Washington State Parks and Recreation Commission

Coastal Facilities Vulnerability Assessment: Implications for Sea Level Rise and Coastal Hazard Planning

WASHINGTON STATE PARKS

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Science + Planning + Design

Coastal Facilities Vulnerability Assessment

Washington State Parks and Recreation Commission

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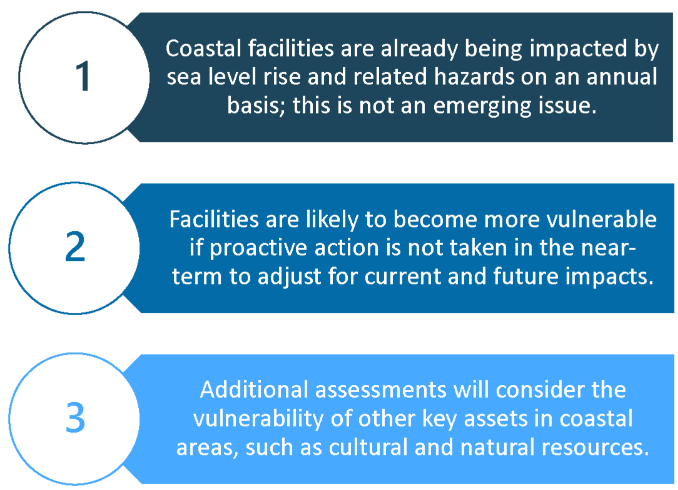
EXECUTIVE SUMMARY

The Washington State Parks and Recreation Commission (Parks) manages some of Washington's most iconic and appreciated coastal areas. These coastal areas include diverse landscapes and habitats, historic properties, and cultural heritage sites, as well as a complex range of facilities – buildings, infrastructure, and utilities – that are owned, managed, or extensively used by Parks.

The State Park system is already experiencing climate-related impacts that will increase in scale and magnitude in the future. While Parks has many vulnerable assets, including natural, cultural, and historic resources, this assessment focused on coastal facilities and their vulnerability to sea level rise and the related impacts of coastal flooding and erosion. The focus on coastal facilities and sea level rise stems from the immediacy of need: many of Parks' coastal facilities are either currently exposed to hazards, or likely will be in the coming decades. Recognizing this challenge, Parks conducted a field and geospatial-based vulnerability assessment that pinpoints which facilities are most vulnerable and what adaptation options may be considered to increase park resilience. The assessment also produced tailored coastal inundation and erosion geospatial data that can be used to inform Park's future hazard planning efforts. Key messages from the assessment are shown in Figure 1.

Figure 1. Key Messages from the Coastal Facility Vulnerability Assessment.



Across the state park system, there are 93 coastal state park properties, 74 of which have facilities in the shoreline zone. In addition, there are 25 ocean beach approaches (OBAs) that facilitate public access to the Pacific Ocean, At present, 53 buildings, 96 infrastructure pieces (notably shoreline armor), and 75 utility systems are exposed to inundation and/or erosion. In the coming decades, these numbers could more than triple. Some of the most vulnerable facilities are wastewater facilities including sewer lift stations, roofed accommodations, piers and docks, bathrooms, and shoreline armor. These facilities will require proactive planning to protect human health and safety, the health of surrounding ecosystems, and to reduce costly damage and disruptions to park operations.

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Increasing the resilience of park infrastructure to sea level rise will require a park-by-park approach given the complexity of facilities threatened by climate change impacts. Addressing vulnerable coastal facilities will require routine monitoring and investment to plan and adapt for future conditions. This assessment provides the initial screening to identify the most vulnerable facilities based on best available science. To support adaptation of facilities, policy and management changes will also be necessary, such as:

- Increase capacity for monitoring and responding to impacts from extreme tide and storm events.
- Restrict or stop new development in coastal hazard areas and consider options for retreat.
- Develop and prioritize long-term strategies for facility adaptation relocation, including phased facility relocation plans.

Parks can continue leading by example by adapting facilities and altering management and policy in ways that educate the public, promote stewardship, and increase resilience.

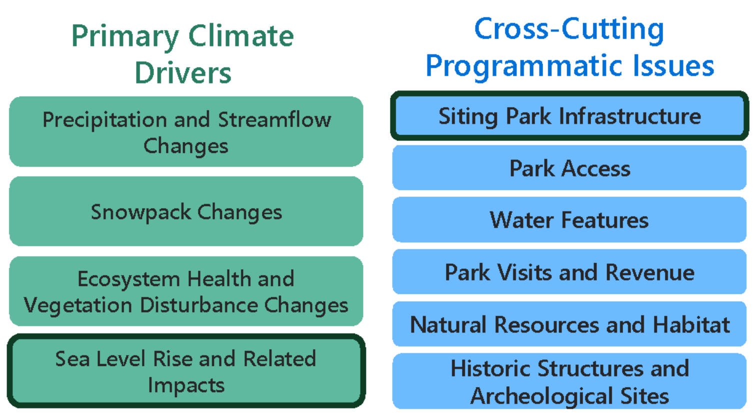
INTRODUCTION AND BACKGROUND

How Is Washington State Parks Preparing for Climate Change?

Motivated by concerns related to the challenges that climate change poses for the agency, the Washington State Parks and Recreation Commission (Parks) passed a resolution in November of 2015. The resolution stated that the impacts of climate change "will have an impact on the stewardship, operation, and placement of park resources and facilities" and that actions taken at all levels of the agency "shall be evaluated in the context of climate change."

In response, Parks contracted the University of Washington's Climate Impacts Group (CIG) to conduct a rapid climate change vulnerability assessment for Parks' operations and state-wide programs (CIG 2017). This effort was followed by development of a climate adaptation framework (CIG 2019) to consider identified climate vulnerabilities and concerns through a programmatic lens (Figure 2). This project with Herrera Environmental Consultants, Inc. (Herrera) focuses on sea level rise and related impacts as the primary climate driver and park facilities as the primary asset.

Figure 2. Climate Change Drivers and Cross-Cutting Programmatic Issues.

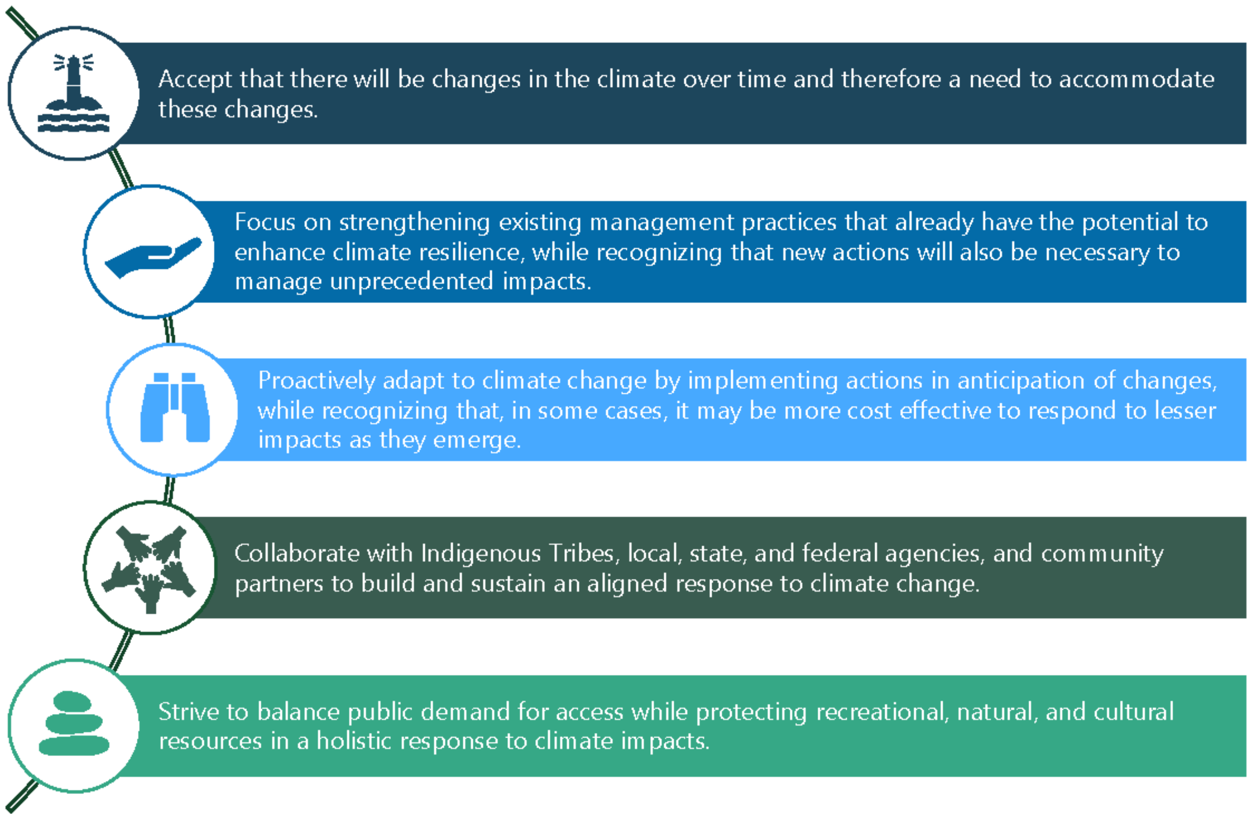


The Climate Change Vulnerability Assessment outlined four primary climate drivers that are expected to affect Parks and six cross-cutting programmatic issues and concerns that were common across climate change impacts, regions, and statewide programs.

What Principles Are Guiding Climate Change Adaptation?

Discussions related to the climate adaptation framework (CIG 2019) and two workshops conducted in October 2022 and January 2023 led to the development of five over-arching principles for Parks' approach to climate change adaptation (**Figure 3**).

Figure 3. Guiding Principles for Climate Adaptation.



Why Is this Assessment Focused on Coastal Facilities and Sea Level Rise and Related Impacts?

Many of the possible actions identified in the 2019 framework related to sea level rise and associated impacts on the siting and design of infrastructure. While Parks has many vulnerable assets, including natural, cultural, and historic resources, the need to focus initially on coastal infrastructure was apparent: many of the coastal facilities managed by Parks are either currently exposed to sea level rise and its related impacts, or likely to be exposed in the coming decades (**Figure 4**). Recognizing the challenge, Parks conducted this focused vulnerability assessment on sea level rise and related impacts on coastal facilities to develop planning-level tools and identify potential adaptation opportunities. Future work may focus developing an implementation strategy for sea level rise and related impacts and/or conduct additional analysis on different combinations of climate drivers (e.g., precipitation and streamflow, snowpack changes, ecosystem health and vegetation disturbance,) and assets (upland infrastructure, park access, water features, visits and revenue, natural resources, and historic and cultural resources). To have a holistic picture of park vulnerability, other assets will need to be considered.

Figure 4. Image of Coastal Facilities.

Washington State Parks have thousands of coastal facilities—buildings, infrastructure, and utilities—that support park users and park operations, like this parking area, pier, boat launch, and shoreline armor at Sequim Bay State Park.

What Goals Are Guiding Sea Level Rise and Coastal Hazard Planning?

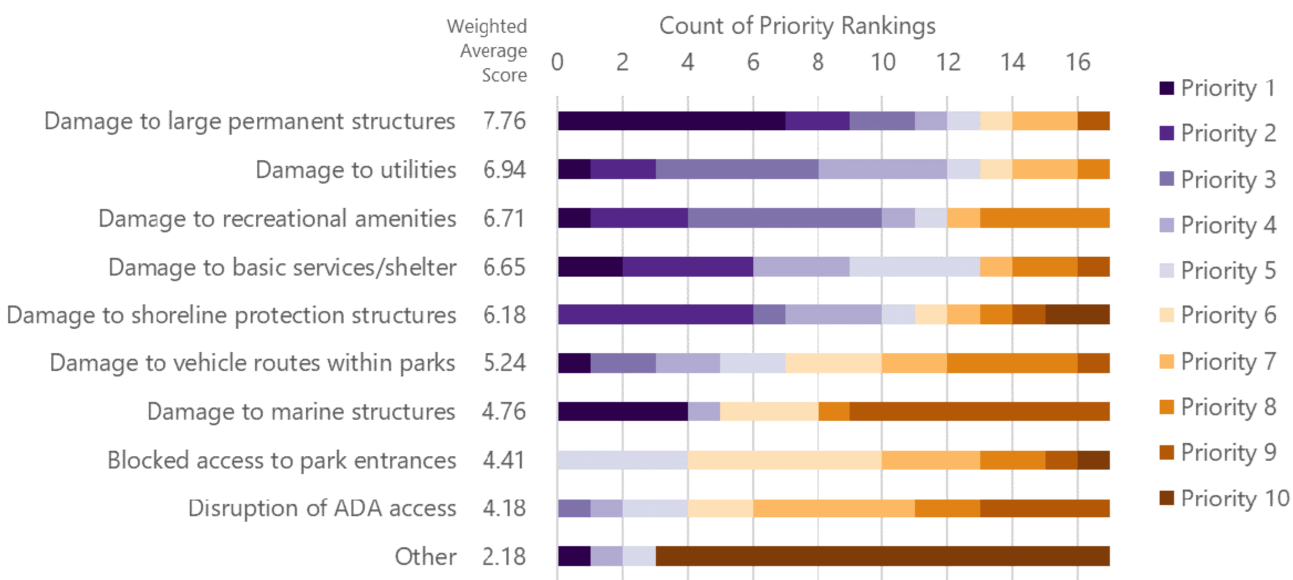
Additional goals specific to sea level rise and coastal hazard planning were drafted based on conversations with Parks staff and the October 2022 and January 2023 workshops. These goals are:

1. Incorporate best available science into adaptation planning and project scoping.
2. Integrate equity and social justice considerations into sea level rise adaptation decision making.
3. Invest in opportunities to model adaptation practices that demonstrate climate resilient design solutions and/or restoration benefits.
4. Increase public awareness and understanding of sea level rise impacts on park resources and services through visitor education and engagement.
5. Minimize or avoid disruption to core park facilities and services.
6. Incorporate design solutions that realize co-benefits of climate adaptation and mitigation, including reduction of greenhouse gas emissions.

What Sea Level Rise Related Impacts Are Parks Currently Experiencing?

Washington State Parks is already experiencing many coastal challenges related to flooding and erosion. These challenges will expand in scale and magnitude in the future with continued sea level rise. To first better understand the range of concerns that Parks staff had around shoreline infrastructure and sea level rise, the Herrera team administered a survey to Parks' staff and held two workshops (**Figure 5**).

Figure 5. Internal Survey Responses on Top Concerns Related to Impacts from Coastal Hazards.



Workshop participants identified damage to large permanent structures, utilities, and recreational amenities as their top concerns.

At the workshops, staff provided feedback on the initial approach and methods and discussed current impacts and challenges. Following the first workshop, Parks staff weighed in on priority parks to prioritize for field work. After receiving a prioritized list of parks for field assessment, a Herrera field team, consisting of an engineer and a geomorphologist or geographer, assessed each priority park. Field teams documented some of the current issues through conversations with Parks staff and during fieldwork in February and March 2023, soon after the historical tidal flood events of December 2022 and January 2023 (Figure 6 through Figure 13). Related issues observed in the field, such as erosion, compound flooding from rivers and tides, and flooding of low-lying areas, are more chronic.

Figure 6. Shoreline Armor.

***Shoreline armor**, like this at Cama Beach State Park, are protecting expensive investments but have been damaged by flooding and erosion and will eventually fail.*

Figure 7. Piers and Docks.

***Piers and docks**, like one in Bowman Bay at Deception Pass State Park, sit on bluff crests that are eroding and could compromise the structure.*

Figure 8. Day Use Areas and Campsites.

***Day use areas and campsites**, like this one at Fort Casey State Park, are actively being eroded from wave action and logs. Beach erosion reduces the available area for these facilities.*

Figure 9. Key Access Roads.

***Key access roads**, like this one in Birch Bay State Park, flood during high water events and must be closed. Regular flooding and waves exacerbate erosion, threatening the integrity of access infrastructure.*

Figure 10. Bathrooms.

***Bathrooms**, like this one at Potlatch State Park, regularly flood and are especially threatened during king tide flooding like here on December 27, 2022.*

Figure 11. Utilities.

***Utilities**, like this electrical hub at Cape Disappointment State Park, are exposed and at high risk of being damaged during high water events*

Figure 12. Campsites.

***Campsites**, like this one at Turn Island State Park, are covered in driftwood and woody debris during high water events and must be cleared before being usable again.*

Figure 13. Roads.

***Roads**, like this one in Dosewallips State Park, can be impacted by compound flooding from coastal and riverine sources.*

SEA LEVEL RISE PROJECTIONS AND SHORELINE RESPONSES

How Much Sea Level Rise Is Expected in the Coming Decades?

Sea level has been slowly rising over the past centuries, driven by global warming triggered by the burning of fossil fuels and land use practices, and is expected to increase in the coming decades. Greenhouse gas emissions trap heat in Earth's atmosphere. The ocean absorbs that heat and as it warms, it expands, taking up more space. This thermal expansion, in combination with melting of land-based ice (glaciers, ice caps, and ice sheets) cause sea level to rise. Past emissions have already "baked in" some amount of rise, which helps narrow expected rise by 2050. However, how much sea level rise to expect beyond 2050 depends on the degree to which current and future emissions will be curbed and contributions from large inputs, such as the West Antarctic and Greenland ice sheets.

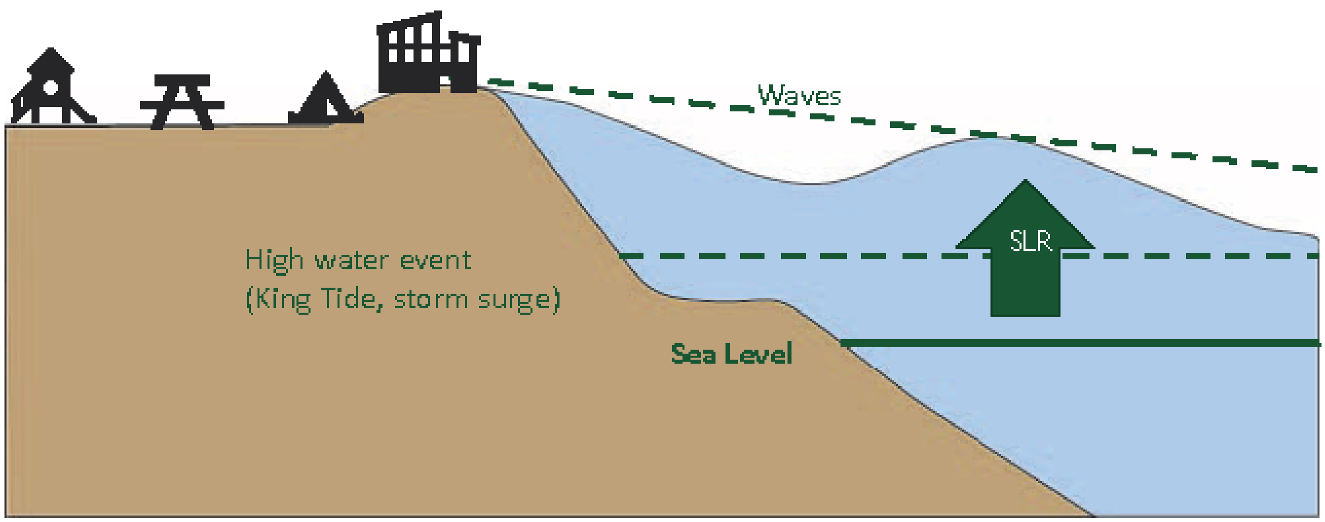
Across Washington state park properties, assuming a "business as usual" high greenhouse gas scenario, by 2050 sea level may rise between 0.3 to 1.3 feet for the Pacific Coast parks and 0.8 to 1.6 feet for the Puget Sound parks. Two different factors, likelihood and location, describe this range. Likelihood refers to the *probability of exceedance*, or the likelihood that by 2050 a certain amount of sea level rise will be met or exceeded. This analysis considers both the 50 percent and 1 percent likelihood scenarios. For example, there is a 50 percent likelihood by 2050 that the amount of sea level rise at Dash Point State Park in Puget Sound will meet or exceed 0.9 foot. However, there is a 1 percent likelihood by 2050 that sea level rise will meet or exceed 1.6 feet.


Dash Point State Park

Location is important because different geographies experience different amounts of *relative sea level rise*. Land slowly sinks and rises over time, in a process called vertical land motion, due to a range of geologic processes and human activities. In places where the land is sinking or subsiding, like in southern Puget Sound, this *relative sea level rise* is higher. Conversely, in places where land is rising, or where up-lift is occurring, like around the mouth of the Columbia River, relative sea level rise is lower. At Ocean City State Park on the Pacific Coast, projected sea level rise is lower than at Dash Point State Park for this reason. At Ocean City, there is a 50 percent likelihood that sea level rise will meet or exceed 0.4 foot by 2050 and a 1 percent likelihood that it will meet or exceed 1.1 feet. Beyond 2050, there is much greater uncertainty in how quickly sea level rise will accelerate because there is uncertainty in human behavior and emissions as well as physical processes like the melting of ice sheets.

Sea level rise exacerbates flooding by pushing up the baseline water level (**Figure 14**). With sea level rise, storm surge and waves can reach higher and high tides are pushed farther inland. All of this can lead to more frequent and damaging flooding and inundation. Sea level rise can also elevate groundwater tables and combine with riverine flooding to create compound flooding.

Figure 14. Sea Level Rise Makes High Water Events and Wave Heights Even Higher.



What Causes Erosion and How Does Sea Level Rise Exacerbate Erosion?

Erosion and deposition are natural processes. In coastal areas, erosion occurs when sediments and woody debris are moved from the coast by water, wind, ice, or gravity. Deposition is the opposite process and occurs when those materials are dropped in place and accumulated over time. Erosion and deposition can be caused by longshore currents, wave processes, storms, flooding, and human activities such as shoreline development and vegetation removal. Sea level rise can also cause and accelerate erosion as water will be pushed to higher elevations and further inshore thus enabling the water to erode more material.

Erosion and deposition are often tied together: material eroding from one beach feeds deposition in another beach (Figure 15). Similarly, erosion on the lower part of a beach can supply sediment to the upper part of the same beach, enabling the upper beach to build higher and shift landward. In additional to this cross-shore transport, many coastal areas are connected through littoral drift, which is the process of sediment moving parallel to the shoreline. Littoral drift occurs in sections of the shore called net shore-drift cells. These cells are distinct sections of shoreline in which sand and gravel naturally move in a dominant direction of sediment transport. The shores of Washington encompass over 900 net shore-drift cells.

Figure 15. Drift Cell with Camano Island and Cama Beach State Parks.

Sediment moves along the orange line from south to north. Bluffs at Camano Island feed the beach at Cama Beach.

Within Washington’s state park properties, there are three primary types of erosion described in the images below: bluff and bank erosion, shoreline translation, and beach and foreshore narrowing. All three are visible at Camano Island and Cama Beach State Parks (Figure 16 through Figure 19).

Figure 16. Bluff and Bank Erosion.

Eroding banks at Camano Island State Park supply sediment that is transported by longshore currents north to Cama Beach State Park.

Figure 17. Beach and Foreshore Narrowing.

Shoreline armor at Cama Beach State Park is trying to protect the cabins by preventing bank erosion. As longshore currents try to move beach sediment northwards, the beach and foreshore narrow.

Figure 18. Shoreline Translation, Armored.

The northern part of Cama Beach State Parks receives the sediments and logs transported in the drift cell. The beach would move landward by building upwards but is impeded by armor.

Figure 19. Shoreline Translation, No Armor.

The southern shore of Camano Island State Park receives the sediments and logs from another drift cell. The beach is building upwards and moving landward.

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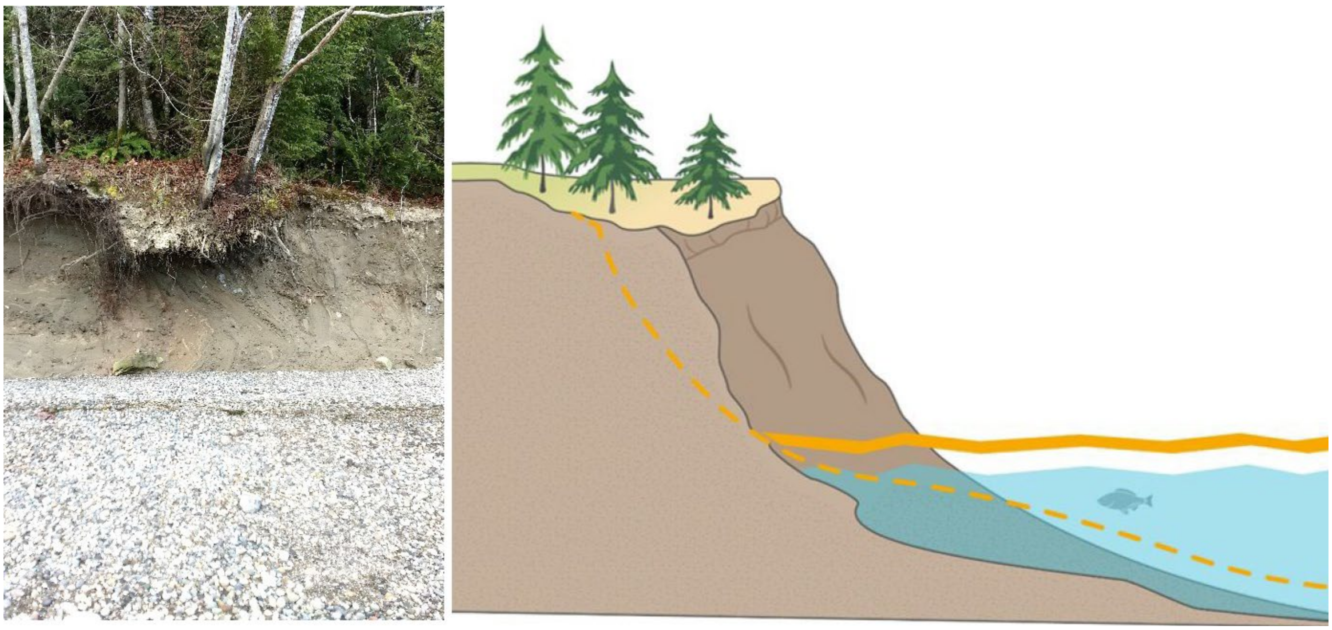
How Do Shorelines Respond to Sea Level Rise?

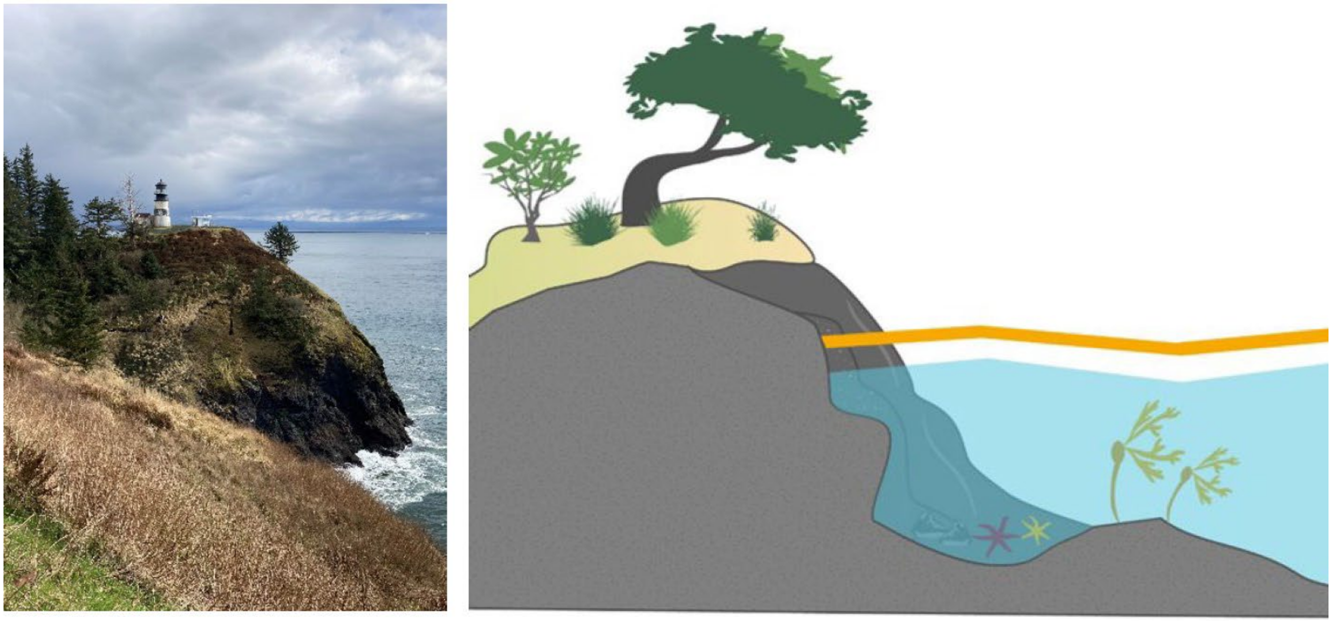
Washington's state park properties contain a diverse array of coastal landforms, also known as shoretypes. These large landscape features include familiar coastal environments such as coastal bluffs, rocky beaches, pocket beaches, and barrier beaches or spits. Within a single park there are often multiple shoretypes. Although each shore varies in its upland topography, geology, and site constraints, most shoretypes respond similarly to sea level rise (Figure 20 through Figure 23).

Figure 20. Coastal Bluffs.



Bluff erosion is a natural process. However, erosion rates are linked with water level. As the sea level rises, bluffs like this one at Penrose Point State Park may see accelerated erosion. As the bluff erodes, the entire bluff and beach profile shift landward. The sediment from bluff erosion supplies downdrift beaches, helping them to adjust to rising water levels.

Figure 21. Rocky Shorelines.



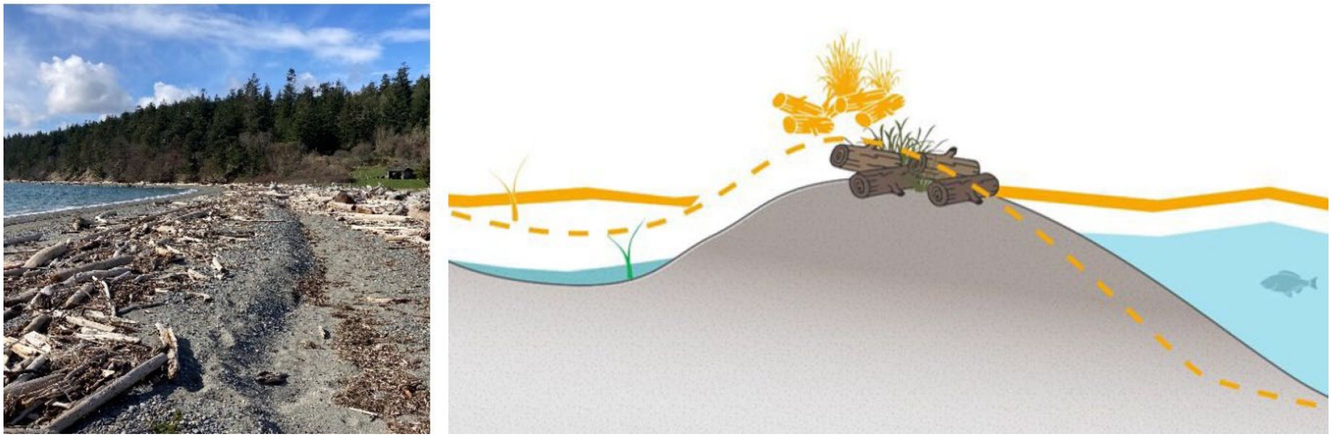
Shorelines that are rocky, like this one at Cape Disappointment State Park, are already more resistant to erosion than coastal bluffs. As sea level rises, tidal height, water levels, and intertidal habitats will also rise upwards and landwards.

Figure 22. Armored Beaches.

Armored beaches are those with rigid, permanent materials or structures used to stabilize the shore and prevent erosion, like this one at Illahee State Park. Static shoreline armor prevents the beach from building up and migrating landward. Higher water levels can also overtop and compromise armor.

Maintaining armor with rising sea levels will ultimately result in the loss of beach area and intertidal habitat. The cost of protecting upland infrastructure with shoreline armor will be degraded habitats and loss of beach recreational areas.

Figure 23. Barrier Beaches.



Barrier beaches characteristically have a linear ridge of sand or gravel extending above the high tide line. These beaches, like this one at Spencer Spit State Park, are built by wave action and sediment deposition seaward of the original coastline. With sea level rise, the crest of the berm will build higher, and the beaches will shift landward. Coastal squeeze can occur if there is no space for the beach to migrate landward.

COASTAL FACILITIES VULNERABILITY ASSESSMENT

What Is a Vulnerability Assessment?

Climate vulnerability assessments (VAs) are tools to identify and rank assets that may be vulnerable to changing climate conditions and support planning and projects to reduce those vulnerabilities. This VA focused specifically on the asset of coastal facilities in Washington's state park properties and their vulnerability to sea level rise and related impacts of coastal flooding and erosion. Future climate VAs by Parks may focus on other assets (e.g., natural resources, cultural resources, park access, inland facilities) and other climate impacts (e.g., changes in precipitation and streamflow, changes in snowpack, changes in ecosystem health and vegetation disturbance).

Vulnerability is typically measured as a function of an asset's exposure, sensitivity, and adaptive capacity (Table 1). Therefore, the most vulnerable assets are those that are the most exposed, the most sensitive, and the least able to adapt (U.S. Climate Resilience Toolkit 2023). When considering the built environment, exposure and sensitivity are the most appropriate to consider. Adaptive capacity is more resource specific. For example, assets in the built environment cannot inherently adapt to climate change or hazards whereas natural resources often can. Accordingly, and consistent with the approach used for coastal facilities by other researchers in Puget Sound (Miller et al. 2023) and the National Park Service (Peek et al. 2017), this VA has been focused to only consider exposure and sensitivity in the creation of vulnerability scores. Adaptive capacity of coastal facilities is still important and is considered in the menu of adaptation options to support future planning and project scoping efforts.

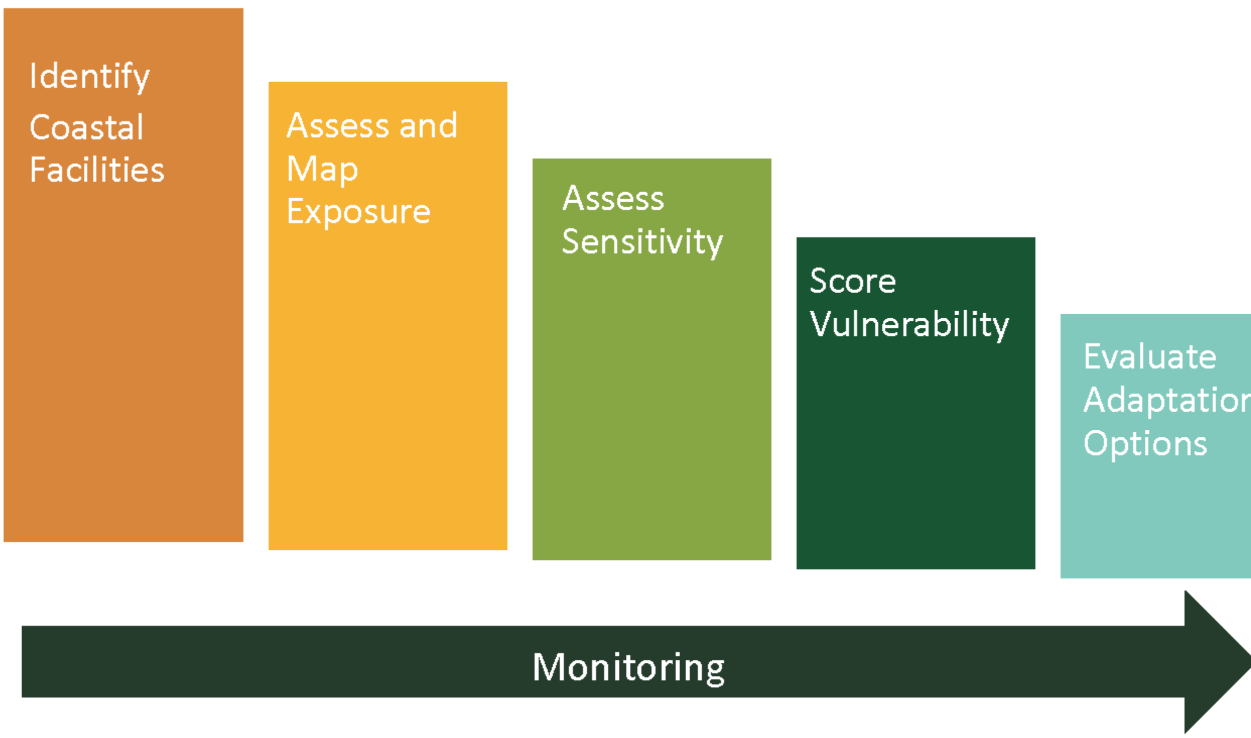
Table 1. Definitions Used in the Coastal Facilities Vulnerability Assessment.

Name	Source
Coastal state park property	A state park property, or property managed by Parks, with existing or potential public access to saltwater and related recreation amenities (i.e. Puget Sound, Strait of Juan de Fuca, Salish Sea, or Pacific Coast). Access can be land- or tideland-based.
State park with coastal facilities	A coastal state park property (described above) with facilities - buildings, infrastructure, or utilities that are owned, managed, or extensively used by Parks. Facilities range from pedestrian trails to toilets to piers and dock access.
Ocean Beach Approach (OBA)	A property that provides public access to the Seashore Conservation Area (ocean beach) that is typically co-managed with local jurisdictions.
Exposure	The degree to which a coastal facility is exposed to coastal hazards, and the nature of the coastal hazards.
Sensitivity	The degree to which a coastal facility may be negatively affected when exposed to coastal hazards.
Vulnerability	Openness or susceptibility to harm; a function of both exposure to coastal hazards and sensitivity if exposed. *Vulnerability = Exposure + Sensitivity*

How Was Vulnerability Assessed?

Identifying the most vulnerable coastal facilities followed the five steps pictured in the graphic below and is described in the following sections (Figure 24). It is important to note that this vulnerability assessment is a snapshot in time of what coastal facilities are currently most vulnerable and anticipated to be most vulnerable in the future under projected flooding/inundation and coastal erosion scenarios. This assessment will need to be updated if there are significant changes to climate projections and as monitoring identifies additional facilities that are exposed to coastal hazards. This approach does provide some measures of relative hazard exposure and vulnerability, that will maintain value as climate science progresses over the coming decades.

Figure 24. Steps in the Vulnerability Assessment Process.



Monitoring underpins the entire process as it helps determine exposure, vulnerability, adaptation opportunities, and timelines.

This assessment is focused only on coastal facilities, and not the many other assets of recognized importance to Parks, including natural, cultural, and historic resources and park access that are also vulnerable to sea level rise. Understanding the vulnerability of a park will require a holistic approach. For example, a parking lot may not be particularly sensitive to coastal flooding, however the cultural resources located beneath the parking lot could be very sensitive. Likewise, a park may not have any significant coastal facilities that are threatened, but accessing the park will be made difficult by sea level rise. As additional assets beyond coastal facilities are assessed, the park-scale geospatial tools developed for this assessment can also be used for measuring exposure of the assets. Assessing sensitivity will require a different approach than that used in this assessment.

The vulnerability assessment consists of a quantitative, Geographic Information System (GIS) based, data-driven framework that uses the best available existing data to evaluate and communicate the vulnerability of Parks' coastal facilities to sea level rise and coastal hazards such as flooding and erosion. Through standardizing the data and methodology used in this assessment, managers can compare the vulnerability of coastal facilities within individual parks as well as across park, area, region, and statewide levels. Geospatial hazard polygons created to show various likelihoods and time periods for coastal inundation and erosion can also be used by Parks in future park planning and project analysis. All data and results about coastal facilities, sea level rise, inundation, and erosion are stored in geodatabases maintained by Washington State Parks. More detailed information on the vulnerability assessment methodology is included in Appendix A.

Identifying Coastal Facilities

Knowing what facilities within Washington's state park properties are most vulnerable to sea level rise and related impacts requires first knowing what facilities exist within the coastal zone. Identifying coastal facilities was done through a combination of geospatial analysis and fieldwork.

Enhancing and Sorting Facility Geodatabase

All existing geospatial data on mapped coastal facilities were compiled into a single database. Additional data sources were added including building footprints and CAD basemaps, where available. All facilities were then split by function into eight categories and 25 subcategories to support future analysis (Table 2).

Table 2. Facility Subcategories and Definitions.

Name	Source
Administrative	Used for park administration. Includes administrative buildings and storage (both hazardous and non-hazardous).
Circulation	Facilitates the movement of people, vehicles, and equipment through a park. Includes bridges, emergency evacuation routes, parking, roads, and trails.
Day Use	Supports recreational and day use activities. Includes day use structures with and without utilities.
Marine	Supports the use of and access to saltwater bodies. Includes land-based (e.g., boat ramps) and over-water (e.g., piers) infrastructure.
Sanitation	Toilet and shower facilities for park users. Includes facilities with and without utilities.
Shoreline	Protects park shorelines. Includes hard shore protection (e.g., sea wall, rip rap).
Overnight Accommodations	Locations where park visitors spend the night. Includes camping (with and without utilities) and roofed accommodations.
Utilities	Utilities not located within the footprint of a building. Includes communications, electric, emergency, gas, sewage/wastewater, stormwater, and water.

Augmenting Spatial Data with Field Visits

Field teams visited 52 of the 93 coastal state park properties, as well as all 25 OBAs, to capture any unmapped facilities and gather missing information about existing facilities such as current or historical exposure to coastal hazards, damage, presence of utilities, presence of subsurface facilities (such as septic drain fields, culverts, and tide gates), and elevation data (Figure 25). In addition to assessing facilities, field visits were used to verify and ground truth hazard data. Parks were prioritized for fieldwork by Parks staff based on known coastal facilities and overwater infrastructure as well as ongoing facility and resource management issues, pending investments in coastal facilities, and/or cultural resource monitoring needs. All priority parks were evaluated during fieldwork as well as any additional parks that were possible to visit with extra time on field visits.

Creating Final Facilities Geodatabase

Following field-based data collection, all facilities data were reviewed and merged into a single, unified database. This new database consisted of new features that were mapped in the field but had been absent from Parks-sourced spatial data, as well as features present in the Parks-sourced data but that were updated with supplemental attributes and, in many cases, improved spatial footprints. This geodatabase is the basis for the vulnerability analysis. Metadata and a simple user guide for the geodatabase are included in Appendix C.

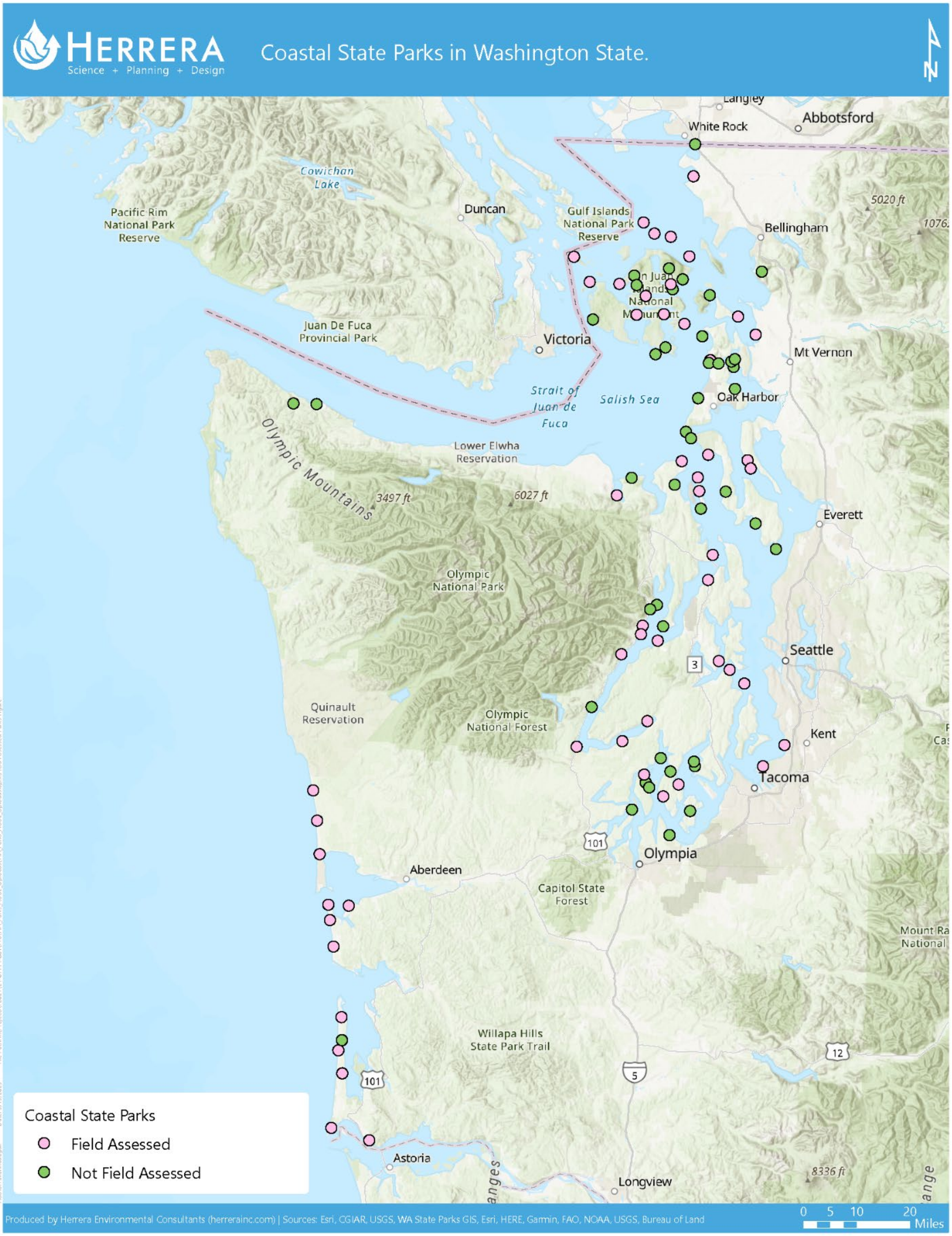
Assessing Exposure

Coastal facilities in Washington's state park properties are exposed to natural coastal processes including coastal flooding and erosion. Sea level rise is increasing the magnitude and frequency of impacts from these natural processes and will continue to do so into the future. This vulnerability assessment focuses specifically on the hazards of coastal flooding and erosion. Exposure is the degree to which a facility is exposed to coastal hazards, and the nature of those hazards. The first phase of the vulnerability assessment used a quantitative approach to assess which "assets," or coastal facilities, are exposed to coastal flooding and erosion, exacerbated by sea level rise. This exposure analysis used geospatial (GIS) data because exposure is directly dependent on location relative to a mapped hazard.

Coastal inundation occurs when water levels are elevated above the normal tidal range. High tides, storm surge, wave runup, and sea level rise allow water to move further inland. Other sources of flooding, including riverine, groundwater, and flash flooding, can also combine with coastal flooding to create compound flooding.

Figure 25. Coastal State Parks in Washington State.

Locations of Washington coastal state park properties assessed with a field visit. The 25 Ocean Beach Approaches located on the Pacific Coast are not shown.



Compiling and Creating Datasets For Coastal Hazards

Coastal hazards evaluated in this assessment included inundation and coastal erosion (Figure 26 and Figure 27). Inundation mapping incorporated flooding from relative sea level rise, storm surge, wave runup, and compound flooding. Coastal erosion was also assessed. Hazard data was downscaled to the level of each park. Different data sources and methods were used to develop hazard polygons for parks located within Puget Sound than those located on the Pacific Coast because of differences in both data availability and physical processes: the wave climate within Puget Sound is significantly different from the Pacific Coast and thus considered differently. While the source data for the two regions were different, the same likelihood scenarios (50 percent and 1 percent) and recurrence intervals (20-year) were used. Recurrence intervals are the average number of years between events of a certain size. For detailed explanations of data sources, see Appendix A.

Inundation exposure for both Pacific Coast and Puget Sound parks were only analyzed to the 2050 timeframe for three reasons: 1) feedback from Parks staff to focus on the near-term, 2) the desire to have consistent time frame to compare across the Puget Sound and Pacific Coast geographic areas as well as across inundation and erosion hazards, and 3) the recognition that any hazard assessment beyond 2050 will need to be updated in the next decade. Beyond 2050, there is greater uncertainty in sea level rise projections because of uncertainty in how much current and future greenhouse gas emissions will change, thus changing which greenhouse gas concentration trajectory and which sea level rise scenario. There is also significant uncertainty in physical climatic processes post 2050 and coastal erosion rates depend on sea level rise projections.

Figure 26. Inundation Scenarios Considered in the Vulnerability Analysis.

Inundation Scenarios

50% likelihood by 2050	Sea level rise about MHHW (RCP 8.5) + 20-year high water event
50% likelihood by 2050, with waves.	Sea level rise about MHHW (RCP 8.5) + 20-year high water event + waves
1% likelihood by 2050	Sea level rise about MHHW (RCP 8.5) + 20-year high water event
1% likelihood by 2050, with waves	Sea level rise about MHHW (RCP 8.5) + 20-year high water event +waves
Compound flooding	FEMA 100-year base flood elevation (coastal, riverine, and surface)

Figure 27. Erosion Scenarios Considered in the Vulnerability Analysis.

Erosion Scenarios

High confidence bluff erosion	Puget Sound minimum long-term bluff recession rate
Intermediate confidence bluff erosion	Puget Sound median long-term bluff recession rate Pacific Coast shoreline change rate
Low confidence bluff erosion	Puget Sound maximum long-term bluff recession rate

Scoring Coastal Facility Exposure to Coastal Hazards

Assessing the exposure of coastal facilities to coastal hazards considers both the magnitude of the hazard as well as the likelihood of experiencing that hazard. The coastal facilities geodatabase was overlain with the coastal hazard polygons in GIS to identify facilities vulnerable to inundation and/or erosion. Coastal facilities intersecting one or more of the hazard polygons, or within a calculated distance from a polygon (e.g., wave height in Puget Sound), were identified as exposed and further assessed for sensitivity and adaptation strategies. Each facility was given a score based on the likelihood and severity of exposure between 2023 and 2050. For example, a bathroom that chronically floods every winter received a higher exposure score than a bathroom located within the 1 percent likelihood by 2050 scenario.

Despite only including inundation and erosion estimates projected to 2050, exposure scores provide information beyond this timeframe. The actual year is not as relevant as the relative increases in water level and erosion rates that the different scenario scores represent. For example, reaching the 1 percent likelihood by 2050 scenario in 2050 has a low likelihood. However, after 2050, the likelihood of reaching that scenario increases. In the meantime, the water level represented by that scenario may be exceeded temporarily by high tide flooding and waves.

When considering future sea level rise, the question generally is not *if* the water level will be exceeded, but *when*.

In addition, all facilities are attributed with elevation data and elevations relative to local MHHW, which can inform their relative hazard exposure. Facilities that are located on higher ground are less likely to be inundated by a given year than those located on lower ground. Similarly, along bluffs, the proximity of the facilities to the bluff crest is noted in the feature attribute tables. Facilities located close to the bluff crest are more likely to be subject to erosion than those located further from the crest (regardless of the confidence level of the bluff hazard polygon that encompasses the structure).

Assessing Sensitivity

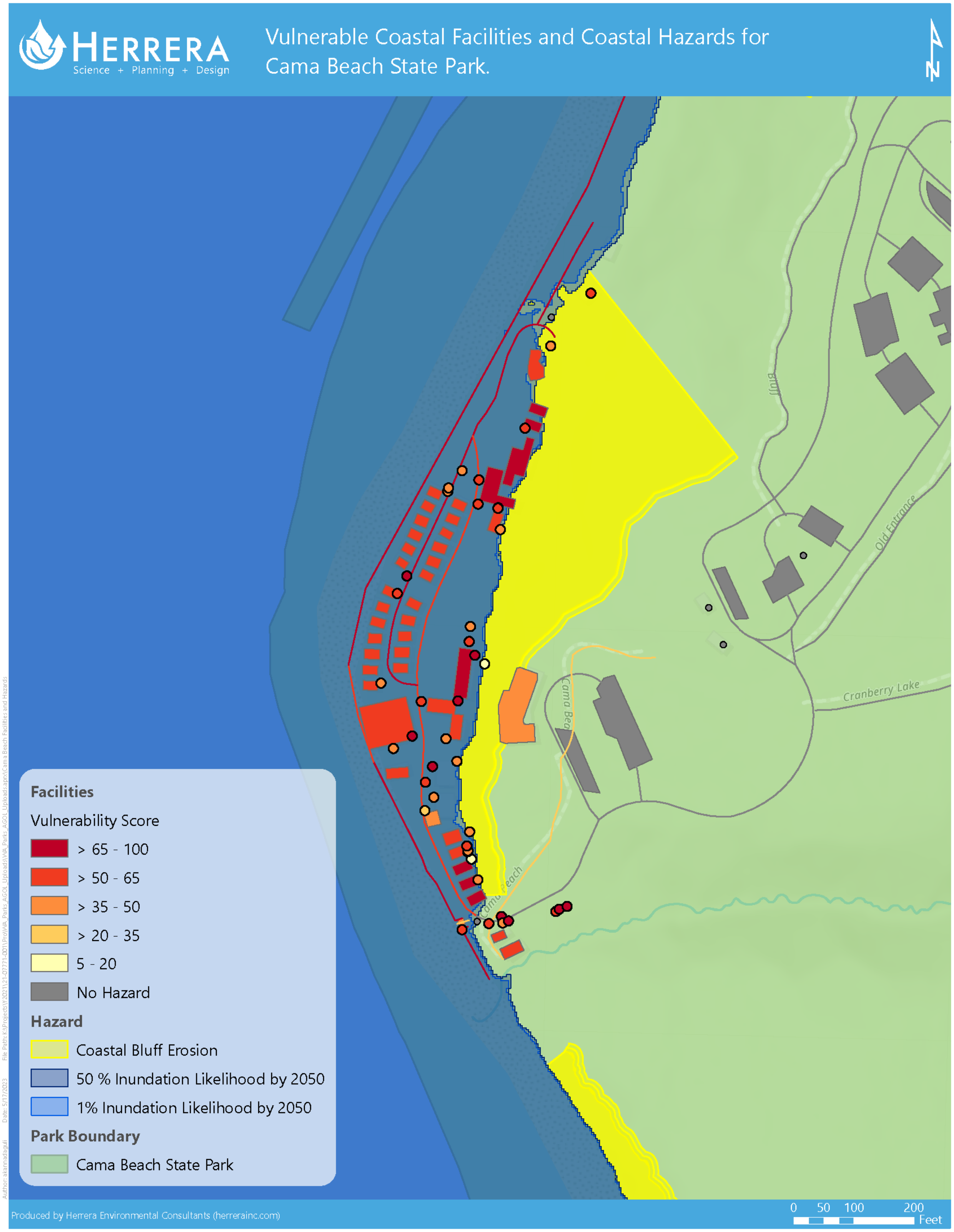
Sensitivity, the second component of vulnerability, is associated with the nature of the impacts resulting from when a coastal facility is exposed to coastal hazards. Sensitivity is tied to the inherent properties of an asset and is independent of location. Facilities with no exposure were excluded from the sensitivity analysis because an asset must be exposed to coastal hazards to be sensitive to it. Three potential impacts were considered: impact to human health and safety, impact to environment, and impact to operations. In other words, how much risk are we willing to accept with this facility? The coastal facility sensitivity index ranked the relative potential impacts of flooding and erosion. A facility was considered more sensitive if, when exposed, the function of the facility would be impaired (i.e., weakened, compromised, or damaged) by the impacts of erosion or flooding. Likewise, a facility was considered more sensitive if human health and safety or the environment would be impaired by the impacts of flooding and erosion. For example, a parking lot may be able to be temporarily flooded during an extreme high-water event without sustaining damage and without posing a significant threat to human health and the environment. However, a sewer lift station would be much more sensitive to flooding because it would potentially impact human health and ecological function.

Scoring Vulnerability and Prioritizing the Most Vulnerable Facilities and Parks

The combination of exposure and sensitivity is **vulnerability.** The most vulnerable facilities across all parks were assessed by both total vulnerability score (5 to 100). State park properties were selected for field visits based on an initial assessment of potential vulnerability and the scale and uses of infrastructure. It is important to note that park properties visited in the field likely have more facilities with vulnerability scores than those not visited in the field. This is because field visits allowed more facilities to be surveyed and added to the geodatabase. Vulnerability scores are just for physical infrastructure, and do not take into consideration additional agency filters such as visitation, facility condition, or uniqueness. They also do not consider the proximity of other assets that may have different vulnerability scores, such as cultural and natural resources. Additional analysis and overlaying of results will need to be conducted to consider multiple asset types within a park. An example of vulnerability scores is shown for Cama Beach (Figure 28).

Figure 28. Vulnerable Coastal Facilities and Coastal Hazards for Cama Beach State Park.

See map legend for scoring of facility vulnerability (associated color of dots, lines, and polygons) based on inundations and/or erosion assessment.



What Adaptation Options Are Available?

As sea level rise continues to exacerbate coastal hazards like flooding and erosion, adaptation options are needed to help avoid and minimize impacts for vulnerable infrastructure. A framework for identifying initial adaptation options and ideas for coastal infrastructure was identified in previous efforts (CIG 2019). This work advances those concepts by identifying appropriate uses, timeframes, and potential sequencing, based on both hazard type and facility type (Figure 29). All potential options have tradeoffs. Each coastal facility identified as exposed in the vulnerability assessment has potential adaptation options assigned to it that are viewable in the geodatabase. Monitoring underpins actions and can help identify triggers or tipping points. A menu of potential adaptation options fall under four broad **strategies** and eight potential *adaptation options*, defined as follows:

*A note on **shoreline armor**: maintaining shoreline armor with rising sea levels will ultimately result in the loss of beach area and intertidal habitat. The cost of protecting upland infrastructure with shoreline armor will be degraded habitats and loss of beach recreational areas.*

1. No Action. With this approach, no physical action is taken, and monitoring is the primary focus. This is only a short-term strategy. For facilities identified as vulnerable, it is a question of "when" not "if" they will be impacted by flooding and/or erosion. Adaptation option: *No Action*.
2. Make Space. Also known as retreat, move, or avoid, this approach manages impacts from flooding and erosion by avoiding exposure entirely. In the long-term, making space for the ocean is the only guaranteed approach and may ultimately be the most cost-effective. Adaptation options: *Remove, Relocate*.
3. Adapt in Place. Also known as accommodate or host, this approach encompasses a range of potential options designed to decrease the impacts of flooding and erosion. This approach largely works by reducing a facility's sensitivity to coastal hazards through engineering, design, and restoration. Adaptation options: *Restore, Redesign, Replace*.
4. Delay. Also known as resist, this approach encompasses both hard and soft shore protection or armoring and works to reduce exposure in the short-term by trying to prevent erosion and keep water out. Adaptation options: *Protect, Mitigate*.

Figure 29. Menu of Potential Adaptation Options for Vulnerable Coastal Facilities.

This graphic outlines four broad strategies and eight adaptation options that may be viable for coastal facilities in state park properties. Adaptation options are suited to specific hazards and timeframes and address vulnerability differently. Parks is already implementing a version of all of these adaptation options.

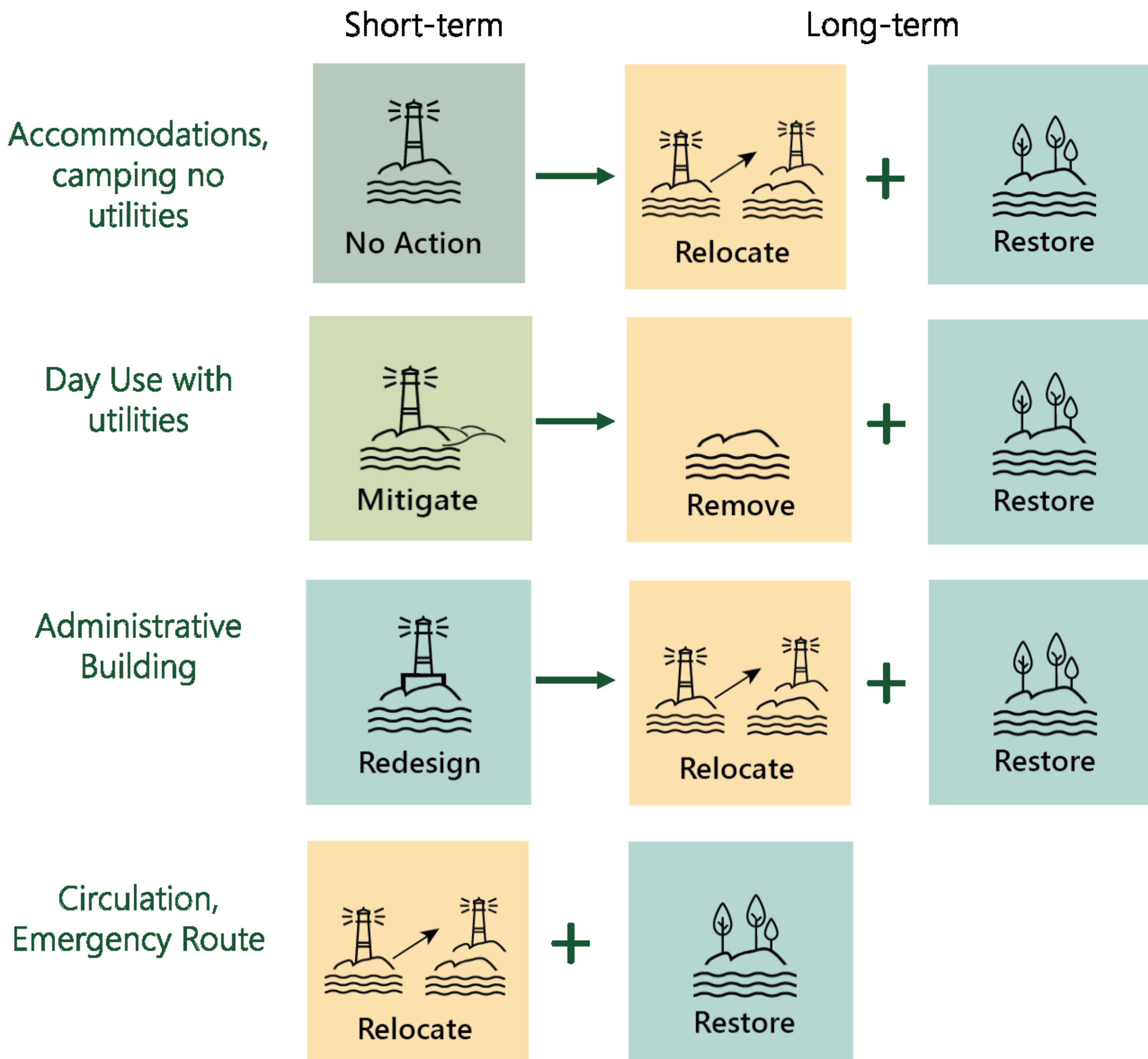
Approach	No Action	Make Space (Retreat)		Adapt in Place (Accommodate)			Delay (Resist)	
Action	No Action	Remove	Relocate	Restore	Redesign	Replace	Protect	Mitigate
Action description	Leave infrastructure as is.	Remove and do not replace infrastructure.	Relocate infrastructure to area outside of coastal hazard areas.	Restore shoreline areas and allow them to migrate and move naturally.	Redesign infrastructure to accommodate higher water levels by elevating or introducing storm-resistant design.	Replace services in high-use areas where facilities were relocated/ removed with facilities that are temporary/ moveable/ adaptable.	Protect infrastructure with hard or soft shore protection structures.	Mitigate for erosion in the short-term with beach nourishment.
Hazard	Inundation and erosion	Inundation and erosion	Inundation and erosion	Inundation and erosion	Inundation	Inundation	Erosion	Erosion
Effect on Vulnerability	No effect	Eliminates vulnerable facility	Reduce exposure	Reduce exposure and/or sensitivity	Reduce sensitivity	Reduce sensitivity	Reduce exposure and/or sensitivity	Reduce exposure
Timeframe	Short-term	Short-term to Long-term	Shor-term to Long-term	Short-term to Long-term	Short-term	Short-term to Long-term	Short-term	Short-term
Example(s) in Washington State Parks	*Posey Island:* Campsites temporarily flood during winter high water events.	*Cape Disappointment:* Campground damaged by flooding and erosion had utilities removed.	*Clark Island:* Low-lying campgrounds were relocated to high ground.	*Sucia Island:* Road along marsh to administrative building was removed and tidal flushing restored.	*Camano Island:* Vault toilet at boat launch is elevated ~five feet, allowing parking lot to temporarily flood. The comfort station is designed to flood with elevated utilities.	*Saltwater:* Food trucks will provide food when a vulnerable concession stand is removed.	*Cama Beach* and *Pacific Beach:* Shoreline armor protects cabins and campground infrastructure from erosion.	*Deception Pass:* Bowman Bay had armor removal coupled with beach nourishment to build up a storm berm to a higher elevation.

All approaches can be effective at reducing the vulnerability of coastal facilities; however, the timeframe for which they are effective varies. Each option and its appropriate timeframe, hazard, and effect on vulnerability are described in an "Adaptation Option Menu" that also includes examples of these options currently being applied in Washington's state park properties. When considering which options that may be most appropriate, there are several important considerations including:

- Which coastal hazards the asset is exposed to and over what timeframe
- The sensitivity of the asset
- The design life of the asset and the design life of the adaptation approach
- Whether the potential adaptation approach will reduce vulnerability

All options will not be viable in all locations. The facilities geodatabase can be used as high-level screening tools to narrow in on potential actions. Options may be selected from the menu over a desired planning period. Below are some examples of adaptation pathways that could be selected (Figure 30).

Figure 30. Potential Short-Term and Long-Term Adaptation Pathways, Depending on Coastal Facility Type.



VULNERABILITY ASSESSMENT FINDINGS

The following section describes high-level findings about the vulnerability of coastal facilities to sea level rise and related impacts. Summaries of the most vulnerable facilities across the park system, organized by facility type can be found in Appendix B.

How Exposed to Coastal Hazards Are Different Types of Coastal Facilities?

When people visit a state park property, they interact with numerous facilities from the entrance road to the parking lot or pier to the day use facilities or overnight accommodations. These facilities support park users as well as park administration, and, if located in a coastal hazard area, will need to have a plan to ultimately adapt the infrastructure to be able to withstand future exposure. Of Washington State's 93 coastal state park properties, 74 have coastal facilities. In addition, all 25 OBAs have coastal access facilities. The number of facilities exposed are summarized by five categories, which are a regrouping of the facility subcategories (Table 2):

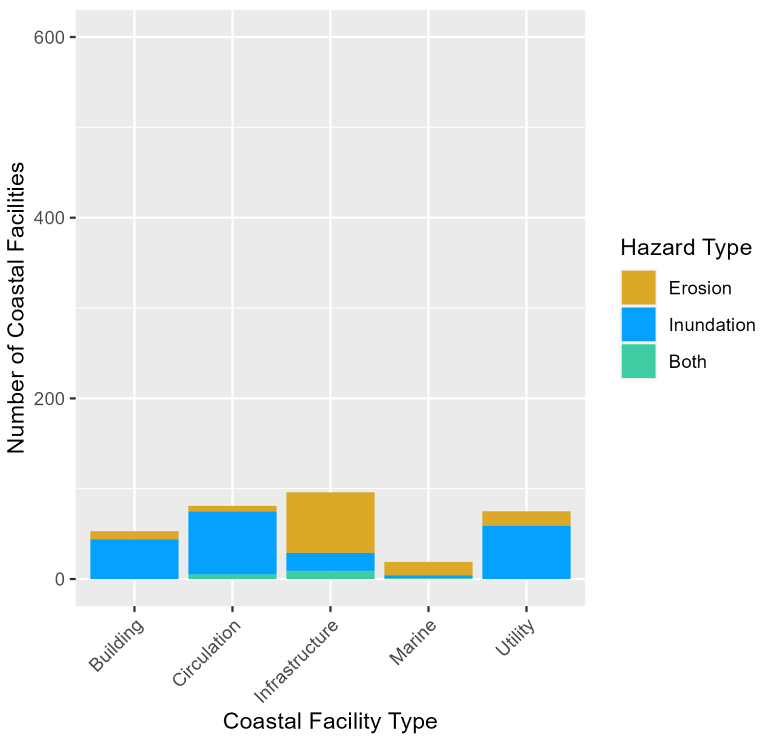
1. Infrastructure (day use facilities with no utilities, camping, and shore protection)
2. Circulation
3. Utilities
4. Buildings (administrative, day use with utilities, roofed accommodations, and sanitation),
5. Marine

Field visits and conversations with park staff revealed that many coastal facilities are already exposed to the impacts of inundation and erosion and require immediate action (Figure 31). Other facilities will likely be exposed in the near-term (Figure 32).

Inundation is a consistent challenge, especially during winter storms and high tide events, and currently threatens more facilities than erosion (Figure 31). Infrastructure (including campgrounds and shore protection structures) as marine (piers and boat ramps) are especially vulnerable to erosion.

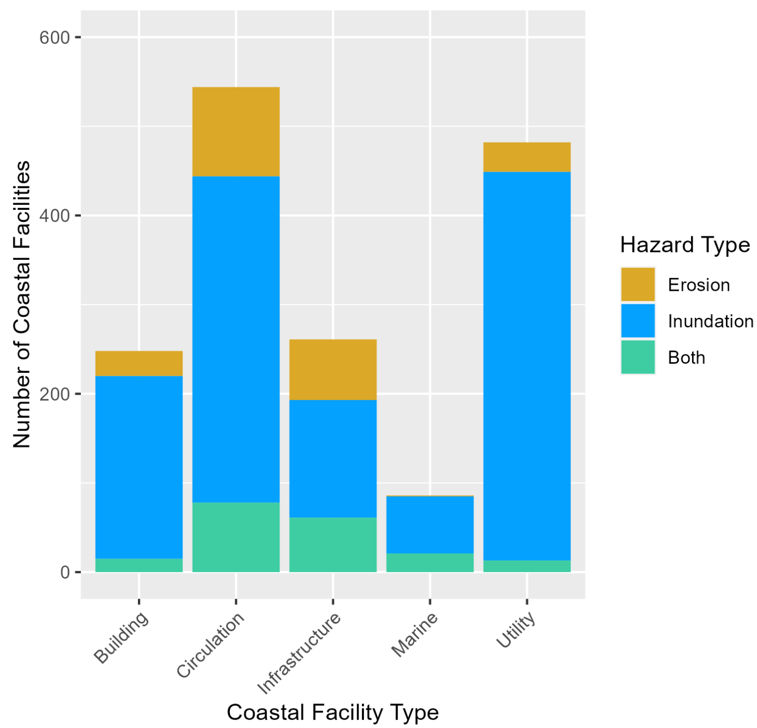
Additional facilities will be exposed as sea level continues to rise and erosion keeps pace over the next couple decades (Figure 32). As this happens, there are many additional facilities located in hazard areas for sea level rise-induced inundation or erosion. More coastal facilities will likely be exposed to both inundation and erosion. These coastal facilities will require proactive planning in order to maintain park operations and services.

Figure 31. Count of Coastal Facilities that Are Currently Exposed to Erosion, Inundation, or Both.



Currently, many facilities are exposed to erosion, inundation, or both. Infrastructure (including campgrounds and shore protection structures) has the most facilities exposed to hazards.

Figure 32. Count of Coastal Facilities that May Be Exposed in the Near Term to Erosion, Inundation, or Both.



In the coming decades, considerably more facilities will be exposed to coastal hazards. Most facilities will be exposed to inundation and increasingly more will be exposed to inundation and erosion.

Which Facilities Are Most Vulnerable to Coastal Hazards?

Evaluating vulnerability and not just exposure adds additional nuance and value to planning. It is not enough to just consider what facilities are exposed. With potentially thousands of facilities, it is important to triage by identifying which facilities would have the most severe consequences if exposed to inundation or erosion. Therefore, vulnerability scores account for a facility's exposure (what hazards it is exposed to and when) and its sensitivity (how affected would the facility be if exposed). Across all parks, the following combinations of facilities and hazards had the highest vulnerability scores:

- Shoreline armor that currently experiences regular flooding and is undermined by erosion (e.g., Fort Flagler, Saltwater, and Cama Beach State Parks; Figure 33).
- Piers and docks that are either currently exposed to hazards, or likely will be soon (50 percent likelihood inundation scenario and high confidence bluff erosion) (e.g., Mystery Bay, Olga, Cornet Bay in Deception Pass, Pleasant Harbor, Joemma Beach, and Blake Island State Parks).
- Wastewater facilities including sewer lift stations and maintenance access that experience current flooding and erosion or are likely to in the near-term (e.g., Penrose Point, Potlatch, Fort Flagler, and Cama Beach State Parks).
- Bathrooms exposed to hazards at present or in the near-term (e.g., Twanoh, Potlatch, Deception Pass, and Dosewallips State Parks).
- Roofed accommodations that are currently or will soon be exposed to inundation (e.g., Cama Beach State Park).

Figure 33. Shoreline Armor at Saltwater State Park Is in the Planning and Design Process To Be Removed and Restored.

FUTURE CONSIDERATIONS OR RECOMMENDATIONS

How Can the Vulnerability Assessment Results Be Used?

This vulnerability assessment produced a suite of planning tools, including an enhanced geodatabase of Parks' coastal facilities, park-level maps, and hazard polygons for various inundation and erosion scenarios. These tools can be used to support planning to increase the resilience of current coastal facilities as well as to inform placement and relocation of future coastal facilities. Some key uses of the vulnerability assessment include:

- Pinpoint coastal facilities that are known to be currently impacted by flooding and/or erosion.
- View at varying level – park, region, state – which facilities are most exposed and which are most vulnerable.
- Screen locations for future investments by evaluating if construction of new facility is located within the coastal hazard areas, and the potential timeline for exposure.
- Summarize the most vulnerable facilities of a certain type (e.g., campground- no utilities, road, administrative building) across a park, region, or statewide (see Appendix B).
- Identify coastal hazard zones and use them to update land classification and related permitted uses and activities.
- Conduct initial screening for what adaptation opportunities may be most appropriate for a vulnerable facility.


Matia Island State Park

HERRERA

What Policy and Management Changes Could Help Increase the Resilience of Park Properties and Their Coastal Facilities to Sea Level Rise and Erosion?

Through conversations with State Park staff during workshops and field visits, review of the framework identified in Parks' previous climate adaptation work (CIG 2019), and data collected in the field, the Herrera team identified the following policy and management changes that could help increase the park resilience. The recommendations are based on Herrera's best professional judgement and experience facilitating client feedback (Table 3). Policy and management considerations are organized into seven categories—Practice and Behavior, Evaluation and Assessment, Partnerships, Outreach, Policy, Capacity Building, and Monitoring and Data Collection—as outlined in the climate adaptation framework (CIG 2019).

Table 3. Policy and Management Considerations and Recommendations.

Suggested Change	Description
Practice and Behavior	
Adapt Vulnerable Facilities	Use data and findings from the vulnerability assessment to triage infrastructure that needs to be decommissioned and/or adapted. Communicate with park users around planned changes and accept the temporary or permanent loss of some facilities.
Adjust Storm Clean-Up Practices	When cleaning up after storms, start by filling any scour holes in the beach with sediment and driftwood to help protect against future erosion. Pocket beaches and barrier beaches want to translate landward. Allow them to do so by letting driftwood and sand be more landward than they were before. This helps the beach build up and be protected against future events.
Improve Stormwater Drainage	Numerous parks have erosion issues exacerbated by poor stormwater management near bluff areas and shorelines. Reducing impervious surfaces, promoting infiltration (away from bluff crests), and diverting water away from sensitive slopes can help reduce the magnitude of bluff erosion.
Pursue Restoration Opportunities	Removal and relocation of coastal facilities often opens land for new uses, including restoration. Capitalizing on restoration opportunities could simultaneously increase the adaptive capacity and resilience of the beach and park.
Evaluation and Assessment	
Identify Upland Parcels for Relocation	For parks with highly vulnerable infrastructure or extensive infrastructure that is exposed, relocation of facilities is likely the best long-term approach. To support this, evaluate upland areas and establish a land acquisition program to purchase less vulnerable parcels and allow the inland/upland migration of facilities.
Update Climate Projections	Update sea level rise inundation and coastal hazard erosion areas, and related policy and planning documents as best-available science becomes available that has increased certainty on the timing and magnitude of future changes.

Table 3(continued). Policy and Management Considerations and Recommendations.	
Suggested Change	**Description**
Partnerships	
Build Partnerships	Nurture strong partnerships with local jurisdictions, Tribal governments, state and federal government agencies, private residents, and organizations to enable programmatic responses to the highest and most immediate threats, as many parks contain or depend on infrastructure owned by another entity. Many parks also have cultural resources near threatened infrastructure.
Outreach	
Educate and Demonstrate Climate Adaptation	Support Parks' mission to provide educational experiences through implementing programs around sea level rise and related impacts. Some options could include crowd sourced data collection, adaptive management, community engagement, and stewardship programs.
Policy	
Restrict Development in Coastal Hazard Areas	Use policy tools to stop or limit new development and rebuilding within coastal hazard zones if the design life of the infrastructure exceeds the anticipated timing of exposure of sea level rise and/or erosion. Consider tools such as increased setback distances and updating land classifications.
Capacity Building	
Enhance the Facilities Inventory	Expand the Facility Inventory and Condition Assessment Program (FICAP) to include marine over-water and land-based facilities and shoreline protection structures.[a] Establish damage evaluation metrics and provide training to staff making observations to increase consistency.
Monitoring and Data Collection	
Monitor Impacts	Create a long-term monitoring program, and train and support on-the-ground staff in monitoring and documenting changes in natural disturbance regimes (e.g., flooding, vegetation change, erosion, saltwater intrusion) as well as current impacts and damage. Track FEMA claims. Maintain data in a centralized location and use to update the vulnerability assessment and make data-informed decisions.

[a] Field assessments captured many marine facilities in the 52 parks visited; however, since over-water facilities at many parks were in their winter configurations, not all data could be collected. In addition, there may be marine facilities in parks not visited during fieldwork.

For Especially Complex Park Properties, How Can Facility Transition Planning Be Used?

The impact of climate change on coastal facilities from rising sea level and more intense flooding and erosion presents a major challenge for park properties with extensive investements in coastal buildings and infrastructure and rapidly changing conditions (e.g., Cama Beach, Cape Disappointment). Whereas adaptation opportunities identified above (Figure 28) are important tools to buy time, they may not be feasible or cost-effective for parks with extensive facilities. For these park properties with complex scenarios, a transition plan or phased approach will be necessary to reduce and ultimately remove coastal facilities from the highest-risk areas. Making space for the ocean (retreating) can have steep political hurdles and upfront costs, but is the only guaranteed way to remove vulnerability and may also be the most cost-effective option over long timeframes when implemented proactively (Miller et al. 2022). Transition planning typically requires the following elements:

- Highly participatory planning process. Plans serve as the strategic and guiding mechanism for evaluating and implementing facility transitions. Planning should be done proactively, and in concert with key local, tribal, and state stakeholders and agencies.
- Analysis of risk and locations for relocation. In some cases, finer-scale analysis of hazards at a particular park property may be needed to define the coastal facilities that are at the greatest risk. In parallel, suitable locations for relocation of coastal facilities should be identified and the appropriate policy tools leveraged to prepare the land for new facilities.
- Moratorium on new development. Areas with the greatest exposure should have a moratorium on new development to ensure that park staff, visitors, and coastal facilities are not put in harm's way.
- Adjustment of land classification or zoning. A comprehensive overhaul of land classification and zoning can be used to discourage building and rebuilding in high-risk areas, and encourage building in upland areas.
- Monitoring and adaptive management. Proactively monitoring hazards, impacts, and costs can help inform future adaptation, realignment, or disinvestment policies and approaches. With adaptive management approach, it is important to develop environmental or policy transition points (e.g., number of times inundated in a year, implementation of specific policy tools) that trigger changing course to a more viable, permanent solution.
- Phased, proactive long-term implementation and restoration. Transition plans are implemented as defined thresholds are met, and can occur in phases with clusters of facilities being relocated, removed, or abandoned together. As facilities are moved, opportunities for restoration or re-wilding should be considered as they can increase the resilience of the shoreline and protect against future hazards.

What Comes Next?

As the largest manager of public coastal land in Washington State, Parks has an enormous opportunity to lead by example in implementing adaptation actions that increase resilience. Through this vulnerability assessment, Parks has developed a data-based screening tool that can be used to plan for current and future impacts related to sea level rise on coastal facilities. There are multiple next steps stemming from this effort:

- First, facilities that are already chronically impacted by flooding or erosion should be considered for adaptation opportunities that will reduce their vulnerability. Some parks with a high number of vulnerable facilities will require focused transition plans that include site-specific assessment and partnership building with relevant stakeholders.
- At the same time, planning should begin for facilities that may not be currently exposed but that have high vulnerability.
- As part of triaging which investments to prioritize, it may be important for Parks to apply additional filters. These could include considerations at the park scale (e.g., visitation or use level, social equity, or impacts to a unique park experience) or at the facility scale (e.g., facility condition, historic status, proximity to cultural resources, ADA access).

Beyond this assessment's focus on coastal facilities, future assessments should consider other critical park assets including cultural resources, natural resources, and historic resources. The coastal hazard exposure geospatial data created for this vulnerability assessment can be easily applied to future assessments.

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Lime Kiln State Park