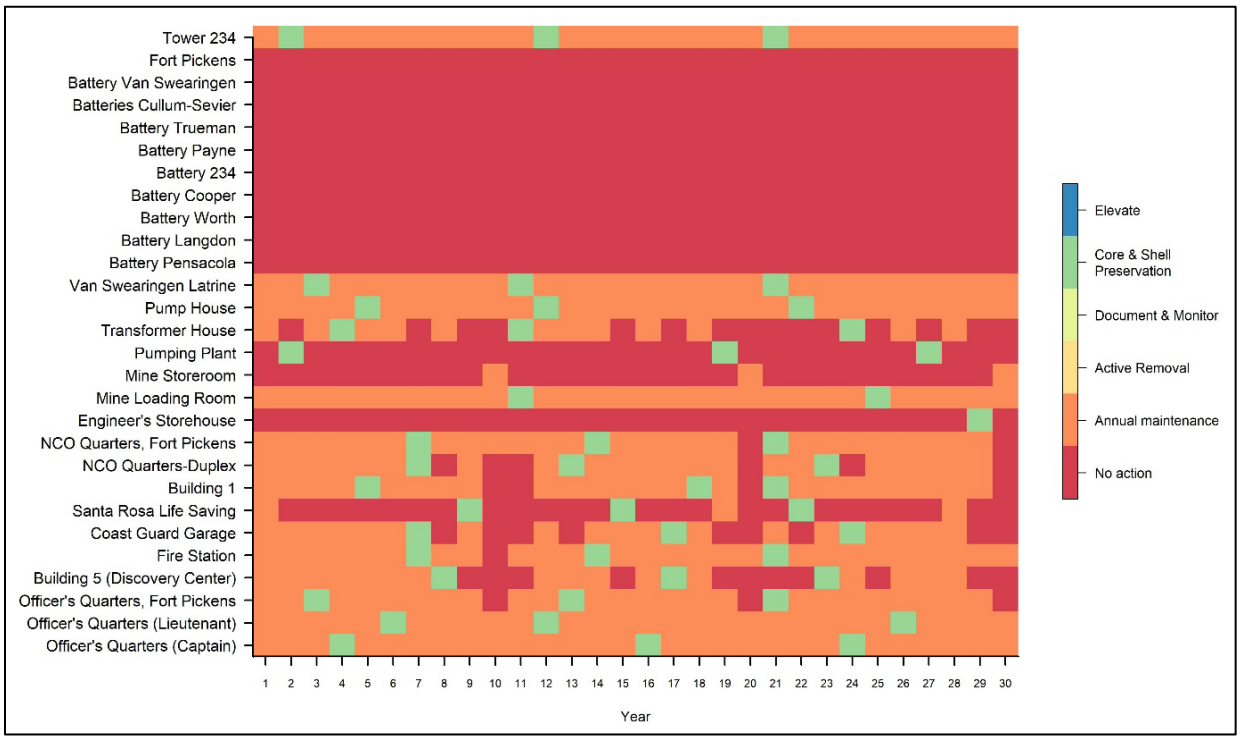


Figure 41. Actions applied under a $300,000 annual budget allocation (Updated Model B).

The total resource value (136) of this scenario improved by 3% (Figure 42) from the value under the same budget scenario in the original model (Figure 8). The total cost ($8,823,877) of this scenario was slightly lower than the cost of the same budget scenario in the original model ($8,859,019). These results document that, under the same budget, updating the constraints of core and shell preservation to allow its application once in 10-year cycles (as opposed to once in the 30-year planning horizon) achieved higher accumulated resource value, while using less of the allocated budget, when compared to the original model.

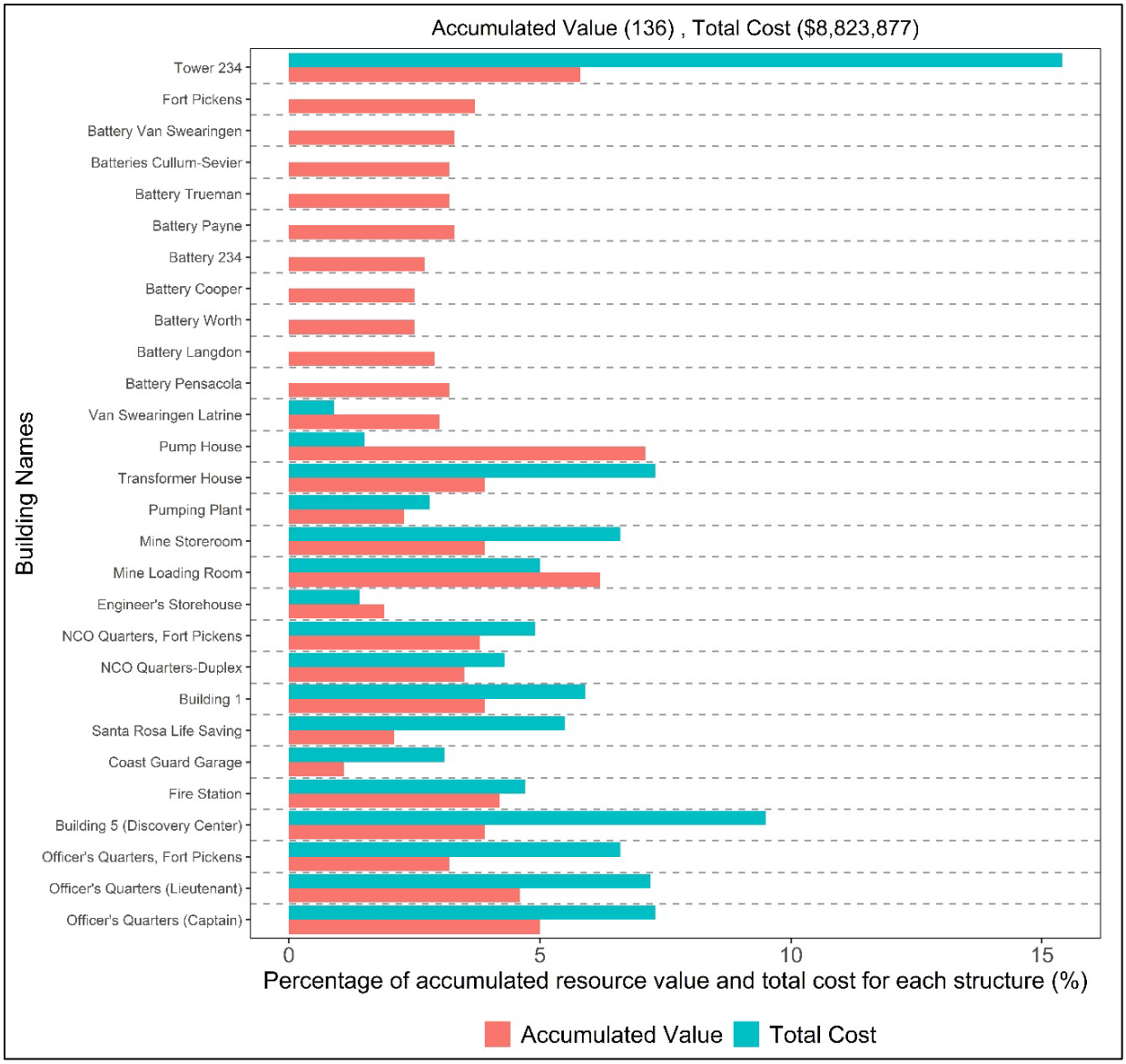


Figure 42. Percentage of accumulated resource value for each structure under a $300,000 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B).

The patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario (Figure 42; Appendix 4, Tables 9 and 12). A few structures with lower percentage of accumulated value used relatively higher proportions of the total budget. For example, Tower 234 accounted for 6% of accumulated value at the end of planning horizon by spending 15% of budget. However, the Pump House accounted for more of the accumulated value (7%) but only used 1% of budget.

Portfolio for a Budget of $400,000 (Updated Model B)

The optimal strategy under this budget allocation was very similar to the strategy of previous scenario ($300,000 annual budget allocation). Under this budget scenario, annual maintenance was

still the dominant action for most wooden and masonry buildings, as well as Tower 234, and core and shell preservation actions were applied to all of these structures multiple times across the planning horizon (Figure 43). Fort Pickens and all of the batteries were not eligible for any adaptation actions across the planning horizon. Perhaps the biggest difference of portfolios between this budget scenario and the previous budget scenario was that a masonry building (Pumping Plant) received annual maintenance for more than 40% of planning period comparing to 0% in the previous scenario. In addition, due to increased funding allocation in this scenario (60% of total cost of annual maintenance for all wooden structures, masonry structures, and Tower 234), the number of structures that had to forgo annual maintenance to allocate funding for core and shell preservation for other structures was reduced (compared to the previous scenario). The relative value changes for each building across the 30-year planning horizon are displayed in Appendix 3, Figure 67.

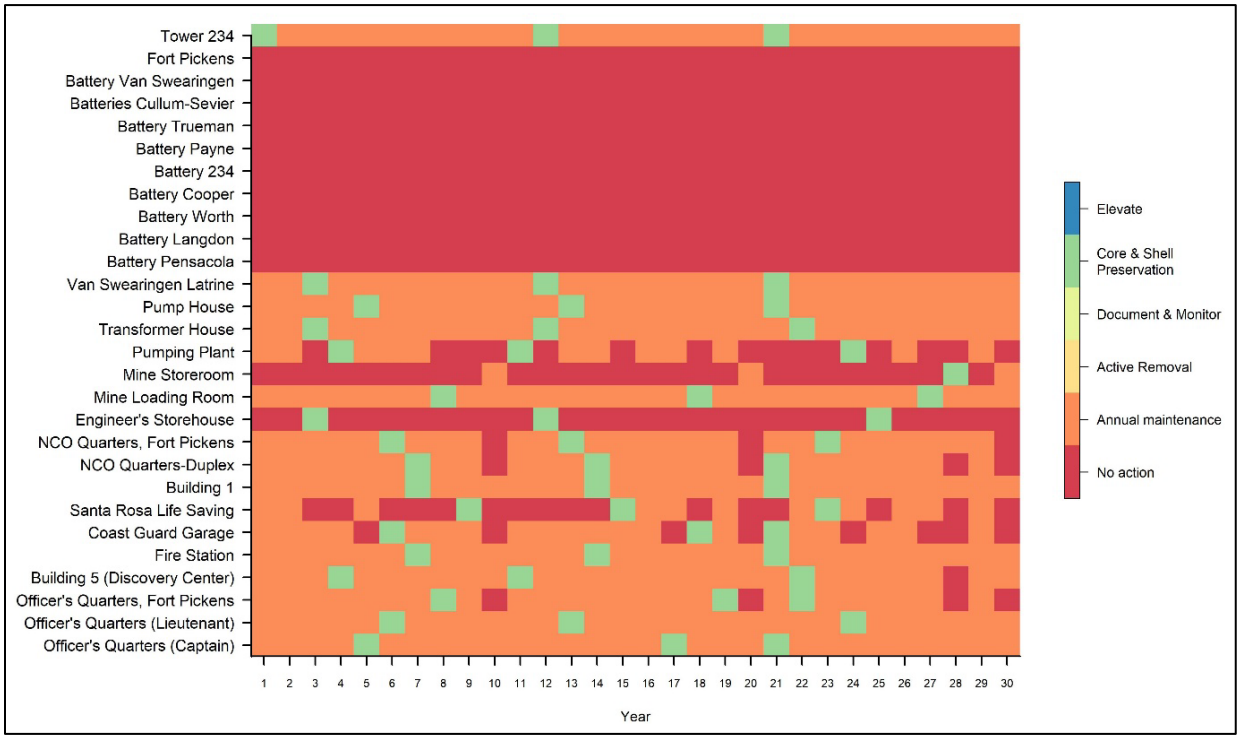


Figure 43. Actions applied under a $400,000 annual budget allocation (Updated Model B).

The total resource value (140) under this scenario (Figure 44) increased 4% of the value under the previous scenario of a $300,000 annual budget. Comparing to the same scenario in the original model (Figure 10), the total resource value increased by 2%. The percentage contribution of each structure was very similar to that of the previous scenario, except for the Pumping Plant, which increased 1% in accumulated resource value compared to the previous scenario. Similar to the previous scenario, the patterns of percentage contributions of accumulated value and total cost ($11,661,275) were greatly asymmetric under this scenario (Appendix 4, Tables 9 and 12). It is important to note that the total resource value under this scenario (typical annual budget scenario) was 20% less than the total

resource value associated with the original model (Figure 3), even though core and shell preservation actions were applied to 18 structures multiple times during the planning period.

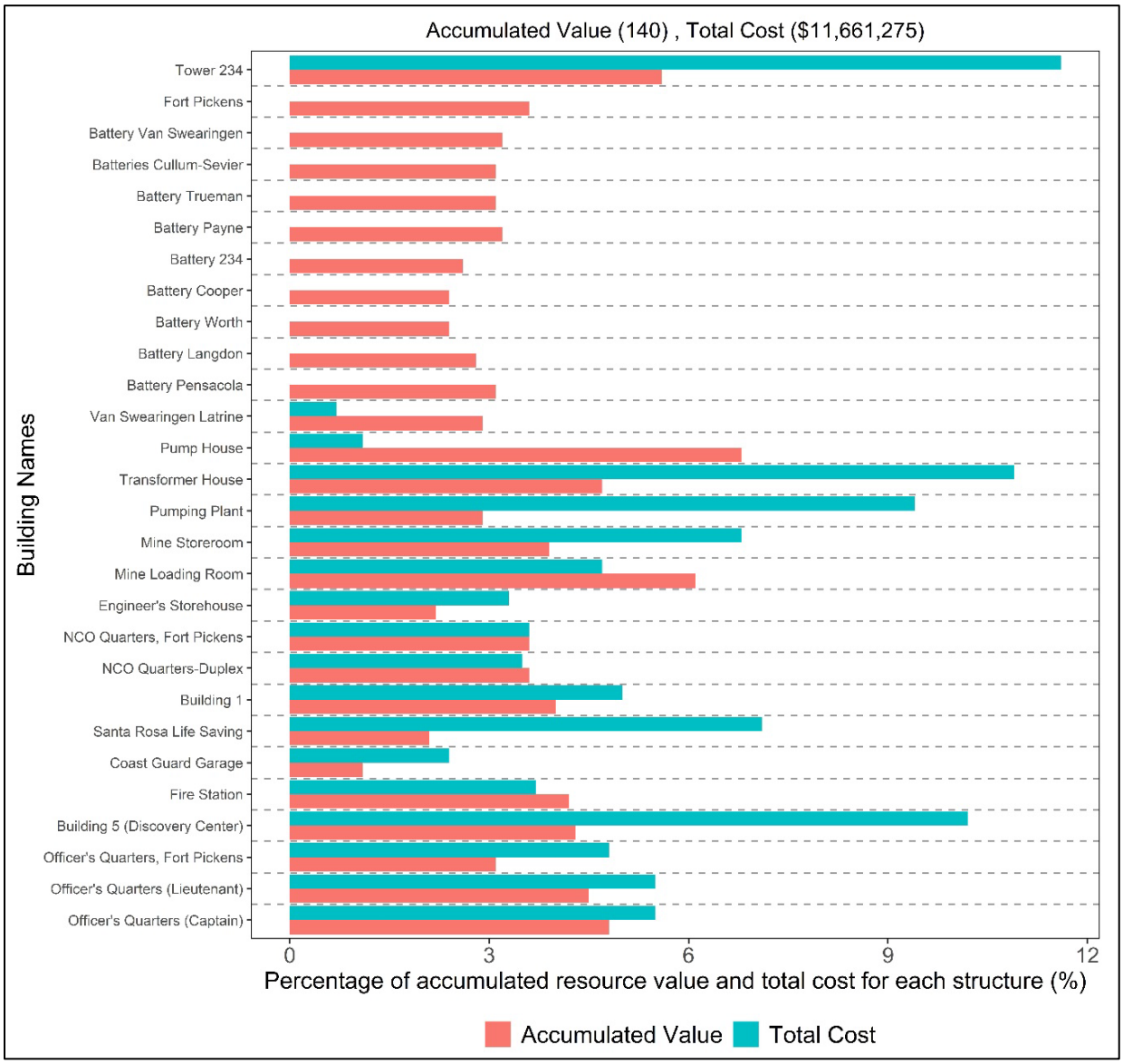


Figure 44. Percentage of accumulated resource value for each structure under a $400,000 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B).

Portfolio for a Budget of $500,000 (Updated Model B)

The optimal strategy under this budget allocation (Figure 45) was very similar to the strategy of the typical annual budget scenario (Figure 43). Under this budget scenario, annual maintenance was still the dominant action for most wooden and masonry buildings and Tower 234, and core and shell preservation actions were applied to all of these structures multiple times across the planning horizon. Fort Pickens and all of the batteries remain ineligible for any adaptation actions across the planning horizon. The increased funding enabled one more masonry building (Engineer's

Storehouse) to receive annual maintenance (and it received it for 30% of the planning period compared to 0% under the typical annual budget scenario). In addition, the increased funding allocation reduced the number of times no action was selected for wooden and masonry buildings when compared to the typical annual budget scenario. The relative value changes for each building across the 30-year planning horizon are displayed in Appendix 3, Figure 68.

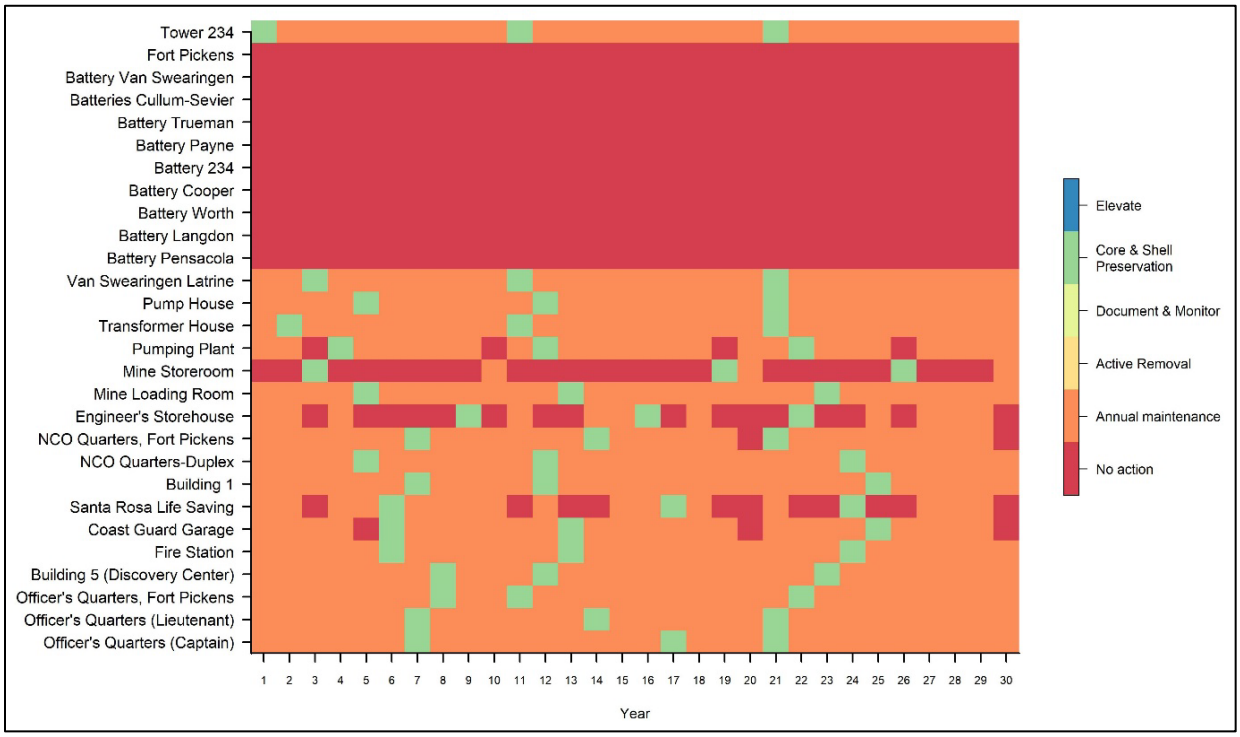


Figure 45. Actions applied under a $500,000 annual budget allocation (Updated Model B).

The total resource value (143) under this scenario (Figure 46) was 2% greater than the value under the typical annual budget scenario (Figure 44). Comparing to the same scenario in the original model (Figure 14), the total resource value and the total cost ($14,541,967) have increased 3% and 1%, respectively. The percentage contribution of each structure was very similar to that of the typical annual budget scenario, except for the Engineer's Storehouse, which contributed an additional 1% to the accumulated resource value (compared to the typical annual budget scenario). Similar to the previous scenario, the patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario (Appendix 4, Tables 9 and 12). In particular, the cost of actions applied to masonry buildings accounted for nearly 50% of the total cost of all structures.

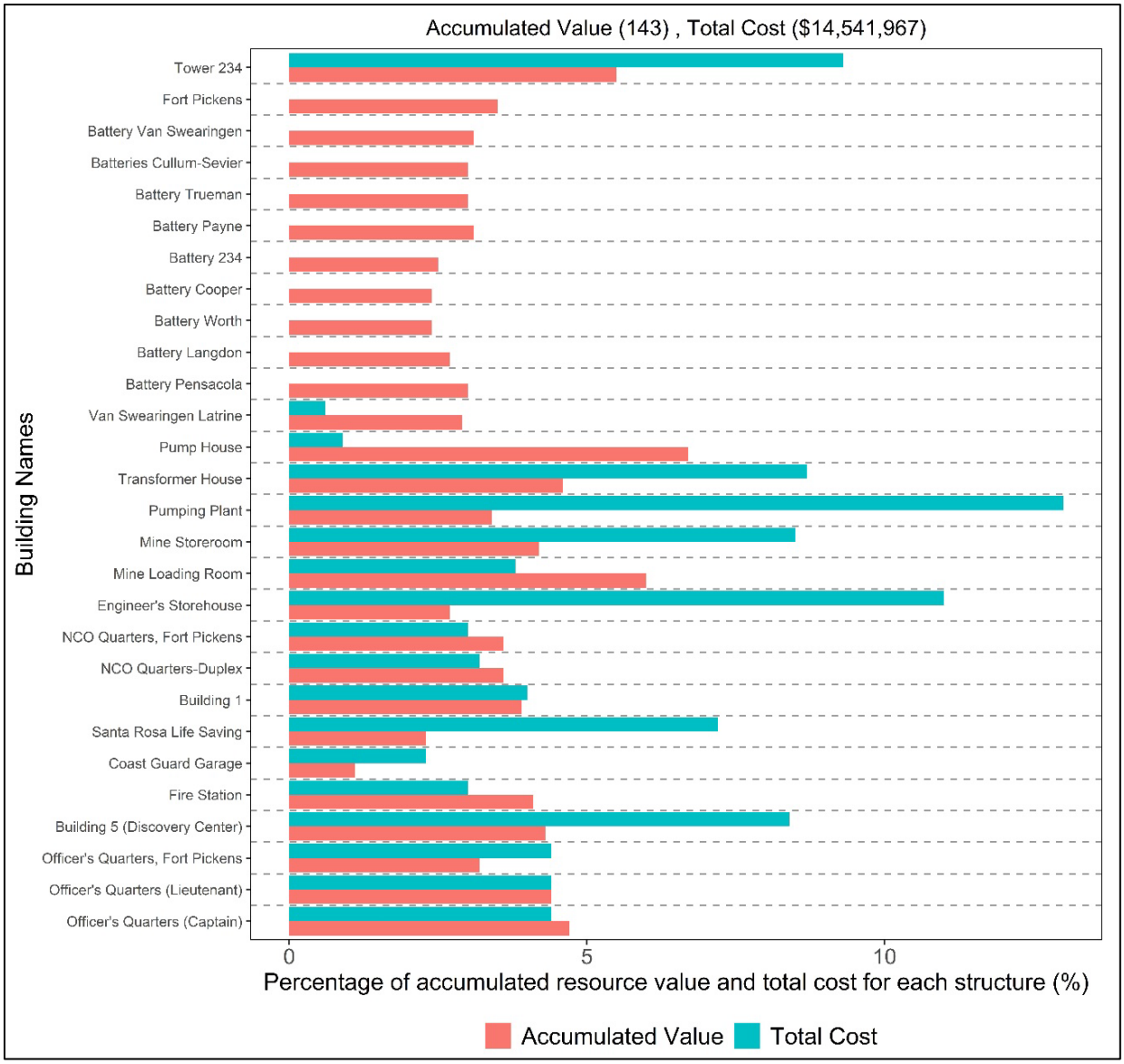


Figure 46. Percentage of accumulated resource value for each structure under a $500,000 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B).

Scenario 3—Sufficient Annual Maintenance Budget (Updated Model B)

The optimal strategy under this budget allocation suggested annual maintenance for all structures for as many years as possible and core and shell preservation actions 3 times for all structures across the planning horizon (Figure 47). Because the funding allocation for this scenario was affordable for annual maintenance for all structures, Fort Pickens and all of the batteries were eligible for management action and continuance of their associated historical values (but with some annual decay) throughout the planning period (Appendix 3, Figure 69). Yet, the optimal solution was to withhold annual maintenance on some structures in some years to enable the application of core and shell preservation to other structures. For example, applying core and shell preservation actions to other structures was selected over annual maintenance of Battery Worth in 3 years, which was likely

related to its relatively high cost of annual maintenance and low historical value. The optimal strategy suggested that, when the budget was equal to the total cost of annual maintenance, applying core and shell preservation at the cost of "freeing up" one battery achieved higher resource value than applying annual maintenance for all structures.

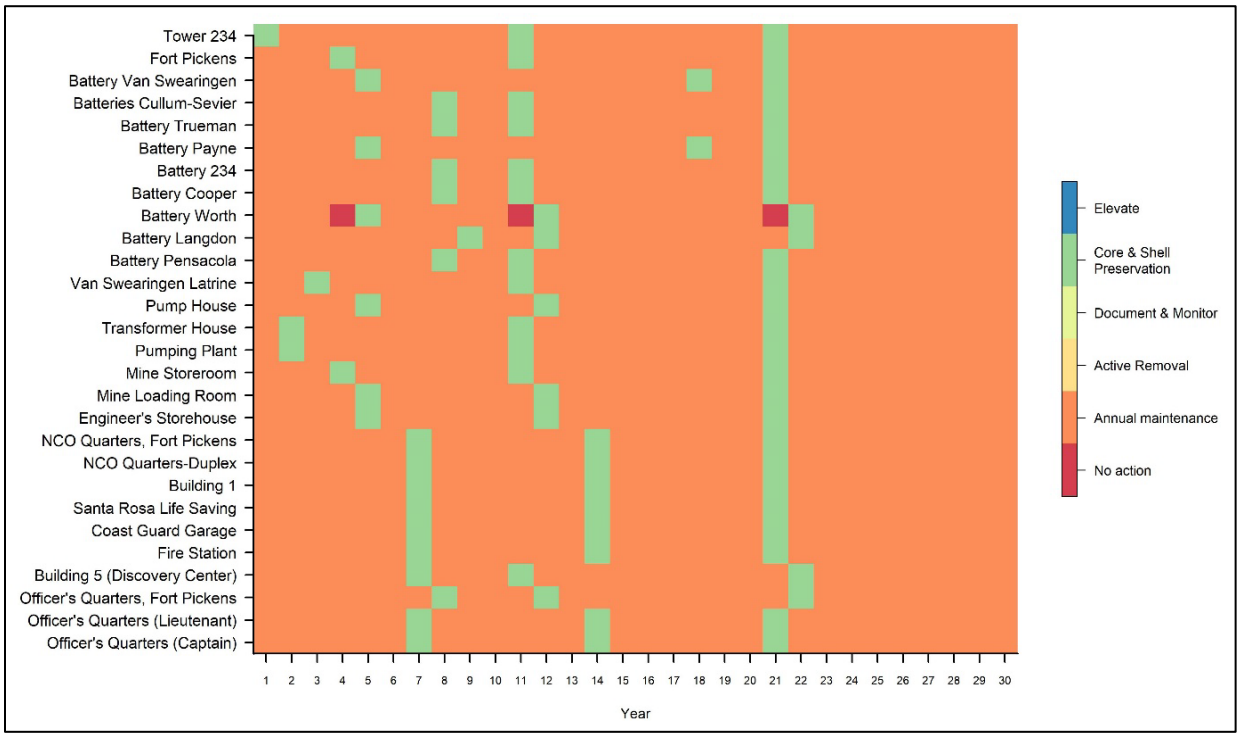


Figure 47. Actions applied under a $57,232,370 annual budget allocation (Updated Model B).

Comparing to the portfolio under the same scenario in the original model (Figure 15), the updated model selected core and shell preservation for most structures 3 times during the planning period, while reducing the number of structures that did not receive any management action due to the significantly lower cost of annual maintenance for Fort Pickens (1/10th of the cost in the original model). The timing of core and shell preservation actions being applied highlighted a tradeoff between accumulated historical value and one-time improvement of conditions. More specifically, applying core and shell earlier increased the accumulated historical value but the one-time improvement of condition was lower; however, applying core and shell later reduced the accumulated historical value but the one-time improvement of the condition was higher. Therefore, in the first 10 years, the model applied core and shell preservation earlier to those structures that had relatively higher historical resource values (e.g., Fort Pickens, Tower 234), and applied core and shell preservation later to those structures that had relatively lower historical values (e.g., Coast Guard Garage, Santa Rose Life Saving Station). The timing of core and shell preservation from year 11 to year 20 and from year 21 to year 30 was largely determined by: (a) the condition of a structure and (b) the type of material of the structure. Specifically, the model tended to apply core and shell to wooden structures every 7 years (year 14 and year 21), and to masonry structures every 10 years (year 11 and year 21). This is due to the penalty index we created to reflect cost differences between

structures in fair or poor conditions than structures in good condition; the model applied core and shell preservation actions to structures when their conditions were about to decay to fair condition to achieve higher marginal gains of a structure's condition without the additional costs (penalty) associated with their condition downgrading to poor. It takes 10 years for masonry structures to decay from good condition to fair condition and 7 years for wooden structures to decay from good condition to fair condition.

The total resource value (171) under this scenario (Figure 48) increased by 22% of the value of the typical annual budget scenario (Figure 44) and 19% from the high budget scenario (Figure 46). It is important to note that even under this sufficient annual maintenance budget scenario in which core and shell preservation was applied 3 times for all structures, the total resource value was about 2% lower than the original resource value of the historical structures. This reduction accounts for the annual condition decay rates associated with annual maintenance, even though there was no decay to historical value except in the 3 years in which Battery Worth received no action. The percentage contribution of each structure was similar to that found at the beginning scenario because each structure received similar types of adaptation actions (annual maintenance or core and shell preservation) in most years.

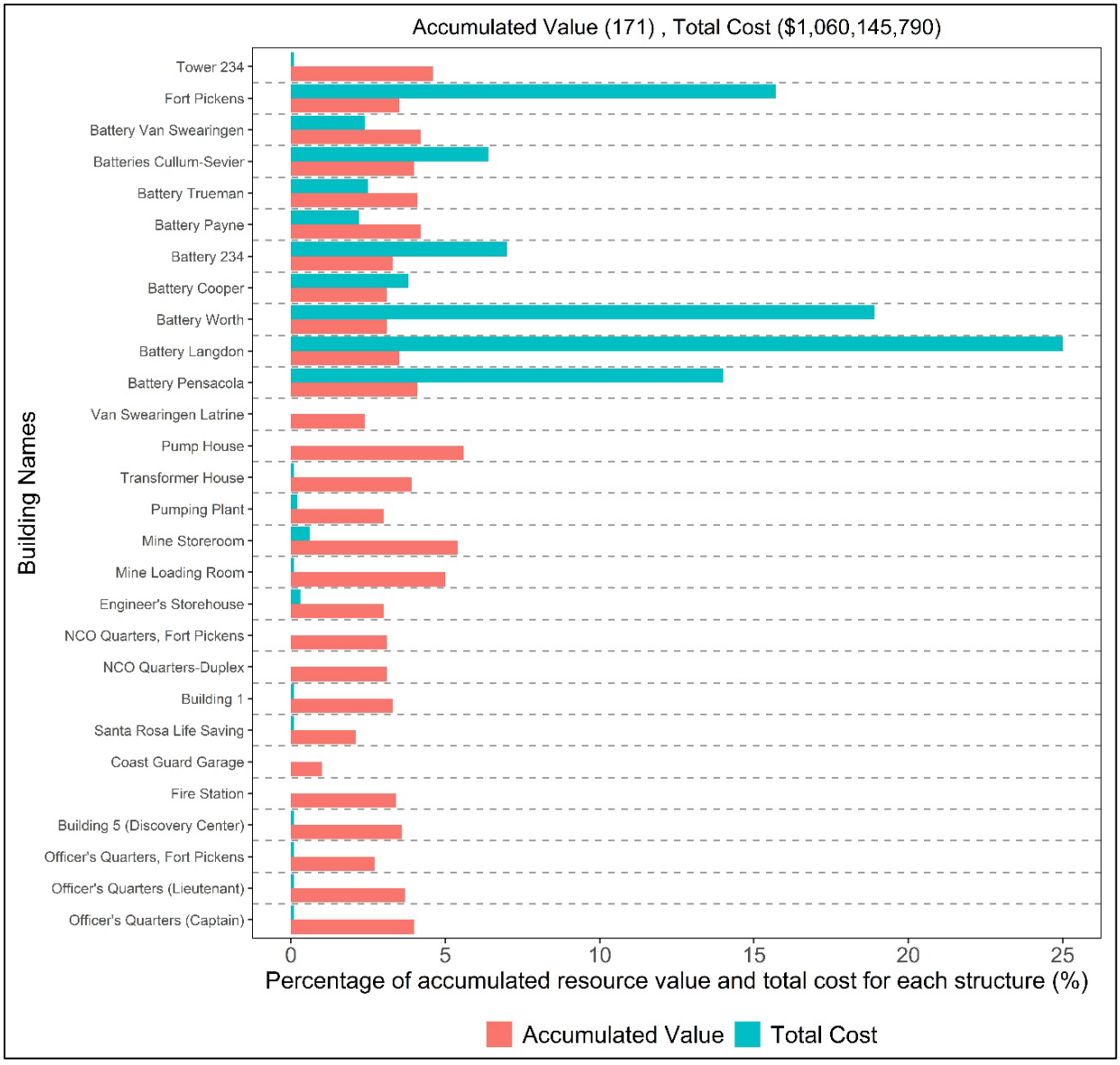


Figure 48. Percentage of accumulated resource value for each structure under a $57,232,370 annual budget allocation and total cost for each structure receiving some type of action (Updated Model B).

The patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario (Figure 48; Appendix 4, Tables 9 and 12). Fort Pickens accounted for 4% of accumulated resource value by spending 16% of total cost due to its extremely large area. The batteries encompassed more than 82% of the total cost, but only accounted for 33% of the accumulated resource value. The adaptation costs of all wooden and masonry buildings account for less than 2% of total costs.

Scenario 4—Accounting for Periodic Funding (Updated Model B)

The optimal portfolio for this scenario ($400,000 annual allocation, with an additional $400,000 allocation every 5 years) suggested that all wooden and masonry buildings and Tower 234 were

eligible for core and shell preservation 3 times each, as well as annual maintenance in most years of the planning horizon, with exceptions of two masonry structures that had relatively high costs of annual maintenance (Figure 49). These two masonry buildings with relatively high cost of annual maintenance (Mine Storeroom and Engineer's Storehouse) received core and shell preservation actions when the additional funding was allocated at the 5-year interval. As the typical annual budget scenario alone cannot afford the cost of annual maintenance for all wooden and masonry buildings and Tower 234, the surge of funding made it possible to maintain all of these structures within most of the 5-year intervals. The timing to apply core and shell preservation was the result of tradeoffs between improving the historical value earlier or enhancing the condition later to maximum one-time improvement of condition. In general, the model applied core and shell earlier to those structures having higher historical value (Tower 234, Pumping Plant, Transformer house) during the first 10 years. For the second and third ten-year time intervals, the model attempted to apply the core and shell to structures just before they decayed to a lower condition class (Appendix 3, Figure 70). Similar to the typical annual budget scenario (Figure 43), the conditions and historical values of Fort Pickens and all of the batteries decayed dramatically, as they were left "unmanaged" throughout the planning horizon.

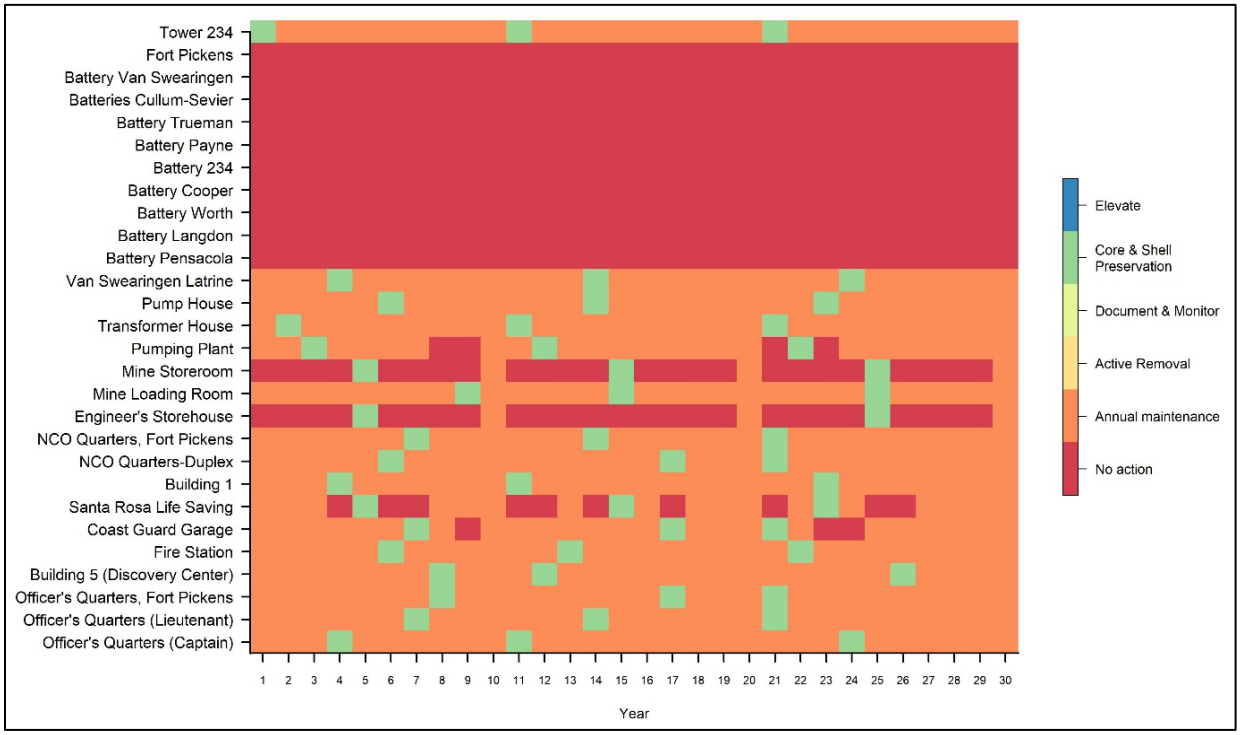


Figure 49. Actions applied under a $400,000 annual budget allocation with additional $400,000 allocation every five years (Updated Model B).

The total resource value (143) under this scenario (Figure 50) was higher than the value of the typical annual budget scenario (Figure 44) but slightly lower than the value of the high budget scenario (Figure 46). Comparing to the same budget scenario in the original model (Figure 18), the total resource value increased by about 4%. The pattern of percentage contribution of each structure was

very similar to that of high budget scenario, except for Engineer's Storehouse, which increased its contribution by 1% (compared to the typical annual budget scenario).

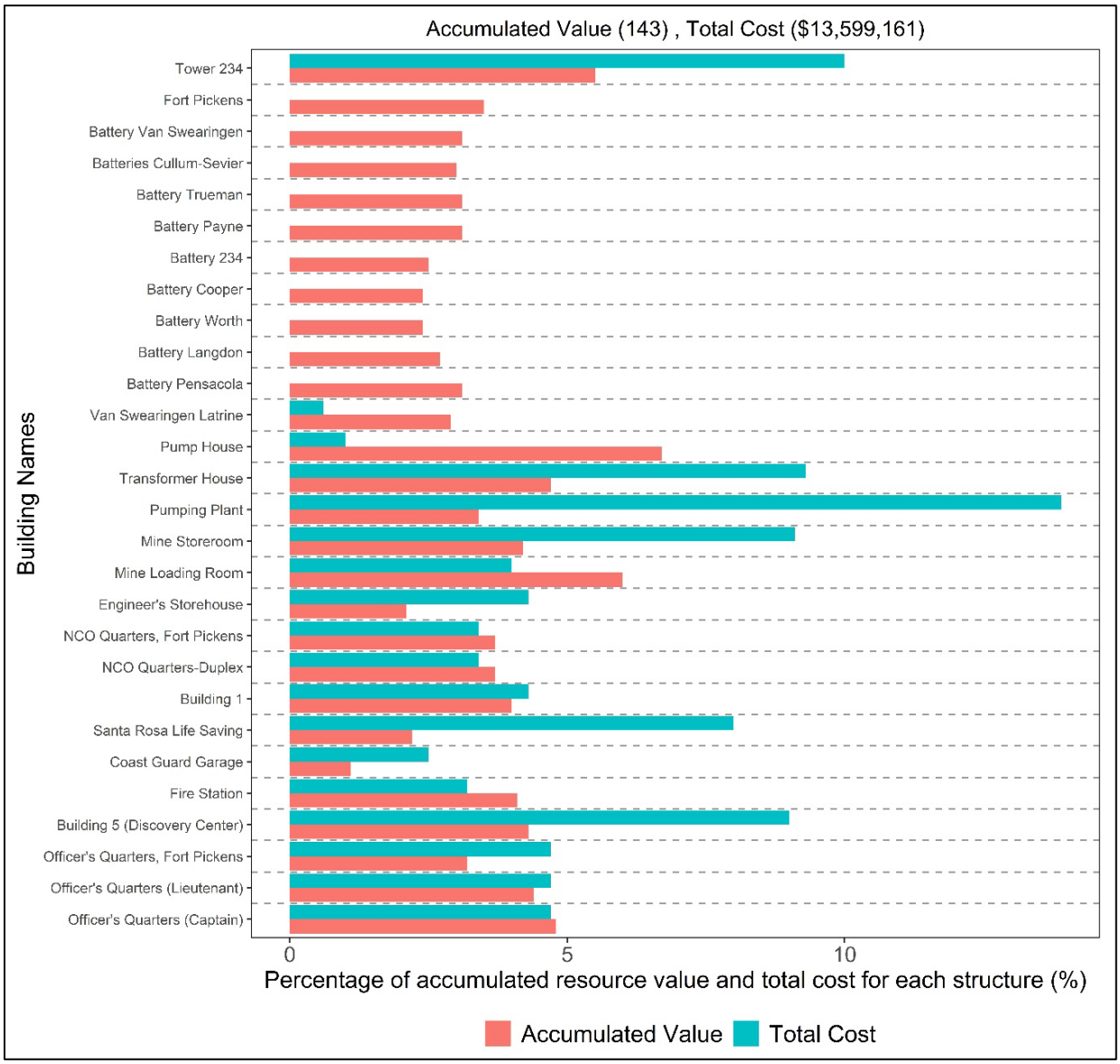


Figure 50. Percentage of value of each building under a $400,000 annual budget allocation with additional $400,000 allocation every five years (Updated Model B).

The patterns of percentage contributions of accumulated value and total cost were greatly asymmetric under this scenario (Figure 48; Appendix 4, Tables A9 and 12). The Pumping Plant and Transformer House accounted for 3% and 5% of accumulated resource value by spending 13% and 9% of total cost. Discovery Center also spent relatively high percentage of cost (9%), but its resource value only accounted for 4% of the total accumulated resource value.

Discussion

Insights from the Transferability Study

The first goal of the study was to assess the transferability of the OptiPres Model from the pilot location (Cape Lookout National Seashore; CALO) to another study site (Gulf Islands National Seashore; GUIS). In selecting the Pensacola Harbor Defense Project Historic District at GUIS, we recognized there would be the need to not only apply the OptiPres Model to other (predominately) wooden-structure buildings located in historic districts but also apply the OptiPres Model to other types of structures: masonry forts and concrete batteries, as well as masonry and concrete buildings. Our findings related to these transferability tests warrant two primary conclusions: (1) the OptiPres Model is transferable to other national park units and (2) the OptiPres Model is transferable to historic structures beyond wooden buildings. In addition, the transferability test demonstrated that the OptiPres Model enables the integration of localizable value-judgments about the relative importance of significance and use potential attributes. Although the National Park Service may want to set final weighting schemes in future applications of the OptiPres Model, the ability to incorporate local-level perceptions about the relative weights of the historic value and use potential attributes enables park-level priorities to be integrated into the decision framework. Moreover, this flexibility enhances the marketing potential of the decision framework to both park managers and other agencies and organizations charged with stewardship of vulnerable historic districts.

It is important to note that there are some caveats regarding a few constraints within the study that need to be discussed in relation to our two primary conclusions. First, the cost estimates associated with the maintenance and adaptation action far exceed the annual budget allocation range and, thus, the results demonstrated substantial loss in accumulated resource value. Insufficient financial resources are a common constraint of resource management, which provides the basic motivation for portfolio optimization as described in this report. These insufficiencies also challenge the ability of the OptiPres Model to provide management guidance. In particular, budget allocations were never sufficient for even the annual maintenance of Fort Pickens or any of the batteries. Yet, the OptiPres Model still functioned as expected for the remaining structures within the landscape: it identified triage options for lower resource value structures (for example, Engineer's Storehouse, Mine Storeroom, Pumping Plant would go predominately unmaintained in most cases) when budgets were insufficient to maintain higher-valued structures. When the annual budget allocations were sufficient to maintain the remaining structures (excluding Fort Pickens and the batteries), the OptiPres Model attempted to minimize decay by selecting core and shell preservation at optimal times in the planning period to avoid the penalties (heighted condition decay rates) associated with the 'poor' condition class, thereby maximizing the benefits (that is, improved condition) associated with core and shell preservation. The same patterns of findings were found when we tested the model at sufficient budget allocations to perform annual maintenance on all structures (including Fort Pickens and the batteries). Additionally, the transferability test also documented that periodic funding enables some structures to receive core and shell preservation earlier in the planning cycle. As such, this report evidences the financial burden facing managers in their stewardship of the structures located within the Pensacola Harbor Defense Project Historic District and may provide necessary support in future requests for increased allocations.

The second constraint with this study is associated with the vulnerability data and the eligibility of structures to receive adaptation actions. Specifically, many historic structures are located within the Fort Pickens' sea wall and sited at the highest elevation within the historic district, which in combination with their current floor elevations would result in no change in the vulnerable scores if an adaptation action (i.e., elevate) were to be selected. As such, the costs associated with elevating the buildings deterred the model from selecting elevation for any of the structures as the optimal solution because there were no associated reductions in vulnerability, particularly given the negative impacts to historic values associated with elevating a building. However, this limitation appears to be directly related to the study location and the available adaptation actions included in the modeling effort, rather than a limitation of the modeling effort itself. In fact, elevation was frequently selected as an optimal adaptation action in the CALO pilot study (Seekamp et al. 2019). Therefore, it is likely that it would be an optimal adaptation action at other NPS coastal sites, provided the siting of the structures yield reductions in its vulnerability when elevated.

It is also important to note that the OptiPres Model never selected two of the other adaptation actions (i.e., document and monitor, active removal) as optimal solutions. This finding mirrors results found in the CALO pilot study and can be interpreted as a function of the model's objective function: maximizing resource value. In other words, the losses to accumulated resource values associated with documenting and monitoring a structure or actively removing a structure do not outweigh the costs associated with maintaining the structures. However, it is important to note a few concerns with these findings: (1) the lack of actions applied to Fort Pickens and the batteries would actually benefit from full documentation (to ensure stewardship of the resource at least in written and digital form) and necessitate the costs associated with limiting public access for safety concerns (fencing), which are embedded within the document, and monitor adaptation action; (2) it is likely that the structures may deteriorate to such an extent that removal would be warranted during or following the 30-year planning horizon; and (3) the decaying conditions would likely increase the sensitivity of the structures to destruction in the event of strong storms. Future research is needed to determine what "a point of no return" threshold for inaction would be, which could be modeled through penalties that "raise the stakes" of doing nothing. Alternatively, future applications of the model could include changes to the algorithm that limit the number of times no action can be selected and then force either document and monitor or active removal to be applied. Such model changes would likely accommodate additional subobjectives (in addition to historic significance and use potential), such as public safety and contamination from decaying conditions that result from inaction and, simultaneously, reflect realities in which costs are incurred without any value gained.

Insights from Model Enhancements

In this project, we also sought to enhance the OptiPres by: (1) incorporating use potential dynamics and (2) altering the cyclic maintenance (core and shell preservation) restrictions from once in the 30-year planning period to once in 10-year cycles within the 30-year planning period. Additionally, we sought to (3) enhance the likelihood that Fort Pickens could be maintained throughout the planning cycle; therefore, we changed the annual maintenance to $1/10^{th}$ of the original cost estimate under the assumption that the ability to invest in a fraction of maintenance costs was more feasible in terms of park capacity related to budgets, human capital, or both. This fractional approach to annual

maintenance may be worthy of future exploration as a new category of actions (that is, partial annual maintenance) that could be applied in future modeling efforts; however, the algorithm may need to be updated in such a way that if partial annual maintenance was selected in one year, it must be selected in subsequent years until the structure is fully maintained. It was our intention that these model enhancements would increase the utility of the OptiPres Model by more accurately reflecting park management realities. Our findings suggested that the reduced annual maintenance costs (and efforts) were still too high to include Fort Pickens in any of the annual budget allocation scenarios provided to us by park managers ($300,000–$500,000). However, it is in the examination of the scenarios in which we use the sufficient annual maintenance budget allocation that allows us to understand the implications of the model updates.

Integrating the use potential dynamics ensures that structures that do not receive annual maintenance are not unsafe for human use. Specifically, if a structure is not maintained, then it can no longer be used for park operations, by third-parties, or by the visiting public. However, if a structure that was once used for any of those purposes receives core and shell preservation, then the dynamics allow for the previous use(s) to be reinstated. In comparison to the original model outputs when there are sufficient annual allocations to perform annual maintenance on all structures, the updated model achieves higher budget efficiency for maintaining the total resource value of historical structures, with costs 40% lower than the cost in the original model and the same accumulated resource values. The key difference (except for the timing of preservation for one building)—when comparing the original and use potential updates for the same budget scenarios (e.g., $300,000, 400,000, 500,000 annual allocation, etc.)—is that the accumulated resource values are lower at the end of the 30-year planning period. This loss in value is directly associated with the declining use potential of structures that do not receive annual maintenance and, as such, have declining conditions.

Altering the core and shell preservation action enabled the OptiPres Model to more accurately reflect typical, cyclic maintenance schedules. Our results demonstrated that when funding is available, it is optimal to apply core and shell preservation 3 times during the 30-year planning period (1 time in each of the 10-year cycles within the 30-year planning period). The key implication here is that the enhanced condition associated with cyclic maintenance improves the accumulated resource value scores from the original model. Moreover, when annual allocations are low ($50,000), we found that many structures are left to decay (that is, receiving no action), while structures with lower costs associated with core and shell preservation receive that action in each of the three 10-year cycles. It seems that decay associated with not applying annual maintenance periodically on some buildings to accommodate the benefits of cyclic maintenance (that is, increased condition) might be an appropriate tradeoff in the stewardship of historic structures given extreme fiscal constraints.

Considerations for Future Applications of the OptiPres Model

This study's findings highlight several considerations for future applications of the OptiPres Model:

The development of cost estimates for the maintenance and adaptation actions that could be universally applied across all structures within a study site is needed. This study used a combination of estimates provided by GUIS staff based on prior experience and information contained within agency databases, as well as multipliers for some structures. However, the high costs estimated for

actions (including annual maintenance) for Fort Pickens and the batteries have been identified by one reviewer appear out of scale and present improbable management situation. With the deferred maintenance backlog that faces park management today, it is likely that future applications of the OptiPres Model may also be restricted by typical annual budget allocations that cannot address maintenance needs, let alone climate change adaptation. However, this does not help managers proactively address resource stewardship, particularly in parks where moving or elevating buildings (or some combination of both) could increase historic preservation goals and lead to in situ retention of historic structures that would otherwise be sacrificed to storm surge, hurricane impacts, and coastal retreat.

A study that incorporates more localized vulnerability data, including the integration of stochastic storm events, is needed. Enhancing the sensitivity of the climate change vulnerability attributes may increase the likelihood of adaptation actions to be selected as optimal solutions. Moreover, there is a need for modeling extreme storm events that may result in the destruction of structures. Modeling these dynamics may provide further inference on the need for consideration of other post-storm recovery actions, and the ability to examine the consequences of post-storm recovery funds (i.e., emergency funds) on optimal adaptation priorities. Such advancements can enhance the utility of the model to provide managers with considerations for proactive planning, reactive decision-making, or both.

Currently, the OptiPres Model functions well (and is transferable) to determine how to maximize accumulated resource value of structures within a historic district or a national park unit. However, we have speculated that there may be consequences of this objective that present unacceptable management outcomes, such as the inability to manage the most iconic structure on a landscape (e.g., Fort Pickens). Therefore, it would be important to determine what other management objectives (e.g., ensuring that all or part of Fort Pickens remains on the landscape and is accessible to visitors) need testing and devise model updates around those studies. For example, the model could be updated by adding an “equitability constraint” to identify the structures that would be associated with specified funding decisions, such as annual and cyclic maintenance or some type of adaptation action. That said, this may also imply insufficiencies in the current attributes, weights of attributes, or both. Regardless, we can conclude that the model is ultimately sensitive to the attribute and weighting inputs.

Continued engagement of different and varied local-level stakeholder groups is important to consider the range of values and preferences during park planning and decision-making. For example, more research to assess stakeholders’ perceptions of the resource value weights, as well as to gauge their perceptions of preservation priorities and acceptable adaptation strategies, would serve to refine efficient use of limited funding allocations.

Additionally, some of the constraints noted in this study have implications for conversations about triage at a much larger scale. The results of this application of the OptiPres Model suggest that GUIS may be quite restricted in terms of the usefulness of climate adaptation actions. Yet, when compared to the results from the original pilot test at CALO, adaptation seemed to be an optimal solution under sufficient annual or periodic funding allocations (Seekamp and others 2019b). This begs the

question: would it be better to shift funding to another NPS asset where adaptation could be done more effectively? Thus, it seems that the OptiPres model could be modified to be used at a regional of national scale to help NPS explore even more challenging tradeoffs. For example, there are multiple forts under the stewardship of Gulf Islands National Seashore and within the NPS, all of which require substantial maintenance and most of which are highly vulnerable to projected climate change impacts. Future studies are needed to separately explore collections of these high-cost structures to determine sets of cumulative needs and adaptation priorities.

Conclusions

The OptiPres Model provides a transparent and multi-decadal approach to facilities management for historic structures while also considering how adaptation to climate change risks affects cultural resource stewardship. This study demonstrated that the OptiPres Model is transferable to coastal sites managed by the National Park Service vulnerable to sea level rise, as well as storm-related flooding and erosion. Moreover, this study enabled updates to the original algorithm of the OptiPres Model that enable more realistic depictions of the (a) dynamics associated with a structure's use potential when annual maintenance is withheld or reinstated and (b) typical cycles during which a structure might require core and shell preservation actions.

Even with the study constraints (i.e., annual maintenance costs that vastly exceed typical annual budget allocations and the siting of structures that inhibit the utility of adaptation actions to reduce their vulnerability), several key findings can help inform planning and decision-making. First, the OptiPres Model results document that spending any money to manage even a subset of structures is better than doing nothing (that is, less decline in accumulated resource value). Second, the results illustrate that spending more money leads to improved management performance. Third, the results highlight that insufficient budget allocations can drastically lower the total resource value within a historic district.

For Gulf Islands National Seashore, we identified two key findings. First, the typical budget allocation for managing the historic structures within Pensacola Harbor Defense Project Historic District is insufficient for annual maintenance of several structures. This is particularly true for Fort Pickens, but also for the batteries. The inability of the model to integrate the annual maintenance of prominent structures within a landscape could lead to unacceptable management outcomes. This finding may provide empirical evidence necessary to support future funding allocation requests. Second, the majority of the wooden and masonry buildings are protected by a sea wall and sited at the highest elevation within the historic district, which in combination with their current floor elevations would result in no change in the vulnerable scores if an adaptation action (i.e., elevate) were to be selected. As such, the costs associated with elevating the buildings deterred the model from selecting this adaptation option for any of the structures. Therefore, the model considers annual maintenance to be the optimal strategy for the historic structures within the Pensacola Harbor Defense Project Historic District under increasing budget scenarios.

The OptiPres Model is not considered finalized and can be improved in future studies that: (a) use enhanced cost estimation procedures; (b) apply more localized vulnerability data that can be more sensitive to the benefits of adaptation actions; (c) integrate stochastic storm events and post-storm recovery into the modeling effort; (d) refine the algorithm to test additional objective functions; and (e) establish stakeholder values and preferences within the decision framework. Regardless, managers must make difficult tradeoffs to achieve stewardship of historic structures in the face of climate change related to maximizing the resource values (for example, historic significance and use potential) within cultural landscapes. Yet, when approached with a systematic process for addressing such complex, portfolio decisions (such as, the OptiPres Model), a management agency can enhance

the transparency of values embedded within planning and decision making and increase its ability to preserve cultural resource values for present and future generations.

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Appendix 1. Study site information.

This appendix includes information about the study site, including a description of The Pensacola Harbor Defense Project Historic District. In Table 1, the structures included in the study are listed, along with relevant information about the date of construction, construction materials, national register status, condition at the time of the study (List of Classified Structures, LCS, score in 2018), uses at the time of the study (2018), and vulnerability scores (1-4 scale) related to sea level rise and storm-related flooding and erosion.

Description of The Pensacola Harbor Defense Project Historic District

The following is the direct text from the summary paragraph of the Pensacola Harbor Defense Project Historic District's National Register of Historic Places Nomination Form (Slaton and others 2016, Section 7, pages 5-6).

> *The Pensacola Harbor Defense Project Historic District occupies the western end of Santa Rosa Island, a linear sand formation that frames Pensacola Harbor approximately one-and-one-half miles to the south of the city of Pensacola, Florida. The historic district falls within a unit of the National Park System known as Gulf lslands National Seashore that encompasses coastal areas of Mississippi and Florida. Gulf lslands National Seashore was established to "preserve the resources, while providing an exceptional variety of outdoor recreation for the enjoyment of present and future generations."(NPS 1968).*
>
> *The historic district preserves surviving examples of military defense structures and features that supported the protection of a Navy base and the deep-water harbor at Pensacola. Santa Rosa Island edges the entry into Pensacola Harbor to the east. The harbor has been recognized as an important strategic locale for shipping and military purposes since the Spanish began to explore and settle West Florida during the seventeenth and eighteenth centuries. The present-day assemblage of Harbor Defense Structures, which were developed between 1893 and 1943 and remained in use until 1947, represent the latest in a series of military fortifications. The Pensacola Harbor Defense Project was conceived in response to the need to defend and protect American shipping interests and shores from the emerging weaponry during the late nineteenth century. Over time, the collection of defensive batteries and supporting structures continued to evolve in response to several new threats, including aircraft, battleships and long-range artillery, U-boats and submarines, and fast motor torpedo boats. The site was operated by the U.S. Army's Coast Artillery Branch, and later the Coast Artillery Corps (CAC). Innovations in range finding, observation, sonar and radar, and mining were also incorporated into the system between the Spanish American War and World War II. The development of the atomic bomb and its employment in ending World War II generally ended the usefulness of the Pensacola Harbor Defense Project, and the Army moved out of the post on Santa Rosa Island in 1947.*
>
> *Surviving evidence of the Pensacola Harbor Defense Project includes adaptive reuse of an antebellum fortification, Fort Pickens, which was built as part of an earlier coastal defense initiative referred to as the "Third System." Coastal defense systems have been established in four phases by the United States government. These are referred to throughout this document as*

the First, Second, Third, and Fourth Systems. The fort was updated through the siting of Battery Pensacola, an example of an Endicott battery, within its parade ground, and use of its casemates to house equipment associated with harbor mining operations. In addition to Battery Pensacola, Santa Rosa Island features several additional batteries associated with the Pensacola Harbor Defense Project: Batteries Van Swearingen, Trueman, Payne, Cullum, Sevier, 234, Cooper, AMTB, GPF, Worth, Langdon, and Fixed. These reinforced structures, which included gun emplacements, were supported by a suite of structures, such as battery commander's stations, radar stations, coincidence range finders, magazines, searchlights and power houses, mine support structures, post housing and administration buildings, roads, a narrow-gauge rail line, a sea wall, and other support facilities.

The historic district encompasses an area 891 acres in size that extends from several defensive structures located near a former U.S. Coast Guard Station and the western end of the island, a total distance of three miles. The district extends to the waterline within this area. The historic district is nationally significant under National Register Criteria A and C in the areas of Architecture, Engineering, and Military History, for its association with the design and engineering of coastal defense systems and their evolution to meet the emerging capabilities of military armaments between 1893 and 1947. The beginning date encompasses the introduction of features of the Endicott system, while the end date represents the year the U.S. Army closed the base at Santa Rosa Island. The historic district features 15 contributing buildings, 35 contributing structures, 19 contributing sites, and no contributing objects, representing two historic contexts: U.S. Military Coastal Defense, 1812-1947, and the Battle of the Atlantic, 1939-1945. The historic district also contains several contemporary features associated with its adaptation as a state park between 1949 and 1971, and a unit of the National Park System beginning in 1972. These features constitute non-contributing features. In total there are 9 non-contributing buildings, 15 non-contributing structures, 2 non-contributing sites, and 5 non-contributing objects. Although modest changes have been made to accommodate public use of the property for education/interpretation and recreation, the historic district possesses a good degree of integrity as one of the most complete surviving collections of late nineteenth and early twentieth century coastal defense structures in the United States. As such, it retains the ability to convey its historic associations with this significant military site and coastal defense operation.

Table 1. Information about the structures within The Pensacola Harbor Defense Project Historic District.

Structure Name	Bldg #	National Register	Year Built	Material	Condition[a]	Current Uses[b]			Vulnerability Score (2030)[c]
						Park Operations	Third-Party	Open to Visitors	
Battery Pensacola	B-01	Contributing	1898	Reinforced Concrete	Fair	N/A	N/A	Yes	3
Battery Langdon	B-02	Contributing	1917	Reinforced Concrete	Fair	N/A	N/A	Yes	4
Battery Worth	B-03	Contributing	1898	Reinforced Concrete	Fair	N/A	N/A	No	4
Battery Cooper	B-04	Contributing	1903	Reinforced Concrete	Fair	N/A	N/A	Yes	4
Battery 234	B-05	Contributing	1943	Reinforced Concrete	Fair	N/A	N/A	No	4
Battery Payne	B-06	Contributing	1904	Reinforced Concrete	Good	N/A	N/A	No	3
Battery Trueman	B-07	Contributing	1905	Reinforced Concrete	Fair	N/A	N/A	Yes	3
Batteries Cullum-Sevier	B-09	Contributing	1896	Reinforced Concrete	Fair	N/A	N/A	Yes	3
Battery Van Swearingen	B-10	Contributing	1898	Reinforced Concrete	Good	Yes	No	No	3
Fort Pickens	P-0	Contributing	1829	Bricks	Fair	N/A	N/A	Yes	3
Building 1	P-01	Contributing	1909	Wood Frame, weatherboard siding	Good	No	No	No	4
Officer's Quarters, Fort Pickens	P-02	Contributing	1900	Wood Frame, weatherboard siding	Fair	N/A	N/A	Yes	4
Officer's Quarters (Lieutenant)	P-03	Contributing	1900	Wood Frame, weatherboard siding	Good	Yes	No	No	3
Officer's Quarters (Captain)	P-04	Contributing	1912	Wood Frame, weatherboard siding	Good	N/A	N/A	No	3
Building 5 (Post Administration Building/ Discovery Center)	P-05	Contributing	1900	Wood Frame, weatherboard siding	Fair	Yes	No	No	4
Fire Station	P-06	Contributing	1940	Wood Frame, weatherboard siding	Good	Yes	No	Yes	4

[a] Based on the List of Classified Structures (LCS) score.

[b] Based on the judgment of park staff.

[c] Based on the vulnerability study conducted by Peek and others (2015).

Table 1 (continued). Information about the structures within The Pensacola Harbor Defense Project Historic District.

Structure Name	Bldg #	National Register	Year Built	Material	Condition[a]	Current Uses[b]			Vulnerability Score (2030)[c]
						Park Operations	Third-Party	Open to Visitors	
NCO Quarters, Fort Pickens	P-07	Contributing	1900	wood frame, weatherboard siding, brick foundation	Good	Yes	No	No	4
NCO Quarters, Fort Pickens	P-08	Contributing	1910	wood frame, weatherboard siding, brick foundation	Good	Yes	No	No	4
Pump House	P-10	Contributing	1940	concrete foundation, wooden walls, asphalt roof	Good	Yes	No	No	2
Pumping Plant/ Maintenance Field Office	P-11	Contributing	1920	Bricks	Fair	No	Yes	Yes	4
Transformer House	P-12	Contributing	1918	concrete	Fair	Yes	Yes	Yes	3
Mine Loading Room	P-15	Contributing	1907	Bricks	Good	Yes	No	No	3
Mine Storeroom	P-16	Contributing	1901	Bricks	Good	No	No	No	3
Engineer's Storehouse	P-17	Contributing	1900	concrete, asphalt shingle roof	Good	Yes	No	Yes	4
Van Swearingen Latrine	P-18	Contributing	1939	weatherboard	Fair	Yes	No	No	4
Santa Rosa Life Saving/Coast Guard Station	P-32	Non-contributing	1908	Wood Frame, shingle walls, asphalt roof	Good	Yes	No	No	4
Coast Guard Garage	P-33	Non-contributing	1939	Wood Frame, weatherboard siding	Good	Yes	No	No	4
Tower 234	P-39	Contributing	1944	Concrete, Metal	Poor	N/A	N/A	No	4

[a] Based on the List of Classified Structures (LCS) score.

[b] Based on the judgment of park staff.

[c] Based on the vulnerability study conducted by Peek and others (2015).

Appendix 2. Weights, resource values and adaptation actions applied in the Optimal Preservation (OptiPres) Model

This appendix provides additional details of the multiple data sources that are used to populate the Optimal Preservation (OptiPres) Model. The OptiPres Model includes measures of a structure's resource value (historical significance and use potential) and vulnerability (sensitivity and exposure), and cost estimates for adaptation actions. Additionally, some adaptation actions affect the attributes, subattributes, or both for resource value and vulnerability. For full details of the metrics that are associated with the various attributes that create resource value and vulnerability, as well as the specifics considered in cost estimates for each action, see Seekamp et al. (2019), Appendix 1.

In Table 2, the weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO) are presented to demonstrate the ability to apply local-level values in the decision framework. In Table 3, the resource value of each structure included in the study are presented by weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO). In Table 4, the actions included within the OptiPres Model are defined and the associated model dynamics (changes to a structure's condition, the historic integrity of a structure, and the vulnerability of a structure). In Table 5, the costs associated with applying each action to each of the 28 historic structures are displayed.

Table 2. Comparison of weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO).

Historical Value Attributes	**Subattributes**	**GUIS Weights[a] (0.74)**	**CALO Weights[b] (0.71)**
Association	–	0.361	0.260
Condition	–	0.167	0.170
Character	–	0.239	0.270
National register	–	0.233	0.300
Character	Defining Character	0.611	0.475
	Uniqueness to Park	0.389	0.525
National register	Spatial Significance	0.433	0.410
	Eligibility	0.567	0.590
Use Potential Attributes	–	0.26	0.29
Operational use	–	0.233	0.170
Third party potential use	–	0.094	0.120
Visitor use	–	0.300	0.170

[a] Mean score based on the evaluations provided by 8 current and 2 retired GUIS staff.

[b] Mean score based on the evaluations provided by 10 NPS staff (at varying federal, regional and park unit offices), 10 State Historic Preservation Office staff, and 2 academics.

Table 2 (continued). Comparison of weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO).

Historical Value Attributes	Subattributes	GUIS Weights[a] (0.74)	CALO Weights[b] (0.71)
Interpretive use	–	0.267	0.260
Scientific use	–	0.100	0.280

[a] Mean score based on the evaluations provided by 8 current and 2 retired GUIS staff.

[b] Mean score based on the evaluations provided by 10 NPS staff (at varying federal, regional and park unit offices), 10 State Historic Preservation Office staff, and 2 academics.

Table 3. Resource value of structures in the Pensacola Harbor Defense Project Historic District by weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO).

Structures	Weighted, normalized resource value score (GUIS weights)	Weighted, normalized resource value score (CALO weights)
Fort Pickens	0.82	0.83
Battery Pensacola	0.64	0.59
Battery Cooper	0.64	0.60
Battery Worth	0.68	0.62
Battery Langdon	0.74	0.72
Battery 234	0.68	0.64
Battery 234 CRF/BCS Tower	0.71	0.68
Battery Payne	0.71	0.66
Battery Trueman	0.64	0.59
Batteries Cullum-Sevier	0.62	0.58
Building 4 (Captain's Quarters)	0.67	0.62
Building 3 (Lieutenant's Quarters)	0.62	0.57
Battery Van Swearingen	0.71	0.66
Building 2 (Lieutenant's Quarters)	0.55	0.50
Building 5 (Post Administration Building/ Discovery Center)	0.75	0.68
Building 6 (Fire Station)	0.77	0.69
Building 17 (Engineer’s Storeroom)	0.67	0.62
Building 15 (Mine Loading Room)	0.83	0.85
Building 16 (Mine Storeroom)	0.89	0.90
Building 11 (Pumping Plant/Maintenance Field Office)	0.63	0.57
Building 10 (Pump House/Paint Locker)	0.62	0.57
Van Swearingen Latrine	0.49	0.45
Building 1 (NCO Quarters/VIP Cottage)	0.74	0.70

Table 3 (continued). Resource value of structures in the Pensacola Harbor Defense Project Historic District by weights applied in this study (Gulf Islands National Seashore; GUIS) and in the pilot study (Cape Lookout National Seashore; CALO).

Structures	Weighted, normalized resource value score (GUIS weights)	Weighted, normalized resource value score (CALO weights)
Building 7 (NCO Quarters-Duplex)	0.69	0.64
Building 8 (NCO Quarters-Duplex)	0.69	0.64
Santa Rosa Life Saving Station/Ranger Station/Campground Registration Office	0.49	0.54
Building 12 (Ordinance Shop/Former Museum Storage)	0.61	0.56
Coast Guard Garage/Ranger Station Garage	0.24	0.23

Table 4. Optimal Preservation (OptiPres) Model dynamics associated with each action.

Action[1]	Definition	Model Dynamics			
		Depreciation of Structure Condition[2]	**Improvement in Condition[3]**	**Change of Historic Integrity[4]**	**Reduced Vulnerability**
No Action	This option allows managers to repurpose annual maintenance from one structure(s) to another as a way to "capture" enough money in any given year to apply a costly adaptation action to another structure.	• Low (8% annual loss): Applied to wooden buildings in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to wooden buildings in "fair" condition (LSC Score of 2). • High (25% annual loss): Applied to wooden buildings in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to masonry buildings in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to masonry buildings in "fair" condition (LSC Score of 2). • High (25% annual loss): Applied to masonry buildings in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to batteries in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to batteries in "fair" condition (LSC Score of 2). • High (19% annual loss): Applied to batteries in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to Fort Pickens in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to Fort Pickens in "fair" condition (LSC Score of 2). • High (19% annual loss): Applied to Fort Pickens in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to Tower in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to Tower in "fair" condition (LSC Score of 2). • High (19% annual loss): Applied to Tower in "poor" condition (LSC Score of 1).	No change to all types of structures (apply annual depreciation rate based on current condition).	• 5% loss in integrity of wooden buildings (reduction in overall significance score at time of action). • 4% loss in integrity of masonry buildings (reduction in overall significance score at time of action). • 3% loss in integrity of batteries (reduction in overall significance score at time of action). • 4% loss in integrity of Fort Pickens (reduction in overall significance score at time of action). • 7% loss in integrity of Tower (reduction in overall significance score at time of action).	No change to all types of structures.

[1]Any structure that does not have a Historic Structure Report (HSR) also includes associated costs to develop one for all actions except "no action" and "annual maintenance."

[2]An estimate of how much a structure's condition would annually decay over a 30-year planning horizon. Rates determined through consultation with National Park Service (NPS) personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value. Starting values are the List of Classified Structures (LCS) condition class scores (i.e., good, fair, or poor).

[3]An estimate of how much a structure's condition would improve in the year an adaptation action is applied. In the year an action is applied, the model would not include the depreciation rate; however, in the subsequent years (if no action is applied to that structure), the decay rate would be reintroduced to the model. Rates determined through consultation with NPS personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value.

[4]An estimate of how much historical integrity would be lost by applying specific actions, with the assumption that any action would change the historic fabric of the structure and, consequently, decrease its integrity. Rates determined through consultation with NPS personnel, then updated to reflect values that account for percentage of integrity loss to the seven criteria of integrity. This rate is applied to each of the historical significance attributes at the time of action, except for condition of the structure (because actions either improve or depreciate the condition of the structure), affecting both the structure's historical significance score and the structure's resource value.

Table 4 (continued). Optimal Preservation (OptiPres) Model dynamics associated with each action.

Action[1]	Definition	Model Dynamics			
		Depreciation of Structure Condition[2]	**Improvement in Condition[3]**	**Change of Historic Integrity[4]**	**Reduced Vulnerability**
Annual Maintenance	Regular, annual maintenance that is supposed to occur to keep structures in good condition (base funded operations; inspections, corrective maintenance, and preventative maintenance). Note: values are lower corrective maintenance costs than for "Core and Shell Preservation", as they reflect the bare minimum or maintenance of the status quo through application of small fixes.	• Low (6% annual loss): Applied to wooden buildings in "good" condition (LSC Score of 3). • Medium (7% annual loss): Applied to wooden buildings in "fair" condition (LSC Score of 2). • High (15% annual loss): Applied to wooden buildings in "poor" condition (LSC Score of 1). • Low (4% annual loss): Applied to masonry buildings in "good" condition (LSC Score of 3). • Medium (11% annual loss): Applied to masonry buildings in "fair" condition (LSC Score of 2). • High (15% annual loss): Applied to masonry buildings in "poor" condition (LSC Score of 1). • Low (8% annual loss): Applied to batteries in "good" condition (LSC Score of 3). • Medium (5% annual loss): Applied to batteries in "fair" condition (LSC Score of 2). • High (8% annual loss): Applied to batteries in "poor" condition (LSC Score of 1). • Low (6% annual loss): Applied to Fort Pickens in "good" condition (LSC Score of 3). • Medium (11% annual loss): Applied to Fort Pickens in "fair" condition (LSC Score of 2). • High (15% annual loss): Applied to Fort Pickens in "poor" condition (LSC Score of 1). • Low (16% annual loss): Applied to Tower in "good" condition (LSC Score of 3). • Medium (11% annual loss): Applied to Tower in "fair" condition (LSC Score of 2). • High (15% annual loss): Applied to Tower in "poor" condition (LSC Score of 1).	No change to all types of structures (apply annual depreciation rate based on current condition).	0% for all types of structures	No change.

[1]Any structure that does not have a Historic Structure Report (HSR) also includes associated costs to develop one for all actions except "no action" and "annual maintenance."

[2]An estimate of how much a structure's condition would annually decay over a 30-year planning horizon. Rates determined through consultation with National Park Service (NPS) personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value. Starting values are the List of Classified Structures (LCS) condition class scores (i.e., good, fair, or poor).

[3]An estimate of how much a structure's condition would improve in the year an adaptation action is applied. In the year an action is applied, the model would not include the depreciation rate; however, in the subsequent years (if no action is applied to that structure), the decay rate would be reintroduced to the model. Rates determined through consultation with NPS personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value.

[4]An estimate of how much historical integrity would be lost by applying specific actions, with the assumption that any action would change the historic fabric of the structure and, consequently, decrease its integrity. Rates determined through consultation with NPS personnel, then updated to reflect values that account for percentage of integrity loss to the seven criteria of integrity. This rate is applied to each of the historical significance attributes at the time of action, except for condition of the structure (because actions either improve or depreciate the condition of the structure), affecting both the structure's historical significance score and the structure's resource value.

Table 4 (continued). Optimal Preservation (OptiPres) Model dynamics associated with each action.

Action[1]	Definition	Model Dynamics			
		Depreciation of Structure Condition[2]	Improvement in Condition[3]	Change of Historic Integrity[4]	Reduced Vulnerability
Core & Shell Preservation	Maintenance of historic character of the structure & its historic materials (i.e., similar as possible to the materials used in the original construction), which includes annual maintenance (inspection, full corrective maintenance and preventive maintenance) and non-annual maintenance to bring to standard (cyclic maintenance & recurring maintenance, also referred to as deferred maintenance). This action also included costs affiliated with fully (extensively) documenting the alterations to the resource (conditions report).	• 0% to all types of structures	• Structures in the condition between “good” to “fair” changes to “good” condition class. • Structures in the condition between “fair” to ”poor” changes to 80% of “good” condition class. • Structures in the condition lower than “fair” class: changes to 67% of “good” condition class.	Improvement of 1.5% of historical integrity for all types of structures	No change to all types of structures

[1]Any structure that does not have a Historic Structure Report (HSR) also includes associated costs to develop one for all actions except “no action” and “annual maintenance.”

[2]An estimate of how much a structure’s condition would annually decay over a 30-year planning horizon. Rates determined through consultation with National Park Service (NPS) personnel. The rate is applied to only the “condition of the structure” attribute but affects the structure’s historical significance and, thus, the structure’s resource value. Starting values are the List of Classified Structures (LCS) condition class scores (i.e., good, fair, or poor).

[3]An estimate of how much a structure’s condition would improve in the year an adaptation action is applied. In the year an action is applied, the model would not include the depreciation rate; however, in the subsequent years (if no action is applied to that structure), the decay rate would be reintroduced to the model. Rates determined through consultation with NPS personnel. The rate is applied to only the “condition of the structure” attribute but affects the structure’s historical significance and, thus, the structure’s resource value.

[4]An estimate of how much historical integrity would be lost by applying specific actions, with the assumption that any action would change the historic fabric of the structure and, consequently, decrease its integrity. Rates determined through consultation with NPS personnel, then updated to reflect values that account for percentage of integrity loss to the seven criteria of integrity. This rate is applied to each of the historical significance attributes at the time of action, except for condition of the structure (because actions either improve or depreciate the condition of the structure), affecting both the structure’s historical significance score and the structure’s resource value.

Table 4 (continued). Optimal Preservation (OptiPres) Model dynamics associated with each action.

		Model Dynamics			
Action[1]	**Definition**	**Depreciation of Structure Condition[2]**	**Improvement in Condition[3]**	**Change of Historic Integrity[4]**	**Reduced Vulnerability**
Elevate	This action consists of (a) bringing the building to standard (Core & Shell Preservation: Maintain Integrity) and (b) raising the minimum floor elevation to reduce the likelihood of structural damage from storm-related flooding and/or sea level rise. This action also included costs affiliated with fully (extensively) documenting the alterations to the resource condition (historic structure report), as well as minimal interpretation (e.g., one panel sign that addresses adapting to climate change).	• 0% to all types of structures	• Building changes to "good" condition class for wooden buildings. • Not applicable to masonry buildings, batteries, Fort Pickens, and tower.	Not applicable to masonry buildings, batteries, Fort Pickens, and tower	Sensitivity changed to "low" (1).

[1]Any structure that does not have a Historic Structure Report (HSR) also includes associated costs to develop one for all actions except "no action" and "annual maintenance."

[2]An estimate of how much a structure's condition would annually decay over a 30-year planning horizon. Rates determined through consultation with National Park Service (NPS) personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value. Starting values are the List of Classified Structures (LCS) condition class scores (i.e., good, fair, or poor).

[3]An estimate of how much a structure's condition would improve in the year an adaptation action is applied. In the year an action is applied, the model would not include the depreciation rate; however, in the subsequent years (if no action is applied to that structure), the decay rate would be reintroduced to the model. Rates determined through consultation with NPS personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value.

[4]An estimate of how much historical integrity would be lost by applying specific actions, with the assumption that any action would change the historic fabric of the structure and, consequently, decrease its integrity. Rates determined through consultation with NPS personnel, then updated to reflect values that account for percentage of integrity loss to the seven criteria of integrity. This rate is applied to each of the historical significance attributes at the time of action, except for condition of the structure (because actions either improve or depreciate the condition of the structure), affecting both the structure's historical significance score and the structure's resource value.

Table 4 (continued). Optimal Preservation (OptiPres) Model dynamics associated with each action.

Action[1]	Definition	Model Dynamics			
		Depreciation of Structure Condition[2]	Improvement in Condition[3]	Change of Historic Integrity[4]	Reduced Vulnerability
Document & Monitor	This action includes costs associated with fully (extensively) documenting the resource (historic structures report) and erecting a six-foot chain-link fence around a structure and monitoring the condition. The fencing reduces the potential for human injury as there is potential for the structure to deteriorate by the natural elements. This action also includes costs affiliated with extensive interpretation (e.g., multiple panel signs that address adapting to climate change).	• Low (8% annual loss): Applied to wooden buildings in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to wooden buildings in "fair" condition (LSC Score of 2). • High (25% annual loss): Applied to wooden buildings in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to masonry buildings in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to masonry buildings in "fair" condition (LSC Score of 2). • High (25% annual loss): Applied to masonry buildings in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to batteries in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to batteries in "fair" condition (LSC Score of 2). • High (19% annual loss): Applied to batteries in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to Fort Pickens in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to Fort Pickens in "fair" condition (LSC Score of 2). • High (19% annual loss): Applied to Fort Pickens in "poor" condition (LSC Score of 1). • Low (13% annual loss): Applied to Tower in "good" condition (LSC Score of 3). • Medium (17% annual loss): Applied to Tower in "fair" condition (LSC Score of 2). • High (19% annual loss): Applied to Tower in "poor" condition (LSC Score of 1).	No change to all types of structures (apply annual depreciation rate based on current condition).	• 5% loss in integrity of wooden buildings (reduction in overall significance score at time of action). • 4% loss in integrity of masonry buildings (reduction in overall significance score at time of action). • 3% loss in integrity of batteries (reduction in overall significance score at time of action). • 4% loss in integrity of Fort Pickens (reduction in overall significance score at time of action). • 7% % loss in integrity of Tower (reduction in overall significance score at time of action).	No change to all types of structures

[1]Any structure that does not have a Historic Structure Report (HSR) also includes associated costs to develop one for all actions except "no action" and "annual maintenance."

[2]An estimate of how much a structure's condition would annually decay over a 30-year planning horizon. Rates determined through consultation with National Park Service (NPS) personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value. Starting values are the List of Classified Structures (LCS) condition class scores (i.e., good, fair, or poor).

[3]An estimate of how much a structure's condition would improve in the year an adaptation action is applied. In the year an action is applied, the model would not include the depreciation rate; however, in the subsequent years (if no action is applied to that structure), the decay rate would be reintroduced to the model. Rates determined through consultation with NPS personnel. The rate is applied to only the "condition of the structure" attribute but affects the structure's historical significance and, thus, the structure's resource value.

[4]An estimate of how much historical integrity would be lost by applying specific actions, with the assumption that any action would change the historic fabric of the structure and, consequently, decrease its integrity. Rates determined through consultation with NPS personnel, then updated to reflect values that account for percentage of integrity loss to the seven criteria of integrity. This rate is applied to each of the historical significance attributes at the time of action, except for condition of the structure (because actions either improve or depreciate the condition of the structure), affecting both the structure's historical significance score and the structure's resource value.

Table 4 (continued). Optimal Preservation (OptiPres) Model dynamics associated with each action.

		Model Dynamics			
Action[1]	**Definition**	**Depreciation of Structure Condition[2]**	**Improvement in Condition[3]**	**Change of Historic Integrity[4]**	**Reduced Vulnerability**
Active removal	This action includes costs associated with fully (extensively) documenting the resource (historic structures report) and then physically removing the structure from the historic district (debris and hazard demolition) and disposing the materials according to federal guidelines (debris and hazard disposal). This action also included costs affiliated extensive interpretation (e.g., multiple panel signs that address adapting to climate change).	N/A to all types of structures	N/A: Condition score set to 0 for all types of structures	90% permanent loss in integrity for all types of structures (structure removed from landscape; extensive interpretation to “tell the story” – retains 10% integrity from interpretive panels).	• Sensitivity removed (0) for all types of structures • Exposure removed (0) for all types of structures

[1]Any structure that does not have a Historic Structure Report (HSR) also includes associated costs to develop one for all actions except “no action” and “annual maintenance.”

[2]An estimate of how much a structure’s condition would annually decay over a 30-year planning horizon. Rates determined through consultation with National Park Service (NPS) personnel. The rate is applied to only the “condition of the structure” attribute but affects the structure’s historical significance and, thus, the structure’s resource value. Starting values are the List of Classified Structures (LCS) condition class scores (i.e., good, fair, or poor).

[3]An estimate of how much a structure’s condition would improve in the year an adaptation action is applied. In the year an action is applied, the model would not include the depreciation rate; however, in the subsequent years (if no action is applied to that structure), the decay rate would be reintroduced to the model. Rates determined through consultation with NPS personnel. The rate is applied to only the “condition of the structure” attribute but affects the structure’s historical significance and, thus, the structure’s resource value.

[4]An estimate of how much historical integrity would be lost by applying specific actions, with the assumption that any action would change the historic fabric of the structure and, consequently, decrease its integrity. Rates determined through consultation with NPS personnel, then updated to reflect values that account for percentage of integrity loss to the seven criteria of integrity. This rate is applied to each of the historical significance attributes at the time of action, except for condition of the structure (because actions either improve or depreciate the condition of the structure), affecting both the structure’s historical significance score and the structure’s resource value.

Table 5. Adaptation actions and maintenance costs for the 28 historic structures.

Structure	Active Removal	Core & Shell - Maintain Integrity	Elevate the Building	Document & Monitor	Annual Maintenance
Building 4 (Captain's Quarters)	$365,021.80	$50,908.00	$647,046.40	$116,773.80	$18,189.60
Building 3 (Lieutenant's Quarters)	$361,448.16	$50,409.60	$640,711.68	$115,630.56	$18,011.52
Building 2 (Lieutenant's Quarters)	$361,448.16	$50,409.60	$640,711.68	$115,630.56	$18,011.52
Building 5 (Post Administration Bldg/Discovery Center)	$690,733.56	$96,333.60	$1,224,410.88	$220,971.96	$34,420.32
Building 6 (Fire Station)	$243,645.67	$33,980.20	$431,892.16	$77,944.47	$12,141.24
Coast Guard Garage/Ranger Station Garage	$207,398.75	$28,925.00	$367,640.00	$66,348.75	$10,335.00
Santa Rosa Life Saving Station/Ranger Station/Campground Registration Office	$859,205.16	$119,829.60	$1,523,047.68	$274,867.56	$42,815.52
Building 1 (NCO Quarters/VIP Cottage)	$331,838.00	$46,280.00	$588,224.00	$106,158.00	$16,536.00
Building 7 (NCO Quarters-Duplex)	$261,641.50	$36,490.00	$463,792.00	$83,701.50	$13,038.00
Building 8 (NCO Quarters-Duplex)	$261,641.50	$36,490.00	$463,792.00	$83,701.50	$13,038.00
Building 17 (Engineer Storeroom)	$158,261.20	$126,641.20	N/A	$189,186.80	$110,632.80
Building 15 (Mine Loading Room)	$9,780,341.76	$117,653.76	N/A	$175,760.64	$7,326.72
Building 16 (Mine Storeroom)	$18,338,140.80	$220,600.80	N/A	$329,551.20	$192,715.20
Building 11 (Pumping Plant/Maintenance Field Office)	$6,791,904.00	$81,704.00	N/A	$122,056.00	$71,376.00
Building 12 (Ordnance Shop/Former Museum Storage)	$3,973,263.84	$47,796.84	N/A	$71,402.76	$41,754.96
Building 10 (Pump House/Paint Locker)	$73,514.88	$10,252.80	N/A	$23,518.08	$3,663.36
Van Swearingen Latrine	$45,946.80	$6,408.00	N/A	$14,698.80	$2,289.60
Battery Pensacola	$463,547,448.00	$5,576,298.00	N/A	$8,330,322.00	$4,871,412.00
Battery Langdon	$829,885,770.00	$9,983,207.50	N/A	$14,913,717.50	$8,721,255.00
Battery Worth	$695,321,172.00	$8,364,447.00	N/A	$12,495,483.00	$7,307,118.00
Battery Cooper	$126,286,965.00	$1,519,183.75	N/A	$2,269,478.75	$1,327,147.50
Battery 234	$231,391,679.40	$2,783,553.15	N/A	$4,158,295.35	$2,431,691.10

Table 5 (continued). Adaptation actions and maintenance costs for the 28 historic structures.

Structure	Active Removal	Core & Shell - Maintain Integrity	Elevate the Building	Document & Monitor	Annual Maintenance
Battery Payne	$71,909,283.60	$865,041.10	N/A	$1,292,267.90	$755,693.40
Battery Trueman	$83,540,419.20	$1,004,959.20	N/A	$1,501,288.80	$877,924.80
Batteries Cullum-Sevier	$212,247,000.00	$2,553,250.00	N/A	$3,814,250.00	$2,230,500.00
Battery Van Swearingen	$79,337,928.60	$954,404.85	N/A	$1,425,766.65	$833,760.90
Fort Pickens	$2,588,734,210.00	$31,141,479.60	N/A	$46,521,644.40	$27,204,962.40

Table 6. Updated Optimal Preservation (OptiPres) Model dynamics for Use Potential associated with each action (Updated Model A).

Action	Definition	Model Dynamics for Use Potential[1]		
		Operational Use	Third-Party Use	Visitor Use
No Action	This option allows managers to repurpose annual maintenance from one structure(s) to another as a way to “capture” enough money in any given year to apply a costly adaptation action to another structure.	When no action is applied to any structure for the first year, the operational use will be downgraded to a lower metric level. After the first year of no action, if no action is still applied to the structure in subsequent years, the operational use will downgrade to the next lower metric level after 5 consecutive years.	When no action is applied to any structure for the first year, the third-party use will be downgraded to a lower metric level. After the first year of no action, if no action is still applied to the structure in subsequent years, the third-party use will downgrade to the next lower metric level after 5 consecutive years.	When no action is applied to any structure for the first year, visitor use will be downgraded to the metric level of “closed but may be open in the future”. After the first year of no action, if no action is still applied to the structure in subsequent years, visitor use will downgrade to the next lower metric level after 5 consecutive years.

[1]The scientific use metric levels and interpretive use metric levels will remain the same for all actions.

Table 6 (continued). Updated Optimal Preservation (OptiPres) Model dynamics for Use Potential associated with each action (Updated Model A).

Action	Definition	Model Dynamics for Use Potential[1]		
		Operational Use	**Third-Party Use**	**Visitor Use**
Annual Maintenance	Regular, annual maintenance that is supposed to occur to keep structures in good condition (base funded operations; inspections, corrective maintenance, and preventative maintenance). Note: values are lower corrective maintenance costs than for "Core and Shell Preservation", as they reflect the bare minimum or maintenance of the status quo through application of small fixes.	n/a	n/a	n/a
Core & Shell Preservation	Maintenance of historic character of the structure & its historic materials (i.e., similar as possible to the materials used in the original construction), which includes annual maintenance (inspection, full corrective maintenance and preventive maintenance) and non-annual maintenance to bring to standard (cyclic maintenance & recurring maintenance, also referred to as deferred maintenance). This action also included costs affiliated with fully (extensively) documenting the resource in its new condition (conditions report).	If core and shell preservation is applied to any structure, then the operational use will be reset to its original metric level (if it had been downgraded by prior inaction).	If core and shell preservation is applied to any structure, then the third-party use will be reset to its original metric level (if it had been downgraded by prior inaction).	If core and shell preservation is applied to any structure, visitor use will be reset to its original metric level (if it had been downgraded by prior inaction).

[1]The scientific use metric levels and interpretive use metric levels will remain the same for all actions.

Table 6 (continued). Updated Optimal Preservation (OptiPres) Model dynamics for Use Potential associated with each action (Updated Model A).

Action	Definition	Model Dynamics for Use Potential[1]		
		Operational Use	**Third-Party Use**	**Visitor Use**
Elevate	This action consists of (a) bringing the building to standard (Core & Shell Preservation: Maintain Integrity) and (b) raising the minimum floor elevation to reduce the likelihood of structural damage from storm-related flooding and/or sea level rise. This action also included costs affiliated with fully (extensively) documenting the resource in its new condition (historic structure report), as well as minimal interpretation (e.g., one panel sign that addresses adapting to climate change).	n/a	n/a	n/a
Document & Monitor	This action includes costs associated with fully (extensively) documenting the resource (historic structures report) and erecting a six-foot chain-link fence around a structure and monitoring the condition. The fencing reduces the potential for human injury as there is potential for the structure to deteriorate by the natural elements. This action also includes costs affiliated with extensive interpretation (e.g., multiple panel signs that address adapting to climate change).	If document and monitor is applied to any structure, the operational use will be set to a metric value of 0.0.	If document and monitor is applied to any structure, the third-party use will be set to a metric value of 0.0.	If document and monitor is applied to any structure, visitor use will be set to a metric value of 0.0.

[1]The scientific use metric levels and interpretive use metric levels will remain the same for all actions.

Table 6 (continued). Updated Optimal Preservation (OptiPres) Model dynamics for Use Potential associated with each action (Updated Model A).

Action	Definition	Model Dynamics for Use Potential[1]		
		Operational Use	**Third-Party Use**	**Visitor Use**
Active removal	This action consists of physically removing the structure from the historic district (debris and hazard demolition) and disposing the materials according to federal guidelines (debris and hazard disposal). This action also included costs affiliated extensive interpretation (e.g., multiple panel signs that address adapting to climate change).	If active removal is applied to any structure, the operational use will be set to a metric value of 0.0.	If active removal is applied to any structure, the third-party use will be set to a metric value of 0.0.	If active removal is applied to any structure, visitor use will be set to a metric value of 0.0.

[1]The scientific use metric levels and interpretive use metric levels will remain the same for all actions.

Appendix 3. Value of condition, remaining significance, and use potential for 28 structures associated with each scenario

In this appendix, the relative value for each historic structure is presented by year for each scenario, with the relative value displayed in terms of the structure's condition, remaining significance, and use potential. In the Optimal Preservation (OptiPres) Model, we separate the historical significance attribute "condition" in this presentation because it is directly altered by the application of different actions. Condition has a weight of 0.167 within the historical significance score. The remaining significance includes three other components of historical significance: association to fundamental purpose, character, and national register (total weight 0.843 of historical significance). Historical significance accounts for 0.74 of relative value, and use potential accounts for 0.26 of relative value (Appendix 1, Table 1). The model dynamics for changes in conditions, remaining significance, and use potential by different adaptation actions are described in Appendix 2, Table 5.

The figure numbering reflects the original model scenarios (Figures 51 through 58), the updated model accounting for use potential dynamics and fractional annual maintenance costs for Fort Pickens (Figures 59 through 64), and the updated model accounting for 10-year intervals of core & shell preservation and fractional annual maintenance costs for Fort Pickens (Figures 65 through 70).

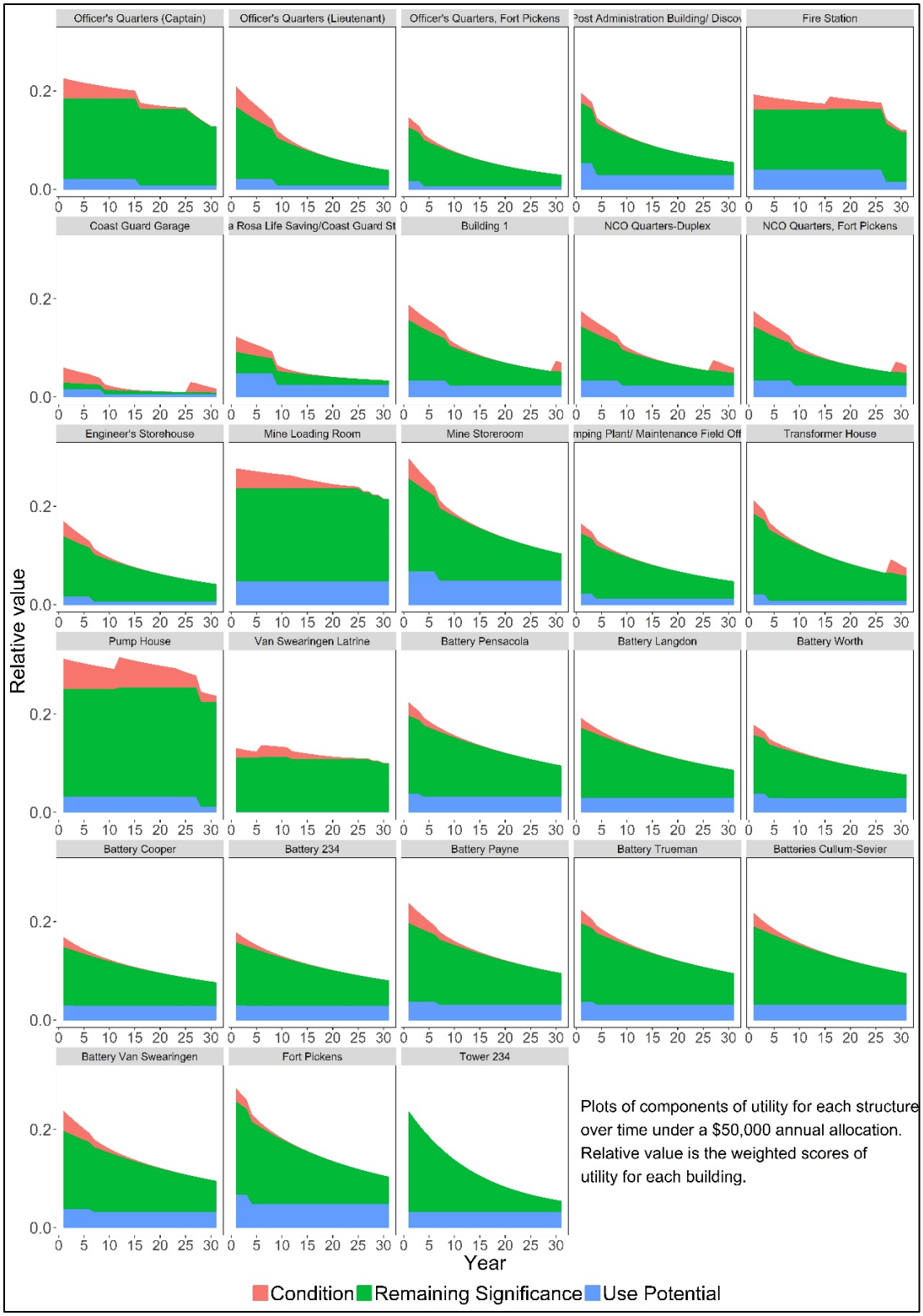


Figure 51. Components of resource value under annual allocation of $50,000.

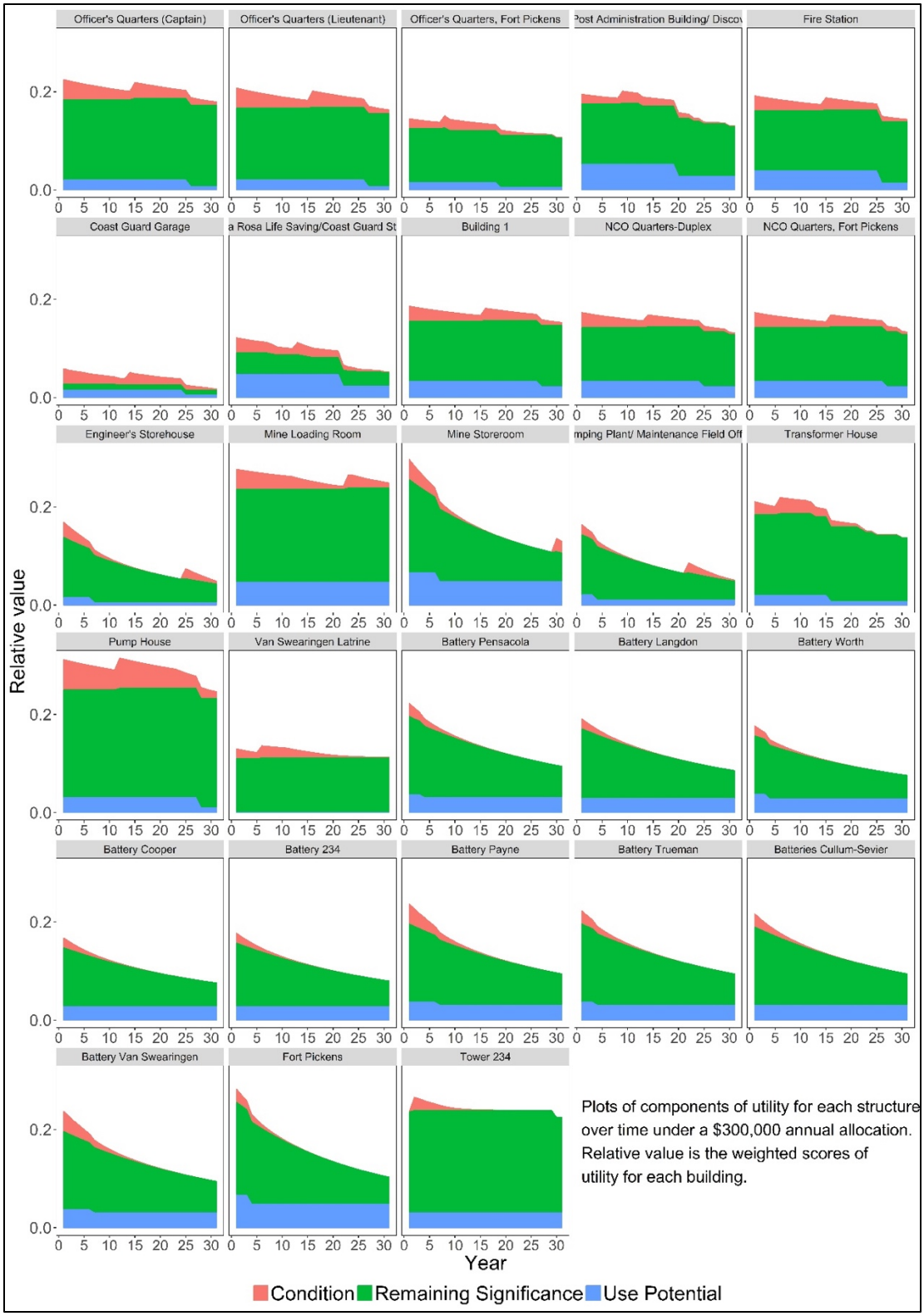


Figure 52. Components of resource value under annual allocation of $300,000.

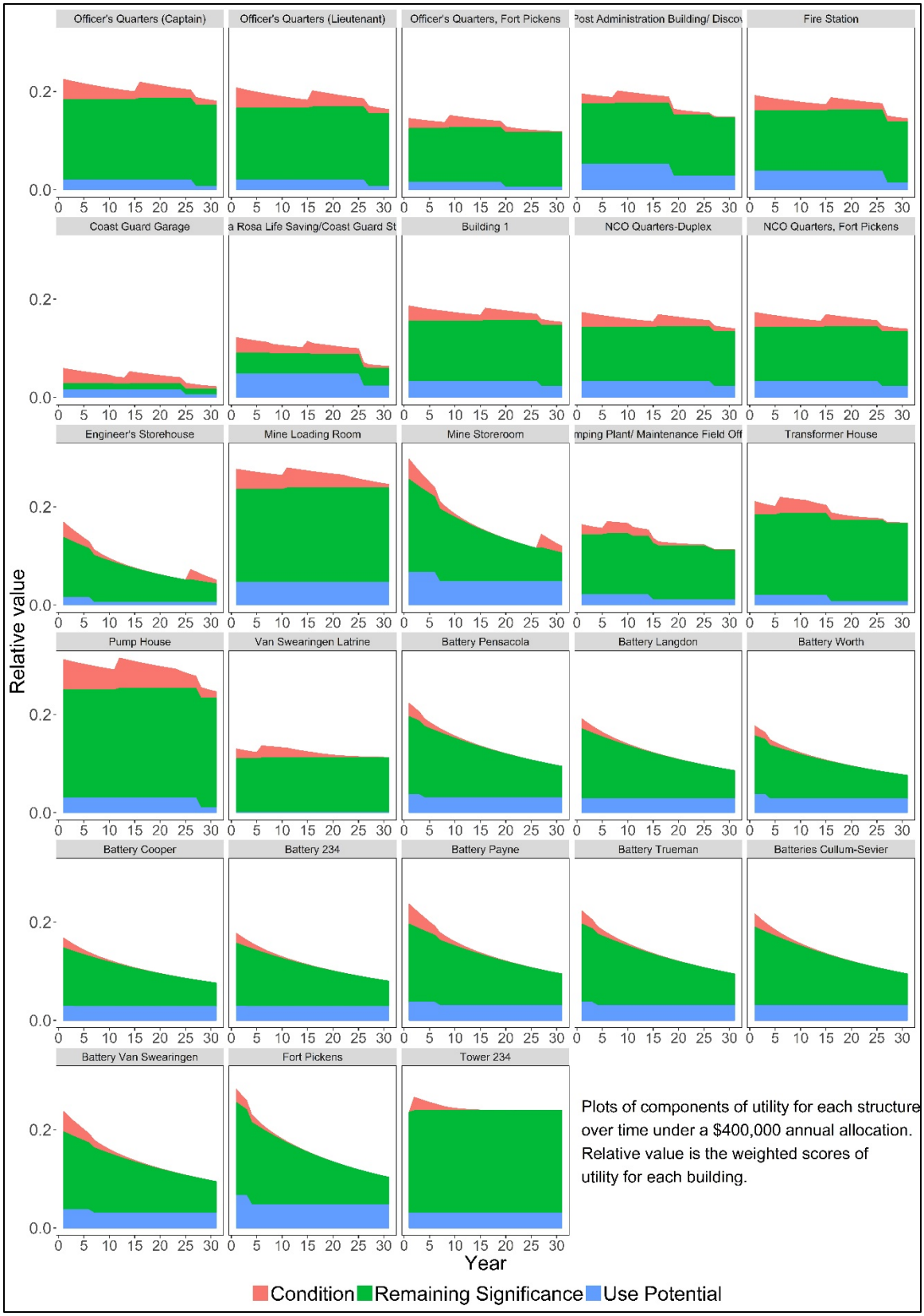


Figure 53. Components of resource value under annual allocation of $400,000.

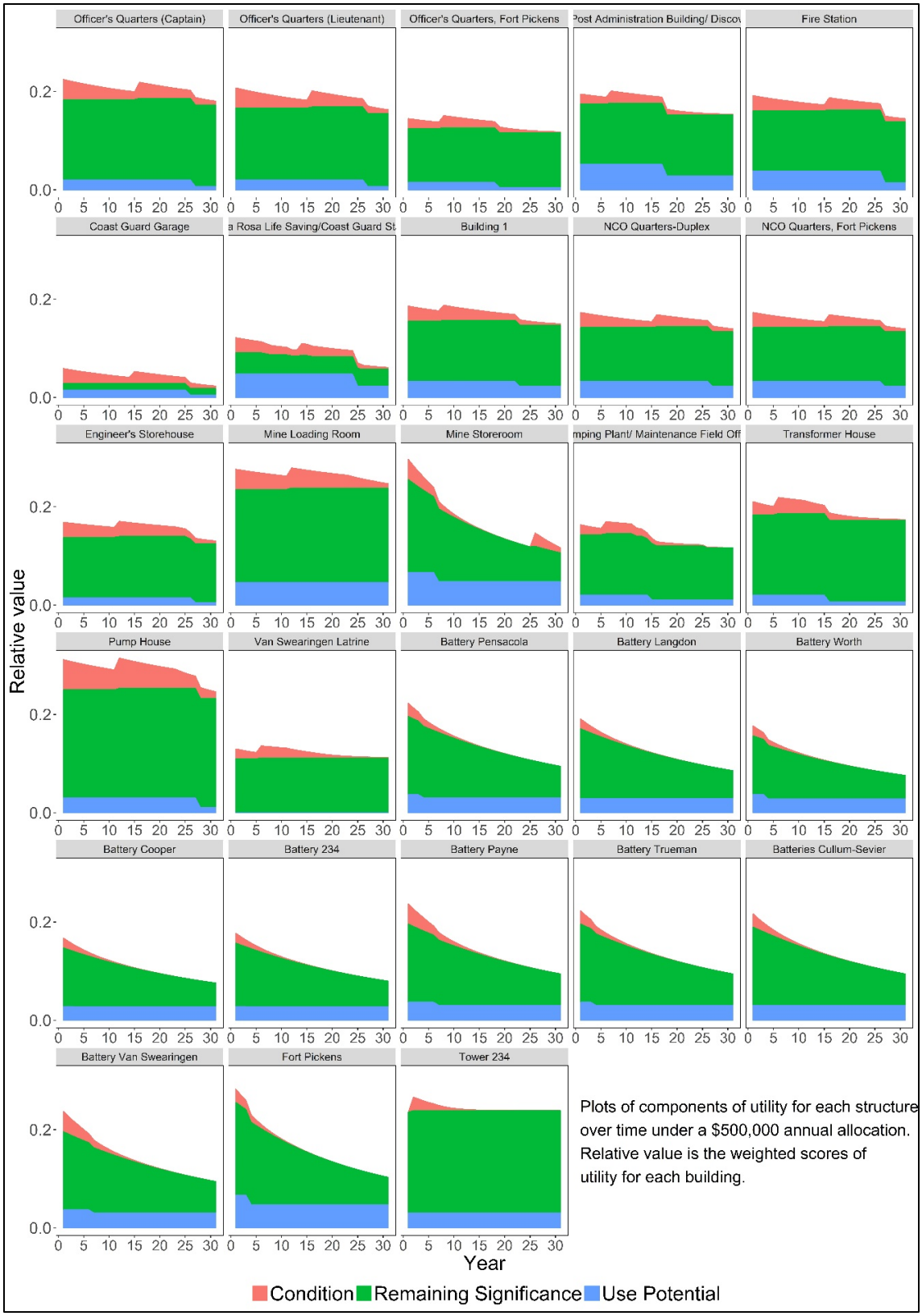


Figure 54. Components of resource value under annual allocation of $500,000.

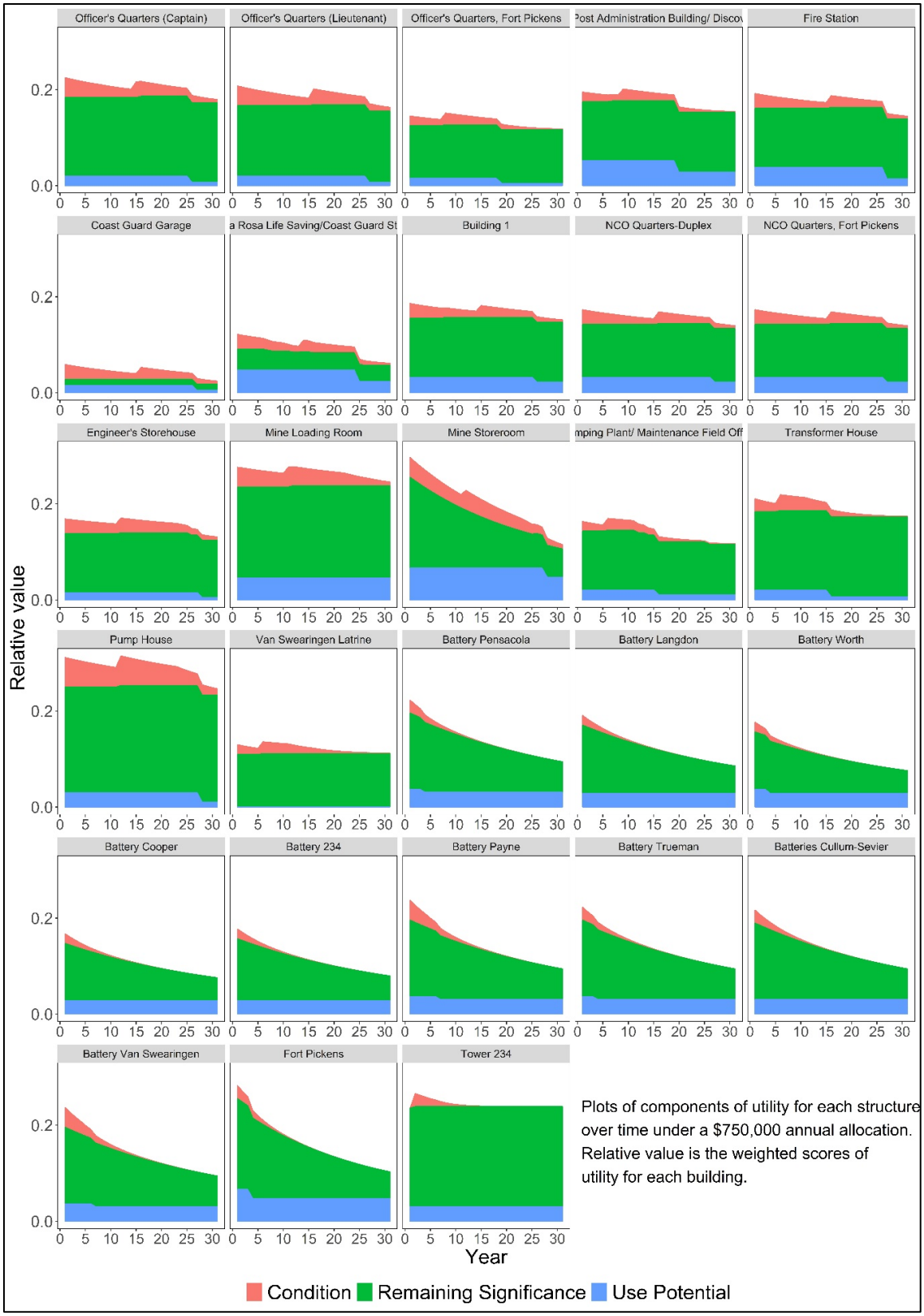


Figure 55. Components of resource value under annual allocation of $750,000.

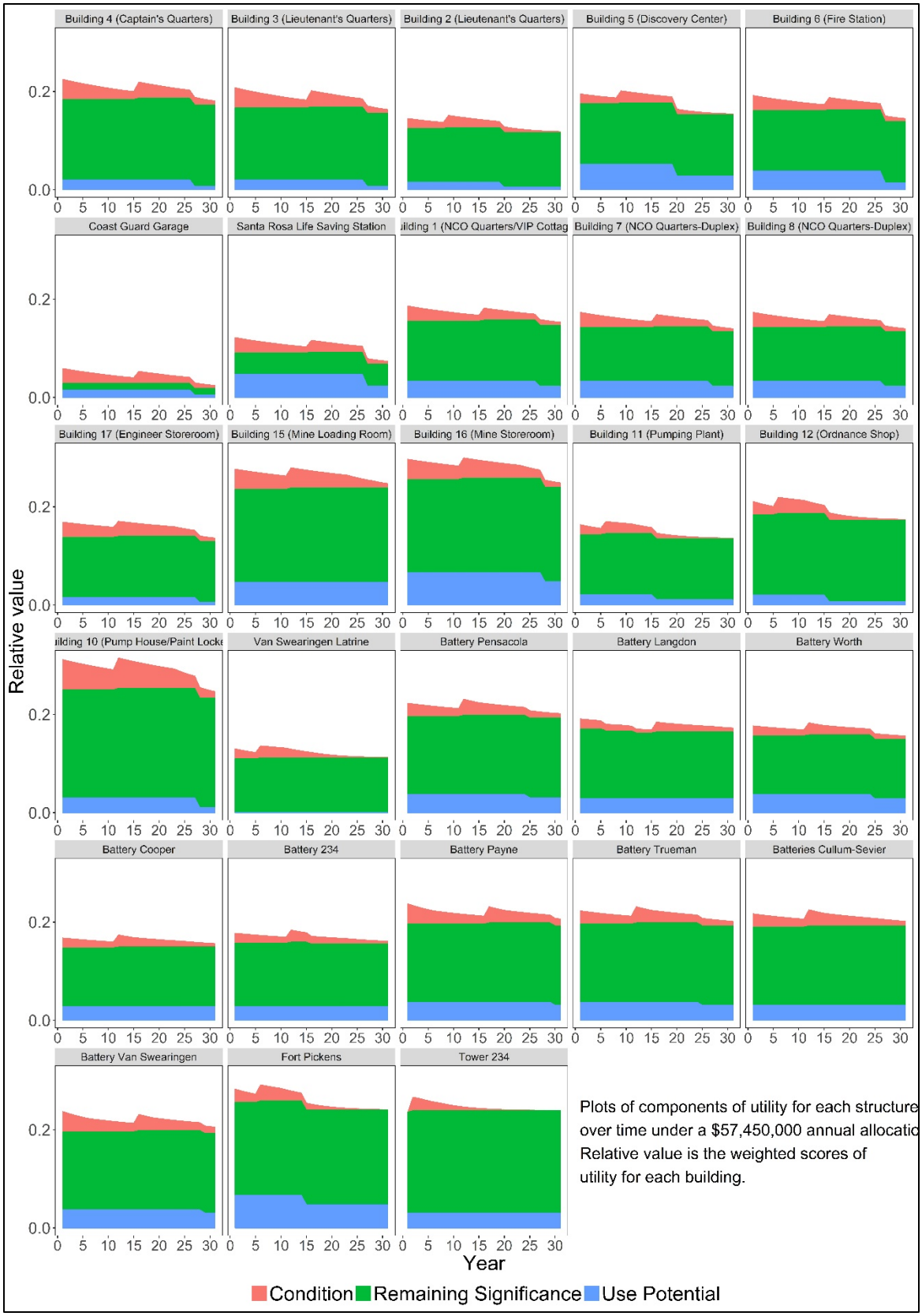


Figure 56. Components of resource value under annual allocation of $57,232,370.

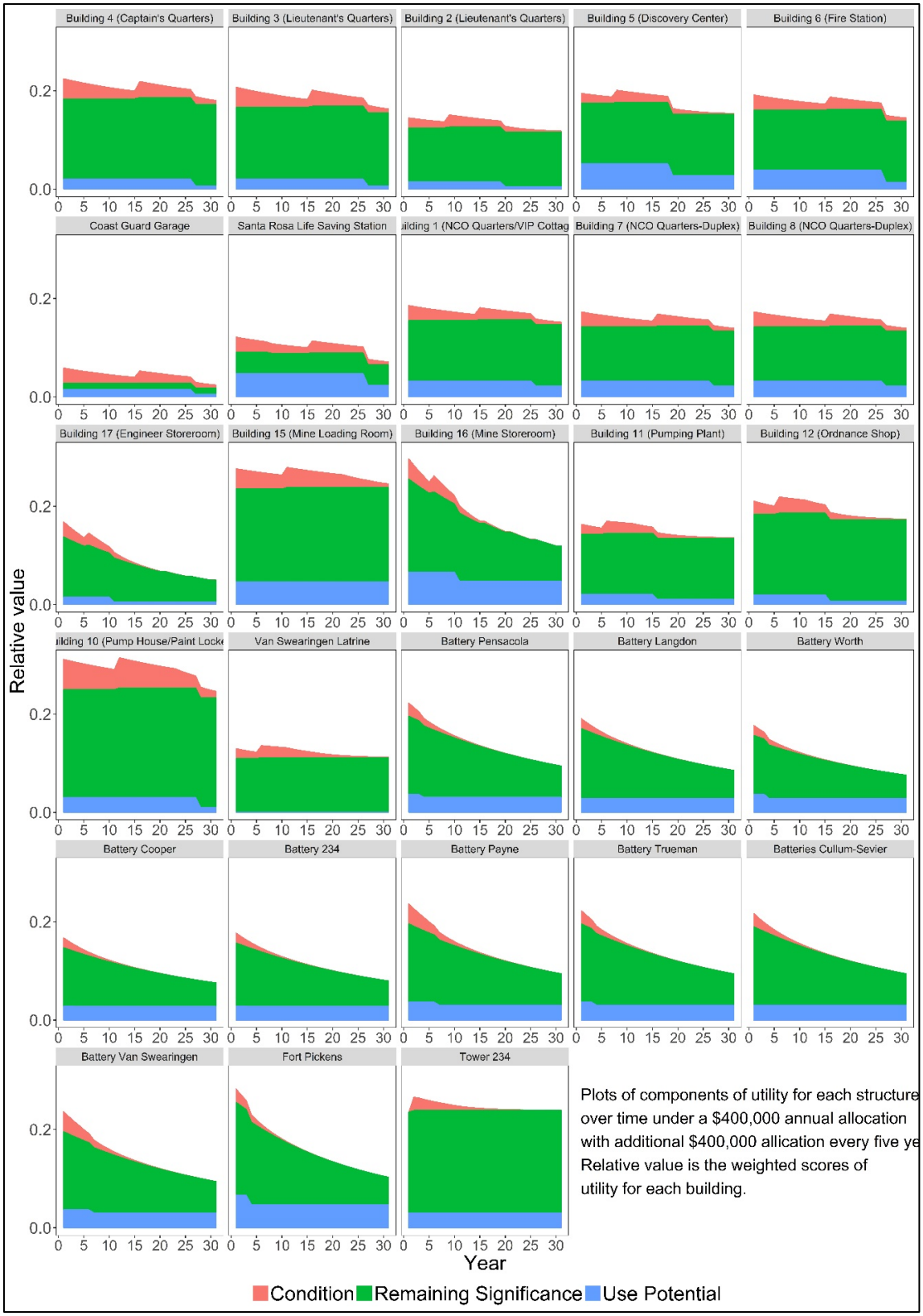


Figure 57. Components of resource value under annual allocation of $400,000 with an additional $400,000 every five years.

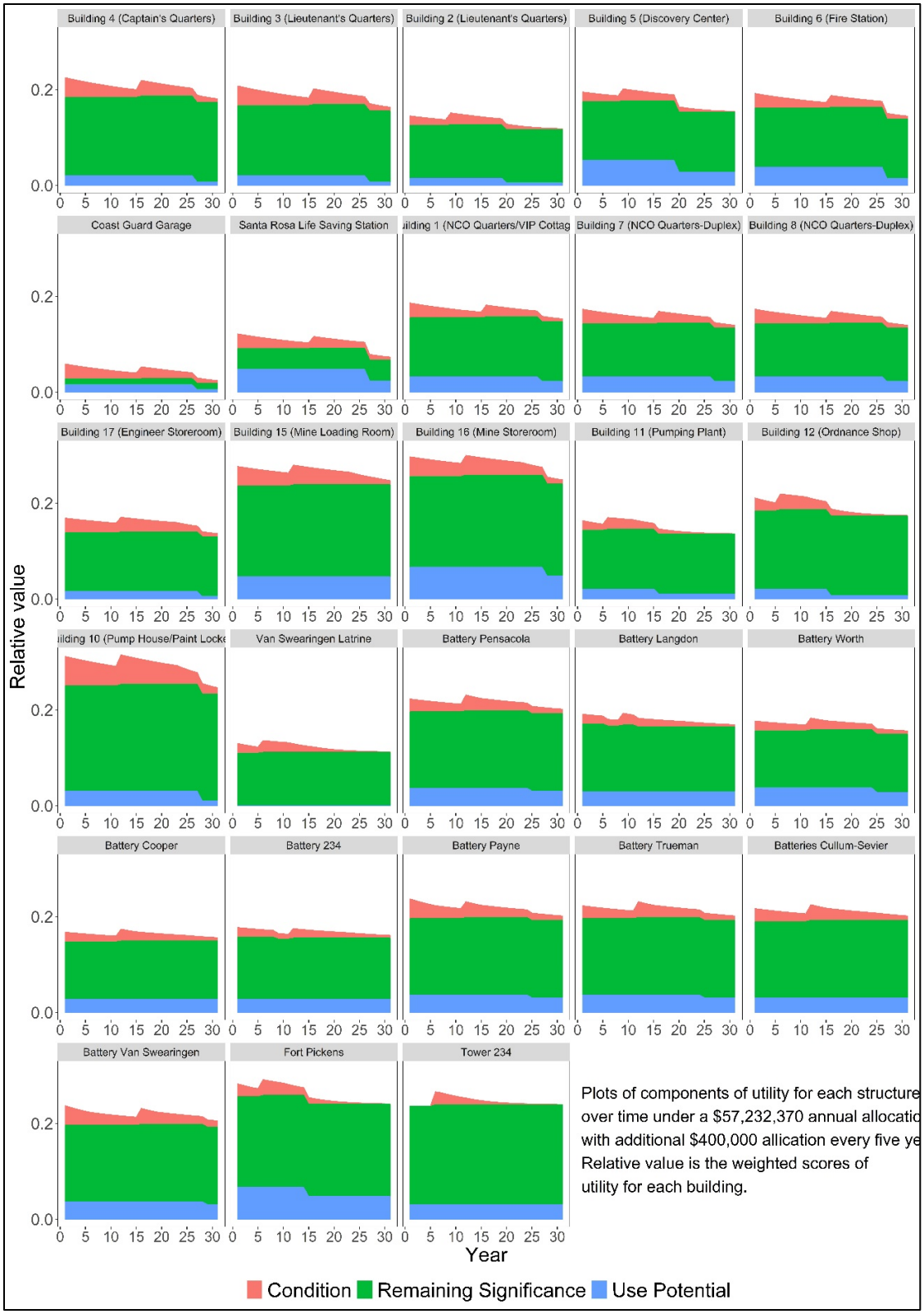


Figure 58. Components of resource value under annual allocation of $57,232,370 with an additional $400,000 every five years.

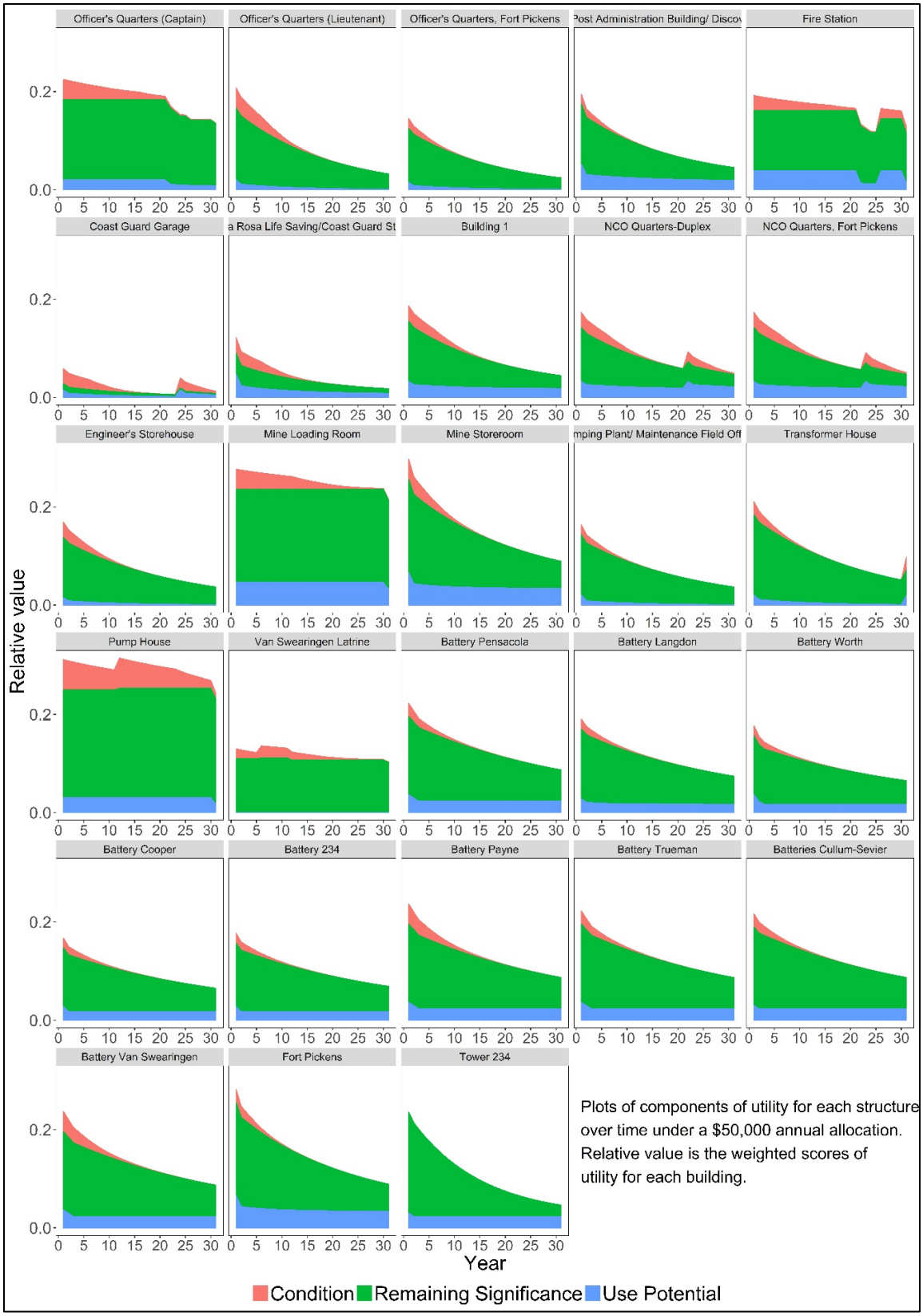


Figure 59. Components of resource value under annual allocation of $50,000 (Updated Model A).

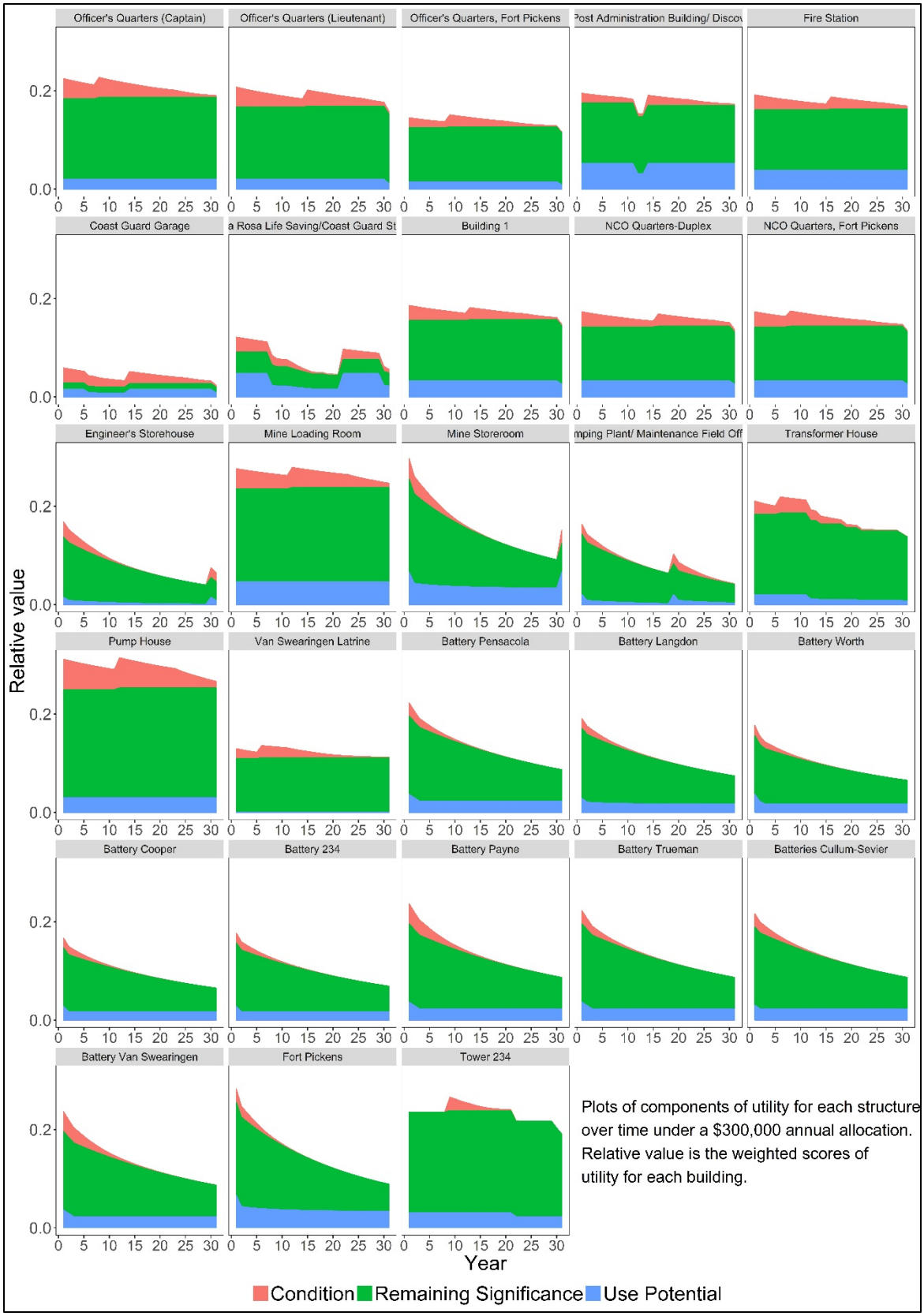


Figure 60. Components of resource value under annual allocation of $300,000 (Updated Model A).

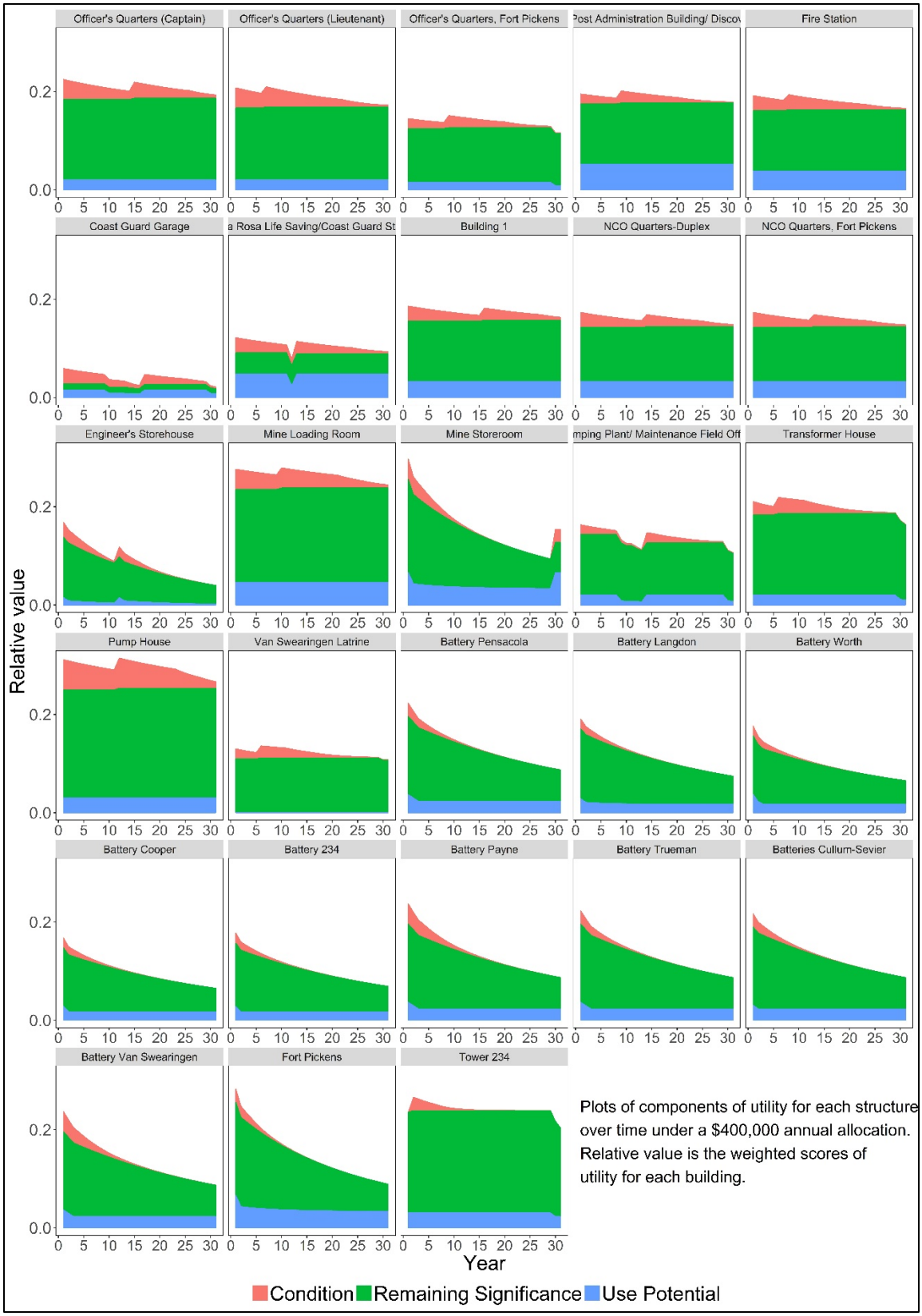


Figure 61. Components of resource value under annual allocation of $400,000 (Updated Model A).

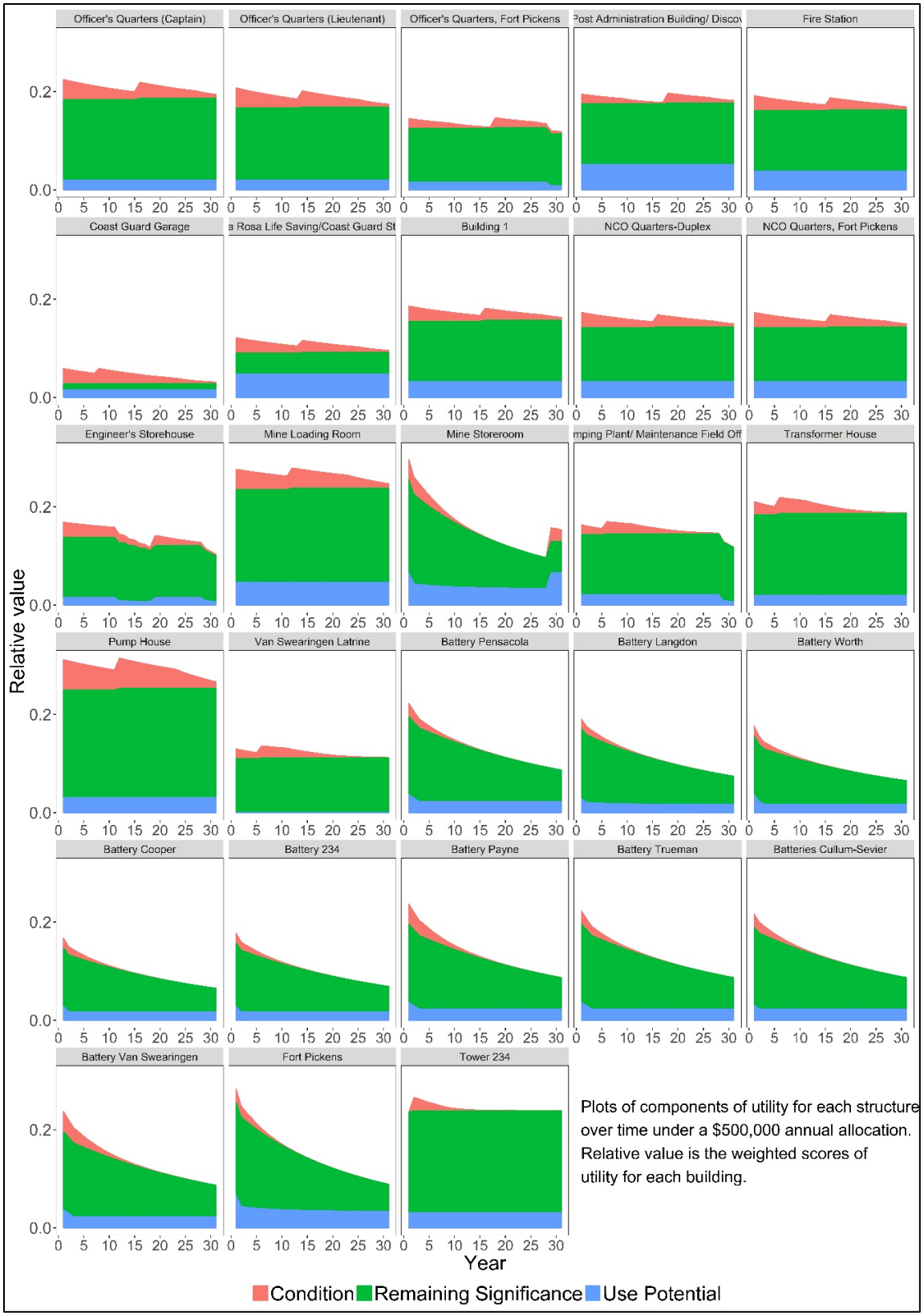


Figure 62. Components of resource value under annual allocation of $500,000 (Updated Model A).

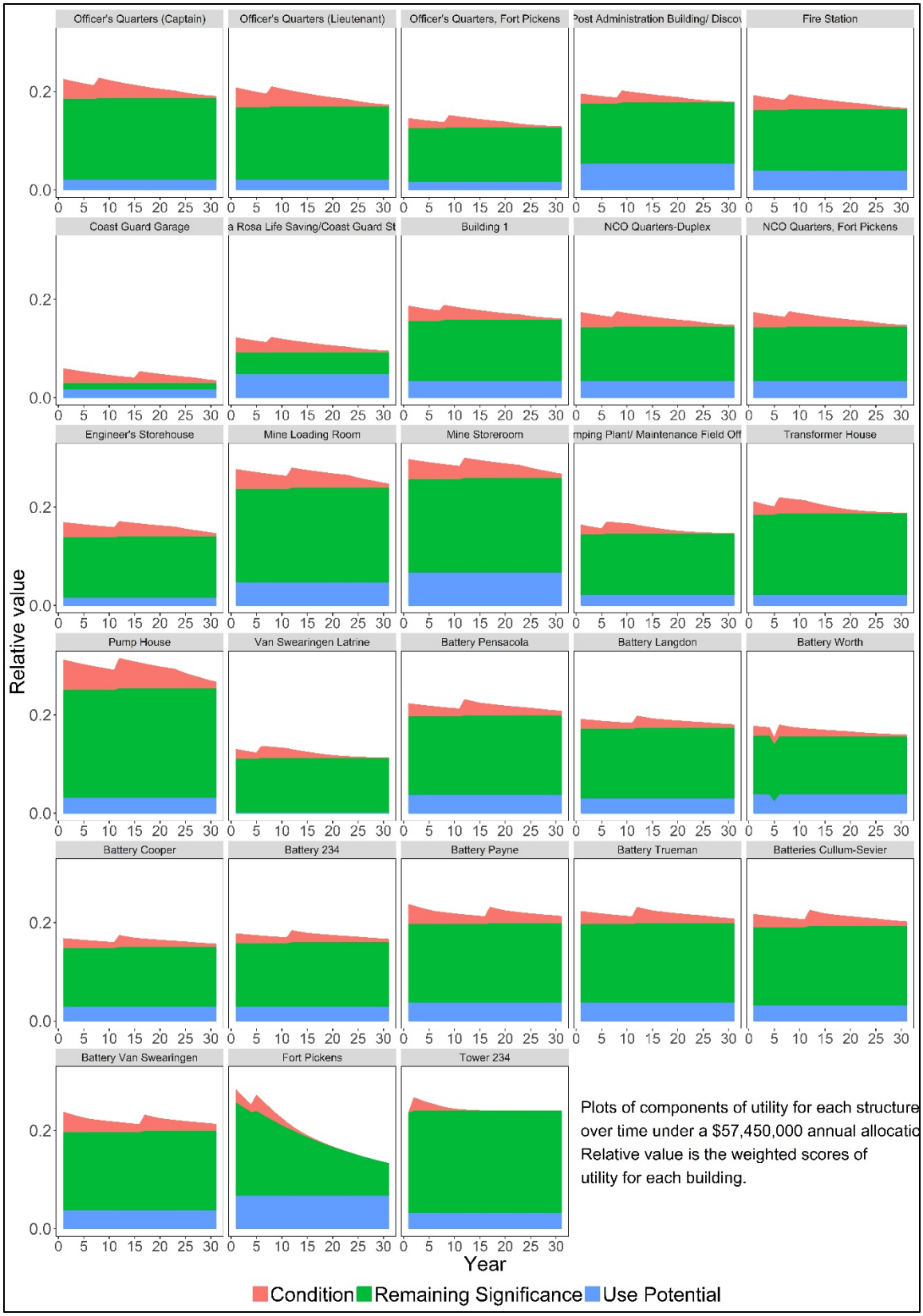


Figure 63. Components of resource value under annual allocation of $57,232,370 (Updated Model A).

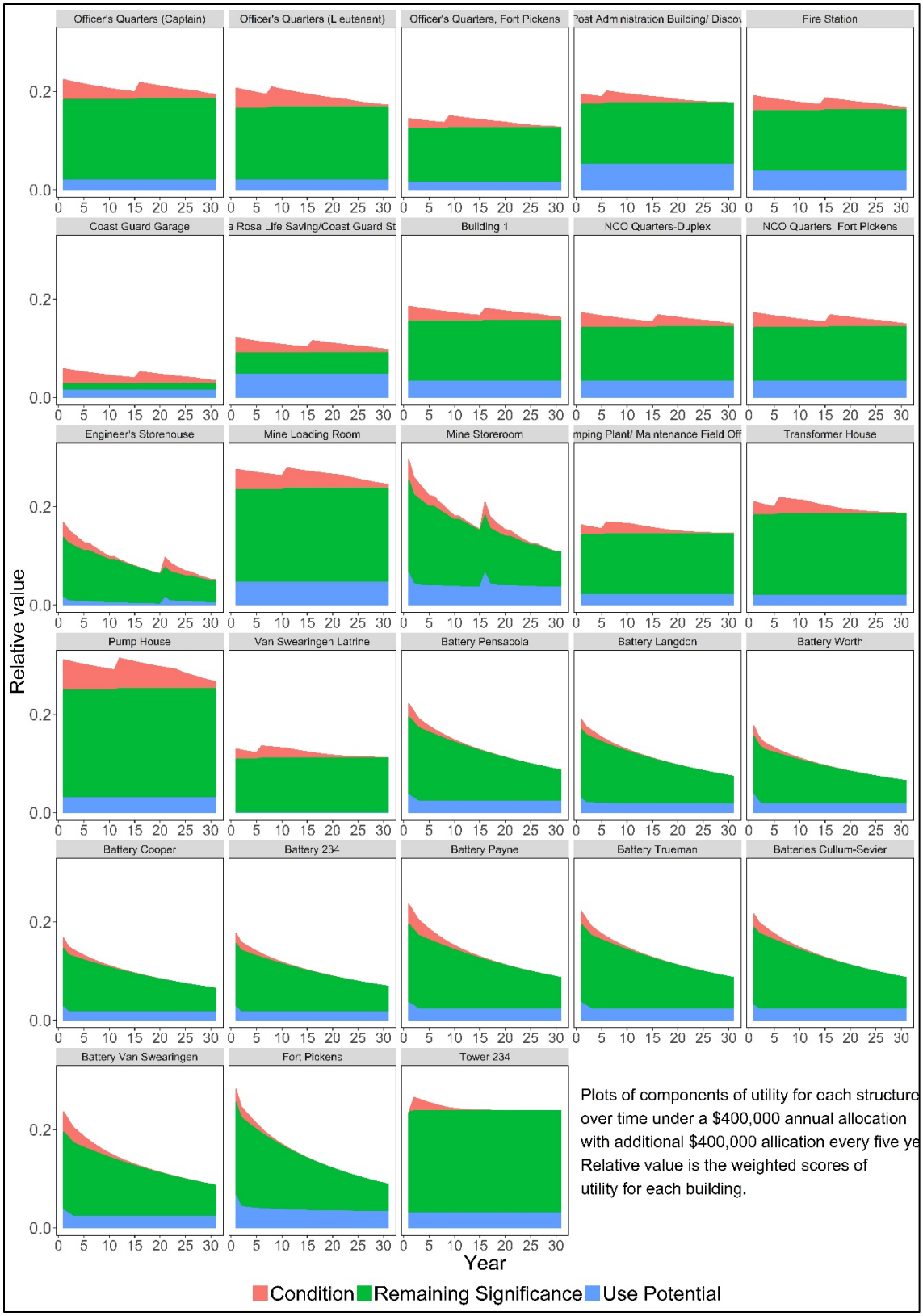


Figure 64. Components of resource value under annual allocation of $400,000 with additional 400,000 allocation every five years (Updated Model A).

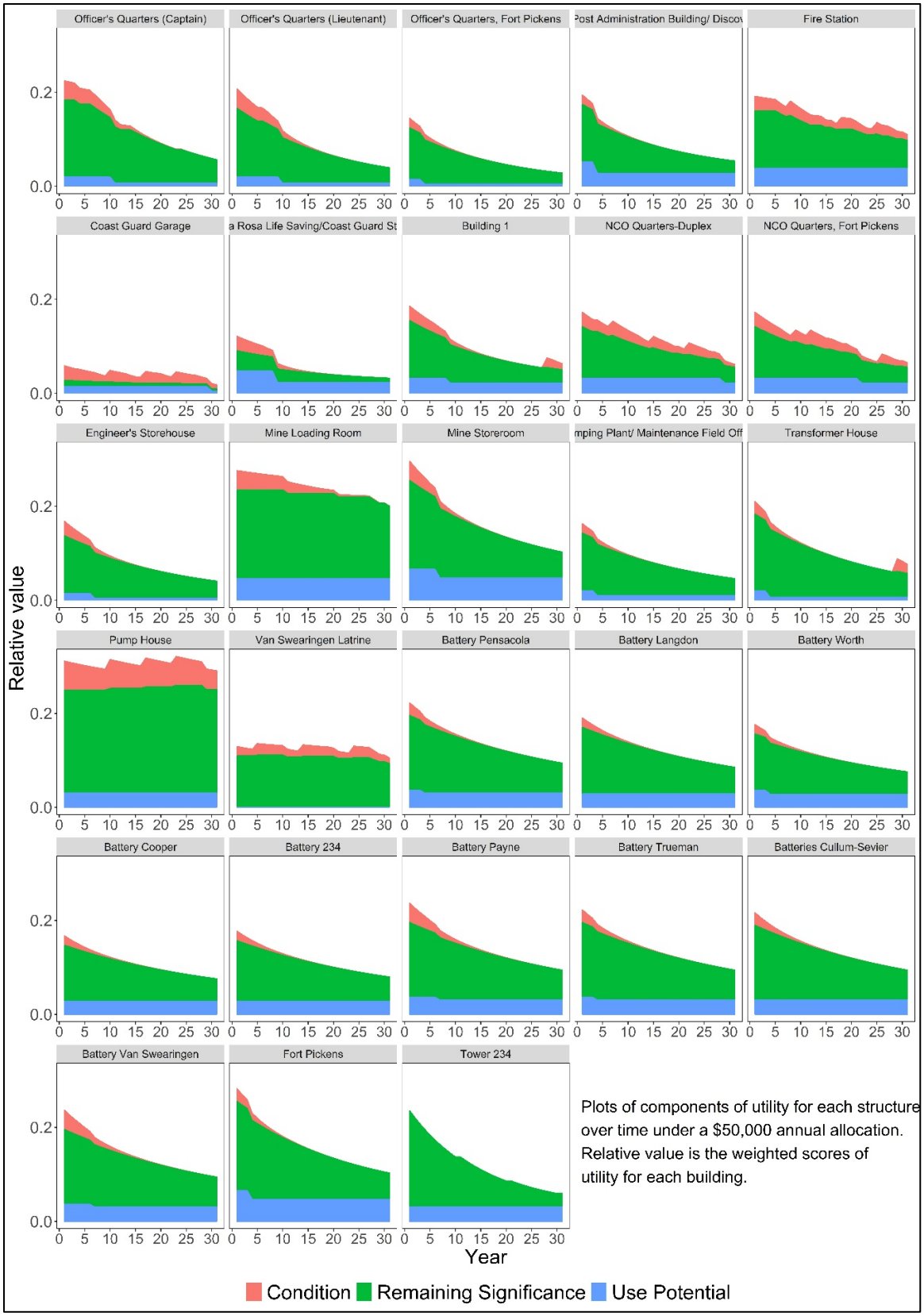


Figure 65. Components of resource value under annual allocation of $50,000 (Updated Model B).

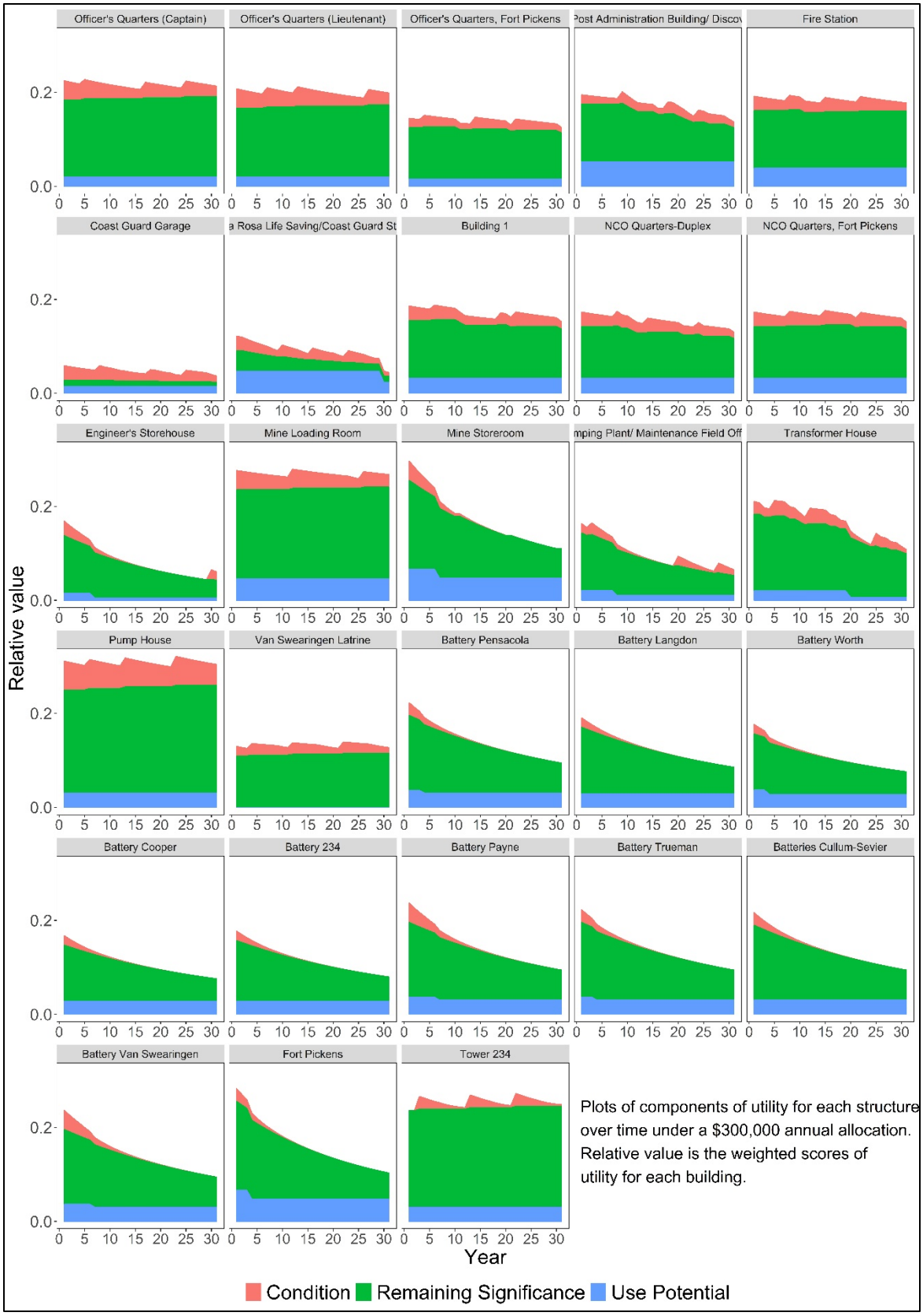


Figure 66. Components of resource value under annual allocation of $300,000 (Updated Model B).

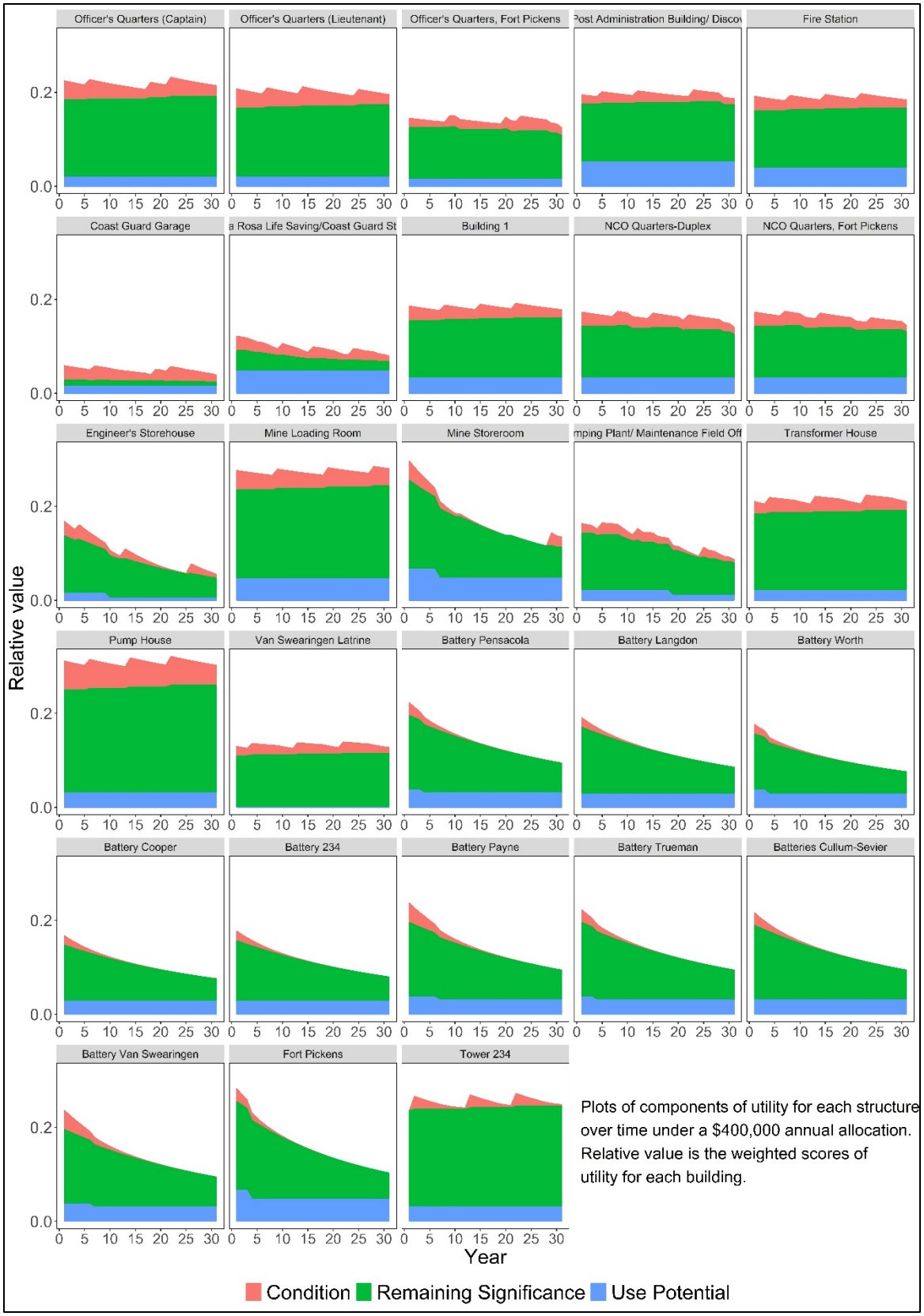


Figure 67. Components of resource value under annual allocation of $400,000 (Updated Model B).

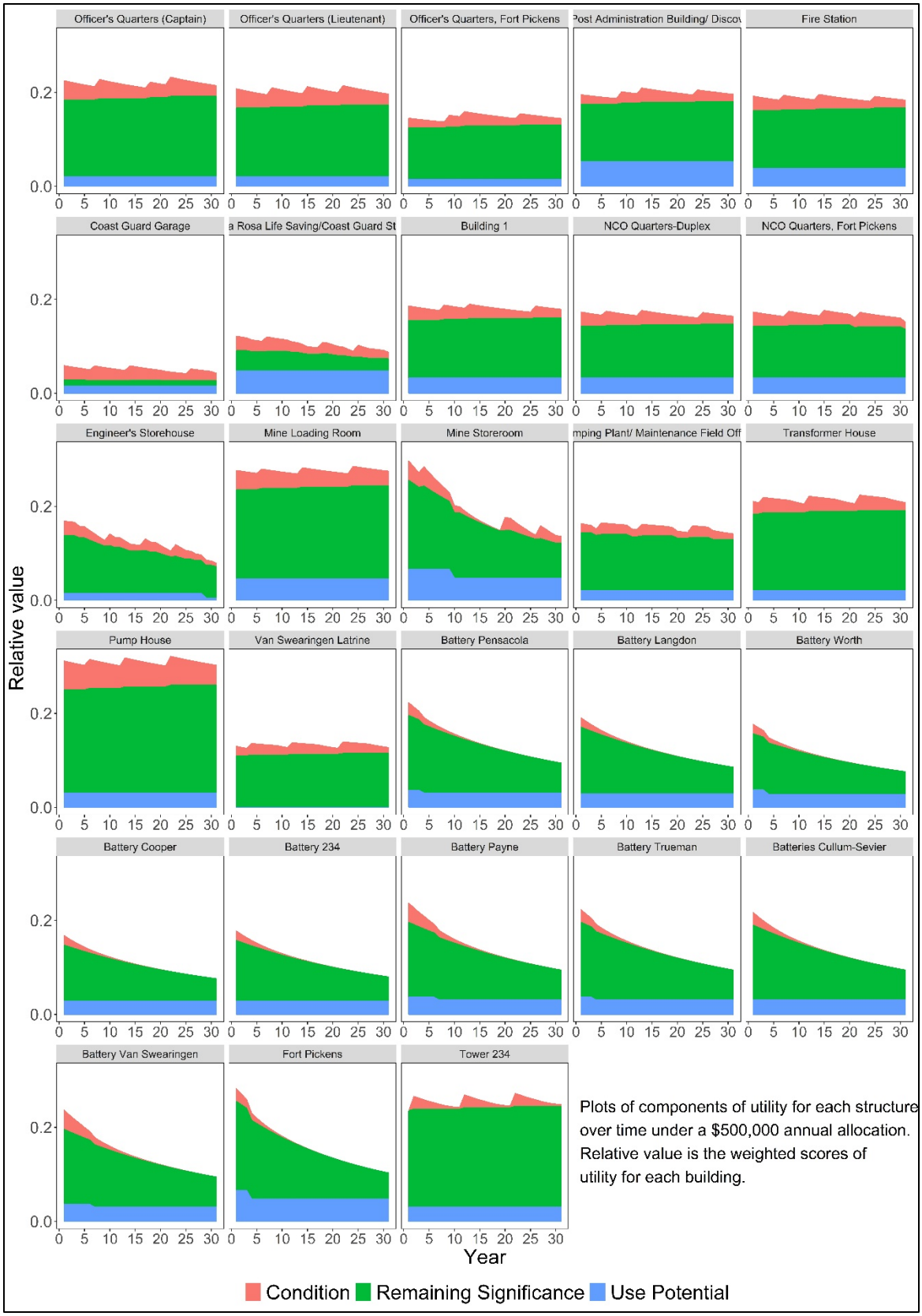


Figure 68. Components of resource value under annual allocation of $500,000 (Updated Model B).

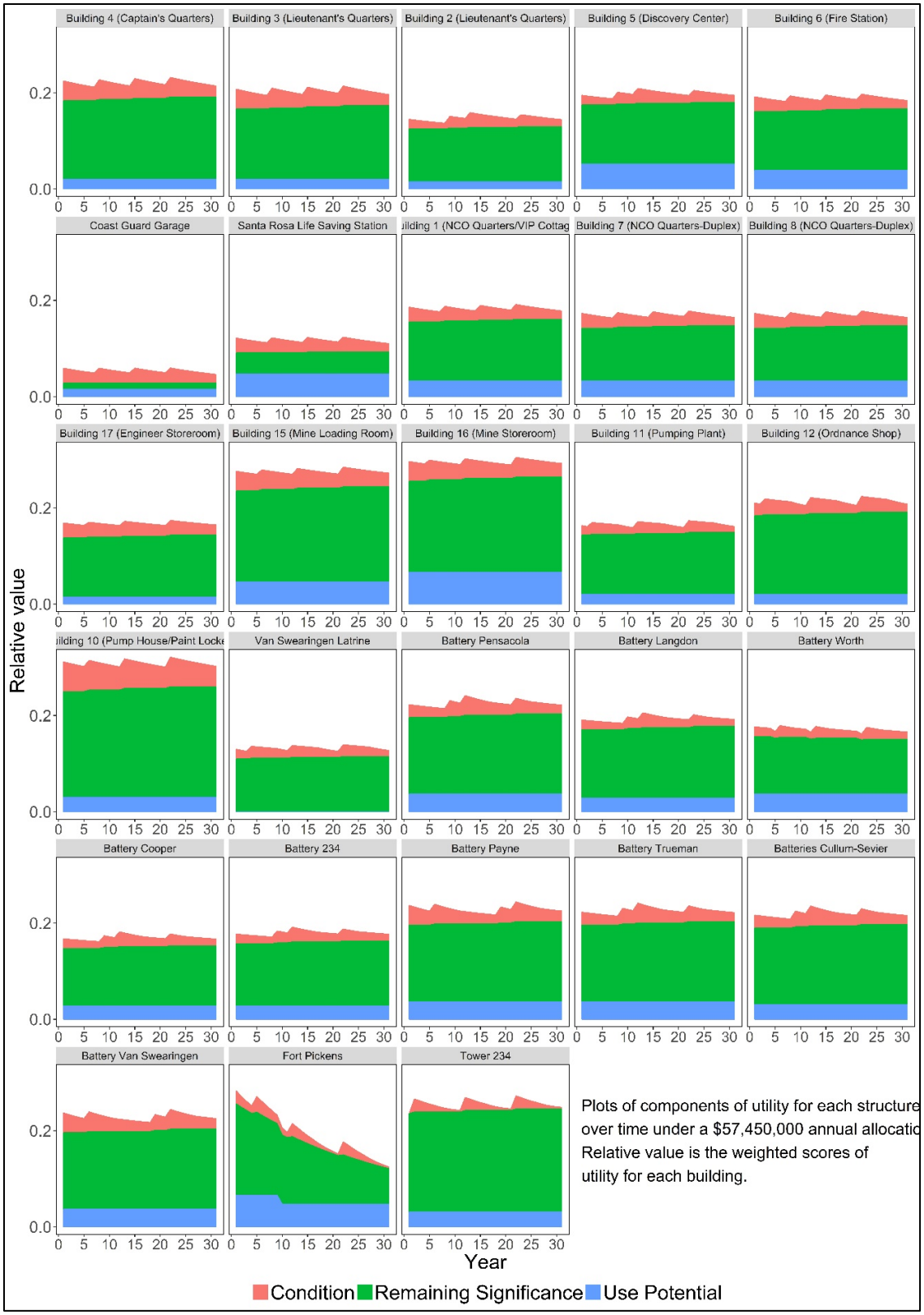


Figure 69. Components of resource value under annual allocation of $57,232,370 (Updated Model B).

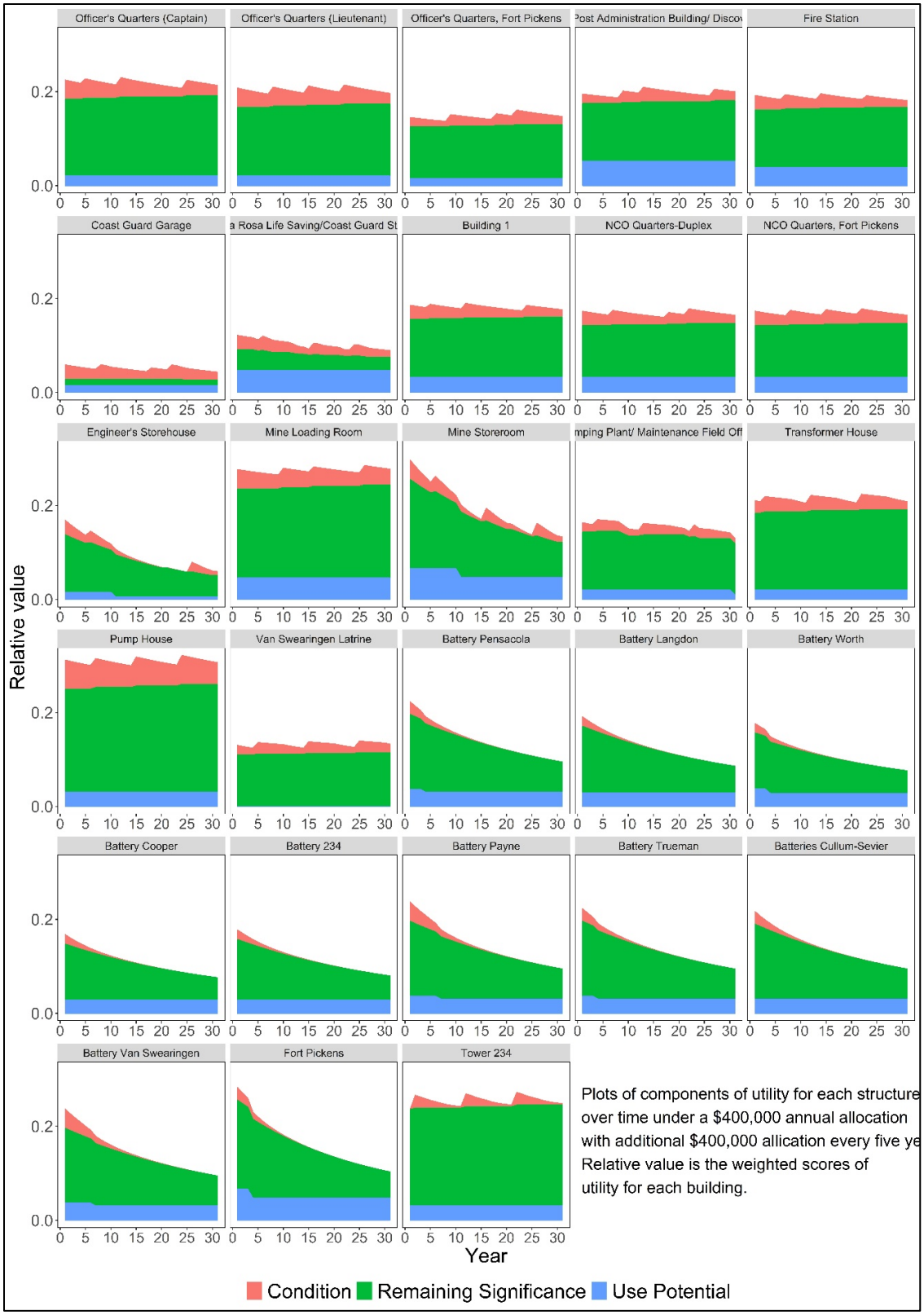


Figure 70. Components of resource value under annual allocation of $400,000 with an additional allocation of 400,000 every five years (Updated Model B).

Appendix 4. Percentage contribution of each structure to the accumulated resource value and total costs at the end of the 30-year planning horizon under each scenario

In this appendix, the percentage contributed to the accumulated resource value (Tables 7 – 9) and total cost (Tables 10 – 12) of each historic structure is presented for each scenario. We also present the beginning resource values and total accumulated value for each scenario (Tables 7 – 9). The original model results are presented in Tables 7 and 10. Model modification A (i.e., inclusion of use potential dynamics and fractional annual maintenance costs for Fort Pickens) results are presented in Tables 8 and 11. Model modification B (i.e., accounting for 10-year intervals of core & shell preservation and fractional annual maintenance costs for Fort Pickens) results are presented in Tables 9 and 12.

Table 7. Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Original Model.

Structure	Beginning Resource Values (174)	Original Model Annual Allocations (Total Accumulated Value)								
		$0 (96)	$50,000 (110)	$300,000 (132)	$400,000 (135)	$500,000 (138)	$750,000 (139)	$57,232,370 (163)	$400,000 + $400,000 every 5 years (137)	$57,232,370 + $400,000 every 5 years (163)
Fort Pickens	5%	5%	5%	4%	4%	4%	4%	5%	4%	5%
Battery Pensacola	4%	5%	4%	3%	3%	3%	3%	4%	3%	4%
Battery Cooper	3%	4%	3%	3%	3%	2%	2%	3%	2%	3%
Battery Worth	3%	4%	3%	3%	3%	2%	2%	3%	3%	3%
Battery Langdon	3%	4%	4%	3%	3%	3%	3%	3%	3%	3%
Battery 234	3%	4%	3%	3%	3%	3%	3%	3%	3%	3%
Battery 234 CRF/BCS Tower	4%	4%	3%	6%	6%	5%	5%	5%	6%	5%
Battery Payne	4%	5%	4%	3%	3%	3%	3%	4%	3%	4%
Battery Trueman	4%	5%	4%	3%	3%	3%	3%	4%	3%	4%
Batteries Cullum-Sevier	4%	5%	4%	3%	3%	3%	3%	4%	3%	4%
Battery Van Swearingen	4%	5%	4%	3%	3%	3%	3%	4%	3%	4%
Building 1 (NCO Quarters/VIP Cottage)	3%	3%	3%	4%	4%	4%	4%	3%	4%	3%
Building 2 (Officer's Quarters, Fort Pickens)	3%	2%	2%	3%	3%	3%	3%	3%	3%	3%
Building 3 (Lieutenant's Quarters)	4%	3%	3%	4%	4%	4%	4%	4%	4%	4%
Building 4 (Captain's Quarters)	4%	3%	5%	5%	5%	5%	5%	4%	5%	4%
Building 5 (Post Administration Building/ Discovery Center)	3%	3%	3%	4%	4%	4%	4%	3%	4%	3%
Building 6 (Fire Station)	3%	3%	5%	4%	4%	4%	4%	3%	4%	3%

Table 7 (continued). Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Original Model.

Structure	Beginning Resource Values (174)	Original Model Annual Allocations (Total Accumulated Value)								
		$0 (96)	$50,000 (110)	$300,000 (132)	$400,000 (135)	$500,000 (138)	$750,000 (139)	$57,232,370 (163)	$400,000 + $400,000 every 5 years (137)	$57,232,370 + $400,000 every 5 years (163)
Building 7 (NCO Quarters-Duplex)	3%	3%	3%	4%	4%	4%	4%	3%	4%	3%
Building 8 (NCO Quarters-Duplex)	3%	3%	3%	4%	4%	4%	4%	3%	4%	3%
Building 10 (Pump House/Paint Locker)	6%	5%	8%	7%	7%	7%	7%	6%	7%	6%
Building 11 (Pumping Plant/Maintenance Field Office)	3%	3%	2%	2%	3%	3%	3%	3%	3%	3%
Building 12 (Transformer House)	4%	3%	3%	4%	4%	4%	4%	4%	4%	4%
Building 15 (Mine Loading Room)	5%	5%	7%	6%	6%	6%	6%	5%	6%	5%
Building 16 (Mine Storeroom)	5%	5%	5%	4%	4%	4%	5%	5%	4%	5%
Building 17 (Engineer Storeroom)	3%	3%	2%	2%	2%	4%	4%	3%	2%	3%
Building 18 (Van Swearingen Latrine)	2%	2%	3%	3%	3%	3%	3%	2%	3%	2%
Building 32 (Santa Rosa Life Saving Station)	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Building 33 (Coast Guard Garage)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

Table 8. Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Modified Model A.

Structure	Beginning Resource Values (174)	Modified Model A Annual Allocations (Total Accumulated Value)						
		$0 (89)	$50,000 (105)	$300,000 (130)	$400,000 (133)	$500,000 (136)	$57,232,370 (163)	$400,000 + $400,000 every 5 years (135)
Fort Pickens	5%	5%	4%	4%	4%	3%	4%	3%
Battery Pensacola	4%	5%	4%	3%	3%	3%	4%	3%
Battery Cooper	3%	3%	3%	3%	3%	3%	4%	3%
Battery Worth	3%	4%	3%	2%	2%	2%	3%	2%
Battery Langdon	3%	4%	3%	2%	2%	2%	3%	2%
Battery 234	3%	4%	3%	3%	2%	2%	3%	2%
Battery 234 CRF/BCS Tower	4%	4%	3%	6%	6%	6%	5%	6%
Battery Payne	4%	5%	4%	3%	3%	3%	4%	3%
Battery Trueman	4%	5%	4%	3%	3%	3%	4%	3%
Batteries Cullum-Sevier	4%	5%	4%	3%	3%	3%	4%	3%
Battery Van Swearingen	4%	5%	4%	3%	3%	3%	4%	3%
Building 1 (NCO Quarters/VIP Cottage)	3%	3%	3%	4%	4%	4%	3%	4%
Building 2 (Officer's Quarters, Fort Pickens)	3%	2%	2%	3%	3%	3%	3%	3%
Building 3 (Lieutenant's Quarters)	4%	3%	3%	5%	4%	4%	4%	4%
Building 4 (Captain's Quarters)	4%	3%	6%	5%	5%	5%	4%	5%
Building 5 (Post Administration Building/ Discovery Center)	3%	3%	3%	4%	4%	4%	4%	4%
Building 6 (Fire Station)	3%	3%	5%	4%	4%	4%	3%	4%
Building 7 (NCO Quarters-Duplex)	3%	3%	3%	4%	4%	4%	3%	4%
Building 8 (NCO Quarters-Duplex)	3%	3%	3%	4%	4%	4%	3%	4%
Building 10 (Pump House/Paint Locker)	6%	5%	9%	7%	7%	7%	6%	7%

Table 8 (continued). Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Modified Model A.

Structure	Beginning Resource Values (174)	Modified Model A Annual Allocations (Total Accumulated Value)						
		$0 (89)	$50,000 (105)	$300,000 (130)	$400,000 (133)	$500,000 (136)	$57,232,370 (163)	$400,000 + $400,000 every 5 years (135)
Building 11 (Pumping Plant/Maintenance Field Office)	3%	3%	2%	2%	3%	4%	3%	4%
Building 12 (Transformer House)	4%	4%	3%	4%	5%	5%	4%	5%
Building 15 (Mine Loading Room)	5%	5%	7%	6%	6%	6%	5%	6%
Building 16 (Mine Storeroom)	5%	5%	5%	4%	4%	4%	5%	4%
Building 17 (Engineer Storeroom)	3%	3%	2%	2%	2%	3%	3%	2%
Building 18 (Van Swearingen Latrine)	2%	2%	4%	3%	3%	3%	2%	3%
Building 32 (Santa Rosa Life Saving Station)	2%	2%	1%	2%	2%	2%	2%	3%
Building 33 (Coast Guard Garage)	1%	1%	1%	1%	1%	1%	1%	1%

Table 9. Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Modified Model B.

Structure	Beginning Resource Values (174)	Modified Model B Annual Allocations (Total Accumulated Value)						
		$0 (96)	$50,000 (110)	$300,000 (136)	$400,000 (140)	$500,000 (143)	$57,232,370 (171)	$400,000 + $400,000 every 5 years (143)
Fort Pickens	5%	5%	5%	4%	4%	4%	4%	4%
Battery Pensacola	4%	5%	4%	3%	3%	3%	4%	3%
Battery Cooper	3%	4%	4%	3%	3%	3%	4%	3%
Battery Worth	3%	4%	3%	3%	2%	2%	3%	2%
Battery Langdon	3%	4%	3%	3%	2%	2%	3%	2%
Battery 234	3%	4%	3%	3%	3%	3%	3%	3%
Battery 234 CRF/BCS Tower	4%	4%	3%	6%	6%	6%	5%	6%
Battery Payne	4%	5%	4%	3%	3%	3%	4%	3%
Battery Trueman	4%	5%	4%	3%	3%	3%	4%	3%
Batteries Cullum-Sevier	4%	5%	4%	3%	3%	3%	4%	3%
Battery Van Swearingen	4%	5%	4%	3%	3%	3%	4%	3%
Building 1 (NCO Quarters/VIP Cottage)	3%	3%	3%	4%	4%	4%	3%	4%
Building 2 (Officer's Quarters, Fort Pickens)	3%	2%	2%	3%	3%	3%	3%	3%
Building 3 (Lieutenant's Quarters)	4%	3%	3%	5%	4%	4%	4%	4%
Building 4 (Captain's Quarters)	4%	3%	4%	5%	5%	5%	4%	5%
Building 5 (Post Administration Building/ Discovery Center)	3%	3%	3%	4%	4%	4%	4%	4%
Building 6 (Fire Station)	3%	3%	4%	4%	4%	4%	3%	4%
Building 7 (NCO Quarters-Duplex)	3%	3%	3%	4%	4%	4%	3%	4%
Building 8 (NCO Quarters-Duplex)	3%	3%	3%	4%	4%	4%	3%	4%
Building 10 (Pump House/Paint Locker)	6%	5%	9%	7%	7%	7%	6%	7%

Table 9 (continued). Percentage of accumulated resource value for each structure under varying annual allocations at the end of the 30-year planning horizon, with units of total accumulated value are included in parentheses below the budget scenario: Modified Model B.

Structure	Beginning Resource Values (174)	Modified Model B Annual Allocations (Total Accumulated Value)						
		$0 (96)	$50,000 (110)	$300,000 (136)	$400,000 (140)	$500,000 (143)	$57,232,370 (171)	$400,000 + $400,000 every 5 years (143)
Building 11 (Pumping Plant/Maintenance Field Office)	3%	3%	2%	2%	3%	3%	3%	3%
Building 12 (Transformer House)	4%	3%	3%	4%	5%	5%	4%	5%
Building 15 (Mine Loading Room)	5%	5%	7%	6%	6%	6%	5%	6%
Building 16 (Mine Storeroom)	5%	5%	5%	4%	4%	4%	5%	4%
Building 17 (Engineer Storeroom)	3%	3%	2%	2%	2%	3%	3%	2%
Building 18 (Van Swearingen Latrine)	2%	2%	4%	3%	3%	3%	2%	3%
Building 32 (Santa Rosa Life Saving Station)	2%	2%	2%	2%	2%	2%	2%	2%
Building 33 (Coast Guard Garage)	1%	1%	1%	1%	1%	1%	1%	1%

Table 10. Percentage of total cost contributions for each structure under varying annual allocations: Original Model.

Structure	Original Model Annual Allocations							
	$50,000	**$300,000**	**$400,000**	**$500,000**	**$750,000**	**$57,232,370**	**$400,000 + $400,000 every 5 years**	**$57,232,370 + $400,000 every 5 years**
Fort Pickens	0%	0%	0%	0%	0%	48%	0%	48%
Battery Pensacola	0%	0%	0%	0%	0%	9%	0%	9%
Battery Cooper	0%	0%	0%	0%	0%	2%	0%	2%
Battery Worth	0%	0%	0%	0%	0%	13%	0%	13%
Battery Langdon	0%	0%	0%	0%	0%	14%	0%	14%
Battery 234	0%	0%	0%	0%	0%	4%	0%	4%
Battery 234 CRF/BCS Tower	0%	15%	12%	9%	7%	0%	10%	0%
Battery Payne	0%	0%	0%	0%	0%	1%	0%	1%
Battery Trueman	0%	0%	0%	0%	0%	2%	0%	2%
Batteries Cullum-Sevier	0%	0%	0%	0%	0%	4%	0%	4%
Battery Van Swearingen	0%	0%	0%	0%	0%	1%	0%	1%
Building 1 (NCO Quarters/VIP Cottage)	3%	6%	5%	4%	3%	0%	4%	0%
Building 2 (Officer's Quarters, Fort Pickens)	0%	6%	5%	4%	3%	0%	4%	0%
Building 3 (Lieutenant's Quarters)	0%	6%	5%	4%	3%	0%	4%	0%
Building 4 (Captain's Quarters)	32%	7%	5%	4%	3%	0%	4%	0%
Building 5 (Post Administration Building/ Discovery Center)	0%	11%	9%	8%	5%	0%	8%	0%
Building 6 (Fire Station)	25%	4%	3%	3%	2%	0%	3%	0%
Building 7 (NCO Quarters-Duplex)	3%	5%	4%	3%	2%	0%	3%	0%
Building 8 (NCO Quarters-Duplex)	3%	5%	4%	3%	2%	0%	3%	0%
Building 10 (Pump House/Paint Locker)	8%	1%	1%	1%	1%	0%	1%	0%

Table 10 (continued). Percentage of total cost contributions for each structure under varying annual allocations: Original Model.

Structure	Original Model Annual Allocations							
	$50,000	**$300,000**	**$400,000**	**$500,000**	**$750,000**	**$57,232,370**	**$400,000 + $400,000 every 5 years**	**$57,232,370 + $400,000 every 5 years**
Building 11 (Pumping Plant/Maintenance Field Office)	0%	1%	16%	13%	10%	0%	16%	0%
Building 12 (Transformer House)	4%	11%	11%	9%	6%	0%	10%	0%
Building 15 (Mine Loading Room)	15%	4%	3%	2%	2%	0%	2%	0%
Building 16 (Mine Storeroom)	0%	2%	2%	2%	28%	0%	9%	0%
Building 17 (Engineer Storeroom)	0%	1%	1%	22%	16%	0%	4%	0%
Building 18 (Van Swearingen Latrine)	5%	1%	1%	1%	0%	0%	1%	0%
Building 32 (Santa Rosa Life Saving Station)	0%	11%	11%	8%	6%	0%	10%	0%
Building 33 (Coast Guard Garage)	2%	3%	3%	2%	2%	0%	2%	0%

Table 11. Percentage of total cost contributions for each structure under varying annual allocations: Modified Model A.

	Modified Model A Annual Allocation					
Structure	**$50,000**	**$300,000**	**$400,000**	**$500,000**	**$57,232,370**	**$400,000 + $400,000 every 5 years**
Fort Pickens	0%	0%	0%	0%	11%	0%
Battery Pensacola	0%	0%	0%	0%	15%	0%
Battery Cooper	0%	0%	0%	0%	26%	0%
Battery Worth	0%	0%	0%	0%	21%	0%
Battery Langdon	0%	0%	0%	0%	4%	0%
Battery 234	0%	0%	0%	0%	7%	0%
Battery 234 CRF/BCS Tower	0%	14%	11%	9%	0%	10%
Battery Payne	0%	0%	0%	0%	2%	0%
Battery Trueman	0%	0%	0%	0%	3%	0%
Batteries Cullum-Sevier	0%	0%	0%	0%	7%	0%
Battery Van Swearingen	0%	0%	0%	0%	2%	0%
Building 1 (NCO Quarters/VIP Cottage)	0%	6%	5%	4%	0%	4%
Building 2 (Officer's Quarters, Fort Pickens)	0%	6%	5%	4%	0%	4%
Building 3 (Lieutenant's Quarters)	0%	6%	5%	4%	0%	4%
Building 4 (Captain's Quarters)	34%	7%	5%	4%	0%	4%
Building 5 (Post Administration Building/ Discovery Center)	0%	12%	10%	8%	0%	8%
Building 6 (Fire Station)	25%	4%	3%	3%	0%	3%
Building 7 (NCO Quarters-Duplex)	3%	5%	4%	3%	0%	3%
Building 8 (NCO Quarters-Duplex)	3%	5%	4%	3%	0%	3%
Building 10 (Pump House/Paint Locker)	8%	1%	1%	1%	0%	1%
Building 11 (Pumping Plant/Maintenance Field Office)	0%	1%	15%	13%	0%	16%
Building 12 (Transformer House)	4%	11%	10%	9%	0%	9%
Building 15 (Mine Loading Room)	16%	4%	3%	2%	0%	2%

Table 11 (continued). Percentage of total cost contributions for each structure under varying annual allocations: Modified Model A.

	Modified Model A Annual Allocation					
Structure	**$50,000**	**$300,000**	**$400,000**	**$500,000**	**$57,232,370**	**$400,000 + $400,000 every 5 years**
Building 16 (Mine Storeroom)	0%	2%	4%	4%	1%	9%
Building 17 (Engineer Storeroom)	0%	1%	1%	18%	0%	4%
Building 18 (Van Swearingen Latrine)	5%	1%	1%	1%	0%	1%
Building 32 (Santa Rosa Life Saving Station)	0%	11%	12%	9%	0%	10%
Building 33 (Coast Guard Garage)	2%	3%	2%	2%	0%	2%

Table 12. Percentage of total cost contributions for each structure under varying annual allocations: Modified Model B.

	Modified Model B Annual Allocation					
Structure	**$50,000**	**$300,000**	**$400,000**	**$500,000**	**$57,232,370**	**$400,000 + $400,000 every 5 years**
Fort Pickens	0%	0%	0%	0%	16%	0%
Battery Pensacola	0%	0%	0%	0%	14%	0%
Battery Cooper	0%	0%	0%	0%	25%	0%
Battery Worth	0%	0%	0%	0%	19%	0%
Battery Langdon	0%	0%	0%	0%	4%	0%
Battery 234	0%	0%	0%	0%	7%	0%
Battery 234 CRF/BCS Tower	0%	0%	0%	0%	14%	0%
Battery Payne	0%	0%	0%	0%	2%	0%
Battery Trueman	0%	0%	0%	0%	3%	0%
Batteries Cullum-Sevier	0%	0%	0%	0%	6%	0%
Battery Van Swearingen	0%	0%	0%	0%	2%	0%
Building 1 (NCO Quarters/VIP Cottage)	3%	6%	5%	4%	0%	4%
Building 2 (Officer's Quarters, Fort Pickens)	0%	7%	5%	4%	0%	5%
Building 3 (Lieutenant's Quarters)	1%	7%	5%	4%	0%	5%
Building 4 (Captain's Quarters)	9%	7%	6%	4%	0%	5%
Building 5 (Post Administration Building/ Discovery Center)	0%	10%	10%	8%	0%	9%
Building 6 (Fire Station)	17%	5%	4%	3%	0%	3%
Building 7 (NCO Quarters-Duplex)	10%	4%	4%	3%	0%	3%
Building 8 (NCO Quarters-Duplex)	10%	5%	4%	3%	0%	3%
Building 10 (Pump House/Paint Locker)	9%	1%	1%	1%	0%	1%
Building 11 (Pumping Plant/Maintenance Field Office)	0%	3%	9%	13%	0%	14%
Building 12 (Transformer House)	3%	7%	11%	9%	0%	9%
Building 15 (Mine Loading Room)	13%	5%	5%	4%	0%	4%

Table 12 (continued). Percentage of total cost contributions for each structure under varying annual allocations: Modified Model B.

Structure	Modified Model B Annual Allocation					
	$50,000	**$300,000**	**$400,000**	**$500,000**	**$57,232,370**	**$400,000 + $400,000 every 5 years**
Building 16 (Mine Storeroom)	0%	7%	7%	9%	1%	9%
Building 17 (Engineer Storeroom)	0%	1%	3%	11%	0%	4%
Building 18 (Van Swearingen Latrine)	5%	1%	1%	1%	0%	1%
Building 32 (Santa Rosa Life Saving Station)	0%	6%	7%	7%	0%	8%
Building 33 (Coast Guard Garage)	10%	3%	2%	2%	0%	2%

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 635/177366, September 2021



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