Quiet Waters Park Resilience Assessment and Planning

Solution Identification Report

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The Resilience Authority of Annapolis and Anne Arundel County
Anne Arundel County Department of Recreation and Parks

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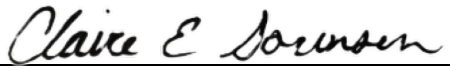
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Executive Summary

In partnership with the Resilience Authority of Annapolis and Anne Arundel County (Resilience Authority) and Anne Arundel Department of Recreation and Parks (DRP), Stantec developed alternatives for upland and shoreline stabilization solutions that will protect the Quiet Waters Park (the Park) shoreline under present and future climate conditions. Integrating the findings from Desktop Data Collection (Appendix A), Field Reconnaissance (Appendix B), and Shoreline Vulnerability Assessment and Prioritization (Appendix C), shoreline protection solutions were developed for six (6) priority shoreline segments. Stantec, the Resilience Authority, and the DRP closely coordinated to recommend solutions that address coastal and climate hazards, support existing and planned Park functions, acknowledge maintenance limitations, promote public safety, and offer community engagement and enrichment. Along with recommended solutions for priority shoreline segments presented below, Stantec has developed order of magnitude cost estimates to aid future implementation efforts.

Shoreline Segment	Recommended Solutions	Total Cost
Quiet Waters Retreat (Segment 1)	• Rock groins • Rock sills • Headland breakwaters with fill and high/low marsh plantings • Upland brush plantings	$ 1,790,000
Entrance to Harness Creek (Segment 4)	• Living breakwaters with oyster spat • Invasives removal • Wood debris barrier • Low/high marsh plantings	$ 840,000
Boat Rental Shoreline (Segment 8)	• Reef balls • Floating wetlands	$ 410,000
Loden Pond (Segment 2)	• Fill and wetland plantings • Submerged Aquatic Vegetation • Coir logs and oyster bags • Shell-filled gabion pens • Infiltration trench	$ 780,000
Harness Creek Inlet Shoreline (Segment 5)	• Submerged breakwaters • Woody debris barrier	$ 720,000
Wildwood Trail Shoreline (Segment 9)	• Reef balls	$ 460,000

Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
AASHTO	American Association of State Highway and Transportation Officials
ARF	Arundel Rivers Federation
BMP	Best Management Practice
DRP	Department of Recreation and Parks
EOPC	Engineer's Opinion of Probable Cost
LF	Linear Feet
MDE	Maryland Department of the Environment
MDOT	Maryland Department of Transportation
MDSPGP-6	Maryland State Programmatic General Permit-6
MHW	Mean High Water
MLW	Mean Low Water
NAVD88	North American Vertical Datum of 1988
Park	Quiet Waters Park
QWR	Quiet Waters Retreat
Resilience Authority	Resilience Authority of Annapolis and Anne Arundel County
SLR	Sea Level Rise
SAV	Submerged Aquatic Vegetation
VIMS	Virginia Institute of Marine Science

1 Introduction

In partnership with the Resilience Authority of Annapolis and Anne Arundel County (Resilience Authority) and Anne Arundel Department of Recreation and Parks (DRP), Stantec developed alternatives for upland and shoreline stabilization solutions that will protect the Quiet Waters Park (the Park) shoreline under present and future climate conditions. Integrating the findings from Desktop Data Collection (Appendix A), Field Reconnaissance (Appendix B), and Shoreline Vulnerability Assessment and Prioritization (Appendix C), shoreline protection solutions were developed for six (6) priority shoreline segments. Alternatives explore a multitude of factors – including benefits for shoreline stabilization, climate adaptation, habitat restoration, water quality improvement, educational enrichment, public accessibility, and required maintenance – to identify preferred solutions. Along with a recommended solution for priority shoreline segments, Stantec has developed order of magnitude cost estimates for recommended solutions to aid future implementation efforts.

2 Overview of Shoreline Segments and Prioritization

The Park shoreline was segmented into ten (10) shoreline reaches based on shared shoreline characteristics (Figure 1) and evaluated based on segment exposure, sensitivity, and adaptive capacity of current and future coastal hazards, as detailed in the Shoreline Vulnerability Assessment and Project Prioritization memorandum (Appendix C). The final shoreline prioritization rankings are presented in Table 1. The findings from the vulnerability assessment, knowledge of planned shoreline protection efforts, as well as client feedback, led to the final recommendation to advance solution identification for Quiet Waters Retreat (Segment 1), the Entrance to Harness Creek (Segment 4), the Boat Rental Shoreline (Segment 8), Loden Pond (Segment 2), Harness Creek Inlet Shoreline (Segment 5), and Wildwood Trail Shoreline (Segment 9).

Solutions were not explored for the Harness Creek Trail Shoreline (Segment 7) due to the designed shoreline protection project led by Arundel Rivers Federation (ARF), which began implementation in 2026. Additionally, solutions were not considered for the Harness Creek Embayments (Segment 6) due to the relatively sheltered conditions within the embayments and recent improvement, including the establishment of submerged aquatic vegetation (SAV), associated with the recent installation of a step pool system. Solutions for the South River Overlook Shoreline (Segment 3) and Old Place Cove Shoreline (Segment 10) were also not explored due to their generally low vulnerability assessment scores and more limited opportunities for nature-based shoreline stabilization benefits at the time of this study.



Figure 1. Shoreline segments.

Table 1. Shoreline priority rankings.

Shoreline Priority Rank	Shoreline Segment Name (Segment Number)
1	Quiet Waters Retreat (1)
2	Entrance to Harness Creek (4)
3	Harness Creek Trail Shoreline (7)
4	Boat Rental Shoreline (8)
5	Loden Pond (2)
6	Harness Creek Inlet Shoreline (5)
7	Harness Creek Embayments (6)
8	Wildwood Trail Shoreline (9)
9	South River Overlook Shoreline (3)
10	Old Place Cove Shoreline (10)

3 Solutions Overview and Evaluation Criteria

Stormwater management and coastal protection alternatives offering stabilization and habitat enhancement were explored for the six (6) shoreline segments advanced for solution identification. Upland alternatives reduce stormwater runoff funneling along manmade trails that contribute to shoreline erosion and reduce water quality, while shoreline alternatives reduce wave-induced erosion. An overview of evaluated alternatives, ranging from traditional engineered options (gray infrastructure) to fully nature-based solutions (green infrastructure), is provided. Viable upland and shoreline alternatives were explored based on each priority shoreline's physical and environmental constraints and assessed using the Solution Evaluation Criteria detailed in Section 3.3.

3.1 Upland Stormwater Management Solutions

Shoreline erosion is exacerbated by concentrated stormwater runoff flowing to the South River and Harness Creek shorelines. The stormwater management solutions considered address the need to reduce human impacts exacerbating runoff-induced erosion, provide stormwater detention, or improve water quality.

3.1.1 Wood Debris Barriers

Upland stormwater management concerns at the Park are primarily associated with foot traffic causing undesignated trails, resulting in soil compaction, vegetation disturbance, and increased susceptibility to localized erosion. Repeated foot traffic through sensitive soil and vegetative communities can reduce groundcover density, compromise root structure, and limit the vegetative capacity to stabilize surface soils. A low-impact and low-cost management approach, such as installing woody debris barriers in combination with interpretive or regulatory signage, could help discourage continued access and promote passive restoration of disturbed areas. The wood debris will provide a barrier to runoff concentrating in trails, interrupting flow paths and flow velocities near the shoreline. Optional localized grading and plantings within the vicinity of the barriers will provide additional protection and initiate revegetation along compacted trails. Present undesignated trails will naturally revegetate over time, which will reduce runoff velocities, improve stormwater infiltration, and reduce shoreline erosion. Implementation costs for this measure are anticipated

to be minimal, as wood debris can be sourced from on-site materials and installation would require limited labor and equipment.

3.1.2 Stormwater Best Management Practices

Stormwater Best Management Practices (BMPs) are engineered systems that retain stormwater runoff to improve water quality and reduce flood hazards. Commonly applied BMPs include infiltration trenches and micro-bioretention facilities implemented upland of the Park's steep shorelines would support runoff detention, groundwater recharge, and water quality benefits. The stormwater BMPs explored require the base of the system to be two (2) to four (4) feet from the measured groundwater elevation, and appropriate application and design of these systems to meet the Maryland Department of Environment (MDE) Maryland Stormwater Design Manual specifications requires additional data (MDE, n.d.). Pollutant removal rates for both types of facilities are similar: Sediments 80%; Phosphorus 66%; Nitrogen 56%.

Infiltration trenches are underground, narrow excavations that percolate stormwater runoff into surrounding native soils. They require subsoils with a high infiltration rate (minimum of 0.52 in/hr) and are filled with washed, crushed stone. Infiltration trenches require periodic maintenance, including excavation and replacement of the stone and filter fabric, to ensure proper performance and ensure sediment-laden runoff does not clog stone voids.

Micro-bioretention is a shallow, landscaped surface depression utilizing engineered soil and native plants that retains stormwater as it infiltrates into groundwater. Micro-bioretention facilities can either include or exclude an underdrain system, which alters infiltration rate requirements for the system. While construction of a micro-bioretention system is typically more expensive than an infiltration trench, maintenance is less intensive and primarily consists of surface level horticultural (i.e., weeding, mulching, pruning).

3.2 Coastal Protection Solutions

Coastal protection solutions dissipate wave energy and stabilize the coastline. Application of gray, hybrid (i.e., incorporating gray and green design elements), or green infrastructure for shoreline protection varies based on wave energy, sediment dynamics, environmental goals, physical site constraints, maintenance requirements, and implementation expenses. A range of typical shoreline stabilization techniques based on a site's wave energy is provided in Figure 2, and discussion of hardened, hybrid, and natural shoreline alternatives are discussed in subsequent sections.

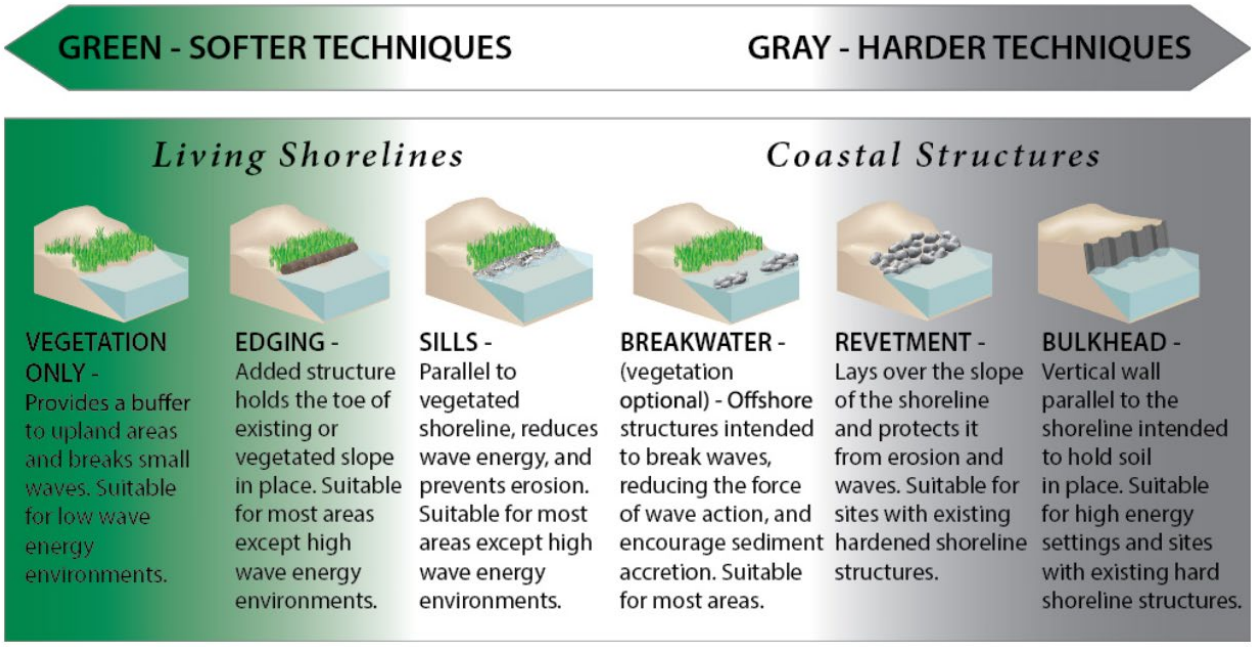


Figure 2. Shoreline stabilization techniques (Systems Approach to Geomorphic Engineering, 2015).

3.2.1 Hardened Solutions

Hardened solutions use rock, metal, or concrete for shoreline stabilization. Hardened shorelines provide robust protection, particularly in high wave energy environments with fetch lengths greater than 5 miles or large boat wakes. A limitation of hardened shorelines is their inherent static nature; the best day of the structure's performance is the first day of implementation. Hardened shoreline solutions existing at the Park or considered in design include:

- Rubble mound structures (i.e., rock toe bank stabilization, rock sills, breakwaters, revetments, jetties/groins)
- Bulkheads and seawalls

Optional design features can be incorporated into hardened shoreline design to enhance the ecological benefits and applications of these features, such as:

- ECOncrete units (Figure 3A)
- Living seawall panels (Figure 3B)
- Riprap scoring

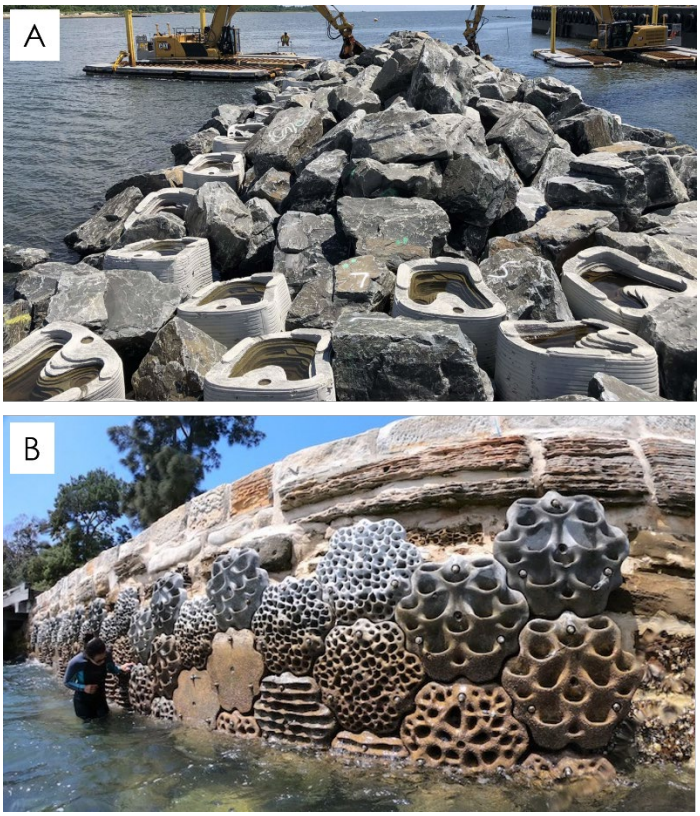


Figure 3. A: ECOncrete units within a breakwater (ECOncrete, 2026). B: Living Walls Panels affixed to a seawall (Molloy, 2021).

3.2.2 Hybrid Solutions

Hybrid solutions combine the wave attenuating features of hardened structures with dynamic, natural elements to dissipate wave-energy and provide habitat. Hybrid solutions perform well in low to moderate wave energy environments with fetch lengths between one (1) and five (5) miles as well as moderate boat wakes. Hybrid solutions considered for the Park include:

- Rubble mound structures backed by fill and plantings
- Dynamic revetments
- Floating wetlands
- Artificial reefs and living breakwaters
- Shell-filled gabion pens



Figure 4. Examples of artificial reef and living breakwaters that facilitate oyster recruitment using (A) oyster bags, (B) reef balls, and (C) oyster castles (Naturally Resilient Communities, n.d.; Reef Ball Foundation, n.d.; U.S. Fish and Wildlife Service, 2022).

3.2.3 Natural Solutions

Natural solutions do not incorporate hardened, structural elements and are designed to mimic the natural environment. These solutions are applicable to low and very low wave energy environments with waves generated over fetch lengths less than one (1) mile and minimal boat wakes. Natural solutions considered for the Park include:

- Brush toe bank stabilization
- Marsh terraces
- Loose or bagged shell sills
- Bluff regrading and plantings
- Fill and coir logs
- SAV and wetland plantings

3.3 Solution Evaluation Criteria

Stantec developed a Solutions Matrix to evaluate shoreline alternatives based on relative solution expense and benefits for shoreline stabilization, climate resilience and adaptation, habitat enhancement, recreational and educational value, maintenance potential, permitting feasibility, and constructability. Relative expenses are categorized as low ($), medium ($$), and high ($$$) based on Stantec's previous project experience; final costs will be determined by subsequent design phases. Anticipated benefits and limitations of each project type are assessed using the rubric in Table 2. The Solutions Matrix is applied to strategically evaluate alternatives for priority Park segments and identify a preferred alternative.

Table 2. Solution benefits evaluation criteria.

Benefits Evaluation	High	Medium	Low
Shoreline Stabilization	Provides long-term, effective erosion control and wave attenuation.	Provides reliable erosion protection under most conditions, with minor limitations or localized vulnerability.	Offers limited stabilization benefits, may reduce erosion in the short-term but is vulnerable to moderate storms.
Nature-based Solution	Composed entirely of natural or nature-based elements.	Incorporates significant nature-based features with limited structural elements.	Includes some natural features but is mainly hardened structures.
Climate Change Resiliency and Adaptability	Highly adaptable to sea level rise, increased storm intensity and changing wave conditions.	Performs well under projected conditions (sea level rise, extreme storm events) with moderate adaptability.	Limited adaptability; performance may decline under future climate stressors.
Habitat Enhancement	Creates additional habitat and improves ecological function/biodiversity.	Provides some additional habitat and supports ecological function/biodiversity.	Provides minimal new habitat and limited support of ecological function/biodiversity.
Recreation, Accessibility, and Educational Enrichment	Provides significant public benefits such as access, recreation, education, or protection of critical infrastructure.	Provides some public benefit.	Provides limited public benefit.
Regulatory Feasibility	Highly likely to receive permits with minimal regulatory obstacles or mitigation requirements.	Likely to receive permits with standard reviews and manageable mitigation.	Significant coordination or mitigation may be required to receive permits.
Ease of Maintenance	Minimal long-term maintenance. Project is naturally adaptive.	Periodic maintenance may be required for project upkeep.	Regular maintenance required for project upkeep.
Constructability	Easily constructable with minimal site constraints with precedence for construction in similar Mid-Atlantic environments.	Constructable with some site challenges. Solution type has been implemented previously in similar Mid-Atlantic environments.	Significant construction challenges (i.e., specialized equipment, sequencing constraints). Solution is novel with limited executed examples in the Mid-Atlantic.

4 Shoreline Segments & Matrices

Stantec identified stormwater management, shoreline protection, and habitat enhancement solutions for Quiet Waters Park's priority shorelines. Solutions considered shoreline wave exposure, physical attributes (existing vegetation, bank slopes, etc.), public use, and existing and planned upland infrastructure. Where possible, recommended solutions integrate nature-based elements to improve resilience, ecological habitats, and educational enrichment. Furthermore, Stantec closely collaborated with the Resilience Authority and DRP to ensure recommended solutions account for stakeholder goals and maintenance concerns. Stantec also developed an order of magnitude cost estimate for the recommended solution at evaluated shorelines. The Engineer's Opinion of Probable Cost (EOPC) was developed based on Stantec's review of past purchase orders, cost estimation tools, construction estimates from other consultants, industry knowledge, recent contract bids, and historical costs on similar shoreline protection projects. The EOPCs were developed using rough estimates of project quantities and are priced assuming current (2026) construction costs. The EOPCs are intended to be used for planning purposes only.

4.1 Quiet Waters Retreat

4.1.1 Existing Conditions

Quiet Waters Retreat (Segment 1) is located along the South River and exposed to moderate wave energy. The reach is the Park's most complex shoreline – composed of steep, eroding sandy bluffs, low-lying marsh, and previously engineered shoreline infrastructure – and planned upland development, detailed in the Quiet Waters Retreat Master Plan, increases the need for shoreline protection (Anne Arundel Recreation and Parks, 2025). The Quiet Waters Retreat (QWR) shoreline is segmented into six (6) sub cells (Figure 5) based on shoreline type and existing infrastructure (Figure 6).



Figure 5. Quiet Waters Retreat segmented cells.



Figure 6. Quiet Waters Retreat segmented shoreline images from Stantec field reconnaissance (see Appendix B).

Segment A: The entrance to Loden Pond (Figure 6A) is characterized by two damaged wooden groins and an intact rock sill protecting a healthy marsh. This segment is highly visible to the public due to its proximity to the Park's Dog Beach and Loden Pond. The entrance to Loden Pond experiences fluctuating sedimentation, sporadically interrupting the hydraulic connection between the South River and Loden Pond.

Segment B: The segment southeast of the entrance to Loden Pond (Figure 6B) includes a wooden bulkhead protecting an interior healthy wetland. During Stantec's field reconnaissance, localized failure and damage to the wooden bulkhead was noted. Although the bulkhead is deteriorating, there is evidence of the shoreline stabilization capabilities as a healthy marsh system is present behind the structure.

Segment C: The segment is composed of steep, unvegetated bluffs with overhanging sediment at the bluff crest as well as unstable and felled trees (Figure 6C). The Segment C shoreline abuts a wooden bulkhead to the west (Segment B) and a sheet pile bulkhead to the east (Segment D), which may be exacerbating erosion at Segment C. The unstable bluff face threatens the proposed upland infrastructure detailed in the Quiet Waters Retreat Master Plan and poses a risk to public safety. Debris at this shoreline indicates that it is accessed by the public via boat or unofficial trails.

Segment D: Includes a damaged and deteriorating steel sheet pile bulkhead (Figure 6D). The bulkhead fronts a well vegetated, stable bluff with localized disturbances caused by foot traffic. While offering effective shoreline protection along most of the reach, the bulkhead eliminates the intertidal zone and associated habitat. Additionally, the bulkhead lacks the ability to adapt to sea level rise, making it vulnerable

to future conditions. The intended design life for the existing structure is unknown, and the current condition indicates that there has been minimal maintenance.

Segment E: This segment includes a low crested rock sill fronting marsh grasses and an interior bluff (Figure 6E). The bluff face along this reach is gentler and more vegetated than at Segment C and Segment F. Although the bluff appears stable, localized erosion from undesignated, manmade trail were noted along the banks, causing localized erosion and vegetation loss. Generally, the infrastructure appears to function well and integrates nature-based elements in line with the desired shoreline protection measures for the Park.

Segment F: The easternmost section of Quiet Waters Retreat shoreline includes unstable, eroding bluff with overhanging as well as felled trees (Figure 6F). Fronting the bluff is a narrow sandy beach interspersed with small, shore-perpendicular rock groins. Localized erosion from manmade footpaths along the bluff face were also noted.

4.1.2 Desired Project Outcomes and Potential Solutions

Desired outcomes for Quiet Waters Retreat include:

- **Shoreline stabilization** that protects planned upland infrastructure
- **Reliable hydraulic connection and access** between the South River and Loden Pond
- **Improved habitat** and reintegration of the intertidal zone, where possible
- **Enhanced public safety** that promotes access to designated Park amenities and recreational spaces while disincentivizing the use and/or creation of trails along the bluff face to the shoreline
- **Educational enrichment** and demonstration of multiple nature-based solutions

Alternatives explored in Table 3 are appropriate for the moderate wave energy experienced at Quiet Waters Retreat shoreline and can incorporate natural elements for ecological and educational value. Moderate wave energy is associated with wind-waves generated over fetch lengths between one (1) and five (5) miles as well as boat wakes from vessels travelling up to 35 knots (59.1 ft/s) along the South River (Maryland DNR, 2026).

Table 3. Solutions matrix for Quiet Waters Retreat.

Potential Solutions	Relative Expense	Shoreline Cells	BENEFITS EVALUATION (HIGH, MEDIUM, LOW)							
			Shoreline Stabilization	Nature-based Solution	Climate Change Resiliency and Adaptability	Habitat Enhancement	Recreation, Accessibility, and Education Enrichment	Regulatory Feasibility	Ease of Maintenance	Constructability
Rock Groins	$$	A	Medium	Low	Low	Low	Low	Medium	High	High
Steel / Concrete Groin with Living Wall Panels	$$$	A	Medium	Medium	Low	Low	Medium	Low	High	Medium
Rock Sill with Marsh Plantings	$$	B, C, D, F	High	Medium	Medium	Medium	Medium	Medium	Medium	High
Living Breakwaters with Oyster Spat	$$	B, C, D, F	Medium	High	High	High	High	Medium	Medium	Medium
Bluff Regrading and Plantings	$$$	C, D, F	High	High	Low	Medium	Low	High	Medium	Low
Bulkhead with Fill and Plantings	$$$	B, C, D	High	Low	Low	Low	Low	Medium	Medium	Medium
Headland Breakwaters with Fill and Marsh Plantings	$$	B, C, D, F	High	Medium	Medium	Medium	Medium	Medium	Medium	High

4.1.3 Recommended Solution and Cost Estimate

Shoreline protection for Quiet Waters Retreat requires a cohesive solution that accounts for the Park's desired outcomes and integrates existing shoreline infrastructure where possible, such as the functioning rock sill and upland plantings at Segment E. The proposed solution requires removal of damaged infrastructure, including the wooden piles at Segment A and wooden and steel bulkheads at Segments B and D, and small riprap groins at Segment F to support design elements working in concert. A conceptual layout for the recommended solution at Quiet Waters Retreat is provided in Figure 7.

The recommended solution at Segment A is to install two rock groins to reduce sedimentation and maintain the hydraulic connection and access to Loden Pond, as demonstrated via sediment transport model findings for the site (Appendix D). Along Segment B, it is recommended to place three (3) rock sills at the Mean Low Water (MLW) line to protect the interior marsh plantings. Although rock sills themselves are not a green solution, the structures can be enhanced with nature-based elements such as marsh plantings and engineered rock to provide habitat enhancement. Rock sills with fill and plantings are constructable with minimal site constraints, as this type of work is often implemented in this environment. Periodic maintenance may be needed to ensure the marsh plantings establish successfully, remove any invasive plant species, and clear the structures of any debris.

Along the remainder of the Quiet Waters Retreat shoreline (Segments C through F), it is recommended to install headland breakwaters backed by fill and plantings. The breakwaters will dissipate the moderate wave energy experienced along the reach to improve shoreline stability. If desired, engineered armor units can be incorporated into the structures to further enhance their ecological value. Inland of the breakwaters, fill and marsh plantings will be used to further stabilize soils and provide wave attenuation. Upland of the low and high marsh plantings, it is recommended to use felled trees onsite and brush along the bluff face and toe to disincentivize park visitors from straying off designated paths. These systems reduce erosion hazards, preserve the intertidal zone, and create a protective habitat for marine species and native vegetation. Permitting and construction is expected to be manageable, as these types of breakwaters are common within the Chesapeake Bay region.

Planning level construction cost estimates for the implementation of the recommended solution elements are provided with a 20% contingency (Table 4). The estimated cost includes the materials, trucking, and labor required to construct the design. The cost does not account for additional maintenance upon project completion or engineering services during construction. Costs are determined based on linear feet (LF) of shoreline as well as the assumptions provided in Appendix E. Mobilization and demobilization costs are computed based on the entire shoreline reach and cost efficiency is maximized when stabilization solutions are implemented simultaneously. The full mobilization and demobilization cost is distributed among shoreline solutions proportional to anticipated project costs. A cost estimate for the entire shoreline reach is provided in Section 5.

Table 4. Cost estimate for recommended solutions at Quiet Waters Retreat.

Shoreline Segment	Stabilization Solution	Estimated Cost
A	Rock groins	$ 350,000
B	Rock sills with fill and low/high marsh plantings	$ 490,000
C-F	Headland breakwaters with fill and low/high marsh plantings as well as upland brush plantings	$ 950,000
	TOTAL	**$ 1,790,000**

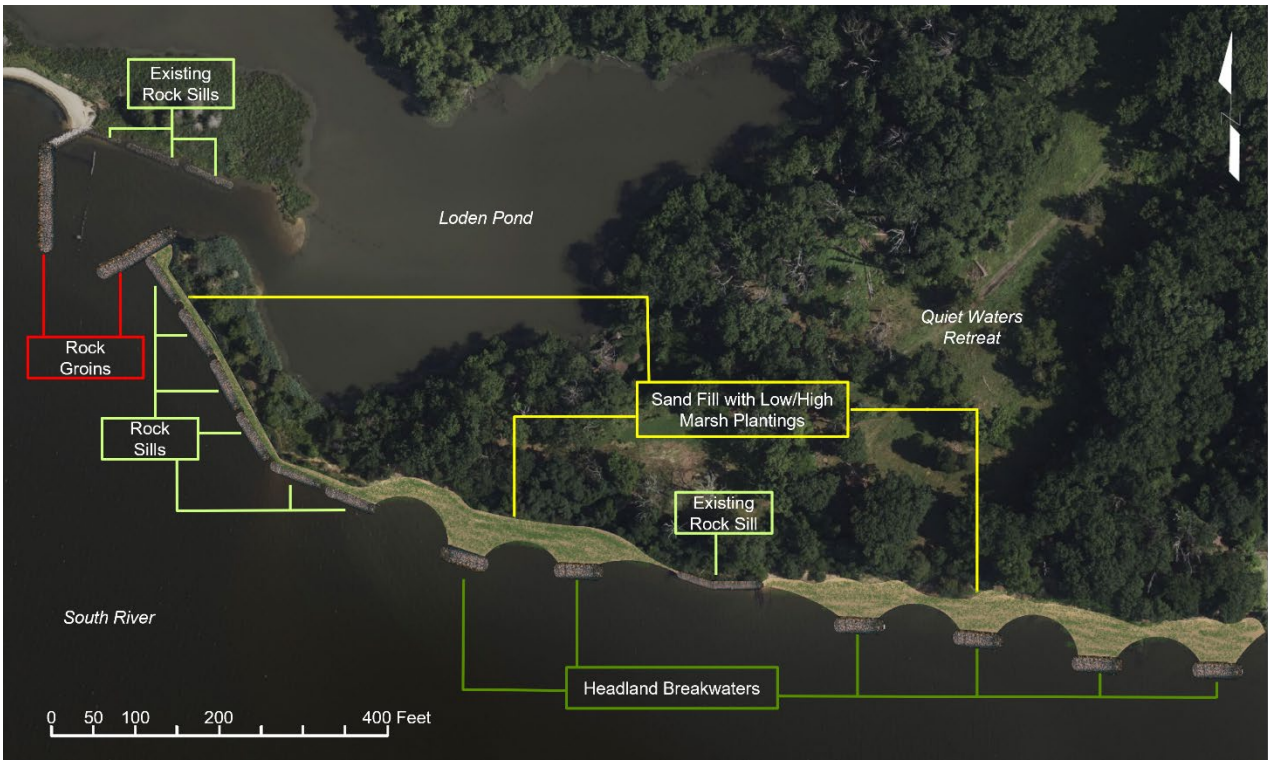


Figure 7. Conceptual layout for recommended shoreline solutions at Quiet Waters Retreat, where the colored labels represent various shoreline protection elements.

4.2 Entrance to Harness Creek

4.2.1 Existing Conditions

The Entrance to Harness Creek (Segment 4) is exposed to moderate wind-wave energy and boat wakes from the South River and Harness Creek, resulting in severe historical erosion along the reach. Shoreline solutions considered account for the two distinct shoreline types and orientations along the reach (Figure 8). Images of the current conditions at the reach are provided in Figure 9.



Figure 8. Entrance to Harness Creek segmented cells.

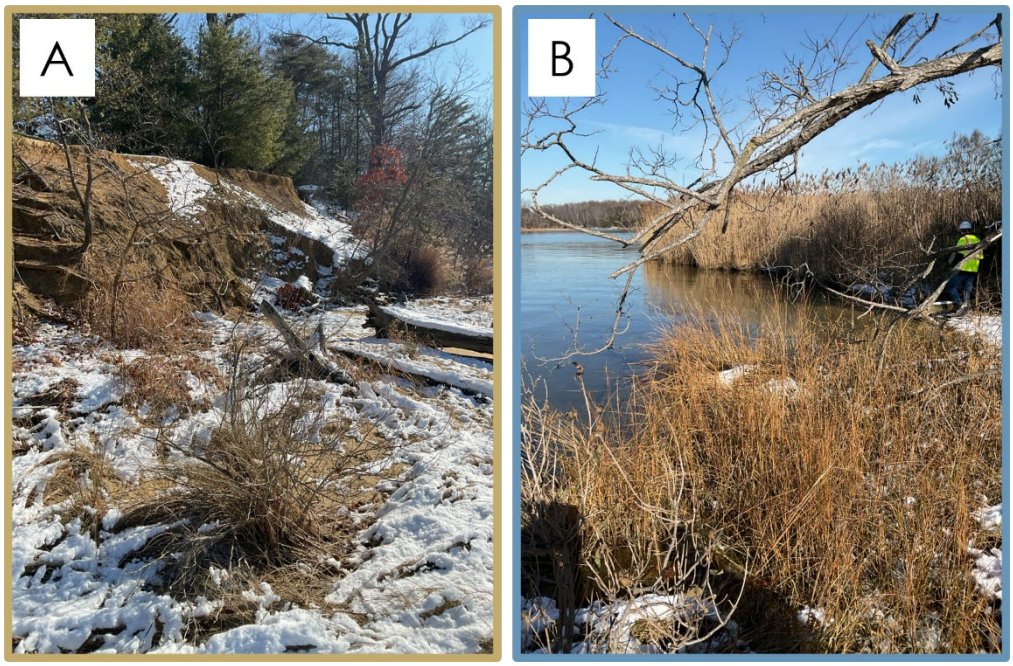


Figure 9. Entrance to Harness Creek segmented shorelines images from Stantec field reconnaissance (Appendix B).

Segment A: The segment is exposed to moderate wave energy from the South River. Adjacent to this shoreline there is a rock sill that abuts the bulkhead along the South River Overlook shoreline. Segment A includes steep, unvegetated bluffs fronted by a beach with occasional planting and oyster shell middens (Figure 9A). Additionally, large manmade footpaths exist with steep banks which may contribute to shoreline conditions.

Segment B: This segment encompasses the marsh at the confluence of the South River with Harness Creek. The marsh is generally healthy with some invasive plants noted by Park staff, and historical erosion rates indicate that the shoreline is receding (Figure 9B). This section historically has the highest erosion rate at the Park.

4.2.2 Desired Project Outcomes and Potential Solutions

Desired outcomes for the Entrance to Harness Creek include:

- **Reduced erosion** and shoreline stabilization
- **A calmer nearshore environment** to foster marsh health
- **Reduced public use**, particularly from boaters accessing the shoreline, of undesignated walkways
- **Educational enrichment** for boaters and park visitors using the South River Overlook walkway
- **Habitat creation** that honors the site's oyster middens

Stantec explored hybrid solutions that are compatible with the site's moderate wave energy and the desire to promote oyster recruitment. Upland solutions were also considered to limit trespass on undesignated paths. Potential solutions for the Entrance to Harness Creek shoreline are provided in Table 5.

Table 5. Solutions matrix for the Entrance to Harness Creek.

Potential Solutions	Relative Expense	Shoreline Cells	BENEFITS EVALUATION (HIGH, MEDIUM, LOW)							
			Shoreline Stabilization	Nature-based Solution	Climate Change Resiliency and Adaptability	Habitat Enhancement	Recreation, Accessibility, and Education Enrichment	Regulatory Feasibility	Ease of Maintenance	Constructability
Rock Sill with Fill and Plantings	$$	A, B	High	Medium	Medium	Medium	Medium	Medium	Medium	High
Living Breakwaters with Oyster Spat	$$	A, B	Medium	High	Medium	High	High	Medium	Medium	Medium
Rock Sill with Tide Pool	$$	A, B	High	Medium	Medium	High	High	Medium	Medium	High
Dynamic Revetment	$$	B	Medium	Medium	High	Medium	Medium	Medium	Low	High

4.2.3 Recommended Solution and Cost Estimate

It is recommended to install living breakwaters that honor the existing middens and natural habitat along the Entrance to Harness Creek shoreline as well as provide marsh restoration. The solutions will offer shoreline protection, potential marsh creation, and educational opportunities for park visitors to learn about the historical oyster habitat as well as nature-based solutions. Construction of the living breakwaters is similar to traditional offshore structures and will require a barge to place units; given the exposure to waves and boat wakes, it is recommended to consider design with robust substate units, such as Supra Reef Balls. The level of protection provided depends on successful oyster recruitment, and additional monitoring and maintenance may be needed. It is also recommended to remove invasives from the existing marsh and install native plantings, where necessary, to foster native species growth. It is anticipated that sediment will naturally accrete behind the living breakwaters potentially support natural marsh creation. A conceptual layout for the recommended solution is provided in Figure 10.

Stantec also recommends installing woody debris barriers in combination with interpretive or regulatory signage to address shoreline erosion exacerbated by foot traffic. This approach would help direct visitors to the designated trails and shoreline access points, discourage continued informal shoreline access, and support passive restoration of disturbed areas. Woody debris may be sourced from fallen trees, large branches, or vegetation removed elsewhere in the Park. Because much of the eroded area is within existing forested areas, fill and grading of the large path on site are not recommended, as it could damage or smother tree roots and lead to tree mortality.

Planning level construction cost estimates for the implementation of the recommended solution elements are provided with a 20% contingency (Table 6). The estimated cost includes the materials, trucking, and labor required to construct the design. The cost does not account for maintenance once the project is complete or engineering services during construction. Costs are determined based on linear feet (LF) of shoreline as well as the assumptions provided in Appendix E. Mobilization and demobilization costs are computed based on entire shoreline reach and cost efficiency is maximized when stabilization solutions are implemented simultaneously. The full mobilization and demobilization cost is distributed among shoreline solutions proportional to anticipated project costs. A cost estimate for the entire shoreline reach is provided in Section 5.

Table 6. Cost estimate for recommended solutions at the Entrance to Harness Creek.

Shoreline Segment	Stabilization Solution	Estimated Cost
A-B	Living breakwaters	$ 710,000
A-B	Marsh restoration (invasives species removal and low/high marsh plantings)	$ 120,000
A-B	Wood debris barriers	$ 10,000
	TOTAL	**$ 840,000**

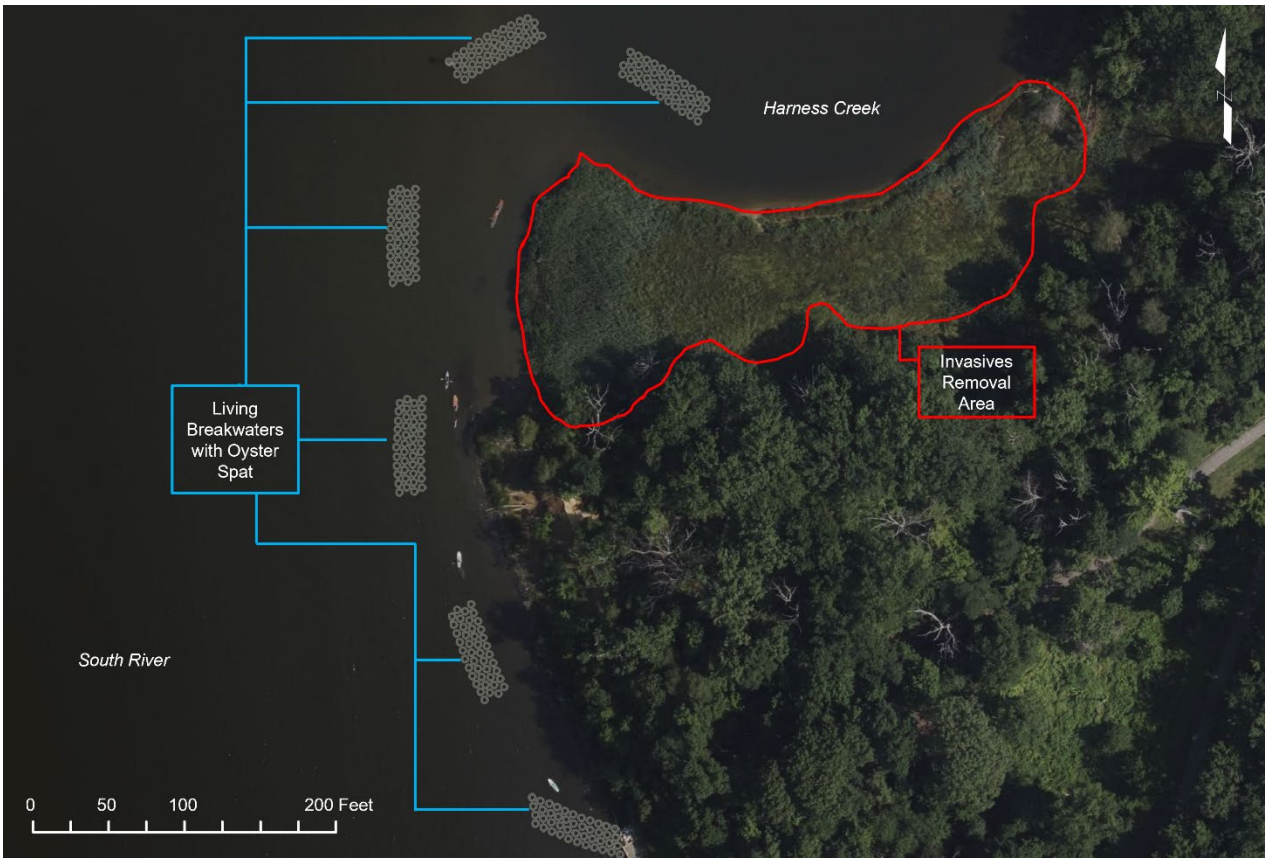


Figure 10. Conceptual layout for recommended solutions at the Entrance to Harness Creek, where the colored labels represent various components of the recommended solution.

4.3 Boat Rental Shoreline

4.3.1 Existing Conditions

The Boat Rental Shoreline (Segment 8) is characterized with steep, unvegetated bluffs and Park amenities offering important water access and recreational amenities to the public. The Boat Rental Shoreline is split into two segments, as depicted in Figure 11, with images of the current conditions provided in Figure 12.



Figure 11. Boat Rental Shoreline segmented cells with ARF project footprint in white.

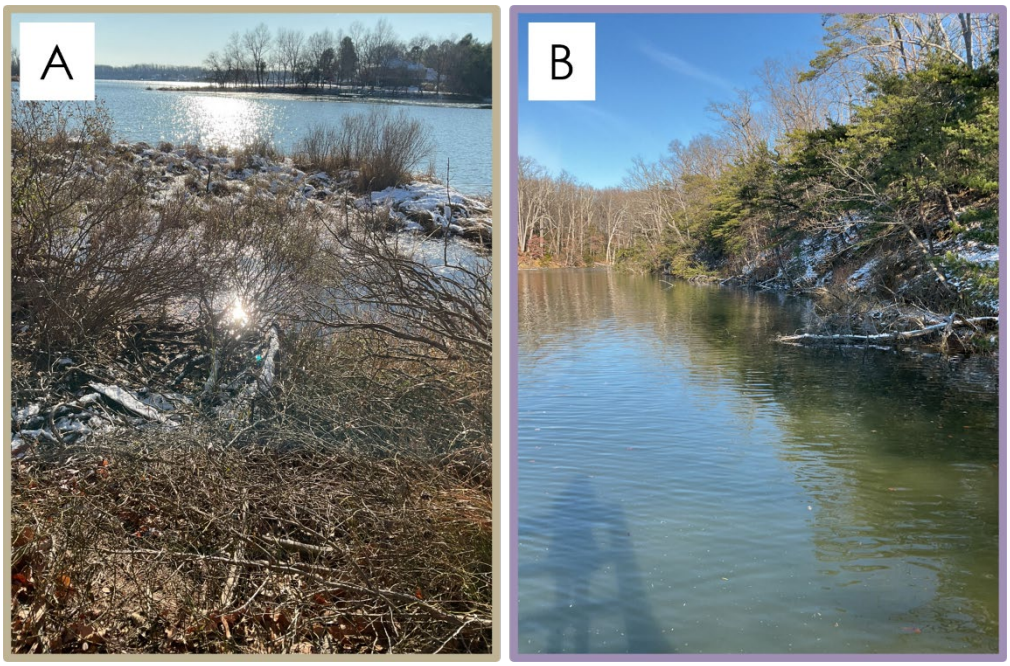


Figure 12. Boat Rental Shoreline segmented shorelines images from Stantec field reconnaissance (Appendix B).

Segment A: The segment includes a small, healthy marsh and the soft kayak launch area to the south of the dock (Figure 12A). Upland of the marsh is a trail system with fenced overlooks and signage indicating unstable bluffs and significant shoreline erosion.

Segment B: The northern portion of the Boat Rental Shoreline (Figure 12B) includes undercut, partially vegetated embankments with fallen brush and trees. The shoreline orientation of Segment B results in a lower energy wave climate than Segment A.

4.3.2 Desired Project Outcomes and Potential Solutions

Desired outcomes for the Boat Rental Shoreline include:

- **Cohesive shoreline protection** with the Anne Arundel River Foundation (ARF) living shoreline project
- **Habitat creation and educational enrichment** for the public

Segment A is adjacent to the ARF project, which includes a variety of hybrid shoreline stabilization solutions (i.e., rock and brush bank toe stabilization, reef balls, marsh fill, etc.). Stabilization measures along Segment A should integrate and work in conjunction with ARF's planned work. In discussion with the Resilience Authority and the DRP, the erosion along Segment B is not inherently problematic to Park functions and offerings. Park staff are interested in allowing this shoreline to naturally adapt and provide solutions that emphasize habitat and educational enrichment.

Segment A experiences moderate wave energy, therefore hybrid solutions were considered. Segment B is in a lower-energy environment, making it well suited for both natural and hybrid approaches. Stantec considered solutions that complement and align with ARF's plans, mitigate erosion, and provide ecological uplift. The potential solutions for the Boat Rental Shoreline are provided in Table 7.

Table 7. Solutions matrix for the Boat Rental Shoreline.

Potential Solutions	Relative Expense	Shoreline Cells	BENEFITS EVALUATION (HIGH, MEDIUM, LOW)							
			Shoreline Stabilization	Nature-based Solution	Climate Change Resiliency and Adaptability	Habitat Enhancement	Recreation, Accessibility, and Education Enrichment	Regulatory Feasibility	Ease of Maintenance	Constructability
Bank Stabilization with Brush Toe	$$	B	Medium	High	Low	High	High	High	Medium	Medium
Living Breakwaters with Oyster Spat	$$	A, B	Medium	High	High	High	High	Medium	Medium	Medium
Reef Balls with Oyster Spat (ARF Project Extension)	$$	A, B	Medium	Medium	Medium	High	High	Medium	Medium	High
Shell-filled Gabions	$	B	Medium	High	Medium	High	High	Medium	Medium	Medium
Bank Stabilization with Rock Toe	$$	B	High	Low	Medium	Low	Low	High	High	High
Floating Wetlands	$$$	B	Low	High	High	High	High	Medium	Low	Medium

4.3.3 Recommended Solution and Cost Estimate

As reef balls are proposed within the ARF Living Shoreline Project, it is recommended to implement reef balls backed with fill and marsh plantings along Segment A. The continuation of shoreline protection will protect the shoreline and marsh system and enhance the aquatic habitat potential. Application of Mini Bay Balls, or a similar sized product, will ensure proposed shoreline protection elements align with reef ball elements used in the ARF Living Shoreline Project. Along Segment B, it is recommended to add floating wetlands. The floating wetlands provide shoreline protection benefits by reducing wave energy approaching the shoreline; however, the primary benefits focus on habitat creation for waterfowl and fish, improved

water quality, and additional educational enrichment for park visitors. Floating wetlands can be rectangular or circular units. A conceptual layout for the recommended solution is provided in Figure 13.

Planning level construction cost estimates for the implementation of the recommended solution elements are provided with a 20% contingency (Table 8). The estimated cost includes the materials, trucking, and labor required to construct the design. The cost does not account for additional maintenance once the project is complete or engineering services during construction. Costs are determined based on linear feet (LF) of shoreline as well as the assumptions provided in Appendix E. Mobilization and demobilization costs are computed based on the entire shoreline reach and cost efficiency is maximized when stabilization solutions are implemented simultaneously. The full mobilization and demobilization cost is distributed among shoreline solutions proportional to anticipated project costs. A cost estimate for the entire shoreline reach is provided in Section 5.

Table 8. Cost estimate for recommended solutions at the Boat Rental Shoreline.

Shoreline Segment	Stabilization Solution	Cost Estimate
A	Reef balls with fill and low/high marsh plantings	$ 280,000
B	Floating wetlands	$ 130,000
	TOTAL	**$ 410,000**

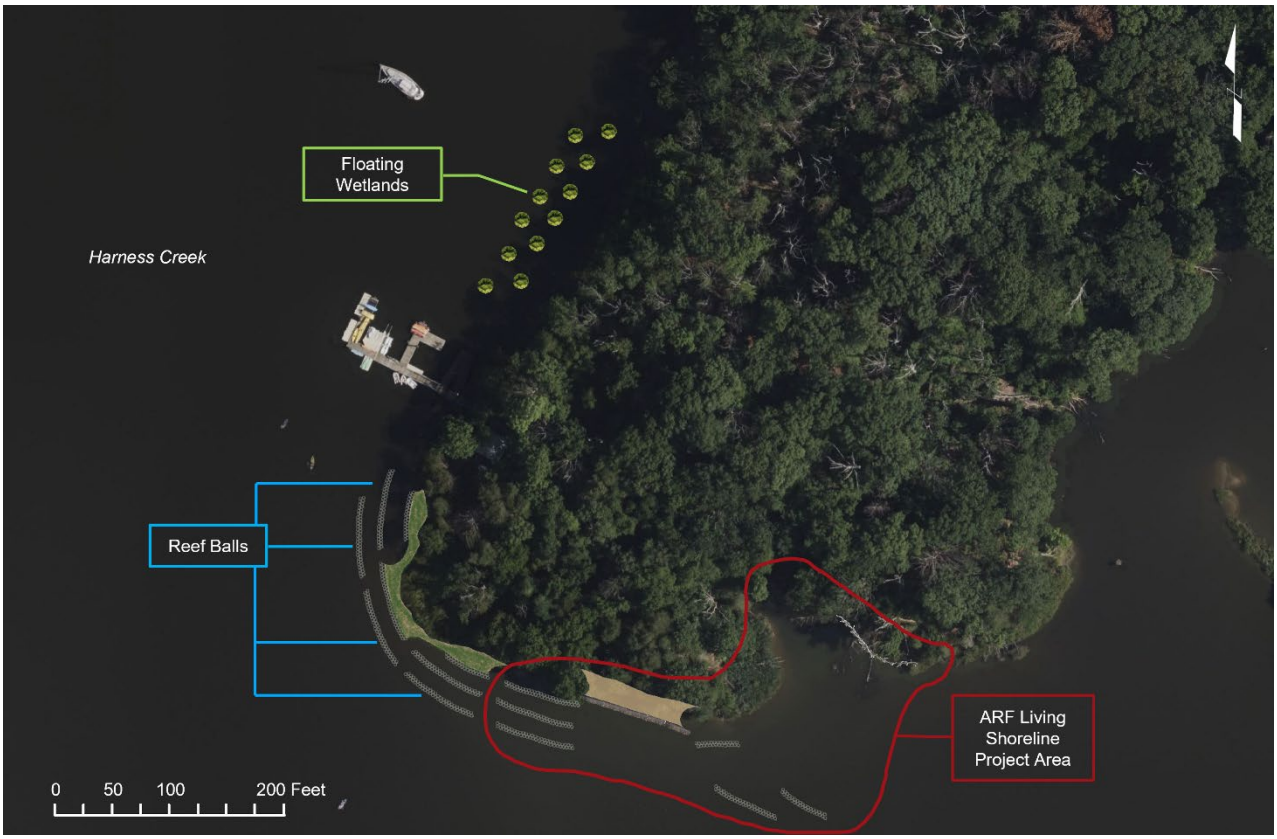


Figure 13. Conceptual layout for recommended solution at the Boat Rental Shoreline, where the colored labels represent different shoreline protection elements.

4.4 Loden Pond

4.4.1 Existing Conditions

Loden Pond (Segment 2) is a protected embayment with low wave energy and healthy wetlands. There is some undercutting along the Pond embankments, which is likely due to currents rather than waves due to the limited fetch within the pond. The entrance to the Pond periodically closes, which interrupts the water access and tidal flushing. Additionally, Park staff are concerned that water quality within Loden Pond is negatively impacted by nutrient loading from runoff at the Dog Park. Furthermore, Loden Pond will be an increasingly visible and visited area for Park visitors with the implementation of upland infrastructure detailed in the Quiet Waters Retreat Master Plan. The Loden Pond shoreline is depicted in Figure 14, with an image of the current conditions at the reach provided in Figure 15.



Figure 14. Loden Pond segmented cells.



Figure 15. Loden Pond shoreline image from Stantec field reconnaissance (Appendix B).

4.4.2 Desired Project Outcomes and Potential Solutions

Desired outcomes for Loden Pond include:

- **Shoreline stabilization** to protect planned upland infrastructure
- **Habitat enhancement** through green infrastructure practices
- **Education enrichment** through demonstration of nature-based solutions for shoreline protection and habitat creation
- **Improved water quality** and reduced nutrient loading from stormwater runoff

Loden Pond is a low wave energy environment suitable for natural shoreline solutions. The Pond presents strong potential for habitat restoration, so habitat enhancement features were incorporated into the development of shoreline alternatives. Additionally, stormwater management strategies were evaluated to reduce nutrient loading and improve overall water quality within the Pond. Potential solutions explored for Loden Pond are provided in Table 9.

Table 9. Solutions matrix for Loden Pond.

Potential Solutions	Relative Expense	Shoreline Cells	BENEFITS EVALUATION (HIGH, MEDIUM, LOW)							
			Shoreline Stabilization	Nature-based Solution	Climate Change Resiliency and Adaptability	Habitat Enhancement	Recreation, Accessibility, and Education Enrichment	Regulatory Feasibility	Ease of Maintenance	Constructability
Loose Shell Sills	$	A	Low	High	Low	High	High	Medium	Low	High
Marsh Terraces	$$	A	Medium	High	High	High	High	Medium	Medium	Medium
Bank Stabilization with Brush Toe	$$	A	Medium	High	Low	High	High	High	Medium	Medium
Floating Wetlands	$$	A	Low	High	High	High	High	High	Low	Medium
SAV and Wetland Plantings	$	A	Low	High	High	High	High	High	Medium	High
Oyster Bags and Coir Logs with Fill	$	A	Medium	High	Medium	High	High	Medium	Medium	Medium
Shell-filled Gabion Pens	$	A	Medium	High	Updated	High	High	Medium	Medium	Medium

4.4.3 Recommended Solution and Cost Estimate

It is recommended to implement a combination of solutions within Loden Pond that offer a multitude of shoreline and habitat benefits along with educational value. Along the sheltered eastern cove of the Pond, it is recommended to add SAV as well as fill and wetland plantings. The plantings will provide an additional buffer to mitigate erosion-inducing forces while increasing biodiversity and habitat. It is recommended to install coir logs and oyster bags along the edge of the pond fronting Quiet Waters Retreat. Bio-degradable, coconut fiber coir logs help stabilize the shoreline in low energy areas and the oyster shell bags will encourage oyster recruitment, which can in turn help with the water quality. Stantec also recommends the use of shell-filled gabion pens along the northern portion of the pond to foster oyster recruitment and improve water quality concerns associated with stormwater runoff. A conceptual layout for the recommended solution is provided in Figure 16.

In addition to shoreline protection measures, upland stormwater management is considered to improve water quality conditions within Loden Pond. Runoff from the Dog Park is a likely contributor to bacteria and nutrient loading in Loden Pond. Given the narrow footprint between the Dog Park and forested areas, it is recommended to install an infiltration trench to capture and treat stormwater. Providing additional waste receptacles, pet waste bag dispensers, and targeted signage would serve as a low-cost measure to improve water quality. An additional stormwater concern noted during field reconnaissance is the eroded drainage swale receiving concentrated discharge from the culvert that conveys runoff from the end of Quiet Waters Park Road near the restroom facilities. The swale exhibits minor channel incision and could be stabilized through appropriately sized riprap armoring or other localized energy-dissipation measures. A combination of upland solutions will likely provide the best results for stormwater flowing into Loden Pond.

Planning level construction cost estimates for the implementation of the recommended solution elements are provided with a 20% contingency (Table 10). The estimated cost includes the materials, trucking, and labor required to construct the design. The cost does not account for additional maintenance once the project is complete or engineering services during construction. Costs are determined based on linear feet (LF) of shoreline as well as the assumptions provided in Appendix E. Mobilization and demobilization costs are computed based on the entire shoreline reach and cost efficiency is maximized when stabilization solutions are implemented simultaneously. The full mobilization and demobilization cost is distributed among shoreline solutions proportional to anticipated project costs. A cost estimate for the entire shoreline reach is provided in Section 5.

Table 10. Cost estimate for recommended solutions at Loden Pond.

Shoreline Segment	Stabilization Solution	Estimated Cost
A	Shell-filled gabion pens (northern portion of Loden Pond)	$ 50,000
A	SAV (eastern embayment of Loden Pond)	$ 190,000
A	Fill and wetland plantings (northern QWR overlook)	$ 380,000
A	Coir logs, oyster shell, fill, and plantings (southeastern QWR overlook)	$ 60,000
A	Infiltration trench	$ 100,000
	TOTAL	**$ 780,000**

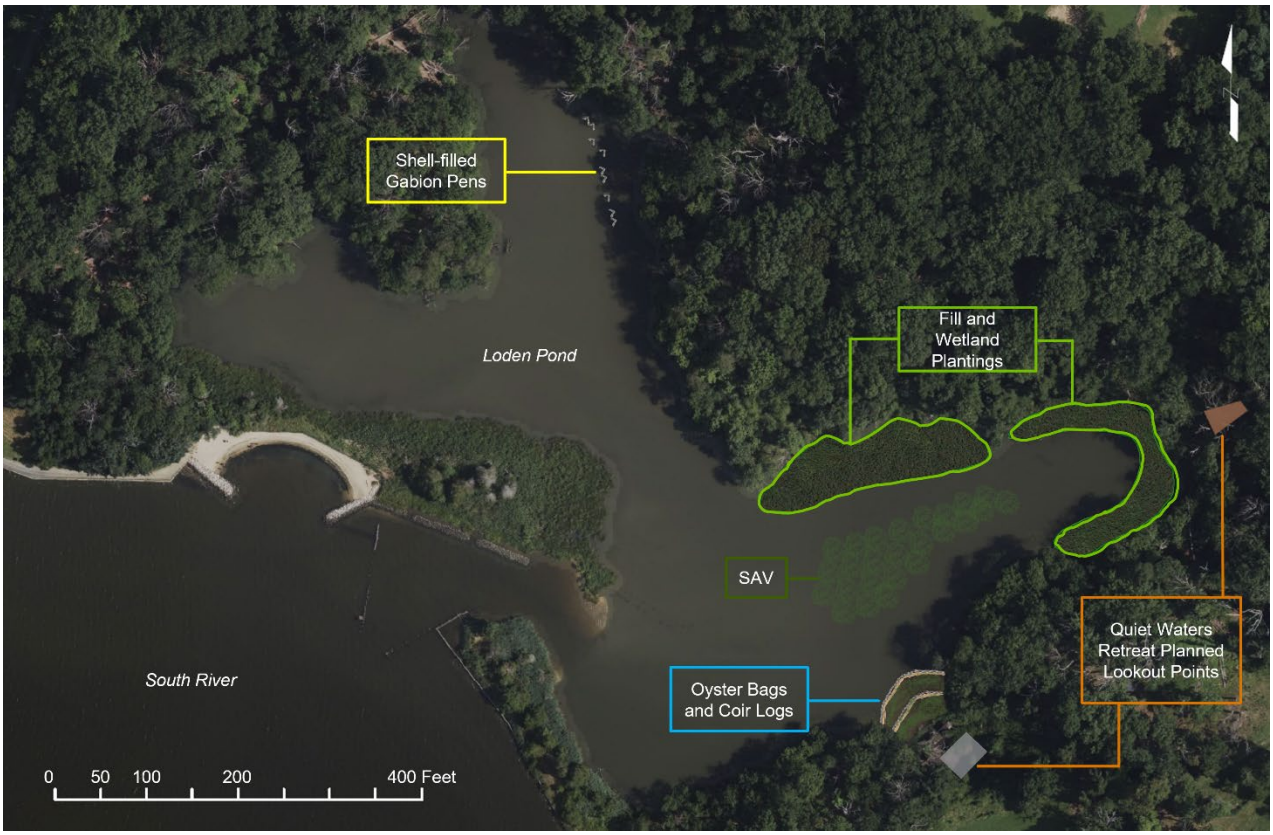


Figure 16. Conceptual layout for recommended solution at Loden Pond, where the colored labels represent various shoreline protection elements.

4.5 Harness Creek Inlet Shoreline

4.5.1 Existing Conditions

The Harness Creek Inlet Shoreline (Segment 5) is characterized by steep bluffs with sparse vegetation. The shoreline experiences moderate wind-generated waves and boat wakes. Notable erosion along undesignated upland trails that act as runnels was observed during field reconnaissance. Conditions along

the Harness Creek Inlet Shoreline are fairly homogenous. The Harness Creek Inlet Shoreline is depicted in Figure 17, with an image of the current conditions at the reach provided in Figure 18.



Figure 17. Harness Creek Inlet Shoreline segmented cells.



Figure 18. Harness Creek Inlet Shoreline image from Stantec field reconnaissance (Appendix B).

4.5.2 Desired Project Outcomes and Potential Solutions

The desired outcome along the Harness Creek Inlet Shoreline include:

- **Shoreline stabilization** that reduces wave energy, boat wakes, and concentrated runoff
- **Improved public safety** through deterred use of undesignated trails from boaters and Park visitors

Stantec explored both in-water and upland solutions to disincentivize shoreline access and reduce erosion hazards. As the Harness Creek Inlet Shoreline experiences both wind and boat wake induced waves, hybrid solutions were considered rather than fully natural solutions. The potential solutions for Harness Creek Inlet are provided in Table 11.

Table 11. Solutions matrix for the Harness Creek Inlet Shoreline.

Potential Solutions	Relative Expense	Shoreline Cells	BENEFITS EVALUATION (HIGH, MEDIUM, LOW)							
			Shoreline Stabilization	Nature-based Solution	Climate Change Resiliency and Adaptability	Habitat Enhancement	Recreation, Accessibility, and Education Enrichment	Regulatory Feasibility	Ease of Maintenance	Constructability
Rock Sill with Fill and Plantings	$$	A	High	Medium	Medium	Medium	Medium	Medium	Medium	High
Headland Breakwaters with Fill and Low/High Marsh Plantings	$$	A	High	Medium	Medium	Medium	Medium	Medium	Medium	High
Submerged Living Breakwaters	$	A	Medium	Medium	Medium	High	High	Medium	High	Medium
Submerged Rubble Mound Breakwaters	$	A	High	Low	Low	Low	High	Medium	High	High

4.5.3 Recommended Solution and Cost Estimate

Stantec recommends implementing submerged living breakwaters, such as reef balls with oyster spat, along the Harness Creek Inlet Shoreline. For project economy, it is recommended to prioritize structure placement along the shoreline reach with upland infrastructure, such as parking lots. The Park can add structures, using robust living breakwater units like Supra Reef Balls, to the northeast shoreline and expand the shoreline protection footprint, if desired. The submerged structures will dissipate wave energy, offer habitat creation, and reduce opportunities for boats to approach the shoreline. Offshore signage will be required to warn boaters of the submerged hazards. A conceptual layout for the recommended solution is provided in Figure 19.

Stantec also recommends installing woody debris barriers, in combination with interpretive or regulatory signage, to discourage undesignated Park access and promote passive restoration of disturbed areas. Woody debris may be sourced from fallen trees, large branches, or vegetation removed elsewhere in the park.

Planning level construction cost estimates for the implementation of the recommended solution elements are provided with a 20% contingency (Table 12). The estimated cost includes the materials, trucking, and labor required to construct the design. The cost does not account for additional maintenance once the

project is complete or engineering services during construction. Costs are determined based on linear feet (LF) of shoreline as well as the assumptions provided in Appendix E. Mobilization and demobilization costs are computed based on the entire shoreline reach and cost efficiency is maximized when stabilization solutions are implemented simultaneously. The full mobilization and demobilization cost is distributed among shoreline solutions proportional to anticipated project costs. A cost estimate for the entire shoreline reach is provided in Section 5.

Table 12. Cost estimate for recommended solutions at the Harness Creek Inlet Shoreline.

Shoreline Segment	Stabilization Solution	Estimated Cost
A	Submerged living breakwaters	$ 700,000
A	Wood debris barriers	$ 20,000
	TOTAL	**$ 720,000**

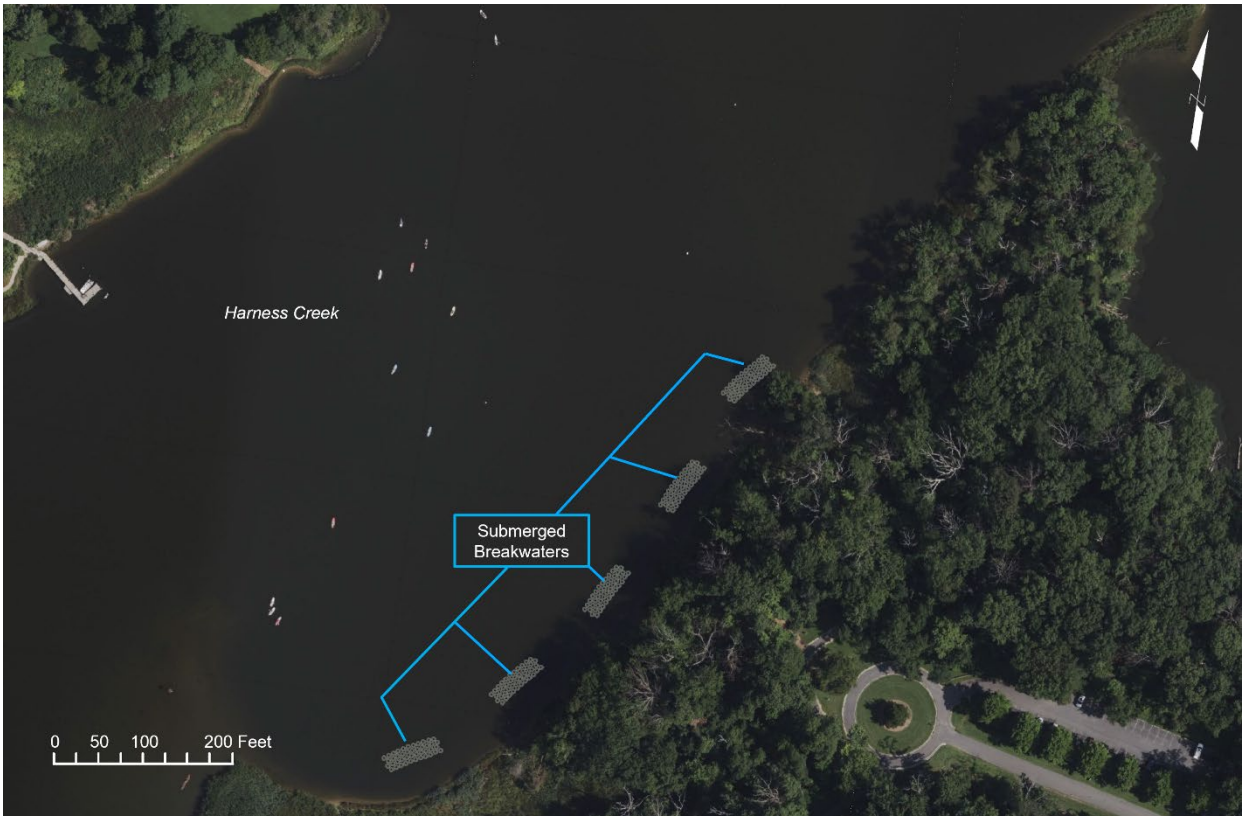


Figure 19. Conceptual layout for recommended solution at the Harness Creek Inlet Shoreline.

4.6 Wildwood Trail Shoreline

4.6.1 Existing Conditions

Wildwood Trail Shoreline is relatively uniform and characterized by eroded, unvegetated banks with no natural buffering system or protective infrastructure. The shoreline experiences moderate boat wake energy

but is in a low energy environment for wind driven waves. The Wildwood Trail Shoreline is depicted in Figure 20, with an image of the current conditions at the reach provided in Figure 21.



Figure 20. Wildwood Trail Shoreline segmented cells.



Figure 21. Wildwood Trail Shoreline image from Stantec field reconnaissance (Appendix B).

4.6.2 Desired Project Outcomes and Potential Solutions

Wildwood Trail Shoreline is currently the lowest priority for implementing protection measures. Although significant erosion has been observed, the retreating shoreline is not expected to threaten critical existing or planned Park infrastructure, and Park staff intend to monitor site conditions before implementing stabilization measures. Park staff have indicated a preference for low-maintenance solutions for this reach that can be implemented as needed. The potential solutions considered for Wildwood Trail Shoreline are provided in Table 13.

Table 13. Solutions Matrix for Wildwood Trail Shoreline.

Potential Solutions	Relative Cost	Shoreline Cells	BENEFITS EVALUATION (HIGH, MEDIUM, LOW)							
			Shoreline Stabilization	Nature-based Solution	Climate Change Resiliency and Adaptability	Habitat Enhancement	Recreation, Accessibility, and Education Enrichment	Regulatory Feasibility	Ease of Maintenance	Constructability
Living Breakwaters with Oyster Spat	$$	A	Medium	High	Medium	High	High	Medium	Medium	Medium
Floating Wetlands	$$	A	Low	High	High	High	High	Medium	Low	Medium
Bluff Regrading and Plantings	$$$	A	High	High	Low	Medium	Low	High	High	Low

4.6.3 Recommended Solution and Cost Estimate

It is recommended to monitor erosion along the Wildwood Trail Shoreline and refrain from implementing designed shoreline protection measures at this time. If action is required or the Park wishes to implement shoreline protection measures, Stantec recommends utilizing living breakwater elements, such as reef balls, that can be readily deployed and implemented for shorter shoreline segments.

Planning level construction cost estimates for the implementation of the recommended solution elements are provided with a 20% contingency (Table 14). The estimated cost includes the materials, trucking, and labor required to construct the design. The cost does not account for additional maintenance once the project is complete or engineering services during construction. Costs are determined based on linear feet (LF) of shoreline as well as the assumptions provided in Appendix E. Due to the extent of the Wildwood Trail Shoreline, the cost estimate reflects only areas of significant erosion, totaling approximately 930 linear feet of shoreline, as depicted in Figure 22. A cost estimate for the shoreline reach is provided in Section 5.

Table 14. Cost estimate for recommended solution at the Wildwood Trail Shoreline.

Shoreline Segment	Stabilization Solution	Estimated Cost
A	Reef balls	$ 460,000
	TOTAL	**$ 460,000**



Figure 22. Area of significant erosion at Wildwood Trail Shoreline.

5 Conclusion

Stantec explored a variety of shoreline protection solutions for six (6) priority shoreline segments at Quiet Waters Park. Stantec, the Resilience Authority, and the DRP closely coordinated to recommend solutions that address coastal and climate hazards, support existing and planned Park functions, acknowledge maintenance limitations, promote public safety, and offer community engagement and enrichment. A summary of recommended solutions for key shoreline segments and estimated project costs are provided in Table 15. Funding is dynamic, so these costs account for contingency and final costs may be different than what is proposed below. The Engineer's Opinion of Probable Costs has been developed based on Stantec's review of past purchase orders, cost estimation tools, construction estimates from other consultants, industry knowledge, recent contract bids, and historical costs on similar projects using the best available information at the time of estimation. Recent market volatility has had significant impacts on material costs and shipping lead times. As solutions at this phase of work are conceptual, estimated costing does not account for detailed design quantities and potential escalation of material and labor pricing at the time of design and construction. All assumptions to compute the cost estimate (i.e., rock sizes, structure dimensions) are provided in Appendix E.

Table 15. Summary of recommended solutions and associated costs.

Shoreline Segment	Recommended Solutions	Total Cost
Quiet Waters Retreat (Segment 1)	• Rock groins • Rock sills • Headland breakwaters with fill and high/low marsh plantings • Upland brush plantings	$ 1,790,000
Entrance to Harness Creek (Segment 4)	• Living breakwaters with oyster spat • Invasives removal • Wood debris barrier • Low/high marsh plantings	$ 840,000
Boat Rental Shoreline (Segment 8)	• Reef balls • Floating wetlands	$ 410,000
Loden Pond (Segment 2)	• Fill and wetland plantings • Submerged Aquatic Vegetation • Coir logs and oyster bags • Shell-filled gabion pens • Infiltration trench	$ 780,000
Harness Creek Inlet Shoreline (Segment 5)	• Submerged breakwaters • Woody debris barrier	$ 720,000
Wildwood Trail Shoreline (Segment 9)	• Reef balls	$ 460,000

References

Anne Arundel Recreation and Parks. “Quiet Waters Retreat Master Plan (Project No.: A720053400, Contract No.: P584607).” Anne Arundel Recreation and Parks, 2025.

ECOncrete. “ECOncrete – Resilience & Ecology Built-in.” *ECOncrete*, https://econcretetech.com/. Accessed 5 July 2026.

Hardaway, Jr., C.S., Milligan, D.A., & Duhring, K. (2017). Living shoreline design guidelines for shore protection in Virginia’s estuarine environment (SCRAMSOE #463). Gloucester Point, VA: Virginia Institute of Marine Science. https://doi.org/10.21220/V5CF1N

Maryland Department of the Environment (MDE). (n.d.). *Maryland Stormwater Design Manual*, Volumes I and II. Baltimore, MD. Available at: https://mde.maryland.gov/programs/water/StormwaterManagementProgram/Pages/stormwater_design.aspx. Accessed July 22, 2026.

Maryland Department of Natural Resources. (2026). *Speed Zone Map*. Retrieved from https://experience.arcgis.com/experience/bad303cdcccf46fc9d4d7accbaa07e47

Molloy, Fran. **“**Living Seawalls in Global Spotlight for Boosting Marine Habitat.” *The Lighthouse*, Macquarie University, Sept. 2021, Available at: https://lighthouse.mq.edu.au/article/september-2021/Living-Seawalls-in-global-spotlight-for-boosting-marine-habitat. Accessed 5 July 2026.

Naturally Resilient Communities. (n.d.). *Living Breakwaters.* The Nature Conservancy and partners. Available at: https://nrcsolutions.org/living-breakwaters/. Accessed July 22, 2026.

Reef Ball Foundation. (n.d.). *Chocolate Bayou BUS 4A Bay Reef Balls.* Available at: https://reefball.com/texas/Livingshoreline/slides/Chocloate_Bayou_BUS_4A_Bay_Reef_Balls.html. Accessed July 22, 2026.

U.S. Fish and Wildlife Service (USFWS). (2022). *Oyster castle barrier at Gandy’s Beach.* U.S. Department of the Interior. Available at: https://www.fws.gov/media/oyster-castle-barrier-gandys-beach. Accessed July 22, 2026.

Appendix A Desktop Data Collection

Quiet Waters Park Resilience Planning & Assessment

Desktop Data Collection Report

Stantec

Prepared for:
The Resilience Authority of Annapolis and Anne Arundel County

Prepared by:
Stantec Consulting Services Inc.

Date:
December 31, 2025

Project/File:
203403333

Stantec Consulting Services Inc.

Revision Record

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
A	Draft	Sebastiao Figueira	12/18/2025	Rebecca Aiken	12/19/2025	N/A	N/A
B	Draft	Sebastiao Figueira	12/30/2025	Rebecca Aiken	12/30/2025	Todd DeMunda	12/31/2025

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Executive Summary

Quiet Waters Park (the Park) is located along the South River and Harness Creek in Anne Arundel County, Maryland. The Park encompasses a combination of natural shorelines, trails, wetlands, and supporting infrastructure that provide significant recreational, ecological, and community value. Like many coastal assets in the Chesapeake Bay region, the Park is increasingly exposed to shoreline erosion, coastal flooding, and long-term sea level rise. In support of the Park's resilience assessment and planning, this Desktop Data Collection effort compiles and evaluates available data relevant to shoreline conditions.

The Desktop Data Collection report summarizes existing regional and site-scale datasets describing physical, meteorological, oceanographic, and environmental conditions as well as climate change risks at the Park. Data sources reviewed include:

- Topographic and Bathymetric Resources
- Meteorological Conditions
- Oceanographic Conditions
- Shoreline Conditions
- Site Features and Upland Drainage
- Existing Habitat
- Critical Areas

The information compiled in this Desktop Data Collection report provides a baseline understanding of existing and future conditions at Quiet Waters Park. The findings are intended to support planning-level decision-making and to guide subsequent phases of work, including field reconnaissance, shoreline prioritization, and viable shoreline protection solution identification. While the datasets reviewed offer valuable regional and site-scale insight, additional detailed investigations will be required to confirm local conditions and advance shoreline resilience strategies toward implementation.

Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
ASOS	Automated Surface Observing System
BFE	Base Flood Elevation
cfs	Cubic Feet Per Second
CHS	Coastal Hazards System
CUDEM	Continuously Updated Digital Elevation Model
DAV	Data Access Viewer
DNR	Department of Natural Resources
FEMA	Federal Emergency Management Agency
ft	Feet
HAT	Highest Astronomical Tide
IEM	Iowa State University Environmental Mesonet
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
mph	Miles Per Hour
MSL	Mean Sea Level
MSSM	Maryland Shoreline Stabilization Mapper
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NDBC	National Data Buoy Center
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
nm	Nautical Miles
NRCS	Natural Resources Conservation Service
NW	Northwest
NWS	National Weather Service
PF	Precipitation Frequency
PDS	Partial Duration Series
RSLR	Relative Sea Level Rise
s	Seconds
S	South
SE	Southeast
SSURGO	Soil Survey Geographic Database
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1 Introduction

Quiet Waters Park (the Park) is a publicly owned recreational asset located along the South River and Harness Creek in Anne Arundel County, Maryland (Figure 1). The entire park is within Anne Arundel County and is divided into several parcels including one (1) large parcel for the Park and thirteen (13) smaller parcels that were acquired more recently, including Quiet Water Retreat on the southeastern corner of the Park. The Park includes a diverse mix of natural shorelines, trails, wetlands, and supporting infrastructure that are increasingly exposed to coastal erosion, flooding, and long-term sea level rise. Understanding existing environmental conditions and historical coastal processes is a critical first step in evaluating shoreline vulnerability and identifying appropriate resilience and shoreline management strategies.

This Desktop Data Collection report summarizes readily available regional and site-scale datasets relevant to coastal resilience planning at Quiet Waters Park. The information compiled herein includes topography and bathymetry, meteorological and oceanographic conditions, historical storms, shoreline change trends, shoreline management classifications, soils, drainage characteristics, ecological resources, and sea level rise projections. The purpose of this effort is to establish a baseline understanding of physical and environmental conditions, identify data gaps, and provide context to support subsequent planning, field investigations, and conceptual design evaluations. The analyses presented are intended for screening- and planning-level purposes and do not replace site-specific surveys or detailed engineering studies.

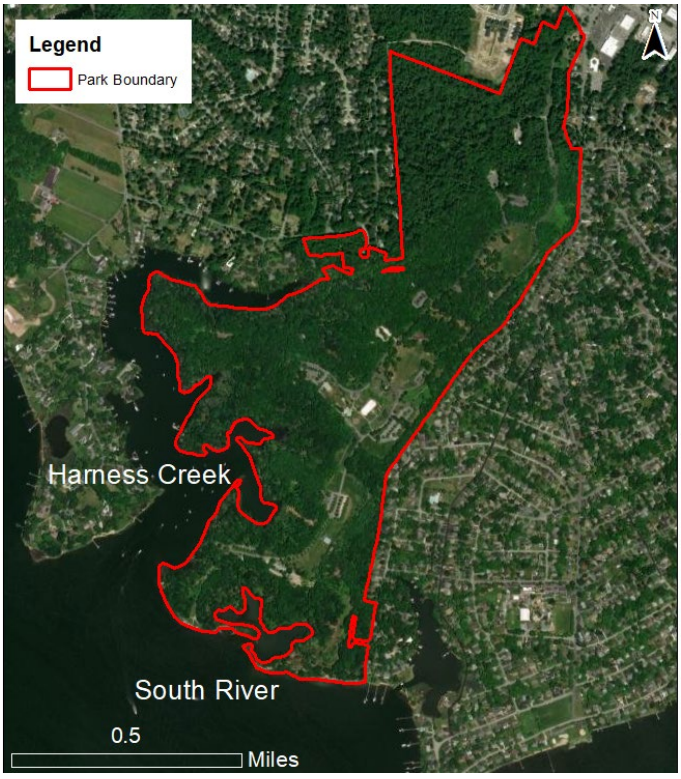


Figure 1. Overview of Quiet Waters Park in relation to the South River and Harness Creek.

2 Historical Data

A summary of existing regional and site-scale datasets describing physical, meteorological, oceanographic, and environmental conditions is provided in support of the Park's resilience assessment and planning.

2.1 Topography and Bathymetry

Topographic and bathymetric data for the project area were obtained using the National Oceanic and Atmospheric Administration (NOAA) Data Access Viewer (DAV; NOAA 2025a). The DAV provides centralized access to NOAA-supported coastal elevation datasets, including LiDAR-derived topography and bathymetry, which are commonly used for coastal analysis, mapping, and modeling applications. The datasets accessed through the DAV are based on remotely sensed and compiled elevation data and represent conditions at the time of data collection. Table 1 summarizes the topographic and bathymetric datasets that are available for Quiet Waters Park. While the data provide regional and site-scale elevation context, site-specific surveys may be required to confirm local conditions where higher accuracy or current bathymetry is needed, particularly for detailed design.

Table 1. Topographic and bathymetric datasets at Quiet Waters Park.

Dataset Name	Publication Date	Resolution (ft)	Coverage
NOAA National Geodetic Survey (NGS) Topobathymetric LiDAR	2019	3.28	Topographic and bathymetric coverage for the nearshore and shallow-water areas.
Maryland LiDAR DEM: Anne Arundel County, MD	2020	1.00	High-resolution topographic representation of upland and coastal areas (no bathymetry).
NOAA NCEI Continuously Updated Digital Elevation Model (CUDEM)	2023	9.33	1/9 arc-second Digital Elevation Model tiles covering both bathymetric and topographic data – upland, nearshore, and deep water. This dataset was initially published in 2014 and last updated in 2023.

The CUDEM data has the most expansive coverage. Figure 2 shows a sample of this dataset that shows the bathymetry and topography of the South River and surrounding area, including Quiet Waters Park.

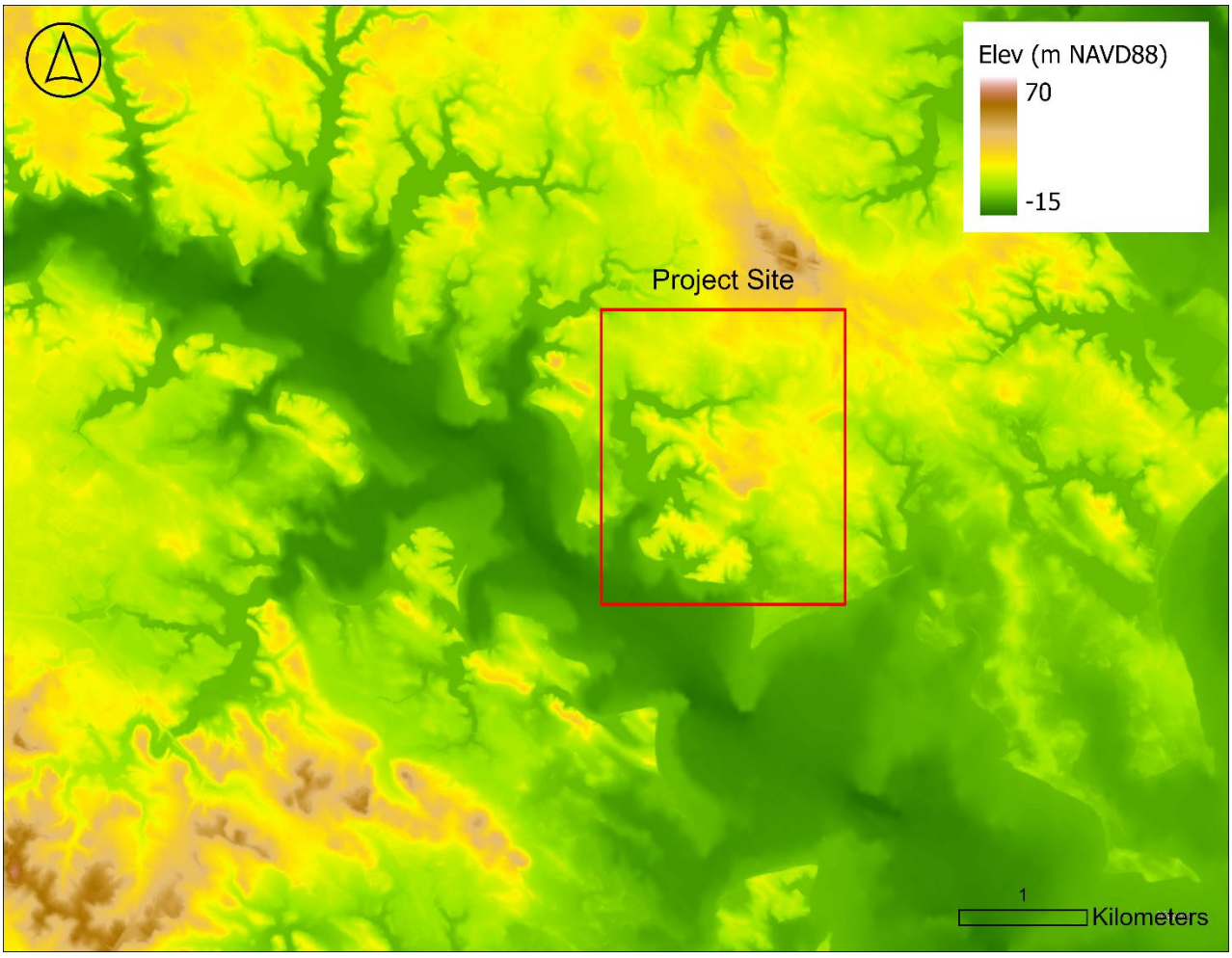


Figure 2. Sample of NOAA CUDEM topography and bathymetry data.

2.2 Meteorological Conditions

Meteorological conditions at Quiet Waters Park were characterized using available regional and site-adjacent monitoring stations. Table 2 and Figure 3 summarize the meteorological gauges reviewed for this assessment, including wind, air temperature, and rainfall datasets used to describe historical atmospheric conditions influencing the Park.

Table 2. Summary of meteorological gauges reviewed for Quiet Waters Park.

Data Type	Source	Gauge ID	Location
Wind	IEM	NAK	U.S. Naval Academy in Annapolis, MD
Wind	NOAA NCEI	TPLM2	Thomas Point, MD
Air Temperature	NOAA NDBC	44063	Offshore Annapolis, MD



Figure 3. Meteorological data stations used to characterize conditions at Quiet Waters Park.

2.2.1 Wind

Wind data for the project site were obtained from the Iowa State University Environmental Mesonet (IEM) using observations from the Automated Surface Observing System (ASOS) Station NAK, located at the U.S. Naval Academy in Annapolis, Maryland approximately 4 miles from Quiet Waters Park (IEM 2025). The station is part of the Maryland ASOS network and reports standard surface meteorological observations collected by the National Weather Service (NWS).

The IEM archive provides access to historical ASOS observations, including wind speed and wind direction, at high temporal resolution. Wind speed and direction are measured at 10 meters (33 ft) above ground

level. Available data at Station NAK begin in December 1947, with continuous digital observations available for recent decades. A wind rose for the station, using observations spanning October 2001 through September 2025, is presented in Figure 4. Wind speeds are reported in miles per hour (mph) and directions are reported using standard meteorological conventions. The wind rose also summarizes the frequency of wind speeds approaching from each direction over the analysis period.

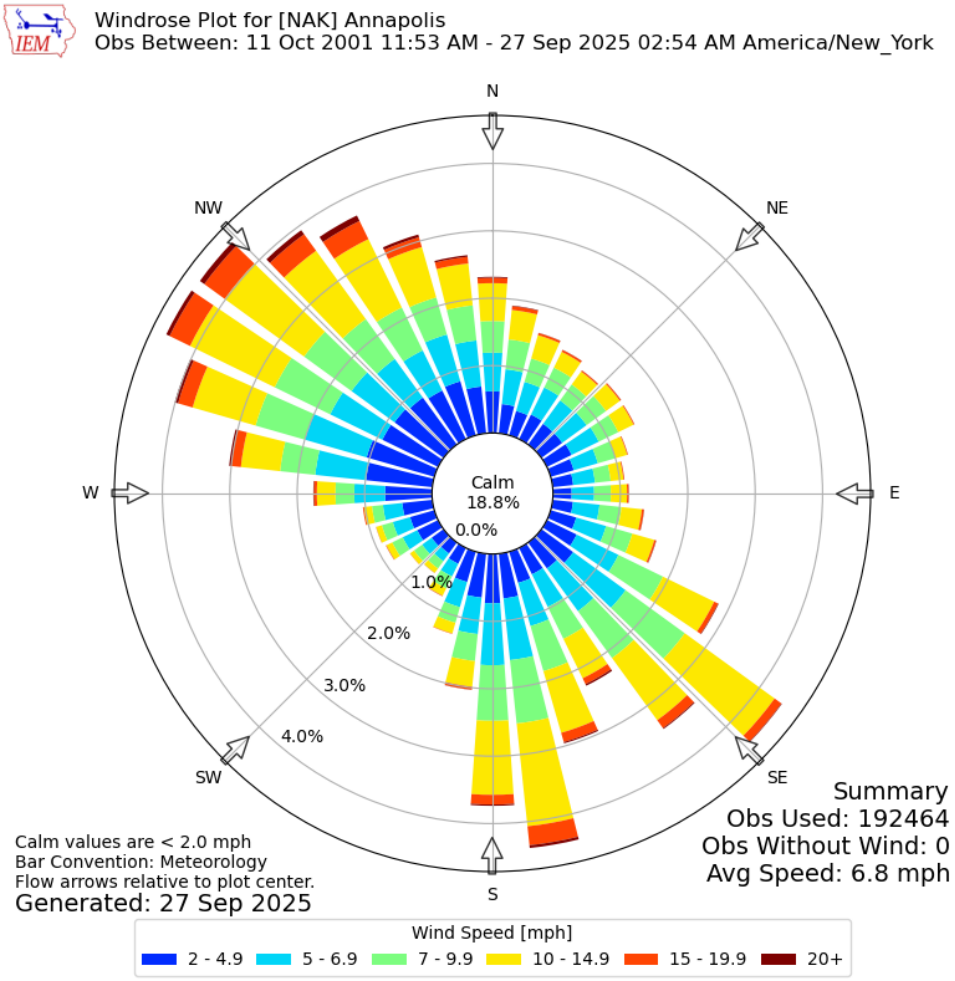


Figure 4. Wind rose at Station NAK.

Figure 4 indicates that winds most frequently occur from the southerly to northwesterly sectors, with notable contributions from the south (S), southeast (SE), west (W), and northwest (NW) directions. Winds exceeding 15 mph occur less frequently but are present across multiple directional sectors, particularly from the most frequent directions. The average wind speed over the analysis period is approximately 6.8 mph.

Winds from the southeast (SE) direction are expected to be the most influential for wind-driven wave generation at the project site due to the relatively long fetch distances across the South River and the adjacent Chesapeake Bay. Under SE wind conditions, unobstructed over-water fetch allows for greater wave development compared to winds from more sheltered directions. As a result, SE wind conditions

represent a controlling case for locally generated wind waves. The dominant wind directions and associated wave energy potential will guide appropriate identification of shoreline protection alternatives.

In addition to the IEM ASOS dataset, supplemental wind and meteorological data are available from the NOAA National Centers for Environmental Information (NCEI) Local Climatological Data archive (NOAA 2025b). The station at Thomas Point, MD (USL000TPLM2) has a period of record from December 1985 to September 2025. Data from the IEM archive and the NOAA NCEI database provide long-term, quality-controlled meteorological observations and are available for use in future analyses.

2.2.2 Air Temperature

Air temperature data for the project site were obtained from the National Data Buoy Center (NDBC) Station 44063, a moored meteorological and oceanographic observation buoy located near Annapolis, Maryland (NOAA 2025c). The buoy records a suite of marine and atmospheric variables, including air temperature measured approximately 9.8 feet (3 meters) above the sea surface, along with wind, pressure, and sea temperature observations. Air temperature data at Station 44063 are available from May 14, 2010 through December 30, 2025. These data provide a continuous, site-adjacent record of air temperature conditions representative of the coastal environment near Quiet Waters Park. Figure 5 summarizes the mean, standard deviation, and extreme atmospheric temperatures from 2010 to 2025.

Temperature data indicates the coolest temperatures occur in January while the warmest temperatures occur in July. Extremes in measured air temperatures fluctuate to below freezing during winter months while summer temperatures can reach nearly 100 °F. Consideration of temperature trends within the vicinity of the Park will support appropriate selection of vegetation in proposed nature-based solutions.

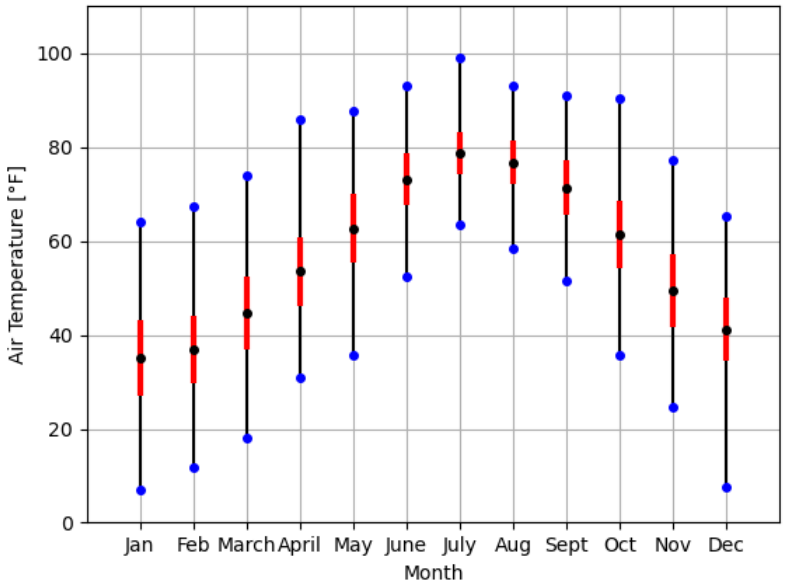


Figure 5. Mean (black dot), standard deviation (red), and maximum and minimum (blue dots) from May 2010 through December 2025 at Station 44063.

2.2.3 Rainfall

Rainfall data are available from the NOAA Atlas14 Precipitation Frequency (PF) estimates and Partial Duration Series (PDS) data at the U.S. Naval Academy Station in Annapolis (NOAA 2025d) and were retrieved on December 30, 2025. NOAA's Atlas 14 data provide a multitude of rainfall depth, duration, and frequency curves. The PF estimates associated with the 24-hour storm duration, however, are commonly applied to design rainfall inputs to stormwater infrastructure design. Precipitation depths associated with the 24-hour storm for various recurrence intervals are provided in Table 3, and may be referenced for future design.

Table 3. Precipitation frequency (PF) estimates for the 24-hour storm duration (NOAA 2025d).

Recurrence Interval (years)	Precipitation Depth (inches)
1	2.7
2	3.2
5	4.2
10	5.0
25	6.3
50	7.4
100	8.7
200	10.1
500	12.3
1,000	14.2

2.2.4 Historical Storms and Cyclones

Maryland is vulnerable to cyclonic storm events, including extratropical and tropical storm events. Since 1960, eighteen (18) storm tracks have passed within 60 nautical miles (nm) of Quiet Waters Park (Figure 6), causing heavy rainfall, high winds speeds, and storm surge (NOAA 2025e). Due to the directionality of cyclonic storm winds, storms making landfall to the south of the Chesapeake Bay – including Hurricane Isabel (2003) – can pose additional flood risks by funneling storm surge into the Chesapeake Bay.

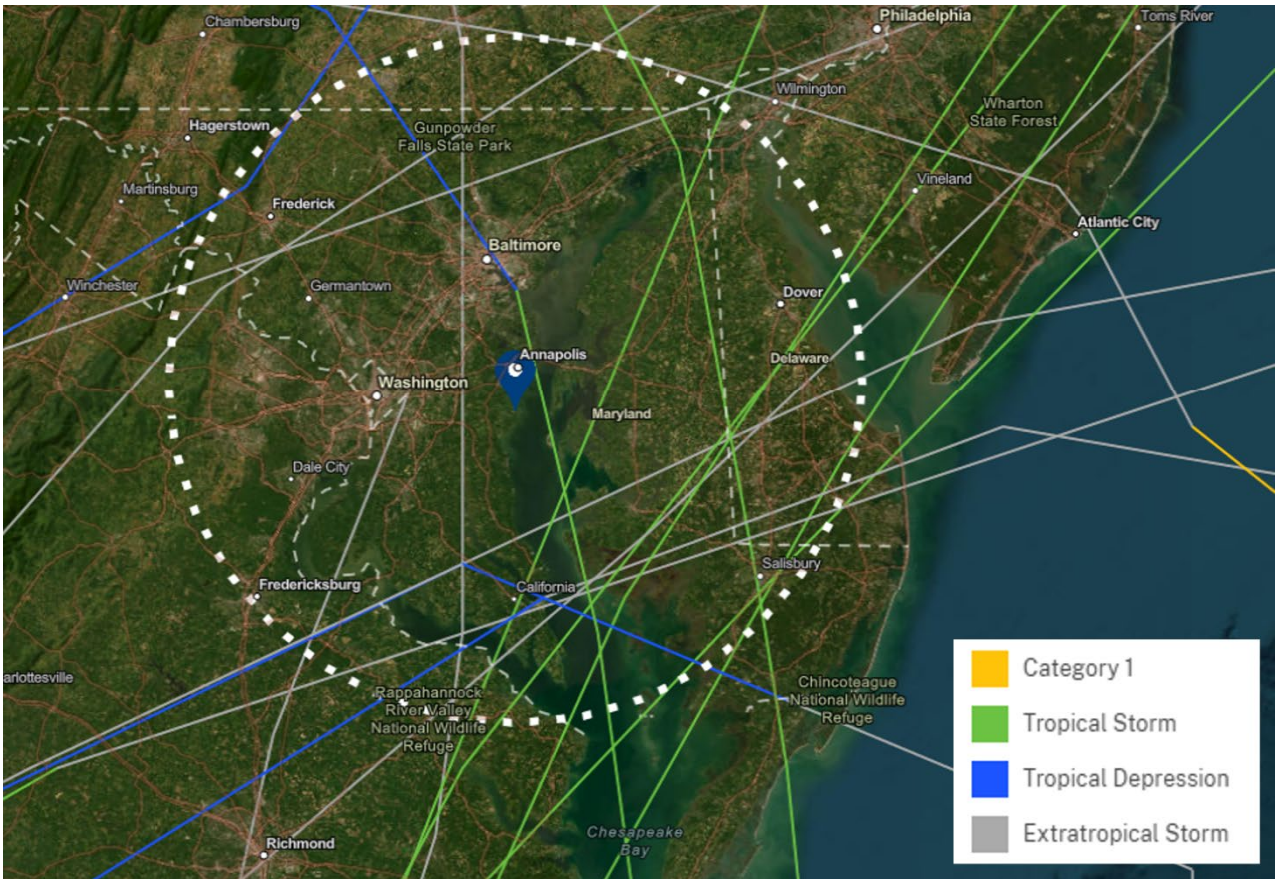


Figure 6. Historical storm tracks passing within 60 nm of Quiet Waters Park (NOAA Historical Storm Tracks, 2025).

Many storms that make landfall along the Delmarva Peninsula, the North Carolina coast, or New Jersey–Long Island corridor or tracking inland through the Mid-Atlantic produce significant storm surge, elevated water levels, rainfall-driven flooding, and wind impacts within the Chesapeake Bay and Annapolis area. This indicates the regional storm behavior and basin-scale response are critical considerations rather than solely considering landfall location. The storms included in Table 4 are historical events with documented impacts to water levels, flooding, or coastal conditions in the Annapolis region.

Table 4. Historical storm events impacting the Park and adjacent region.

Storm Name	Date	Storm Type	Approx. Closest Approach to Annapolis (mi)
1821 Norfolk–Long Island Hurricane	Sept 1821	Hurricane	~40–60
Gale of 1878	Oct 1878	Hurricane (Cat. 2 equivalent)	~50–80
Chesapeake–Potomac Hurricane	Aug 1933	Category 1 Hurricane	~30–50
Hurricane Hazel	Oct 1954	Hurricane (extratropical)	~100–150
Hurricanes Connie & Diane	Aug 1955	Hurricanes / Tropical Storms	~75–125
Tropical Storm Agnes	Jun 1972	Tropical Storm	~25–50
Tropical Storm David	Sept 1979	Tropical Storm	~100–150
Hurricane Floyd	Sept 1999	Hurricane (remnants)	~75–125
Hurricane Isabel	Sept 2003	Category 2 Hurricane	~40–60
Hurricane Irene	Aug 2011	Category 1 Hurricane (offshore)	~80–120

1. Storm events compiled from National Weather Service Baltimore/Washington historical records (NWS 2025), Baltimore Office of Sustainability (2025) flood and storm summaries, and NOAA National Hurricane Center HURDAT2 data (NOAA NHC 2025).
2. Listed storms include events that made landfall within the Mid-Atlantic region or passed offshore but produced documented impacts in the Annapolis and central Chesapeake Bay area.

2.3 Oceanographic Conditions

Oceanographic conditions near Quiet Waters Park were evaluated using long-term water level and wave data from nearby monitoring stations and regional modeling products. Table 5 and Figure 7 identify the available oceanographic gauges and data sources reviewed to characterize water levels, wave climate, and coastal flood conditions relevant to the Park.

Table 5. Summary of water level and wave gauges reviewed for Quiet Waters Park.

Data Type	Source	Gauge ID	Location
Water Levels	NOAA	8575512	U.S. Naval Academy in Annapolis, MD
Waves	CHS	41422	South River, MD
Waves	CHS	22309	Harness Creek, MD

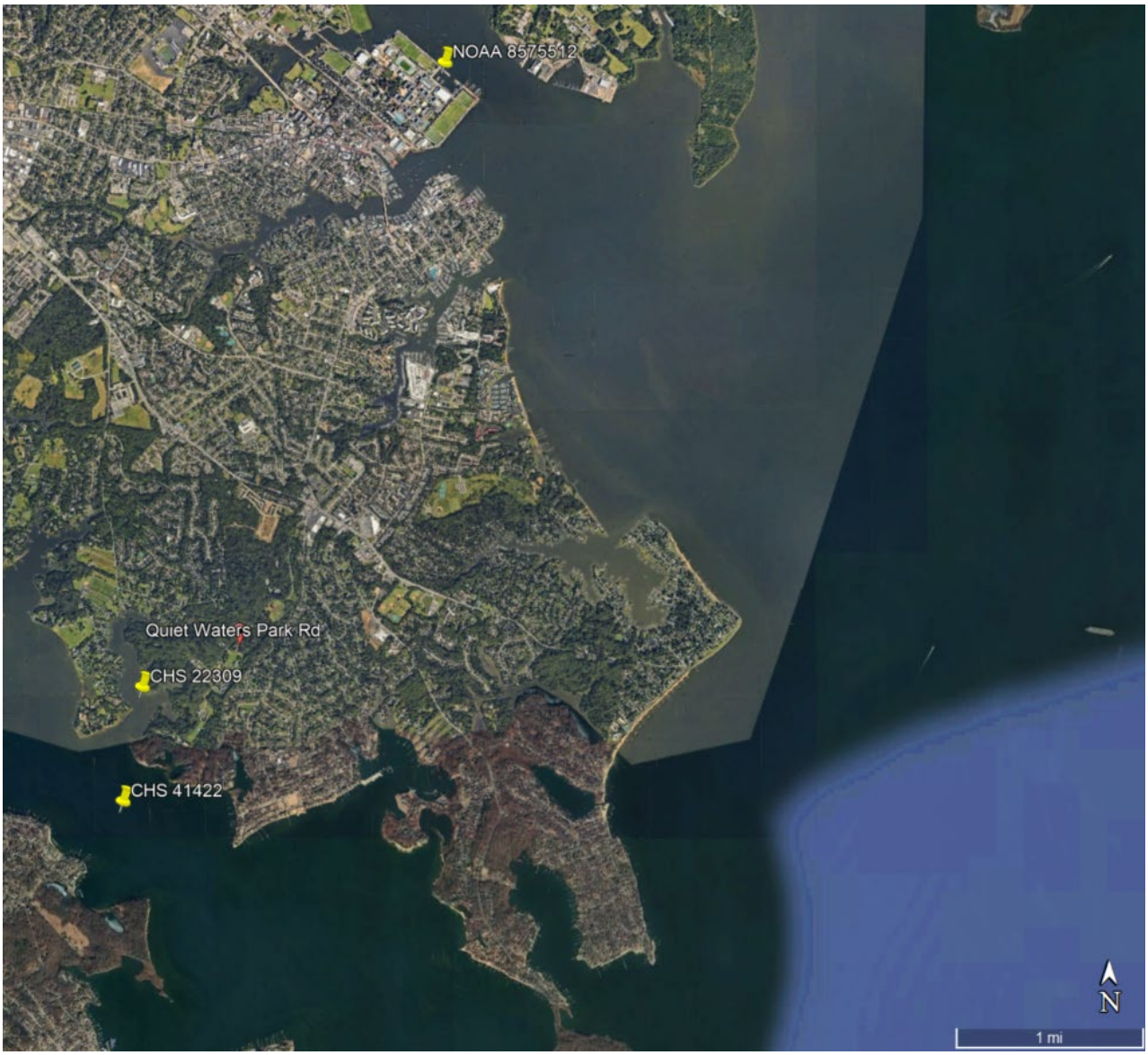


Figure 7. Locations of oceanographic monitoring stations near Quiet Waters Park.

2.3.1 Water Levels

Tidal datums for the Park were obtained from NOAA CO-OPS Station 8575512, located at the U.S. Naval Academy in Annapolis, Maryland (NOAA 2025f). Tidal elevations are referenced to the North American Vertical Datum of 1988 (NAVD88) and are summarized in Table 6. The mean tidal range is 0.97, feet with the Mean High Water (MHW) elevation at 0.42 feet NAVD88 and the Mean Low Water (MLW) elevation at −0.55 feet NAVD88. The highest observed tidal elevation at the station was 6.39 feet NAVD88, recorded on September 19, 2003, during Hurricane Isabel.

Table 6. Tidal datums at NOAA Station 8575512.

Tide Level	Elevation (feet NAVD88)
Mean Higher High Water (MHHW)	0.66
Mean High Water (MHW)	0.42
Mean Sea Level (MSL)	-0.05
Mean Low Water (MLW)	-0.55
Mean Lower Low Water (MLLW)	-0.77
Highest Astronomical Tide (HAT)	1.14
Highest Observed Tide	6.39

Verified hourly water level data are also available at Station 8575512 beginning in August 1928. These data were analyzed to estimate seasonal statistics and extreme water levels using annual maximum values. Estimated extreme water levels include a 100-year (i.e., 1-percent annual chance) stillwater elevation of approximately 5.15 feet NAVD88, with corresponding return period elevations summarized in Table 7 and Table 8. While the data provide valuable information on extreme water levels near Quiet Waters Park, differences in on-site conditions may exist due to local bathymetry or coastal geometry of the South River and Harness Creek.

Table 7. Seasonal minimum, average, and maximum water levels (feet NAVD88) from NOAA Station 8575512.

Season	Minimum	Mean	Maximum
Annual	-4.63	-0.18	6.42
Winter	-5.59	-0.56	4.32
Spring	-4.63	-0.21	3.51
Summer	-2.72	0.06	5.41
Fall	-4.31	0.00	6.42

Table 8. Extreme water levels using annual water level maxima at NOAA Station 8575512.

Recurrence Interval (years)	Water Level (feet NAVD88)
2-year (50%)	2.36
5-year (20%)	3.06
10-year (10%)	3.55
20-year (5%)	4.02
50-year (2%)	4.66
100-year (1%)	5.15
500-year (0.2%)	6.34

2.3.2 Waves

Wave data are available from the U.S. Army Corps of Engineers (USACE) Coastal Hazards System (CHS). Statistical water levels and wave conditions are provided using existing and select future sea level rise scenarios (USACE 2025). Two CHS stations are within the vicinity of Quiet Waters Park. Table 9 presents CHS-derived significant wave heights for CHS Station 41422 in the South River, representing more open-water wave conditions near the project area, while Table 9 presents corresponding wave statistics for CHS Station 22309 within Harness Creek, reflecting the more sheltered wave environment. Values are shown for a range of annual exceedance probabilities and include expected values. Upper confidence limits are also available for more conservative design requirements but are not presented on the tables below.

Table 9. Significant wave height at CHS Stations 41422 and 22309.

Annual Exceedance Probability (Years)	Expected Significant Wave Height (feet) at Station 41422	Expected Significant Wave Height (feet) at Station 22309
1	2.19	1.84
2	2.45	2.00
5	2.76	2.15
10	2.98	2.25
20	3.19	2.36
50	3.52	2.51
100	3.79	2.62
200	4.06	2.73
500	4.42	2.87
1,000	4.72	2.98
2,000	5.06	3.09
5,000	5.55	3.24
10,000	5.94	3.35

Comparison of the two stations indicates systematically higher significant wave heights at the South River station relative to the Harness Creek station across all annual exceedance probabilities. This difference reflects increased wave generation and propagation in the broader, less sheltered fetch conditions of the South River compared to the attenuated wave climate within Harness Creek. For extreme events (e.g., 100-year and greater), the divergence between stations becomes more pronounced, highlighting the sensitivity of open-water locations to large, low-probability storm events.

2.3.3 Coastal Floodplain Conditions

Coastal flood hazard information for the Project was reviewed using the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for Anne Arundel County, Maryland (FEMA 2015). FEMA floodplain mapping provides regulatory flood hazard information, including Base Flood Elevations (BFEs), flood zones, and coastal flood profiles used to delineate the 1-percent-annual-chance floodplain. Park shorelines are mapped within Zone VE (i.e., the coastal high

hazard zone) with BFEs of approximately 7 feet NAVD88, and Zone AE with BFEs of 5 to 6 feet NAVD88, reflecting varying exposure to wave action and coastal processes (Figure 8).

Detailed coastal flood information for the project vicinity is provided in the FEMA FIS, which publishes coastal flood and wave parameters at discrete shoreline transects. Transects 60 and 61 are located near the confluence of the South River and the Chesapeake Bay and represent the closest published FEMA coastal transects to Quiet Waters Park as shown in Figure 8.



Figure 8. FEMA coastal floodplain and analytical transects.

Table 10 summarizes the FEMA-derived coastal flood and wave conditions for Transects 60 and 61, including stillwater elevations (i.e., water surface elevations that include statistical tides and storm surge) and associated wave characteristics for the 1-percent and 0.2-percent annual chance flood events.

Table 10. FEMA wave conditions and stillwater elevations for the 100- and 500-year storm events.

Transect	Annual Chance Event	Significant Wave Height (ft)	Peak Wave Period (s)	Stillwater Elevation (ft NAVD88)
60	1% (100-year)	3.7	4.9	4.5
60	0.2% (500-year)	--[1]	--[1]	6.2 - 6.3
61	1% (100-year)	2.0	3.3	4.5
61	0.2% (500-year)	--[1]	--[1]	6.2

1. Wave height and peak wave period are not reported for the 0.2-percent (500-year) annual chance event at these transects in the FEMA Flood Insurance Study; therefore, only stillwater elevation values are available for those events.

2.3.4 Sea Level Rise

Maryland's sea level rise projections are documented in Sea level Rise Projections for Maryland 2023, prepared by the University of Maryland Center for Environmental Science in accordance with the Maryland Commission on Climate Change Act. The projections are probabilistic, emissions-based estimates of relative sea level rise (RSLR) that account for global ocean warming, land ice loss, ocean dynamics, and regional vertical land motion and do not include tidal extremes or storm surge, which must be evaluated separately for flood risk and design applications (Boesch et al., 2023).

Guidance for applying Maryland's sea level rise projections to planning and engineering projects directs practitioners to use localized RSLR projections based on the most representative NOAA tide gauge for the project area and to evaluate conditions over the full anticipated project lifespan. The Current Commitments scenario (SSP2-4.5) is recommended for project application, and the selected percentile-based RSLR estimates should correspond to the project's flood risk tolerance. Table 11 outlines the median RSLR and the RSLR likely range provided in the guidance. These values are representative of the central Chesapeake Bay and are relative to a 2005 baseline (1995-2014 average). They represent mean sea level rise and exclude tides and storm surge (McClure et al., 2024).

Table 11. Relative Sea Level Rise (RLSR) Projections for Maryland.

Year	Median RSLR (feet)	Likely Range [~66% Probability] (feet)
2030	0.5	0.3-0.7
2040	0.8	0.7-1.1
2050	1.3	1.0-1.6
2070	2.0	1.5-2.6
2100	2.7	2.0-3.5

Quiet Waters Park is a publicly owned recreational facility with a mix of natural areas, trails, shoreline features, and supporting infrastructure. Consistent with Maryland's sea level rise guidance, park facilities are typically categorized with medium tolerance for flood risk, reflecting that periodic flooding can be accommodated for some park assets, while prolonged or frequent inundation could disrupt public access, recreational use, and maintenance operations. Under this classification, upper-likelihood relative sea level rise estimates (approximately the 75th–83rd percentile under the SSP2-4.5 scenario) are appropriate for evaluating future conditions over the project planning horizon. Application of a medium tolerance at Quiet Waters Park supports assessment of future mean sea level conditions that balance continued public use with realistic exposure to increasing tidal flooding and is consistent with Maryland Department of Natural Resources (DNR) guidance for recreational assets (McClure et al., 2024).

2.4 Shoreline Conditions

2.4.1 Soils

Soil data were obtained from the Maryland Soil Survey Geographic Database (SSURGO) maintained by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) to support site characterization and screening-level analyses (USDA 2025). As shown in Figure 9, the Park's shoreline consists of erodible sediments. The Park's Harness Creek shoreline predominantly includes fine silty loam and small regions of silt loam and clay loam near the confluence with the South River. Along the South River shoreline, soils vary among fine sandy loam, silt loam, and mucky peat. Because the dataset is based on mapped soil units and generalized representative attributes, site-specific soil surveys and associated geotechnical analyses will be required during design.



Figure 9. Surface soil classification at Quiet Waters Park.

2.4.2 Shoreline Change and Management Strategies

Maryland Shoreline Change data were compiled for the Park to document historical shoreline position changes. This dataset is maintained by the Maryland DNR and is derived from multiple historical shoreline datasets developed from aerial imagery, LiDAR-based shoreline extractions, and historical mapping (DNR 2025a).

The shoreline change analysis is performed using a standardized set of shore-normal transects at regular intervals along the shoreline. Each transect intersects multiple historical shoreline positions, allowing calculation of shoreline change metrics at fixed spatial locations. Available attributes typically include long-term and short-term shoreline change rates, net shoreline movement, and associated statistical measures describing the temporal record used for each transect. The transect-based shoreline change dataset provides a framework for evaluating historical erosion and accretion trends and serves as a supporting dataset for coastal assessments and shoreline management studies.

Figure 10 illustrates the spatial distribution of the transect-based shoreline change rates across the study area. Transects are symbolized by color-coded vectors representing the magnitude and direction of shoreline change, with warmer colors indicating higher erosion rates and cooler colors indicating stable or accreting conditions.

To facilitate interpretation of the mapped results, shoreline change rates were grouped into qualitative categories based on their magnitude. These categories, summarized in Table 12, provide a consistent basis for describing shoreline conditions and for communicating erosion severity in the context of shoreline management, planning, and preliminary engineering assessments.

Table 12. Shoreline Change Rate Classification (DNR 2025a).

Category	Rate Range (ft/yr)	Description
Accretion	> +0.01	Net shoreline advance (sediment gain)
Slight Erosion	−0.01 to −2.00	Minimal to low erosion; generally stable shoreline
Low Erosion	−2.00 to −4.00	Noticeable erosion with gradual shoreline retreat
Moderate Erosion	−4.00 to −8.00	Significant erosion requiring management consideration
High Erosion	< −8.00	Severe erosion; high priority for mitigation

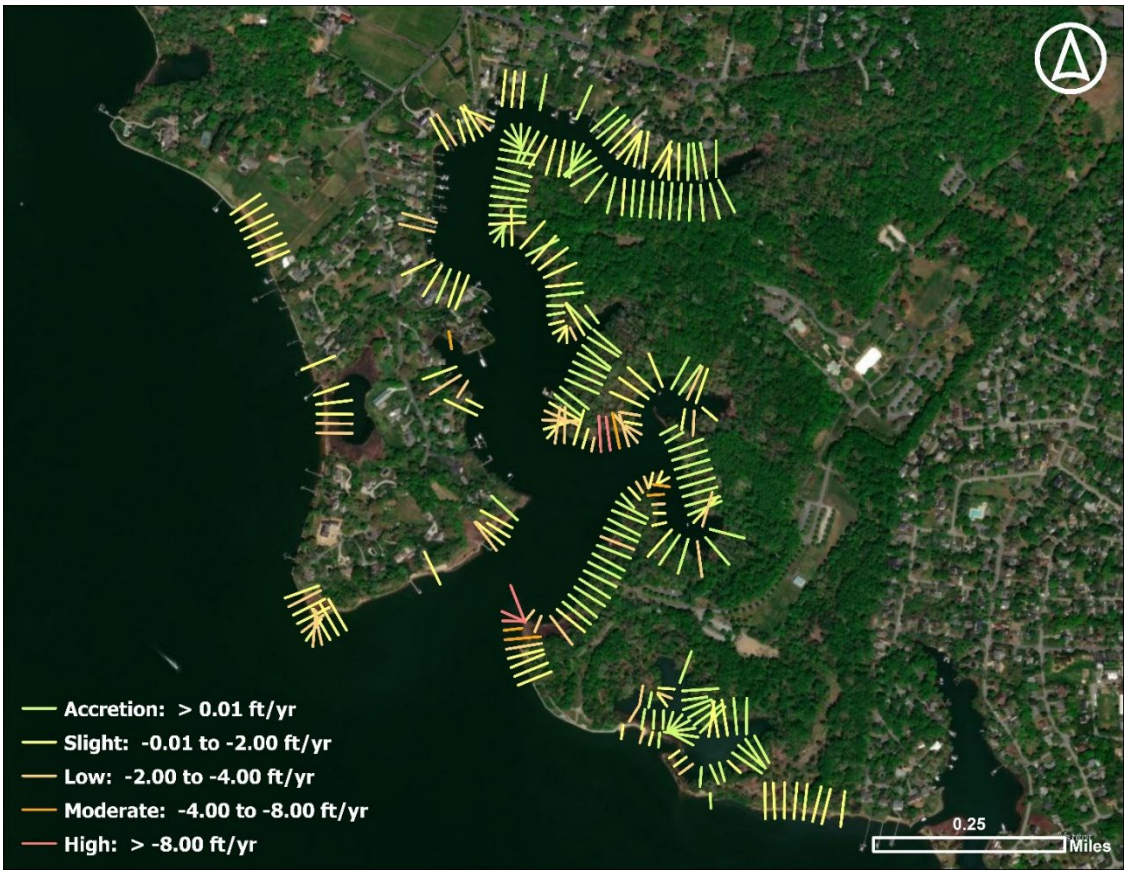


Figure 10. Spatial distribution of transect-based shoreline erosion and accretion rates.

In addition to the shoreline change transect data, information from the Maryland Shoreline Stabilization Mapper (MSSM) was reviewed where applicable. The MSSM is a planning-level dataset developed by the State of Maryland to identify shoreline reaches where different categories of shoreline management approaches may be appropriate based on physical setting, erosion trends, and environmental considerations (DNR 2025b). The dataset classifies shoreline segments into general management categories, such as living shoreline, structural shoreline stabilization, or undetermined, and is intended to support early planning and screening-level decision-making rather than site-specific design.

Figure 11 presents the MSSM shoreline management classifications mapped along Quiet Waters Park. These classifications are used in this study to provide contextual information on existing and recommended shoreline management approaches and to supplement the shoreline change analysis, recognizing that site-specific feasibility and design considerations would require additional evaluation.



Figure 11. Maryland Shoreline Stabilization Mapper (MSSM) shoreline management classifications.

Based on the combined review of Maryland Shoreline Change data, MSSM mapping, and feedback from Park staff during the project kickoff meeting, the following shoreline conditions are identified at shorelines of interest:

- **Wildwood Trail Shoreline:** Maryland Shoreline Change data indicate slight erosion (−0.01 to −2.00 ft/yr). MSSM mapping suggests a structural shoreline stabilization approach in this area at a planning level.
- **Boat Rental Area and Adjacent Harness Creek Trail Shoreline:** Maryland Shoreline Change data indicate moderate erosion (−4.00 to −8.00 ft/yr). Field observations documented severe localized erosion, with trails and paved paths appearing to concentrate stormwater runoff toward the shoreline and dock areas. A nearby kayak soft launch was observed to be degrading; while not intended for long-term maintenance by park staff, the condition was documented for context.

Shoreline Change data south of the boat rental area along the Harness Creek Trail indicate high erosion levels.

- **Harness Creek Inlet:** Maryland Shoreline Change data indicate a high erosion level (< −8.00 ft/yr). SSURGO soils mapping in this area indicates slight erodibility, providing additional context for observed shoreline conditions.
- **Loden Pond Shoreline:** Maryland Shoreline Change data indicate moderate erosion (−4.00 to −8.00 ft/yr) along the inner pond shoreline.
- **Quiet Waters Retreat Shoreline:** Maryland Shoreline Change data indicate slight erosion (−0.01 to −2.00 ft/yr); however, park staff observations and review of recent aerial imagery indicate the presence of actively eroding bluffs, highlighting localized conditions not fully reflected in transect-based erosion rates.

2.5 Park Site Features and Upland Drainage

A sanitary sewer main runs along a southerly direction across the Park, mostly near Quiet Waters Farm Road. Public records of other utilities within the Park were not available. Other site features include paved and unpaved trails around the property and sections of fences around playgrounds, parking lots, gardens, and dog parks. Figure 12 shows the Quiet Waters Park site features.



Figure 12. Quiet Waters Park site features.

The drainage area contributing to the Park's shoreline is composed primarily of woods with some open space, residential, and commercial areas. The overall drainage system on the park is a combination of natural overland flow, ditches, culverts, and underground storm drain systems (Figure 13).

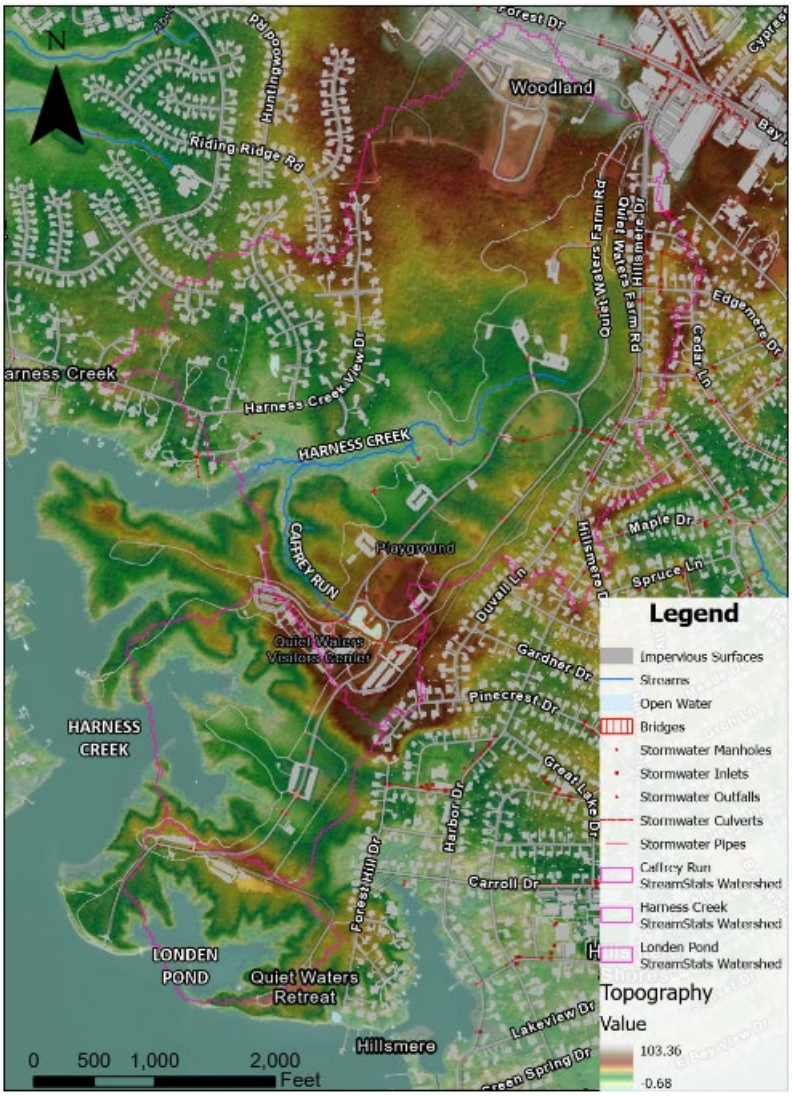


Figure 13. Quiet Waters Park upland drainage system.

The northern side of the Park drains to Harness Creek and Caffrey Run. Harness Creek receives runoff from nearby residential and commercial areas through storm drain systems that discharge directly into the creek. Further upstream, another storm drain discharges to a wetland identified by the DNR, which then conveys flow through a series of ditches and culverts before entering Harness Creek.

Runoff from the residential area west of Quiet Waters Farm Road flows overland toward the center of the Park, where it is collected by inlets and routed to a basin near the Visitor Center. The basin, constructed in 1991 in accordance with the Quest Waters Park Site Development As-Builts, also receives runoff from two large parking lots. Its principal spillway consists of double 42” x 29” Reinforced Concrete Pipe culverts that discharge directly into Caffrey Run.

The shorelines around the Composting Demonstration Area and the Kayak Launch Boat Rental Pier primarily receive runoff from wooded areas with no direct storm drain outfalls. Along the Park’s

southwestern boundary, Harness Creek receives runoff from wooded areas and a nearby parking lot. Drainage toward South River comes from mostly steep, wooded areas. Lastly, Londen Pond collects runoff from wooded and open space areas as well as from Quiet Waters Farm Rd. and two nearby parking lots.

There were no nearby stream gages per the U.S. Geological Survey (USGS) records; therefore, preliminary discharges to specific points of investigation were calculated using regional regression equations through StreamStats. The peak discharges to the northern (Harness Creek and Caffrey Run), middle (Harness Creek) and southern (Londen Pond) for various storm events are summarized in Table 13.

Table 13. Estimated peak discharges for project tributaries based on USGS StreamStats regional regression analysis.

Location	2-YR Discharge (cfs)	5-YR Discharge (cfs)	10-YR Discharge (cfs)	25-YR Discharge (cfs)	50-YR Discharge (cfs)	100-YR Discharge (cfs)
Caffrey Run	120	258	399	668	943	1320
Harness Creek	21	49	79	135	193	273
Londen Pond	13	28	45	77	109	154

Overall, impervious cover within the park is minimal. However, there are opportunities to treat stormwater from parking lots that currently drain directly to the shorelines. Additionally, the existing basin could be retrofitted to improve treatment capacity and meet current regulatory standards.

2.6 Existing Habitat

2.6.1 Submerged Aquatic Vegetation

Submerged Aquatic Vegetation (SAV) mapping for the project area was evaluated using the Maryland SAV Viewer dataset (DNR 2025c). Data layers available through the SAV Viewer represent mapped extents of SAV beds based on aerial imagery interpretation and field verification efforts conducted by DNR biologists and partners. The review of the SAV dataset indicates no mapped submerged aquatic vegetation within or immediately adjacent to the project site.

2.6.2 Wetlands

The National Wetlands Inventory (NWI) database was reviewed to identify wetlands and deepwater habitats (USFWS 2025). Wetlands are classified according to the Cowardin classification system, which distinguishes freshwater and estuarine systems and further categorizes wetlands by vegetation and hydrologic characteristics. Figure 14 shows the NWI data for the Park and surrounding region. The NWI dataset provides a regional, map-based representation of wetland resources; however, on-site field observations are necessary to confirm wetland presence, extent, and classification at specific locations.

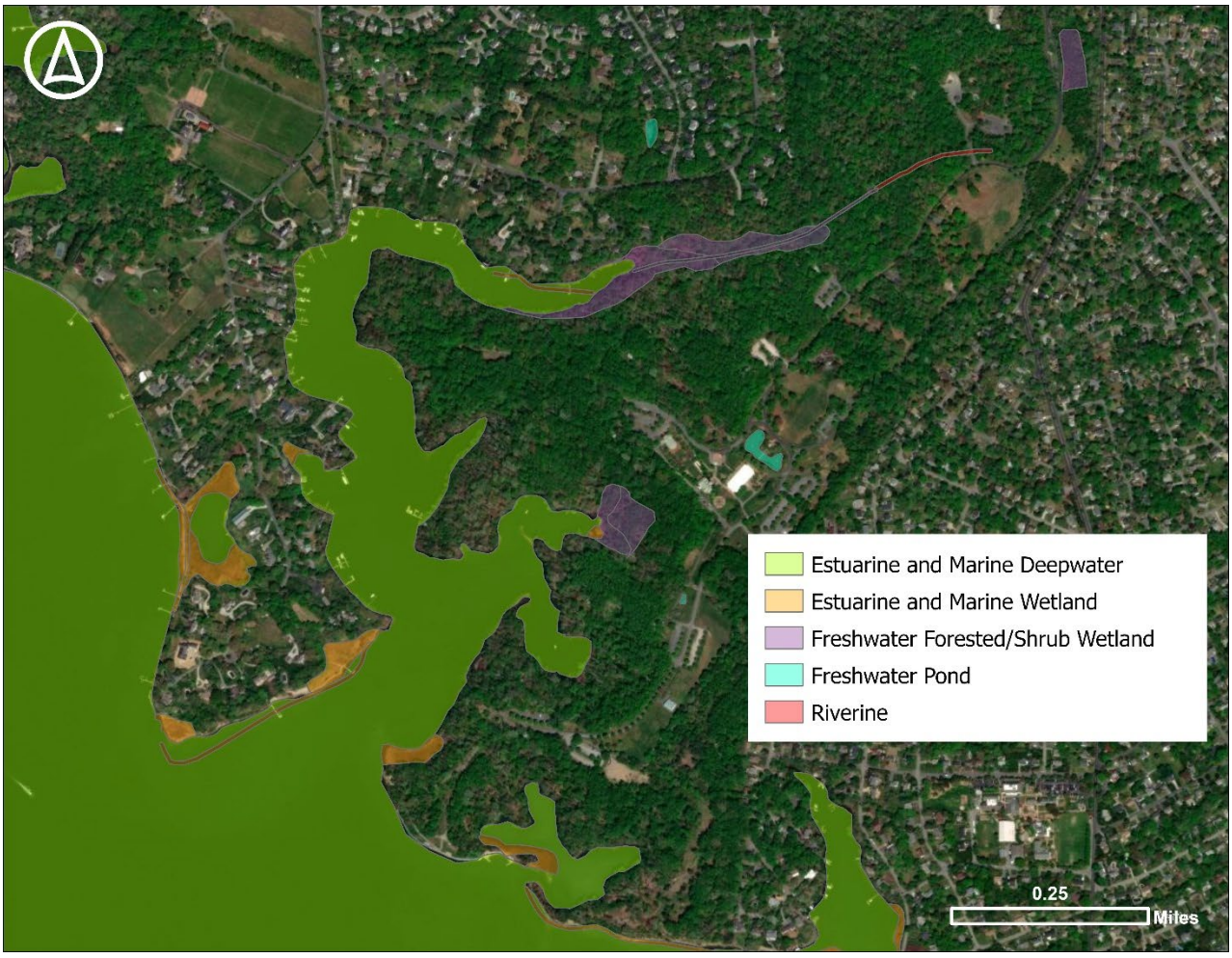


Figure 14. National Wetlands Inventory data for Quiet Waters Park and surrounding region.

A variety of wetlands are identified within the Park or along its shoreline. These include a freshwater forested/shrub wetland, four freshwater forested/shrub wetlands and estuarine and marine wetlands within Harness Creek, a freshwater pond wetland at Lighthizer Gazebo Pond, and a freshwater pond wetland at the Holly Pavilion. An estuarine and marine wetland was also identified in Loden Pond.

2.6.3 Waterfowl Habitat

The Maryland DNR designates certain areas as “Living Resources,” including habitats for forest interior dwelling species, diamondback terrapin habitat, and other unique environments. These natural assets are managed by the DNR to promote their health and use through programs that integrate ecological restoration and community benefits. Quiet Waters Park is classified as a Waterfowl Area, meaning its tidal and marsh zones serve as concentration and staging sites for waterfowl (Figure 15).



Figure 15. Waterfowl habitat (blue) adjacent to Quiet Waters Park.

2.7 Critical Area

Maryland established the Critical Area program in 1984 to manage land use, reduce environmental impact, and conserve natural resources. The Critical Area includes all land within 1,000 feet of tidal waters or wetlands in the Chesapeake Bay and its tributaries. The program includes three classifications: Intensely Developed Area (IDA), Limited Development Area (LDA), and Resource Conservation Area (RCA). Each classification has specific use and intensity restrictions, as well as development performance standards. The Critical Area Buffer is a minimum of 100 feet from the MHW line. This buffer is expanded to include steep slopes, hydric soils, and highly erodible soils, with specific soil types identified and mapped by the USDA Soil Conservation Service. The Critical Area Buffer is a key component, providing critical wildlife habitat and stabilizing soils. The program also addresses climate resilience, with the Critical Area Commission considering how water-dependent uses will be impacted by climate change. Within Quiet Waters Park, areas are designated as Critical Buffer and the RCA of the Critical Area (Figure 16).

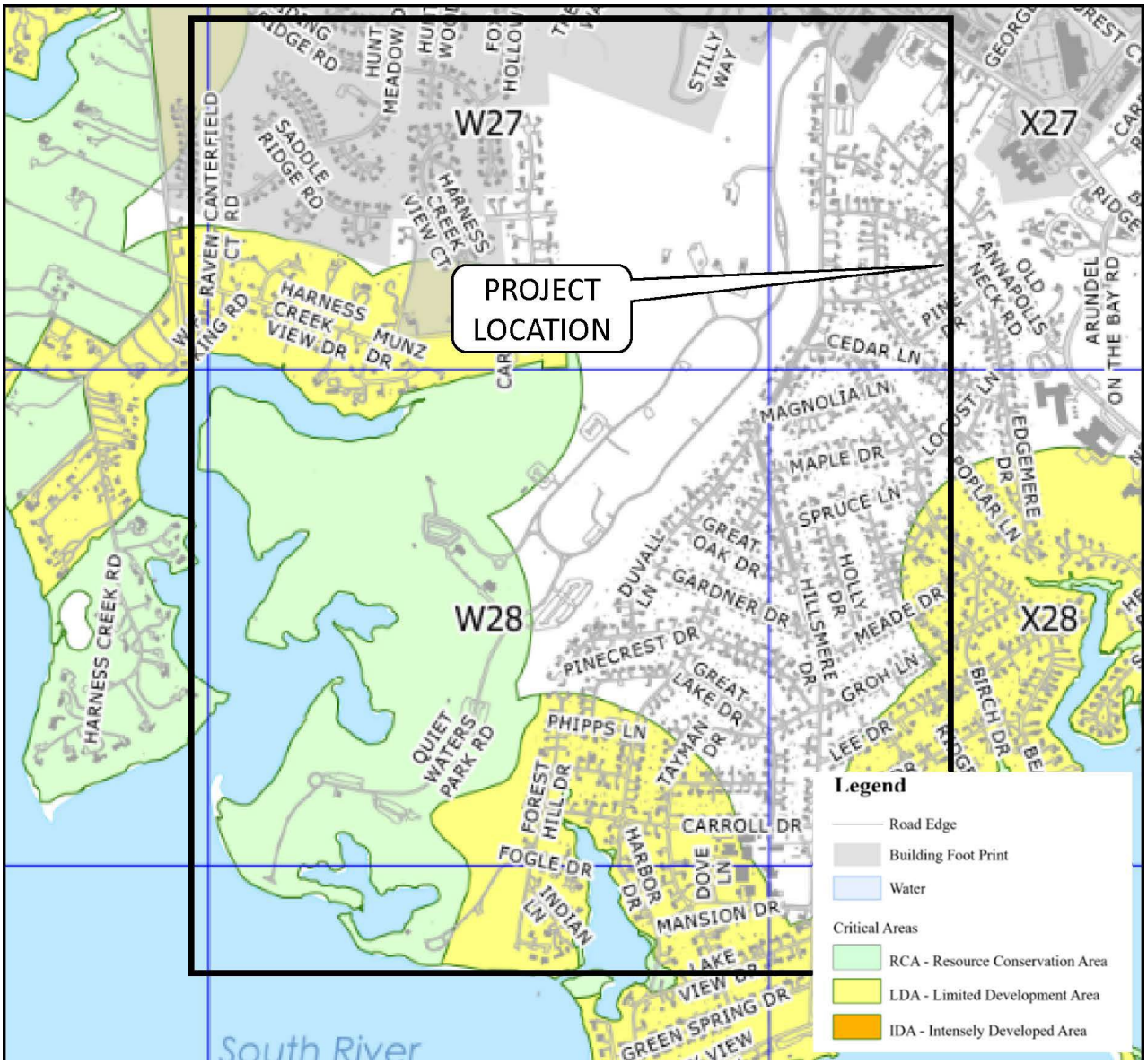


Figure 16. Critical area identification for Quiet Waters Park.

3 Conclusion

The Desktop Data Collection provides an overview of the physical, environmental, and coastal processes influencing shoreline conditions at Quiet Waters Park. The compiled datasets indicate that portions of the Park shoreline are experiencing ongoing erosion, with variability in erosion severity associated with shoreline orientation, exposure, local drainage patterns, and geomorphic setting. Transect-based shoreline change data and Maryland Shoreline Stabilization Mapper classifications together highlight areas where shoreline stabilization or adaptive management approaches may warrant further consideration at a planning level.

In addition, regional water level records, wave statistics, historical storm data, and sea level rise projections indicate increasing exposure to coastal flooding and shoreline stressors over the project planning horizon. While the information presented provides valuable context for understanding existing and future conditions, the results are subject to limitations inherent in regional and map-based datasets. Site-specific field reconnaissance, surveys, and engineering analyses are required to confirm local conditions and to advance shoreline resilience strategies beyond the planning level. The findings from this Desktop Data Collection are intended to inform next steps in the resilience planning process and support the development of feasible, site-appropriate shoreline management and adaptation measures for Quiet Waters Park.

4 References

Baltimore Office of Sustainability. (2025). *Historical flooding and storm events in Baltimore and Maryland*. City of Baltimore. Retrieved December 30, 2025, from https://www.baltimoresustainability.org/

Boesch, D. F., Baecher, G. B., Boicourt, W. C., Cullather, R. I., Dangendorf, S., Henderson, G. R., Kilbourne, H. H., Kirwan, M. L., Kopp, R. E., Land, S., Li, M., McClure, K., Nardin, W., & Sweet, W. V. (2023). *Sea level rise projections for Maryland 2023*. University of Maryland Center for Environmental Science.

DNR (Maryland Department of Natural Resources). (2025a). *Maryland shoreline change data* [Dataset]. Retrieved December 10, 2025, from https://data.imap.maryland.gov/datasets/maryland-shoreline-changes-baseline

DNR. (2025b). *Maryland shoreline stabilization mapper (MSSM)* [Online tool]. Retrieved December 30, 2025, from https://cmap22.vims.edu/MSSMTool/

DNR. (2025c). *Maryland SAV Viewer dataset* [Dataset]. Retrieved November 20, 2025, from https://data.imap.maryland.gov/datasets/maryland-shallow-water-aquatic-vegetation-sav/view

FEMA (Federal Emergency Management Agency). (2015). *Flood Insurance Study (FIS) Anne Arundel County, Maryland and incorporated areas (Study No. 24003CV000B).* Federal Emergency Management Agency.

IEM (Iowa State University Environmental Mesonet). (2025). *ASOS Station NAK – Annapolis, Maryland (MD_ASOS): Historical meteorological observations* (including wind speed and direction). Retrieved November 26, 2025, from https://mesonet.agron.iastate.edu/sites/site.php?station=NAK&network=MD_ASOS

McClure, K., Land, S., & Vogel, K. (2024). *Guidance for using Maryland's 2023 sea level rise projections*. Maryland Department of Natural Resources; University of Maryland Sea Grant Extension.

NOAA (National Oceanic and Atmospheric Administration). (2025a). *NOAA data access viewer: Topographic and bathymetric elevation data* (including 2019 NOAA NGS topobathymetric LiDAR, 2020 Maryland LiDAR DEM, and NOAA CUDEM). https://coast.noaa.gov/dataviewer/

NOAA. (2025b). *National Centers for Environmental Information (NCEI) Local climatological data (LCD) for Thomas Point, MD (USL000TPLM2).* Retrieved November 26, 2025, from https://www.ncei.noaa.gov/

NOAA. (2025c). *National Data Buoy Center (NDBC) Station 44063 (Annapolis, MD): Meteorological and oceanographic observations.* Retrieved December 30, 2025, from https://www.ndbc.noaa.gov/station_page.php?station=44063

NOAA. (2025d). *National Weather Service (NWS) Precipitation Frequency Data Server (PFDS).* Retrieved December 30, 2025, from https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html?bkmrk=md

NOAA. (2025e). *NOAA NCEI historical storm track data.* Retrieved December 30, 2025, from https://www.ncei.noaa.gov/products/international-best-track-archive

NOAA. (2025f). *CO-OPS Station 8575512 Annapolis (Naval Academy), Maryland: Water level observations.* Retrieved November 26, 2025, from https://tidesandcurrents.noaa.gov/stationhome.html?id=8575512

NOAA NHC (National Oceanic and Atmospheric Administration, National Hurricane Center). (2025). *Tropical cyclone reports and historical hurricane database (HURDAT2)* [Dataset]. Retrieved December 30, 2025, from https://www.nhc.noaa.gov/data/

NWS (National Weather Service). (2025). *Baltimore/Washington Weather Forecast Office - Historical hurricane and tropical cyclone impacts in Maryland*. National Oceanic and Atmospheric Administration. Retrieved December 30, 2025, from https://www.weather.gov/lwx/

USACE (U.S. Army Corps of Engineers). (2025). *Engineer Research and Development Center (ERDC) Coastal Hazards System (CHS): Coastal hazard data for stations 22309 and 41422* (including AEP, ADCIRC, STWAVE, and NLR outputs). Retrieved December 30, 2025, from https://chs.erdc.dren.mil/Location/Index

USDA (U.S. Department of Agriculture). (2025). *Natural Resources Conservation Service SSURGO soils data for Maryland.* Retrieved November 20, 2025, from https://data.imap.maryland.gov/datasets/maryland::maryland-ssurgo-soils-ssurgo-soils

USFWS (U.S. Fish and Wildlife Service). (2025). *National Wetlands Inventory (NWI) database* [Dataset]. Retrieved December 10, 2025, from https://www.fws.gov/program/national-wetlands-inventory

Appendix B Field Reconnaissance

Stantec

Memo

To:	Rich Lefebure Anne Arundel County Department of Recreation and Parks	From:	Rebecca Aiken, PE Joseph Smith, PE Claire Sorensen Laurel, MD
Project/File:	203403333	Date:	February 11, 2026

Reference: Quiet Waters Park Resilience Assessment and Planning – Field Reconnaissance

1 Introduction

Stantec conducted field reconnaissance at sites of interest along the Quiet Waters Park (the Park) shoreline and upland drainage features on Tuesday, December 16, 2025, as well as a supplemental visit of the eastern portion of the Quiet Waters Retreat shoreline on Wednesday, February 4, 2026. The intention of the visits was to assess present site conditions and provide field verification of erosion contributors and existing vegetation, particularly at sites of known concern based on insights from Anne Arundel County's Department of Recreation and Parks (DRP) or concerning shoreline elements identified during the Desktop Data Collection. Planned and visited reconnaissance locations are identified in Figure 1. Sites and features inspected include:

- Quiet Waters Retreat Shoreline
- Loden Pond
- Dog Park Parking Lot Stormwater Infrastructure
- Harness Creek Inlet
- Harness Creek Embayment
- Harness Creek Trail Shoreline
- Boat Rental Shoreline
- Wildwood Trail Shoreline
- Caffrey Run Wetlands
- Interior Park Features and Stormwater Infrastructure

Reference: **Quiet Waters Park Field Reconnaissance**

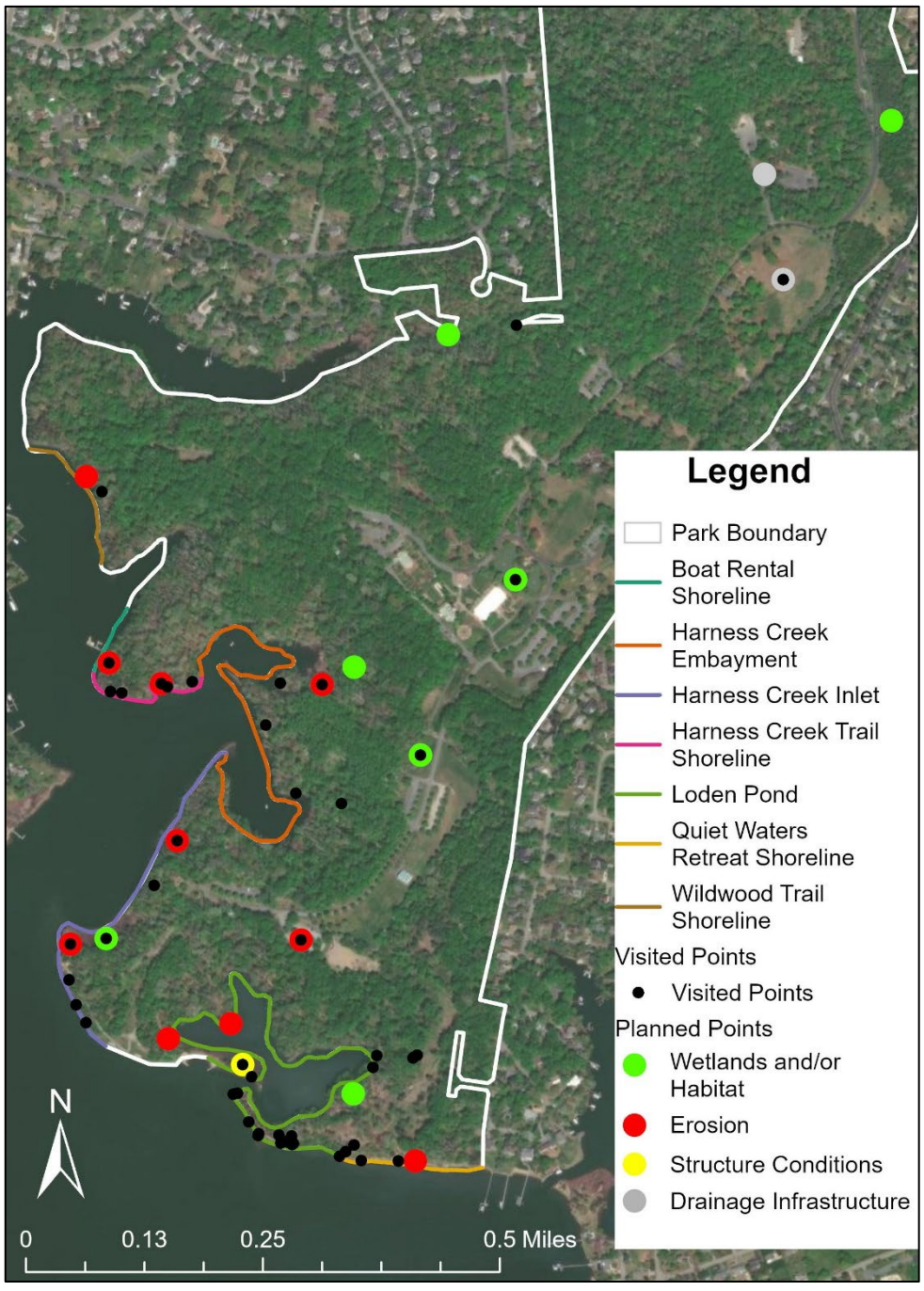


Figure 1. Planned and visited field reconnaissance evaluation points.

2 Field Reconnaissance Evaluation

2.1 Quiet Waters Retreat Shoreline

Quiet Waters Retreat is a newly acquired parcel at the Park with planned development detailed in the Quiet Waters Retreat Master Plan. During the Desktop Data Collection, Maryland Shoreline Change data suggested the shoreline experiences slight erosion. Stantec confirmed during the site visit significant shoreline erosion with unvegetated bluffs and unstable, overhanging sediment along the bluff crest along the western portion of the shoreline (Image 1). A small, dilapidated bulkhead exists along the shoreline and provides some localized protection of the banks based on shoreline position and the presence of bank vegetation upland of the failing structure (Image 2). Inspection of the eastern portion of the bulkhead indicates local failures in the structure caused by fallen trees as well as localized warping of the sheet pile. Areas of focused erosion were also noted along manmade footpaths, particularly along shoreline segments with existing or prior upland paved areas, along the bluff face concentrating upland runoff (Image 3). Along the eastern portion of the Quiet Waters Retreat shoreline, Stantec noted additional shoreline infrastructure, including a rubble mound toe structure backed by a beach platform with plantings (Image 4) as well as shore normal rubble mound groins (Image 5). Although eroding bluffs were noted along the entirety of the shoreline, Stantec noted less severe erosion and more bluff vegetation along portions of the shoreline with alongshore shoreline protection (i.e., existing bulkhead and rubble mound toe infrastructure). Stantec engineers suspect wave energy is a significant contributor to shoreline erosion (Image 6), noting that the Quiet Waters Retreat shoreline has a large fetch exposed to the Chesapeake Bay.

Reference: **Quiet Waters Park Field Reconnaissance**

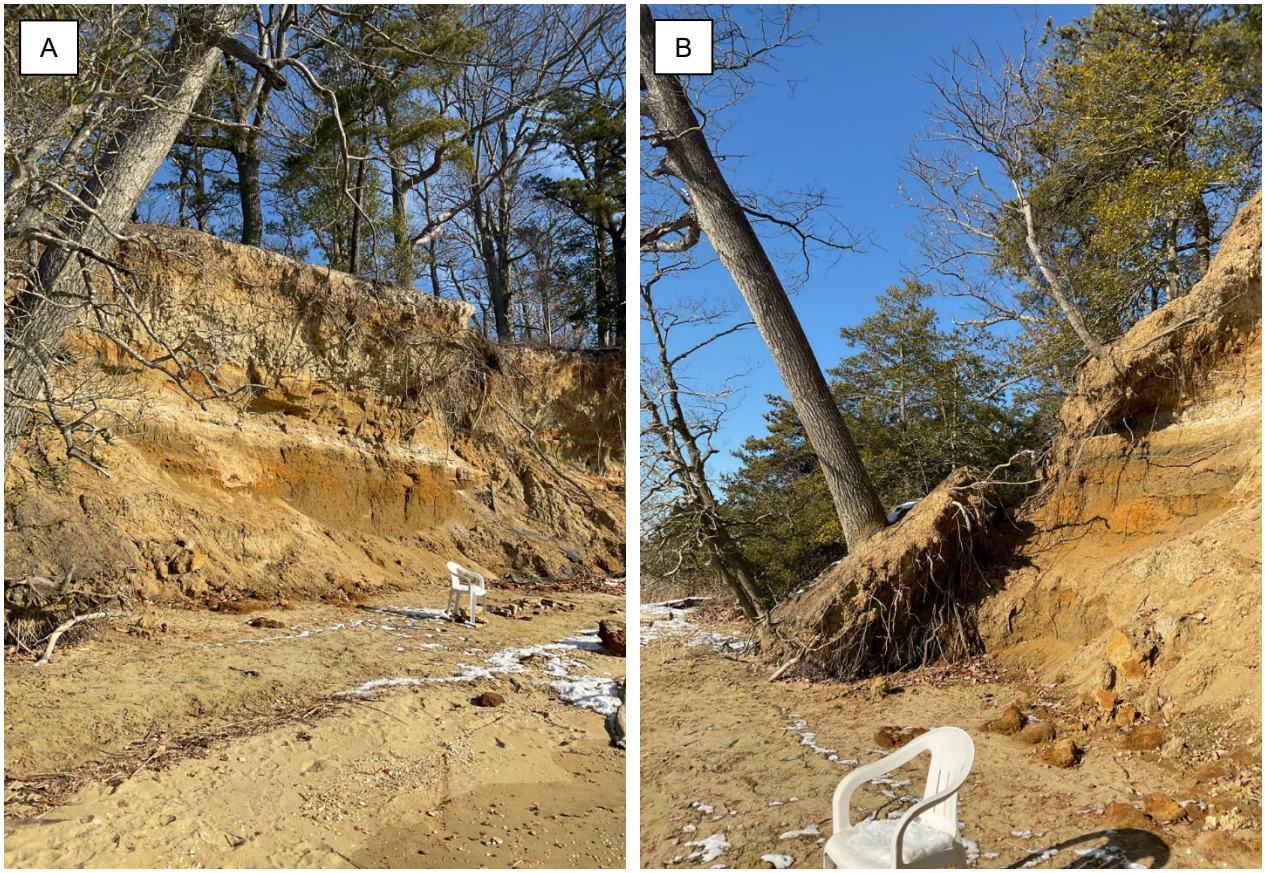


Image 1. Slumping bluff facing north (A) and west-northwest (B) along the western portion of the Quiet Waters Retreat shoreline.



Image 2. Dilapidated bulkhead (photo facing east) along the Quiet Waters Retreat shoreline.



Image 3. Deteriorating bulkhead (A) and bluff erosion from focused runoff (B) along the eastern portion of the Quiet Waters Retreat shoreline (photos facing west [A] and north [B]).

Reference: **Quiet Waters Park Field Reconnaissance**



Image 4. Rubble mound toe structure backed by fill and plants (photo facing west) along the eastern portion of the Quiet Waters Retreat shoreline.



Image 5. Eroding bluff fronted by groins (photo facing east) along the eastern portion of the Quiet Waters Retreat shoreline.



Image 6. Fetch at Quiet Waters Retreat shoreline (photo facing south-southwest).

2.2 Loden Pond

Loden Pond offers critical habitat to waterfowl and recreational value to kayakers and Park visitors. Park staff noted the entrance to Loden Pond occasionally closes, interrupting water access and tidal flushing of Loden Pond. Stantec evaluated structural conditions at the entrance of Loden Pond as well as the interior wetlands and shoreline erosion.

A deteriorated wooden structure was identified at the entrance of Loden Pond, allowing stronger currents, wave energy, and sediment to travel into the pond (Image 7). To the west of the pond entrance is a rubble mound breakwater at the dog beach, which is in good condition, as well as a low-crested rubble mound structure protecting wetlands at the western entrance of the pond (Image 8). The eastern entrance to Loden Pond, however, includes a wooden bulkhead protecting wetland vegetation. The wooden bulkhead is partially damaged, and Stantec noted dislodged portions of the wall that allow localized wetland erosion and sediment loss into the South River (Image 9). Based on field observations, the shorelines along the South River abutting the entrance to Loden Pond are better protected with more robust infrastructure, and hybrid infrastructure could provide appropriate shoreline protection.

The interior portion of Loden Pond was also explored. Wetlands within the pond are healthy and appear to be in good condition (Image 10). Erosion is limited to undercutting of the banks surrounding the pond

(Image 11). Due to limited overwater fetch extents, Stantec anticipates the noted erosion is current-induced rather than wave-induced. Generally, the interior portion of Loden Pond appears suitable to many nature-based solutions for shoreline protection.



Image 7. Opening to Loden Pond (photo facing southwest).



Image 8. Rubble mound structure along the entrance of Loden Pond (photo facing west).

Reference: **Quiet Waters Park Field Reconnaissance**



Image 9. Wooden bulkhead near the entrance of Loden Pond (photo facing west-northwest).



Image 10. Marsh in Loden Pond (photo facing north-northeast).



Image 11. Undercutting along bank of Loden Pond (photo facing south-southwest).

2.3 Dog Park Parking Lot Stormwater Infrastructure

During the project kickoff meeting, Park staff relayed concerns of stormwater-induced erosion within the dog park parking lot. Stantec is aware that the Quiet Water Retreat Master Plan includes modifications to stormwater infrastructure near these parking lots and, therefore, inspected the infrastructure during the field reconnaissance. An investigation of areas at the dog park showed no signs of erosion. Runoff appeared to be safely sheet flowing from the areas of the dog park down into the woods. At the end of Quiet Waters Park Road near the restroom, moderate erosion was observed within a ditch that was draining the parking lot and road. Runoff collects in a swale between the parking lot and Quiet Waters Road and drains to a small culvert which crosses Quiet Waters Park Road. Water discharges at the top of the slope draining to Loden Pond adding to sedimentation of the area. Stantec noted erosion at the outlet of the culvert and down the slope (Image 12 and Image 13). Solutions to the erosion problem include moderate grading of the eroded channel and lining the channel with a natural-colored riprap underlain with geotextile. Alternatively, the culvert could extend down the slope to a flatter grade where discharge energies are less.

Reference: **Quiet Waters Park Field Reconnaissance**



Image 12. Erosion at culvert near the Dog Park Parking Lot.



Image 13. Stormwater induced erosion near the Dog Park Parking Lot.

2.4 Harness Creek Inlet

The inlet of Harness Creek is an area of high erosion. During the project kickoff meeting, Park staff shared that much of the erosion is likely due to boat wakes near the confluence of Harness Creek and the South River. Stantec noted during the Desktop Data Collection that the Maryland Department of Natural Resources Shoreline Change data indicates high levels of erosion while the Maryland Soil Survey Geographic Database (SSURGO) indicates soils in the area are slightly erodible.

Stantec noted the shoreline at Harness Creek inlet shows notable erosion with undercut bluffs that include middens with oyster shells (Image 14 and Image 15). A large manmade footpath exists with steep banks ranging from approximately 2 to 4 feet (ft) in height (Image 16). The manmade footpath causes upland rainfall and stormwater to concentrate along the highly-eroded shoreline and is likely exacerbating the erosion rate and shoreline deterioration.

North of the Harness Creek inlet are steep, unvegetated bluffs and wetlands. Contributors to erosion along the bluffs include wave action and manmade footpaths that collect and concentrate stormwater runoff, creating steep cuts into the bank crest (Image 17). Generally, the wetlands along this reach of shoreline appear healthy and in good condition (Image 18).



Image 14. Undercutting in Harness Creek Inlet (photo facing east).

Reference: **Quiet Waters Park Field Reconnaissance**



Image 15. Middens with oyster shells at the inlet to Harness Creek (photo facing north-northwest).



Image 16. Footpath at the inlet to Harness Creek (photo facing east-southeast).



Image 17. Looking downslope of steep bluff and manmade path near the inlet to Harness Creek (photo facing west-northwest).



Image 18. Marsh with manmade path and associated erosion in the foreground (photo facing north-northwest).

2.5 Harness Creek Embayment

The Harness Creek embayments are relatively sheltered from wave action and are often used by boaters to anchor. The southern embayment is also the location of a recently completed step-pool for stormwater management. Park and DRP staff noted during the project kickoff meeting that submerged aquatic vegetation (SAV) has established near the step-pool, and there are potential opportunities for habitat enhancement within the interior reaches of Harness Creek. Stantec inspected the step-pool and noted it is functioning well and planted vegetation within the vicinity of the step pool is well established (Image 19).

Stantec staff observed some shoreline erosion within the interior embayments, with undercutting ranging from 2 to 4 ft in height, but generally noted erosion was less prevalent relative to more exposed shoreline reaches (Image 20). The wetlands within the interior portions of the embayments were in good condition as well (Image 21 and Image 22).



Image 19. Step-pool in the southern Harness Creek embayment (photo facing east).

Reference: **Quiet Waters Park Field Reconnaissance**



Image 20. Erosion along shoreline in northern embayment (photo facing southwest [A] and north [B]).

Reference: **Quiet Waters Park Field Reconnaissance**



Image 21. Overview of southern embayment of Harness Creek and natural spit (photo facing southwest).



Image 22. Overview of Harness Creek embayments (photo facing northeast from Harness Creek Trail).

2.6 Harness Creek Trail Shoreline

Harness Creek Trail has been identified as a shoreline experiencing high erosion rates, with park signage warning of unstable bluffs along the reach. In response to shoreline erosion, in partnership with the Arundel Rivers Federation (ARF), the Park plans to install shoreline protection with a combination of reef balls, a low crested rubble mound structure, fill, and marsh plantings. Stantec inspected the shoreline to identify shoreline conditions beyond the extents of the ARF project and support the identification of shoreline protection solutions that may work in conjunction with the ARF living shoreline.

The shoreline reach is associated with steep, unvegetated banks at the opening of the embayment near the trail, but the eroded bank height generally tapers down to smaller heights farther inland of the embayment opening (Image 23). Wetlands were noted farther east of the ARF project location (Image 24). To the south, across the inlet, there is a healthy marsh spit that has formed at the entrance of the southern embayment (Image 21).



Image 23. Erosion along Harness Creek trail (photo facing east-southeast).



Image 24. Wetlands east of ARF project location (photo facing southwest).

2.7 Boat Rental Shoreline

There are eroded banks along the shoreline near the boat rental docks. Stantec observed felled trees along the banks and in the water (Image 25). During the project kickoff meeting, DRP expressed concern that concentrated stormwater runoff along the paved trail may be a critical contributor to shoreline erosion. Stantec noted small, manmade footpaths from the bluff crest to the shoreline that can focus stormwater runoff into localized runnels, but there was no evidence of stormwater-created berms or trenches near the paved path leading to the boat rental facility (Image 26). It is Stantec's professional opinion that the primary contributor to shoreline erosion is related to coastal flood hazards and wave conditions rather than from upland drainage. People walking along the shoreline at the boat rental area worsen erosion by trampling the vegetation that helps stabilize the area.



Image 25. Erosion along bank of the boat rental shoreline (photo facing east [A]) and fallen trees (photo facing north-northeast [B]).



Image 26. Apparent footpath leading down bank of the boat rental shoreline, facing southeast.

2.8 Wildwood Trail Shoreline

During the Desktop Data Collection, Stantec noted the Wildwood Trail shoreline was classified as susceptible to slight erosion rates, but the Maryland Shoreline Stabilization Mapper (MSSM) data indicates a need for structural shoreline protection along a small portion of the shore. Stantec visited the location identified for structural protection and observed eroded, unvegetated banks approximately 5 ft in height (Image 27). Inspection of neighboring shorelines identified as suitable for living shorelines in the MSSM database appear similar in erosion profile, sediments, vegetation, and overwater fetch exposure to the segment identified for structural protection. Based on the similarity of shoreline conditions, Stantec believes the entirety of the shoreline is amenable to nature-based shoreline protection alternatives.

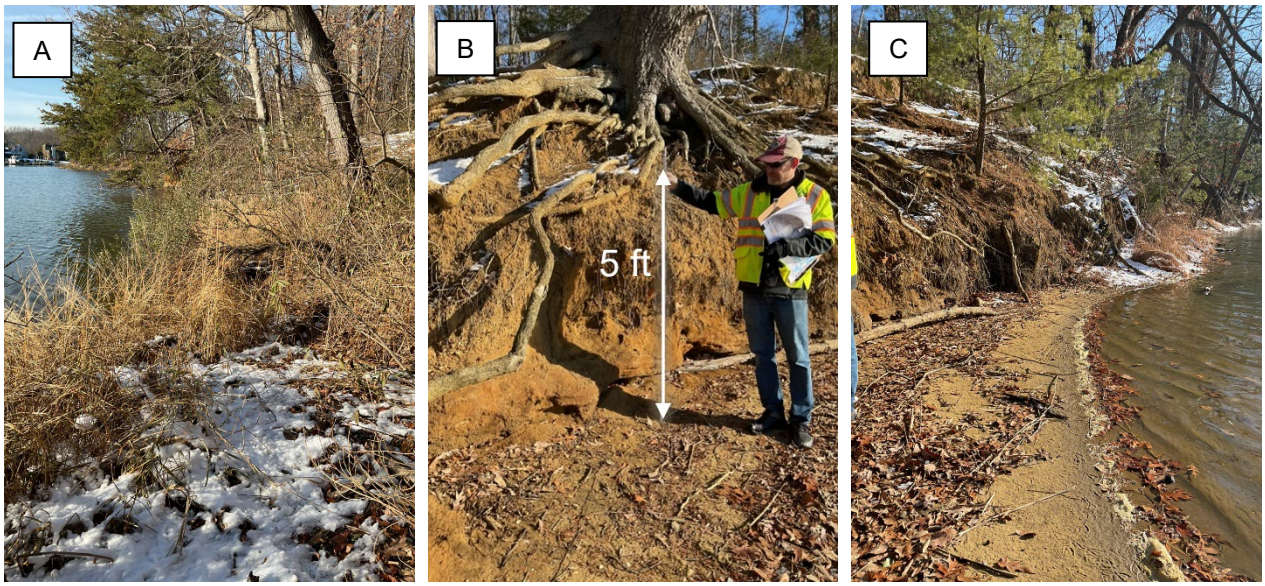


Image 27. Eroding bank along the Wildwood Trail shoreline, facing north (A), east (B), and south (C).

2.9 Caffrey Run Wetlands

Stantec visited the Caffrey Run wetlands to confirm wetland health and discern whether riverine flooding could be a strong contributor to shoreline erosion. Upon inspection, the wetland looks healthy with a strong native vegetation presence, and braided stream flow patterns indicative of low flow velocities within the streams (Image 28). Iron floc, characterized by its natural orange hue in the stream, signifies favorable anaerobic conditions within the wetlands, which facilitate the breakdown of nitrogen pollutants. No channel or bank erosion was observed in the channel. There were also no large sand bars indicating upstream erosion. Based on these observations, Stantec has no concerns about stream flow through the wetlands.



Image 28. Braiding streams in Caffrey Run wetlands.

2.10 Interior Park Features and Stormwater Infrastructure

Stantec also inspected the interior storm water management features, including Holly Pavilion Wetland, Lighthizer Gazebo Pond, and the Parking Lot C culvert. These areas were not investigated in as much depth as others, as they are not the focus of this work, but it was noted that the infrastructure generally appears to be in good condition. The control structures and outfalls for these facilities were observed to be in good condition, and no erosion was observed within or downstream. The vegetation appeared healthy.

3 Conclusions

The field reconnaissance enabled Stantec to verify the shoreline conditions from the Desktop Data Collection as well as discussions with Anne Arundel County's DRP and Park staff. Stantec documented existing shoreline characteristics and key erosion drivers, including exposure to wave energy from large fetch distances and stormwater runoff. Upland runoff contributing to shoreline erosion generally results from manmade walkways through the Park. Nature-based solutions appear particularly suitable for more sheltered areas such as Loden Pond and the Harness Creek embayments, where healthy marshes are already established and indicate strong potential for future enhancement. Locations exposed to higher wave energy, such as the Quiet Water Retreat Shoreline, may require more robust shoreline protection measures to stabilize the banks where significant erosion was observed. The information and insights gained from the Desktop Data Collection and Field Reconnaissance efforts provide crucial knowledge for Stantec engineers and scientists to develop robust and resilient shoreline protection solutions for Quiet Waters Park.

Reference: **Quiet Waters Park Field Reconnaissance**

Best regards,

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Appendix C Site Vulnerability Assessment and Project Prioritization

Stantec

Memo

To:	Gabe Cohee Rich Lefebure Shelley Ridge	From:	Rebecca Aiken, PE Claire Sorensen, EIT Laurel, MD
Project/File:	203403333	Date:	June 4, 2026

Reference: Quiet Waters Park Resilience Assessment and Planning - Site Vulnerability Assessment and Project Prioritization

1 Introduction

In support of the Quiet Waters Park (the Park) Resilience Assessment and Planning project, Stantec performed a site vulnerability assessment and shoreline reach prioritization for future resilience efforts. The Park shoreline was segmented into ten (10) shoreline reaches based on shared characteristics (Figure 1), and evaluated based on each segment's exposure, sensitivity, and adaptive capacity of current and future coastal hazards. The vulnerability assessment applied the scoring rubric to quantify and prioritize resilience planning along Park shorelines. The assessment incorporated desktop and field reconnaissance data collected from Task 2, supplemented by insights from the Resilience Authority of Annapolis and Anne Arundel County (the Resilience Authority) and Anne Arundel County Department of Recreation and Parks (DRP). The final vulnerability assessment scores and prioritizes shoreline rankings, identifying shoreline segments requiring future action. Based on this, Task 4 will focus efforts on solution identification.

Reference: **Quiet Waters Park Resilience Assessment and Planning - Site Vulnerability Assessment and Project Prioritization**



Figure 1. Shoreline segmentation (unique colors represent shoreline segments evaluated).

2 Shoreline Segmentation

The Park shoreline was discretized into ten unique segments based on shoreline characteristics, such as shoreline orientation, shoreline type, exposure to wave action, upland land use, and historic erosion. The shoreline segments and their characteristics are provided in Table 1.

Table 1. Shoreline segmentation key.

Shoreline Segment	Shoreline Name	Shoreline Characteristics
1	Quiet Water Retreat	• Exposed, sandy bluffs • Experiencing severe erosion • Vegetation present behind failing structures • Planned upland infrastructure
2	Loden Pond	• Protected embayment with healthy wetland systems • Experiencing moderate erosion • Planned upland infrastructure
3	South River Overlook Shoreline	• Exposed, hardened shoreline • Existing upland infrastructure
4	Entrance to Harness Creek	• Exposed, eroding headland • Healthy wetland • Experiencing moderate erosion
5	Harness Creek Inlet Shoreline	• Bluffs with limited vegetation • Experiencing moderate erosion
6	Harness Creek Embayments	• Protected area with healthy wetlands • Contains step pool with newly established submerged aquatic vegetation (SAV) • Experiencing moderate erosion
7	Harness Creek Trail Shoreline	• Mainly exposed bluffs with some healthy vegetation at headland • Location of planned Arundel Rivers Federation (ARF) Living Shoreline Project • Experiencing severe erosion
8	Boat Rental Shoreline	• Exposed, eroding shoreline with limited bluff vegetation • Existing upland and shoreline infrastructure critical for waterway access • Experiencing moderate erosion
9	Wildwood Trail Shoreline	• Mainly unvegetated bluffs with some marsh grasses • Experiencing severe erosion
10	Old Place Cove Shoreline	• Protected shoreline with healthy wetlands • No observed erosion

3 Vulnerability Assessment

The vulnerability assessment applied the scoring rubric detailed in Appendix A to strategically quantify and prioritize resilience planning along Park shorelines. The rubric is split into three evaluation categories to assess site exposure, sensitivity, and adaptive capacity to coastal hazards and climate change. Indicators associated with each evaluation category presented in Figure 2. Site exposure indicators account for shoreline vulnerability to wave energy, boat wakes, storm surge, sea level rise, stormwater runoff, erosion, existing shoreline infrastructure, and human interference. The shoreline's sensitivity considers existing wetlands and aquatic habitat and the presence of Park infrastructure. Lastly, adaptive capacity parameters explore impacts to Park accessibility, ecological reintegration potential, inland migration, and connectivity to neighboring shoreline conditions. Analytical details leveraged to support parameter scoring and shoreline rankings are provided in the subsequent sections.

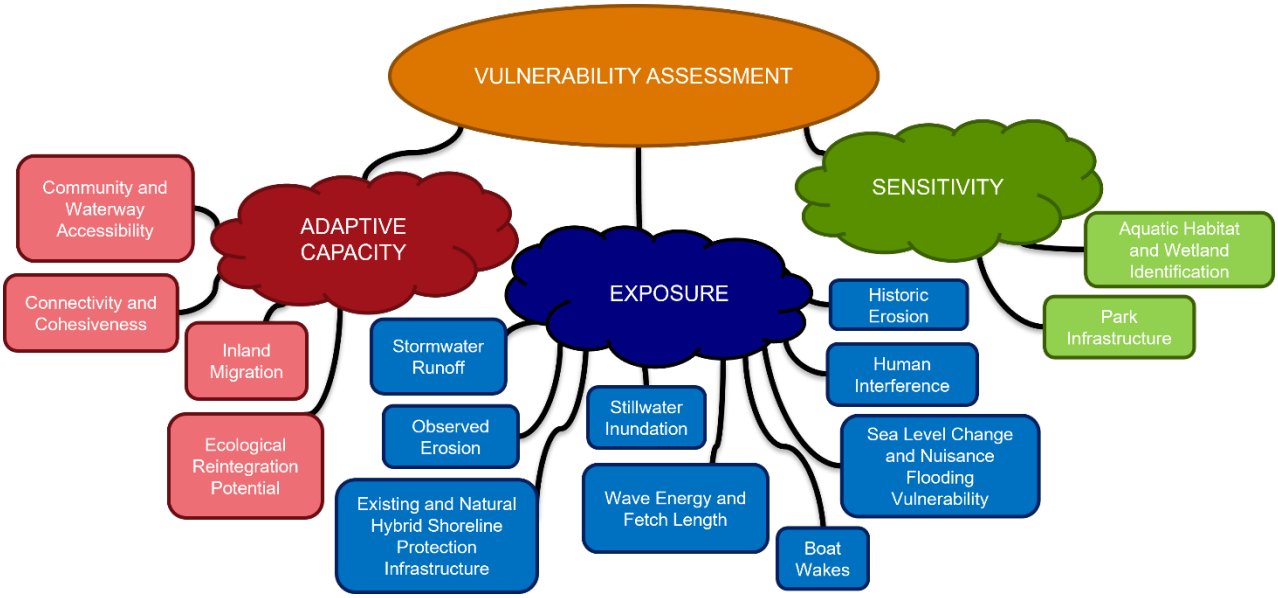


Figure 2. Vulnerability assessment parameters

3.1 Exposure Indicators

3.1.1 Wave Energy and Fetch

Shoreline exposure to wave energy was assessed based on average fetch lengths and associated energy regimes detailed in the Virginia Institute of Marine Science (VIMS) Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments (2017). The average fetch is calculated using the length of five (5) overwater radial fetch lengths. The analysis considers the shore normal fetch length as well as two fetch lengths segmented 22.5° apart on either side of the shore normal direction. Near linear shoreline segments, such as the Harness Creek Inlet Shoreline (Segment 5), analyzed fetch along the midpoint of the shoreline (Figure 3). Shoreline segments with varying shoreline orientation, such as Loden

Pond (Segment 2) and the Harness Creek Embayments (Segment 6), assessed fetch from multiple directions. Up to three additional shoreline points were chosen based on variation in shore orientation, and the maximum of the average fetch lengths from each point was used to rank the wave energy experienced along the shoreline segment. Figure 4 displays the radial fetch lengths originating from various locations along the Loden Pond (Segment 2) shoreline.

VIMS categorizes wave energy as low, medium, or high based on fetch lengths of less than 1 mile, 1-5 miles, and 5-15 miles, respectively. The Quiet Waters Retreat (Segment 1) and South River Overlook (Segment 3) have the greatest exposure along the South River. More enclosed areas, such as Loden Pond (Segment 2) and Old Place Cove (Segment 10), have limited fetch and less exposure to wind wave energy. The average fetch as well as the corresponding vulnerability ranking for each shoreline segment is provided in Appendix B.

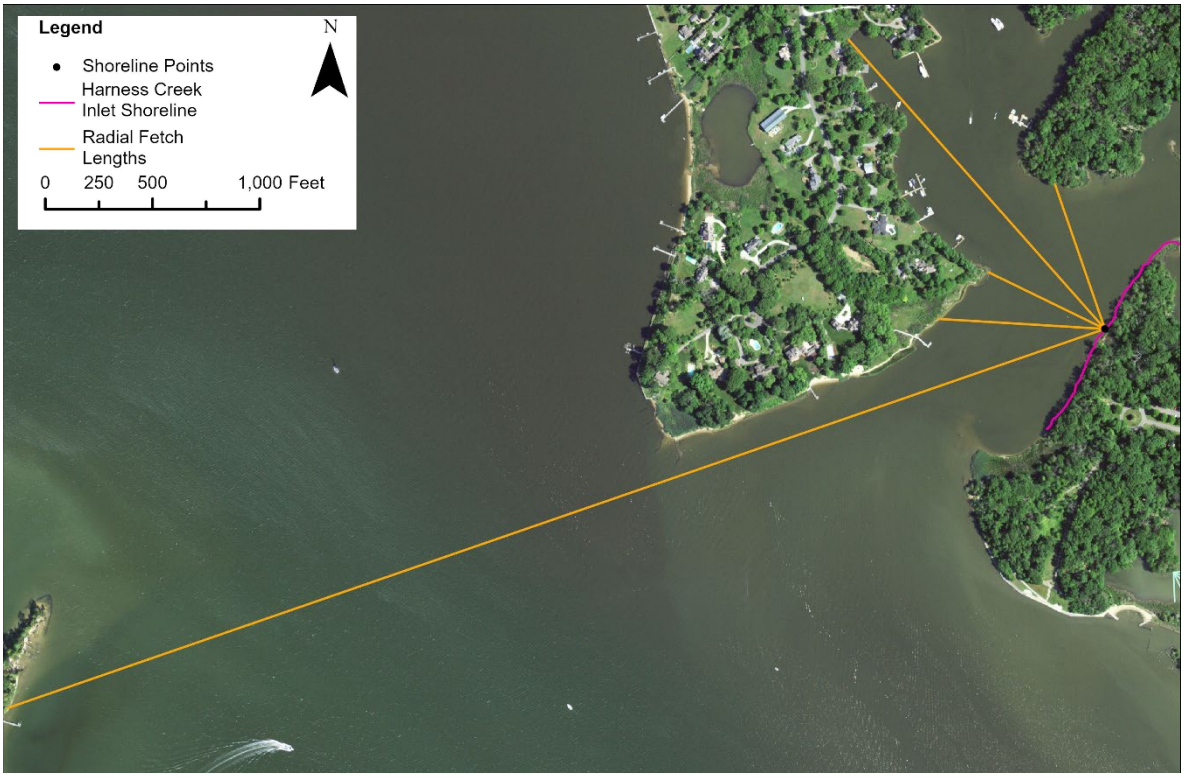


Figure 3. Example radial fetch lengths averaged for a linear shoreline at Harness Creek Inlet (Segment 5).

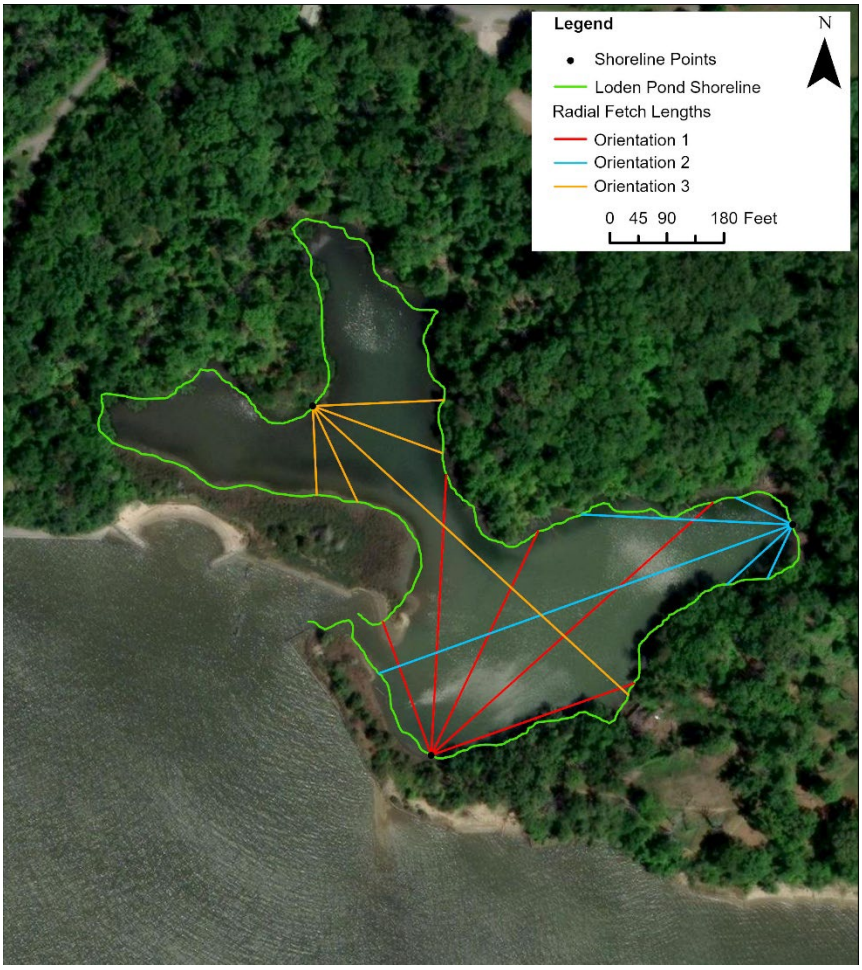


Figure 4. Example fetch length assessment for the non-linear shoreline at Loden Pond (Segment 2).

3.1.2 Boat Wakes

Boat wakes can contribute to shoreline erosion and are a known hazard to the Park's shorelines. The Maryland Department of Natural Resources (DNR) Maryland Speed Zone map provides maximum vessel speeds along the South River and Harness Creek (Figure 4). Based on insights from DRP and Park staff, it is assumed motorized boats do not enter Loden Pond and there are no boat wakes.

Three categories were used to assess the impact on boat wakes on the shoreline segments. The most vulnerable shorelines are those exposed to vessel speeds of 35 knots along the Lower South River. Harness Creek shorelines are moderately vulnerability to vessel speeds of 6 knots. Enclosed areas that are only accessible by kayaks, such as Loden Pond, receive the least vulnerable ranking. Vulnerability rankings based on boat wakes are provided in Appendix B.

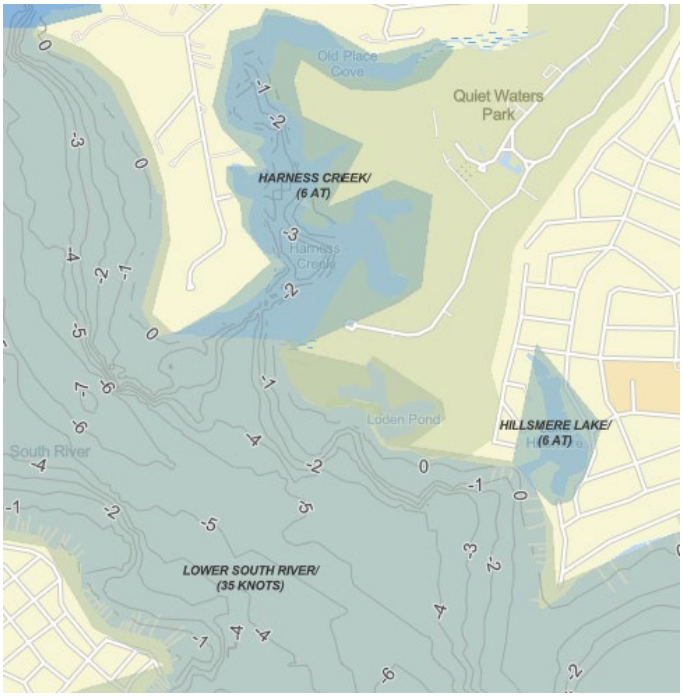


Figure 5. Speed limits within the Lower South River and Harness Creek (Maryland DNR, 2026). AT indicates that the speed limit is enforced at all times.

3.1.3 100-Year Stillwater Inundation

The stillwater elevation (SWEL) associated with the 100-year event, which has 1-percent chance of occurring any given year, includes statistical tides and storm surge. The Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Anne Arundel County published two (2) transects with coastal analyses near the confluence of the South River with the Chesapeake Bay (Figure 6). The 100-year SWEL is report as 4.5 feet referenced to North American Vertical Datum of 1988 (NAVD88) at both Transect 60 and Transect 61 (FEMA, 2015). Additional information available from FEMA's FIS are also reported in the Desktop Data Collection report (Stantec, 2025).



Figure 6. FEMA FIS coastal floodplain and analytical transects proximal to Quiet Waters Park.

The inundation extent of the 100-year SWEL is compared to the normal Mean Higher High Water (MHHW) inundation, pulled from the National Oceanic and Atmospheric Administration (NOAA) station 8575512 located approximately 4 miles north of the Park (NOAA, 2025a), at 0.66 feet NAVD88. Inundation extents were mapped against elevation data from the NOAA National Centers for Environmental Information (NCEI) Continuously Updated Digital Elevation Model (NOAA, 2025b; Figure 7).

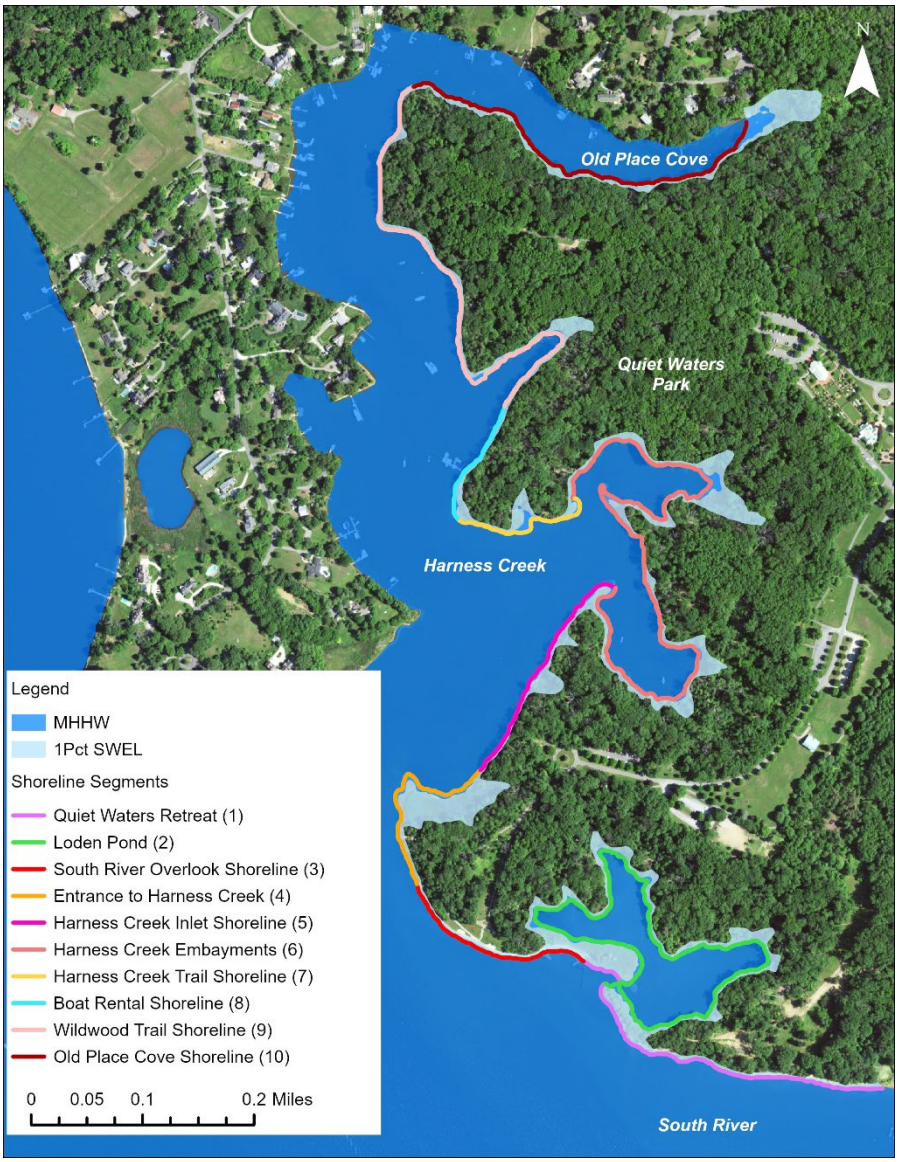


Figure 7. Inundation under normal conditions (MHHW) and 100-year conditions (1Pct SWEL).

Low lying areas that are not typically inundated under high water conditions, such as at the Entrance to Harness Creek (Segment 4), are the most impacted by the 100-year SWEL. The small peninsulas at the entrance to Loden Pond are inundated by the 100-year condition as well. Steeper shorelines, such as the Boat Rental and Wildwood Trail Shorelines (Segments 8 and 9), are less impacted by SWEL inundation. Along each shoreline segment, storm surge vulnerability was assessed by comparing the area between the shoreline (i.e., 0-ft NAVD88 contour) and the SWEL limit to the area typically inundated between the shoreline and the MHHW limit. The percent change in inundation ranged from 250% to 640%. The storm surge vulnerability scoring was segmented into three ranges: high vulnerability shorelines had a percent

change greater than 500%, moderate vulnerability shorelines had a percent change ranging between 350% and 500%, and low vulnerability flooding had a percent change less than 350%. The percent changes and corresponding vulnerability rankings are available in Appendix B.

3.1.4 Sea Level Change & Nuisance Flooding

The Park's tidally influenced location along the South River exposes it to the impacts of sea level rise (SLR). According to the sea level rise Projections for Maryland 2023, waters levels are expected to increase an additional 1.3 feet by 2050 (relative to a 2005 baseline). SLR was added to the MHHW datum for a projected 2050 MHHW of 1.96 feet (NAVD88). The inundation associated with increased water levels is displayed in Figure 8.

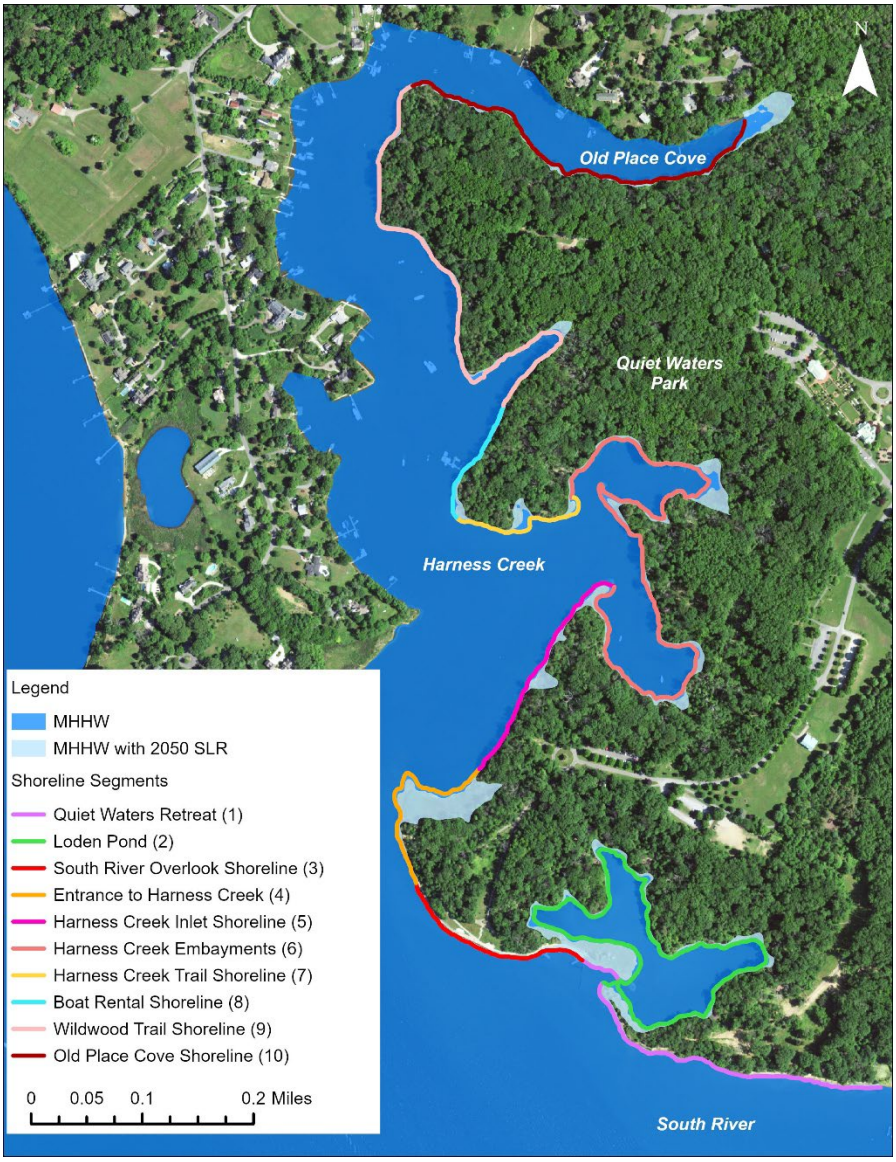


Figure 8. Inundation under normal conditions (MHHW) and under 2050 SLR conditions.

Results under the 2050 SLR condition are similar to those for the 1-percent SWEL conditions, with low lying areas more susceptible to impacts than steeper shorelines. Using the same analytical approach as with storm surge, the 2050 MHHW inundation area was compared with the existing MHHW datum inundation. The percent change ranged from 135% to 530%. Shoreline vulnerability in this case was scored such that the most vulnerable shorelines were those with a percent change greater than 300%, moderately vulnerable segments had percent change ranging from 150% and 300%, and low vulnerability areas had a percent change less than 150%. The percent changes and corresponding vulnerability rankings are available in Appendix B.

3.1.5 Stormwater Runoff

Stormwater runoff contributes to localized erosion and can reduce water quality by way of nutrient and sediment loading. During Stantec's site visit in December 2025, team members noted areas where stormwater runoff contributed to shoreline erosion, predominantly in areas with paved upland and manmade trails. Shoreline segments scored high where stormwater runoff was a notable driver of shoreline erosion, with indicators such as runoff channels or rills and sparser vegetation. Locations showing evidence of stormwater-related erosion were assigned a moderate score. Segments where there was no indication that stormwater runoff was contributing to erosion were scored low. Details for the assessment and vulnerability scores based on stormwater runoff are available in Appendix B.

3.1.6 Historic Erosion

Maryland Shoreline Change data provide historical shoreline positions and associated erosion and accretion rates across the Park shoreline (DNR, 2025). DNR classifies historic erosion based on low (-2.00 to -4.00 ft/yr), moderate (-4.00 to -8.00 ft/yr), and high (> -8.00 ft/yr) erosion rates. Recorded DNR erosion rates along the shoreline segments were leveraged to assign low, moderate, or high erosion scores. The most conservative erosion rate for each specific reach informed the assigned vulnerability score. Segments with erosion rates greater than 8 feet per year were assigned high vulnerability scores, segments with erosion rates ranging from 4 to 8 feet per year were assigned moderate vulnerability scores, and segments with erosion rates less than 2 feet per year or exhibiting accretion were assigned low vulnerability scores. The full assessment and vulnerability scores based on historic erosion are available in Appendix B.

3.1.7 Observed Erosion

In addition to historic erosion, field observations provide direct evidence for site erosion and shoreline stability. Unstable, eroded shorelines were determined by the presence of embankment steepness, signs of slumping and undercutting, and the presence or absence of vegetation along shoreline slopes. In December 2025, Stantec noted areas of significant erosion along the Park shoreline that were not captured in the shoreline change data presented in the Desktop Data Collection Report (Stantec, 2025). For this reason, observed erosion was assessed independently. For the purposes of the vulnerability assessment, observed erosion conditions and shoreline stability were considered twice as important as historic data leveraged from Maryland's Shoreline Change database and were weighted accordingly in the vulnerability scoring. Shorelines with unvegetated embankment faces exceeding 4 ft heights were considered the most vulnerable. Shorelines with unvegetated slopes for 2-4 ft of the embankment face were considered moderately vulnerable. Shorelines with erosion along less than 2 ft of the bank face height were considered the least vulnerable. The full assessment and vulnerability scores based on observed erosion are available in Appendix B.

3.1.8 Existing Natural, Hybrid, and Grey Shoreline Protection Infrastructure

Existing natural or hybrid shoreline protection features, such as healthy marsh systems or living shorelines with green and grey infrastructure, reduce shoreline vulnerability to erosion and coastal flood hazards. Shoreline segments with robust protection, such as intact riprap or sheet piling, received the lowest vulnerability scores, as enhancements are not required to protect the shoreline. Segments without engineered structures but protected by natural features that mitigate coastal hazards, such as existing wetlands, received moderate vulnerability scores. Fully exposed shorelines or those with failing infrastructure received the highest vulnerability scores, as these areas would benefit most from the implementation of shoreline protection. The full assessment and vulnerability scores based on existing natural or hybrid shoreline protection infrastructure are available in Appendix B.

3.1.9 Human Interference

Human interference can exacerbate shoreline erosion by damaging or removing stabilizing vegetation and exposing sediment. Repeated trampling compacts soil, reduces plant cover, and creates local runoff pathways, all of which can accelerate erosion. To assess the extent of human interference and assign a corresponding vulnerability score, Stantec reviewed a combination of site photographs, field notes, and aerial imagery. Evidence of human interference was identified through physical indicators, such as footpaths outside of designated walking paths, areas of bare or compacted ground, and trampled foliage. Shoreline segments that scored highest for human interference were those with significant man-made footpaths and evidence of frequent off-trail use, indicated by deep, bare-earth trenches, such as those observed along the Harness Creek Inlet Shoreline (Segment 5) and Quiet Waters Retreat (Segment 1) shorelines. Segments scoring moderately were those with minor footpaths, evidenced by trampled foliage and shallow walkway trenches, that may lead to future issues. Shoreline reaches that had no evidence of human trespass off designated trails scored low. The full assessment and vulnerability scores based on human interference are available in Appendix B.

3.2 Sensitivity Indicators

3.2.1 Aquatic Habitat and Wetland Identification

Aquatic habitat and wetlands provide critical habitat for native species while buffering the coastline from open-water forces. Shorelines with these elements are valuable, better positioned to support nature-based shoreline protection, and should be protected. This parameter evaluated whether these features are present along each shoreline segment. The highest scores were given to segments with extensive aquatic habitat and/or well-established wetlands, such as areas within Loden Pond (Segment 2). Shorelines with some existing features, such as small marshes, were assigned moderate vulnerability scores. Segments lacking aquatic habitat or wetlands, such as exposed bluffs or hardened shorelines, received low vulnerability scores. These rankings reflect only what is currently present at the site, and do not consider any planned living shoreline projects or natural features that may have historically occupied that reach. The

full assessment and vulnerability scores based on aquatic habitat and wetland identification are available in Appendix B.

3.2.2 Park Infrastructure

Park infrastructure including buildings, paved walkways, boat ramps, and docks, as well as proposed infrastructure detailed in the Quiet Waters Retreat Master Plan and the Arundel Rivers Federation Living Shoreline plans. This parameter captures the importance of existing or planned infrastructure to Park operations. Shoreline segments with critical existing or planned upland infrastructure were assigned high vulnerability scores. These segments include Quiet Waters Retreat and Loden Pond, due to the planned facilities in the Quiet Waters Retreat Master Plan, as well as the South River Overlook Shoreline (Segment 3) and the Boat Rental Shoreline (Segment 8). Segments with non-critical infrastructure, such as Harness Creek Trail Shoreline (Segment 7), which includes proposed living shoreline infrastructure, and Harness Creek Embayments (Segment 6), which includes the step pool, received moderate vulnerability scores. Shoreline segments without any shoreline or adjacent upland infrastructure were assigned the lowest vulnerability scores. The full assessment and vulnerability scores based on park infrastructure are available in Appendix B.

3.3 Adaptive Capacity Indicators

3.3.1 Community and Waterway Accessibility

Community and waterway accessibility reflects whether the shoreline segment is used and provides accessibility for community recreation, Park programs, or water access. This parameter accounts for physical infrastructure such as trails, docks, beaches, and viewing areas. Shorelines with assets that are regularly used for Park activities and provide direct access to the water were assigned high vulnerability rankings. Shorelines with upland areas often used for Park activities, but that do not allow direct access to the water were assigned moderate vulnerability rankings. Shoreline segments that are not regularly used for community recreation or Park programs and have no access to the water were given low priority rankings. The full assessment and vulnerability scores based on community and waterway accessibility are available in Appendix B.

3.3.2 Ecological Reintegration Potential

Ecological reintegration potential reflects the opportunity for enhanced ecological processes along the shoreline. The parameter assigns shorelines with the greatest opportunity for improvement higher scores, such as shoreline segments where failing hardened infrastructure could be replaced with functional living shorelines to restore intertidal habitat. Shorelines with moderate vulnerability scores include areas where living systems are present but declining, such as eroding marshes; these segments could benefit from nature-based interventions to restore ecological function, but impacts to ecological capacity are of moderate significance. Shorelines that are already ecologically healthy or have intact hardened structures receive lower scores. The full assessment and vulnerability scores based on ecological reintegration potential are available in Appendix B.

3.3.3 Inland Migration

Inland shoreline migration assessed the potential impacts of future erosion on existing and proposed park infrastructure. Erosion rates from the Maryland Shoreline Change database were used to project the adjusted shoreline position in 2050 (DNR, 2025). The maximum erosion rates along each segment were applied to assess the potential inland change; however, when shoreline segments contained localized erosion hot spots that were not representative of the broader shoreline reach, a more representative rate was selected (Loden Pond, Segment 2; Entrance to Harness Creek, Segment 4; Harness Creek Trail Shoreline, Segment 7). For shoreline segments that were particularly long or exhibited highly variable erosion rates, multiple erosion rates were applied to more accurately develop the projected 2050 shoreline (Wildwood Trail Shoreline, Segment 9). The current shoreline position, located at an elevation of 0 feet NAVD88, and the 2050 shoreline position are presented in Figure 9. The Quiet Waters Retreat Master Plan layout is projected over Figure 10 to illustrate the impact that shoreline erosion may have on the proposed plans. The Quiet Waters Retreat shoreline was analyzed for migration from the existing shoreline as well as from the existing bluff crest since proposed infrastructure offsets from the bluff crest are critical to ensure community safety. Due to the proposed infrastructure upland, Quiet Waters Retreat (Segment 1) received a high vulnerability score. Other shorelines that were ranked high for impact from inland migration include Loden Pond (Segment 2), Harness Creek Trial Shoreline (Segment 7), and the Boat Rental Shoreline (Segment 8). Shoreline reaches experiencing significant inland migration impacting non-critical infrastructure, such as the Park's "red trails", were assigned moderate vulnerability scores. Moderately vulnerable shorelines for this indicator include the Harness Creek Inlet Shoreline (Segment 5), Harness Creek Embayments (Segment 6), and the Entrance to Harness Creek (Segment 4), were assigned moderate vulnerability scores. The lowest scoring shoreline segments, Wildwood Trail Shoreline (Segment 9) and Old Place Cove Shoreline (Segment 10), experience minimal inland migration that does not pose a threat to infrastructure. The full assessment and vulnerability scores based on inland migration are available in Appendix B.

Reference: **Quiet Waters Park Resilience Assessment and Planning - Site Vulnerability Assessment and Project Prioritization**

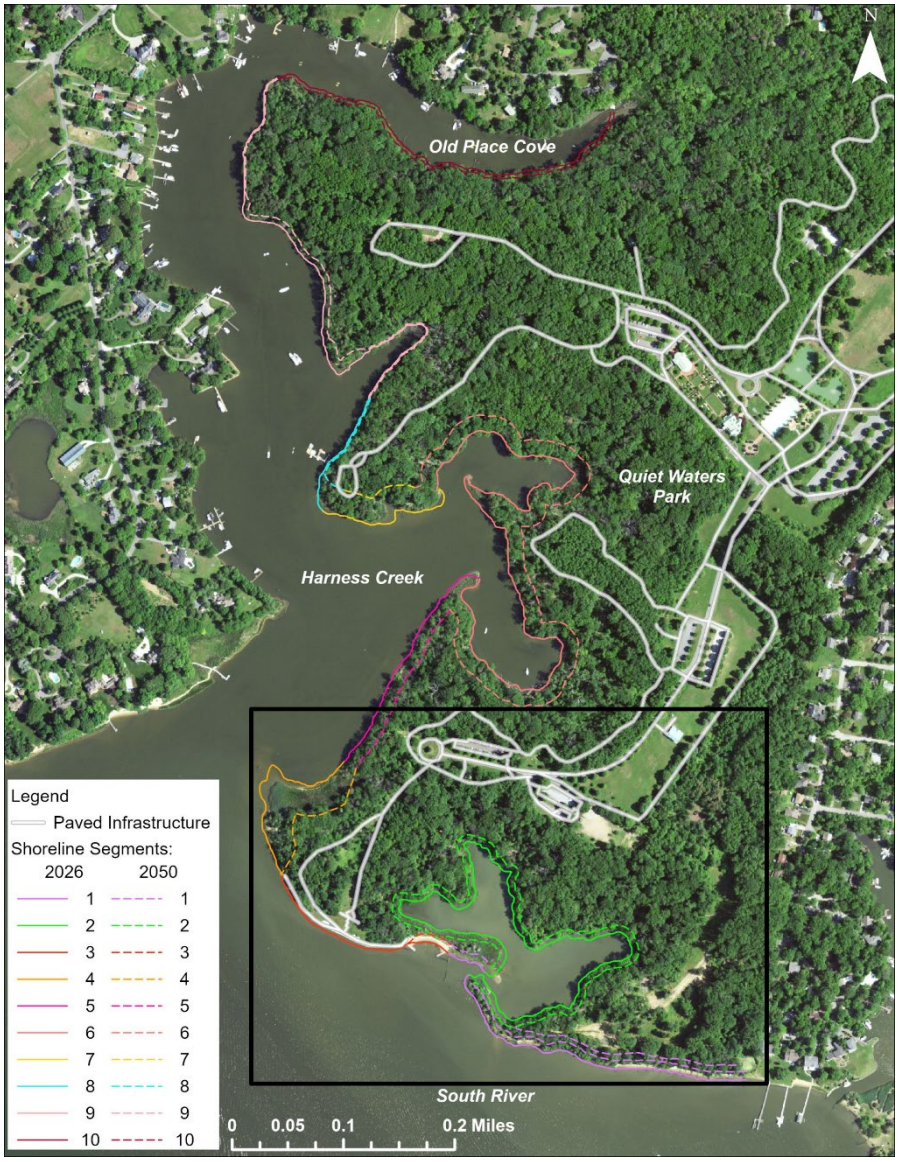


Figure 9. Current (solid lines) and projected 2050 (dashed lines) shoreline positions.

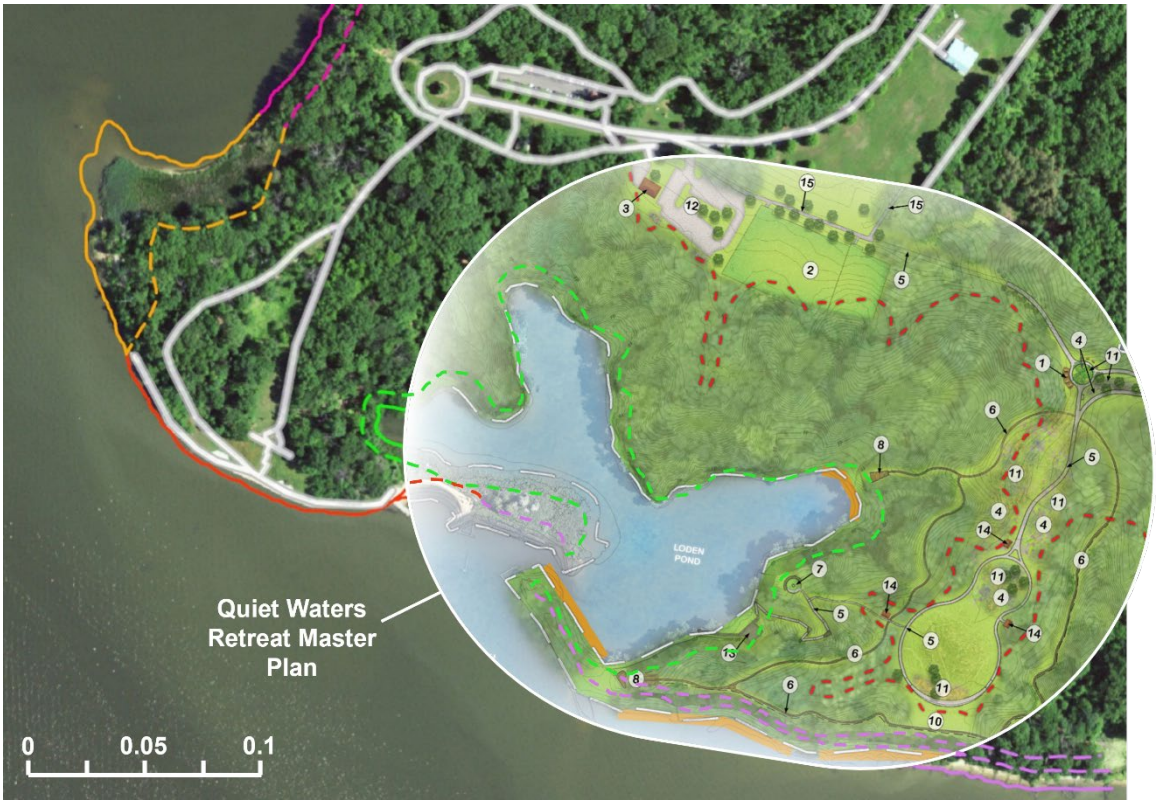


Figure 10. Current and 2050 shoreline positions overlayed with the Quiet Waters Retreat Master Plan layout. Dashed lines represent 2050 shoreline position for Loden Pond (green) and Quiet Waters Retreat (purple).

3.3.4 Connectivity and Cohesiveness

Connectivity and cohesiveness evaluate the potential for proposed shoreline protection along a shoreline segment to benefit adjacent shorelines, such as reducing erosion or wave energy in neighboring areas. Isolated shoreline segments, such as Harness Creek Embayments (Segment 6) and Loden Pond (Segment), received low vulnerability scores because shoreline protection actions at these locations are unlikely to benefit surrounding segments. Shorelines that received moderate scores have the potential to provide some benefit to adjacent areas, but it is project dependent. Segments that scored high are those where implementation would likely result in measurable improvements to neighboring shorelines. For example, protection of the steep eroding bluffs at Quiet Waters Retreat (Segment 1) and replacing infrastructure at the entrance to Loden Pond will limit sedimentation and intermittent closing of Loden Pond (Segment 2). The full assessment and vulnerability scores based on connectivity and cohesiveness are available in Appendix B.

4 Conclusions

The scores for each indicator were summed to compute a total vulnerability score for each shoreline segment, culminating in the prioritized ranking provided in Table 2. The highest priority shorelines will be closely examined for shoreline protection efforts during the solutions identification phase. Of note, the Harness Creek Trail Shoreline (Segment 7) ranked the third most vulnerable shoreline; however, this ranking does not reflect the planned protection and habitat enhancements included in the ARF living shoreline project. Its high ranking nonetheless underscores the value and anticipated benefits of implementing a living shoreline at this location. For shorelines with equal scoring from the vulnerability assessment, final rankings are informed from discussion with Anne Arundel DRP and the Resilience Authority. Loden Pond (Segment 2) ranks higher than Harness Creek Inlet Shoreline (Segment 5) due to the potential for heightened continuity and ecological benefit with prioritized and planned actions at Quiet Waters Retreat. Similarly, the Wildwood Trail Shoreline (Segment 9) is ranked higher than South River Overlook Shoreline (Segment 3) due to the potential for nature-based shoreline protection without impacting designated community shoreline accessibility.

In the next phase of work, it is recommended to prioritize solution identification for Quiet Water Retreat (Segment 1), the Entrance to Harness Creek (Segment 4), and the Boat Rental Shoreline (Segment 8). Additionally, based on feedback from the Resilience Authority and DRP during a meeting on May 21, 2026, solutions for Loden Pond (Segment 2), Harness Creek Inlet Shoreline (Segment 5), and Wildwood Trail Shoreline (Segment 9) are requested due to their potential for habitat enhancement and nature-based solutions. For a complete table of vulnerability scores, see Appendix C.

Table 2. Vulnerability scores and priority rankings.

Shoreline Priority Rank	Shoreline Segment	Total Vulnerability Score
1	Quiet Waters Retreat (1)	64
2	Entrance to Harness Creek (4)	54
3	Harness Creek Trail Shoreline (7)	48
4	Boat Rental Shoreline (8)	44
5	Loden Pond (2)	42
6	Harness Creek Inlet Shoreline (5)	42
7	Harness Creek Embayments (6)	40
8	Wildwood Trail Shoreline (9)	36
9	South River Overlook Shoreline (3)	36
10	Old Place Cove Shoreline (10)	26

Reference: **Quiet Waters Park Resilience Assessment and Planning - Site Vulnerability Assessment and Project Prioritization**

Best regards,

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References

Boesch, D. F., Baecher, G. B., Boicourt, W. C., Cullather, R. I., Dangendorf, S., Henderson, G. R., Kilbourne, H. H., Kirwan, M. L., Kopp, R. E., Land, S., Li, M., McClure, K., Nardin, W., & Sweet, W. V. (2023). Sea level rise projections for Maryland 2023. University of Maryland Center for Environmental Science.

Maryland Department of Natural Resources. (2025). Maryland shoreline change data [Dataset]. Retrieved December 10, 2025, from https://data.imap.maryland.gov/datasets/maryland-shoreline-changes-baseline

Federal Emergency Management Agency. (2015). *Flood Insurance Study (FIS) Anne Arundel County, Maryland and incorporated areas (Study No. 24003CV000B).* Federal Emergency Management Agency.

Hardaway, Jr., C.S., Milligan, D.A., & Duhring, K. (2017). Living shoreline design guidelines for shore protection in Virginia's estuarine environment (SCRAMSOE #463). Gloucester Point, VA: Virginia Institute of Marine Science. https://doi.org/10.21220/V5CF1N

Maryland Department of Natural Resources. (2026). *Speed Zone Map*. Retrieved from https://experience.arcgis.com/experience/bad303cdcccf46fc9d4d7accbaa07e47

McClure, K., Land, S., & Vogel, K. (2024). Guidance for using Maryland's 2023 sea level rise projections. Maryland Department of Natural Resources; University of Maryland Sea Grant Extension.

National Oceanic and Atmospheric Administration. (2025a). CO-OPS Station 8575512 Annapolis (Naval Academy), Maryland: Water level observations. Retrieved November 26, 2025, from https://tidesandcurrents.noaa.gov/stationhome.html?id=8575512

National Oceanic and Atmospheric Administration. (2025b). NOAA data access viewer: Topographic and bathymetric elevation data (including 2019 NOAA NGS topobathymetric LiDAR, 2020 Maryland LiDAR DEM, and NOAA CUDEM). https://coast.noaa.gov/dataviewer/

Stantec. (2025). *Quiet Waters Park Resilience Planning & Assessment Desktop Data Collection Report*.

U.S. Department of Agriculture. (2025). *Natural Resources Conservation Service SSURGO soils data for Maryland.* Retrieved November 20, 2025, from https://data.imap.maryland.gov/datasets/maryland::maryland-ssurgo-soils-ssurgo-soils

Appendix A: Vulnerability Assessment Rubric

TYPE	INDICATOR	SCORE		
		5	3	1
EXPOSURE	Wave energy and Fetch Length	Shoreline exposed to high wave energy with an average fetch greater than 5 miles.	Shoreline exposed to moderate wave energy with an average fetch 1-5 miles.	Shoreline exposed to low wave energy with an average fetch less than 1 mile.
	Boat Wakes	Shoreline is vulnerable to boat wake energy with boat speeds reaching up to 35 knots.	Shoreline is vulnerable to moderate boat wake energy with boat speeds reaching up to 6 knots.	Shoreline is vulnerable to low boat wake energy with posted 'No Wake Zones' or restricted boat access.
	100-Year Stillwater Inundation	Shoreline experiences large amounts of storm surge inundation during the 1-percent-annual-chance event. The extent of inundation is defined as the percent change between the baseline inundated area (from the shoreline, defined by the 0-ft NAVD88 contour, to the MHHW limit) and the inundated area extending from the shoreline to the 1-percent annual chance water level line. High vulnerability shorelines have a percent change greater than 500%.	Shoreline experiences moderate amounts of storm surge inundation during the 1-percent-annual-chance event. The extent of inundation is defined as the percent change between the baseline inundated area (from the shoreline, defined by the 0-ft NAVD88 contour, to the MHHW limit) and the inundated area extending from the shoreline to the 1-percent annual chance water level line. Moderately vulnerable shorelines have a percent change ranging between 350% and 500%.	Shoreline experiences low amounts of storm surge inundation during the 1-percent-annual-chance event. The extent of inundation is defined as the percent change between the baseline inundated area (from the shoreline, defined by the 0-ft NAVD88 contour, to the MHHW limit) and the inundated area extending from the shoreline to the 1-percent annual chance water level line. Low vulnerability shorelines have a percent change less than 350%.
	Sea Level Change and Nuisance Flooding Vulnerability	Sea level rise poses a significant threat to the shoreline (i.e., large amounts of inundation). SLR is projected to be +1.3 feet by 2050[1]. The extent of inundation is defined as the percent change between the baseline inundated area (from the shoreline, defined by the 0-ft NAVD88 contour, to the MHHW limit) and the inundated area extending from the shoreline to the MHHW line with additional sea level rise. High vulnerability shorelines have a percent change greater than 300%.	Sea level rise poses a moderate threat to the shoreline (i.e., moderate amounts of inundation). SLR is projected to be +1.3 feet by 2050[1]. The extent of inundation is defined as the percent change between the baseline inundated area (from the shoreline, defined by the 0-ft NAVD88 contour, to the MHHW limit) and the inundated area extending from the shoreline to the MHHW line with additional sea level rise. Moderately vulnerable shorelines have a percent change ranging between 150% and 300%.	Sea level rise poses minimal threat to the shoreline (i.e., low amounts of inundation). SLR is projected to be +1.3 feet by 2050[1]. The extent of inundation is defined as the percent change between the baseline inundated area (from the shoreline, defined by the 0-ft NAVD88 contour, to the MHHW limit) and the inundated area extending from the shoreline to the MHHW line with additional sea level rise. Low vulnerability shorelines have a percent change less than 150%.
	Stormwater Runoff	Stormwater runoff is a significant contributor to shoreline erosion. Upland runoff is leading to possible loss of life or infrastructure.	Stormwater runoff moderately contributes to shoreline erosion. Upland runoff is leading to increased erosion with a possibility for an impact to infrastructure.	Stormwater runoff is not considered a notable contributor to shoreline erosion.

[1] Boesch, D. F., Baecher, G. B., Boicourt, W. C., Cullather, R. I., Dangendorf, S., Henderson, G. R., Kilbourne, H. H., Kirwan, M. L., Kopp, R. E., Land, S., Li, M., McClure, K., Nardin, W., & Sweet, W. V. (2023). *Sea level rise projections for Maryland 2023*. University of Maryland Center for Environmental Science.

	Historic Erosion	Historical shoreline position changes indicate the shoreline has experienced significant erosion and/or high measured rates of erosion of greater than 8 feet on average per year.	Historical shoreline position changes indicate the shoreline has experienced moderate erosion and/or has moderate measured rates of erosion between 4 and 8 feet on average per year.	Historical shoreline position changes indicate the shoreline has experienced minimal or no erosion and/or has low measured rates of erosion of less than 4 feet on average per year.
	Observed Erosion	Field observations indicate significant erosion of the shoreline with exposed bank heights of > 4 feet.	Field observations indicate moderate erosion of the shoreline with exposed bank heights of 2-4 feet.	Field observations indicate minimal or no erosion of the shoreline.
	Existing Natural, Hybrid, or Grey Shoreline Protection Infrastructure	Shoreline has failing or no shoreline protection infrastructure.	Shoreline has no protective structures, but natural elements are protecting the shoreline (i.e., marsh).	Shoreline has intact and functioning protective infrastructure or natural features (i.e., rock sills, marsh).
	Human Interference	Indication of significant human trespass off designated paths (i.e., eroded footpaths, trampled foliage).	Indication of minor human trespass off designated paths (i.e., eroded footpaths, trampled foliage).	No indications that human trespass is negatively impacting the shoreline.
SENSITIVITY	Aquatic Habitat and Wetland Identification	Shoreline offers significant aquatic habitat and/or wetlands.	Shoreline has some aquatic habitat and/or wetland.	Shoreline does not offer aquatic habitat or include wetlands.
	Park Infrastructure	There is existing or planned upland and/or shoreline infrastructure that is critical to the Park.	There is existing or planned upland and/or shoreline infrastructure, but it is non-critical to the Park.	There is no existing or planned upland or shoreline infrastructure.
ADAPTIVE CAPACITY	Community and Waterway Accessibility	Shoreline is a key feature for community recreation, the Park's programming, and waterway access.	The shoreline is used for community recreation and programming but does not offer waterway access.	The shoreline is not regularly used for community recreation, Park programs, or water access.
	Ecological Reintegration Potential	Shoreline has high potential for nature-based shoreline and ecological reintegration.	Shoreline has moderate potential for nature-based shoreline protection and ecological reintegration.	Shoreline does not have potential for nature-based shoreline protection and ecological reintegration.
	Inland Migration	Inland migration of the shoreline has significant impacts on the environment and the Park's offerings.	Inland migration of the shoreline has moderate impacts on the environment and the Park's offerings.	Inland migration of the shoreline does not have notable impact environment and the Park's offerings.
	Connectivity and Cohesiveness	The implementation of a living shoreline at this segment is expected to improve conditions at neighboring shorelines (reduced wave energy, reduced sedimentation, habitat creation, etc.).	The implementation of a living shoreline at this segment can possibly improve conditions at neighboring shorelines (reduced wave energy, reduced sedimentation, habitat creation, etc.) depending on living shoreline design.	The implementation of a living shoreline at this segment is unlikely to benefit neighboring shorelines.

Appendix B: Parameter Vulnerability Scores

Table 1. Shoreline segment key.

Shoreline Segment	Shoreline Name
1	Quiet Water Retreat
2	Loden Pond
3	South River Overlook Shoreline
4	Entrance to Harness Creek
5	Harness Creek Inlet Shoreline
6	Harness Creek Embayments
7	Harness Creek Trail Shoreline
8	Boat Rental Shoreline
9	Wildwood Trail Shoreline
10	Old Place Cove Shoreline

Table 2. Vulnerability ranking based on wave energy and fetch.

Shoreline Segment	Average Fetch (mi)	Vulnerability Ranking
1	1.02	3
2	0.09	1
3	3.25	3
4	0.72	1
5	0.36	1
6	0.30	1
7	0.30	1
8	0.22	1
9	0.39	1
10	0.08	1

Table 3. Vulnerability ranking based on boat wakes.

Shoreline Segment	Maximum Vessel Speed (knots)	Vulnerability Ranking
1	35	5
2	No Wake Zone	1
3	35	5
4	35	5
5	6	3
6	6	3
7	6	3
8	6	3
9	6	3
10	6	3

Table 4. Vulnerability ranking based on 100-year stillwater inundation.

Shoreline Segment	Percent Change (%)	Vulnerability Ranking
1	358%	3
2	350%	3
3	368%	3
4	639%	5
5	391%	3
6	394%	3
7	250%	1
8	259%	1
9	339%	1
10	326%	1

Table 5. Vulnerability ranking based on inundation from 2050 SLR.

Shoreline Segment	Percent Change (%)	Vulnerability Ranking
1	188%	3
2	205%	3
3	171%	3
4	530%	5
5	223%	3
6	167%	3
7	147%	1
8	136%	1
9	135%	1
10	142%	1

Table 6. Vulnerability ranking due to stormwater runoff.

Shoreline Segment	Stormwater Runoff Identification	Vulnerability Ranking
1	Stormwater runoff noted during site visit, exacerbating erosion.	5
2	No noted erosion from runoff.	1
3	Potential stormwater runoff noted during site visit, dislodged pathway stones possibly due to stormwater runoff.	3
4	Manmade trails creating focused stormwater runoff paths noted during site visit, no impact to current infrastructure but potential impact in future.	5
5	Manmade trails creating stormwater runoff paths noted during site visit, no impact to current infrastructure but potential impact in future. Deep paths could cause injury to park goers.	3
6	No noted erosion from runoff.	1
7	No noted erosion from runoff.	1
8	Small footpaths noted near boat launch that may contribute to concentrated stormwater runoff, no immediate threats.	3
9	No noted erosion from runoff.	1
10	No noted erosion from runoff.	1

Table 7. Vulnerability ranking due to historic erosion.

Shoreline Segment	Historic Erosion Notes	Vulnerability Ranking
1	Slight erosion (-0.01 to -2.00 ft/yr) with a small segment of accretion (>0.01 ft/yr).	1
2	Mainly accretion (>0.01 ft/yr), with small areas of slight erosion (-0.01 to -2.00 ft/yr) as well as low erosion areas (-2.00 to -4.00 ft/yr).	1
3	Slight erosion (-0.01 to -2.00 ft/yr) to low erosion (-2.00 to -4.00 ft/yr) between groins on dog beach, with slight erosion or accretion (>0.01 ft/yr) behind rock sill to the east.	1
4	Slight erosion towards bulkhead (-0.01 to -2.00 ft/yr) that increases to moderate (-4.00 to -8.00 ft/yr) to high (> -8.00 ft/yr) along the headland feature. Low erosion (-2.00 to -4.00 ft/yr) behind headland feature.	5
5	Mainly accretion (>0.01 ft/yr), with small areas of slight erosion (-0.01 to -2.00 ft/yr) as well as low erosion areas (-2.00 to -4.00 ft/yr).	1
6	Moderate erosion (-4.00 to -8.00 ft/yr) at entrance to southern embayment. Mainly accretion within embayments with localized areas of slight (-0.01 to -2.00 ft/yr) and low erosion (-2.00 to -4.00 ft/yr).	3
7	Localized high erosion (>-8.00 ft) at entrance to embayments.	5
8	Slight (-0.01 to -2.00 ft/yr) to low erosion (-2.00 to -4.00 ft/yr) along southern shoreline. Northern portion of shoreline showing mainly accretion (>0.01 ft/yr).	1
9	Mainly accretion (>0.01 ft/yr), with small areas of slight erosion (-0.01 to -2.00 ft/yr) .	1
10	Mainly accretion (>0.01 ft/yr), with small areas of slight erosion (-0.01 to -2.00 ft/yr).	1

Table 8. Vulnerability ranking due to observed erosion.

Shoreline Segment	Observed Erosion Notes	Vulnerability Ranking
1	Extreme erosion along shoreline with falling trees.	10
2	Documented erosion along banks (2-4 ft).	6
3	No observed erosion at bulkhead or dog beach.	2
4	Field notes indicate erosion 2-4 ft along reach.	6
5	Field notes indicate erosion 2-4 ft along reach.	6
6	Field notes indicate erosion 2-4 ft along reach.	6
7	Steep eroded banks exceeding 4 ft.	10
8	Field notes indicate erosion 2-4 ft along reach.	6
9	Eroded banks exceeding 4 ft.	10
10	No observed erosion within wetland area.	2

Table 9. Vulnerability ranking based on existing natural, hybrid, or grey shoreline protection infrastructure.

Shoreline Segment	Existing Natural or Hybrid Structure Identification	Vulnerability Ranking
1	Failing wood and sheet pile bulkheads as well as decrepit wooden jetties. Generally, the shoreline is exposed along the bluffs. Small portions of the shoreline are protected by riprap with marsh plantings upland.	5
2	Healthy marsh, though some exposed shoreline with erosion.	3
3	Bulkhead along main stretch and two groins at dog beach.	1
4	Mainly exposed and unprotected shoreline with some wetlands.	3
5	Exposed and unprotected shoreline.	5
6	Healthy wetland though some exposed shoreline with erosion.	3
7	Some marsh with pockets of exposed shoreline.	3
8	Some marsh with pockets of exposed shoreline.	3
9	Exposed shoreline.	5
10	Marshy shoreline with healthy wetlands.	3

Table 10. Vulnerability ranking based on human interference.

Shoreline Segment	Human Interference Identification	Vulnerability Ranking
1	Manmade footpaths contributing to increased erosion.	3
2	No noted human trespass off designated trails.	1
3	No noted human trespass off designated trails.	1
4	Minor footpaths noted off designated trails.	3
5	Significant manmade footpaths.	5
6	No noted human trespass off designated trails.	1
7	Minor footpaths noted off designated trails.	3
8	No noted human trespass off designated trails.	1
9	No noted human trespass off designated trails.	1
10	No noted human trespass off designated trails.	1

Table 11. Vulnerability ranking based on aquatic habitat and wetland identification.

Shoreline Segment	Aquatic Habitat and Wetland Identification	Vulnerability Ranking
1	Some plantings noted behind infrastructure (i.e., riprap, failing wood bulkhead, and failing sheet piling), but mainly an exposed shoreline.	3
2	Marshy protected area that offers aquatic habitat.	5
3	Hardened shoreline.	1
4	Mostly exposed shoreline but healthy wetland at headland feature.	3
5	Exposed, sandy bluffs with limited vegetation.	1
6	Protected area with existing plantings and newly established submerged aquatic vegetation from the installed step pool.	5
7	Exposed shoreline with significant erosion, some wetlands.	3
8	Exposed shoreline with significant erosion, some wetlands.	3
9	Small pockets of plantings along shoreline stretch.	3
10	Marshy shoreline with healthy wetlands.	5

Table 12. Vulnerability ranking based on park infrastructure.

Shoreline Segment	Park Infrastructure Identification	Vulnerability Ranking
1	Quiet Waters Retreat Master plan incorporates infrastructure near shoreline (critical)	5
2	Quiet Waters Retreat Master plan incorporates infrastructure near shoreline (critical)	5
3	Existing critical infrastructure for visitor accessibility to shoreline	5
4	No existing or proposed infrastructure	1
5	No existing or proposed infrastructure	1
6	No existing or proposed infrastructure	1
7	No existing or proposed infrastructure	1
8	Existing boat launch and ramp infrastructure for visitor accessibility (critical)	5
9	No existing or proposed infrastructure	1
10	No existing or proposed infrastructure	1

Table 13. Vulnerability ranking based on community and waterway accessibility.

Shoreline Segment	Community and Waterway Accessibility Identification	Vulnerability Ranking
1	Quiet Waters Retreat offers Park programs and community recreation. No direct access to water.	3
2	Loden Pond offers community recreation. No access to water from shoreline.	3
3	South River Overlook offers community recreation. Water access via the Dog Beach.	5
4	Shoreline is not regularly accessed (no designated trail systems).	1
5	Shoreline is not regularly accessed (no designated trail systems).	1
6	Overlooks along the shoreline with trails along ridge for community recreation. No direct access to water.	3
7	Overlooks along the shoreline with trails along ridge for community recreation. No direct access to water.	3
8	Boat ramp provides direct access to water.	5
9	Trail systems upland provide community recreation. No direct access to water.	3
10	Trail systems upland provide community recreation. No direct access to water.	3

Table 14. Vulnerability ranking based on ecological reintegration potential.

Shoreline Segment	Ecological Reintegration Potential Identification	Vulnerability Ranking
1	Plantings noted behind existing structures that can be enhanced. Additionally, there are opportunities to remove deteriorating and failing bulkheads and replace with nature-based shoreline protection to reintroduce the intertidal zone and ecology.	5
2	Marshy shoreline with healthy wetlands already exists, but wetlands and SAV can be enhanced.	3
3	Hardened shoreline, minimal potential for nature-based solution integration while honouring Park preference to maintain functioning bulkhead.	1
4	Mostly exposed shoreline but healthy wetland at headland feature that can be enhanced.	3
5	Exposed, sandy bluffs with limited vegetation. Can be enhanced with living shoreline.	3
6	Protected area with existing submerged aquatic vegetation and wetland plants that can be further enhanced.	3
7	Mostly exposed shoreline but healthy wetland at headland feature that can be enhanced.	3
8	Exposed shoreline with significant erosion, would require protection for habitat development.	3
9	Areas with marsh grass present and can be expanded.	3
10	Marshy shoreline with healthy wetlands already exists with limited opportunities for improvement.	1

Table 15. Vulnerability ranking based on inland migration.

Shoreline Segment	Inland Migration Notes	Erosion Rate (ft/yr)	Vulnerability Ranking
1	Inland migration will impact Quiet Waters Retreat Master Plan.	-1.7	5
2	Inland migration will impact Quiet Waters Retreat Master Plan.	-1.3	5
3	Hardened shoreline along south river lookout unlikely to experience migration.	-2.0	1
4	Inland migration may have an impact on the environment and Park offerings.	-5.9	3
5	Inland migration may have an impact on the environment and Park offerings.	-2.5	3
6	Inland migration may have an impact on step pool.	-3.1	3
7	Inland migration will impact current trails and lookout points.	-4.9	5
8	Inland migration will impact boat launch area.	-0.3	5
9	Inland migration will not have an impact on the environment and Park offerings.	-2.0	1
10	Inland migration will not have an impact on the environment and Park offerings.	-0.72	1

Table 16. Vulnerability ranking based on connectivity and cohesiveness.

Shoreline Segment	Connectivity and Cohesiveness Identification	Vulnerability Ranking
1	Living shoreline here will alter sedimentation at Loden Pond.	5
2	Isolated shoreline, no impact on adjacent shorelines.	1
3	No option to implement living shoreline.	1
4	A living shoreline here will reduce erosion and can reduce sedimentation in Harness Creek.	5
5	Living shoreline here may alter sedimentation with the embayments of Harness Creek.	3
6	This shoreline is isolated and will have little impact on neighbouring shorelines.	1
7	Implementation of living shoreline will lead to reduced sedimentation, improved turbidity and water quality.	5
8	Implementation of living shoreline may lead to reduced sedimentation at neighbouring shorelines.	3
9	No expected impact on adjacent shorelines.	1
10	Isolated shoreline, no impact on adjacent shorelines.	1

Appendix C: Vulnerability Assessment Full Results

Indicator	1. Quiet Waters Retreat	2. Loden Pond	3. South River Overlook Shoreline	4. Entrance to Harness Creek	5. Harness Creek Inlet Shoreline	6. Harness Creek Embayments	7. Harness Creek Trail Shoreline	8. Boat Rental Shoreline	9. Wildwood Trail Shoreline	10. Old Place Cove Shoreline
Wave energy and Fetch Length	3	1	3	1	1	1	1	1	1	1
Boat Wakes	5	1	5	5	3	3	3	3	3	3
100-Year Stillwater Inundation	3	3	3	5	3	3	1	1	1	1
Sea Level Change and Nuisance Flooding Vulnerability	3	3	3	5	3	3	1	1	1	1
Stormwater Runoff	5	1	3	5	3	1	1	3	1	1
Historic Erosion	1	1	1	5	1	3	5	1	1	1
Observed Erosion	10	6	2	6	6	6	10	6	10	2
Existing Natural, Hybrid, or Grey Shoreline Protection Infrastructure	5	3	1	3	5	3	3	3	5	3
Human Interference	3	1	1	3	5	1	3	1	1	1
Aquatic Habitat and Wetland Identification	3	5	1	3	1	5	3	3	3	5
Park Infrastructure	5	5	5	1	1	1	1	5	1	1
Community and Waterway Accessibility	3	3	5	1	1	3	3	5	3	3
Ecological Reintegration Potential	5	3	1	3	3	3	3	3	3	1
Inland Migration	5	5	1	3	3	3	5	5	1	1
Connectivity and Cohesiveness	5	1	1	5	3	1	5	3	1	1
Total Score	**64**	**42**	**36**	**54**	**42**	**40**	**48**	**44**	**36**	**26**
Priority*	**1**	**5**	**9**	**2**	**6**	**7**	**3**	**4**	**8**	**10**

* Final prioritization of tied shorelines was based on discussion with Anne Arundel DRP and the Resilience Authority.

Appendix D Sediment Transport Model

1 Modeling Overview

1.1 Model setup

The Quiet Waters sediment transport model was developed using Delft3D, an industry-standard modeling suite for simulating hydrodynamic processes and sediment transport. Delft3D captures the interactions between waves, tides, and sediment dynamics, making it well suited for evaluating channel sedimentation and the effectiveness of proposed structural alternatives. The software was selected for its proven accuracy in modeling long-term sediment dynamics and wave–current interactions.

The model incorporates the following key inputs and configurations:

- **Tidal forcing** derived from NOAA water level station 8575512.
- **Wind and wave conditions** obtained from NOAA NDBC buoy 44063.
- **Bathymetry** compiled from the USGS Coastal National Elevation Database (2015), merged with NOAA hydrographic survey data (2019).
- **Computational grid:** A rectilinear grid tapering from 200 m × 215 m offshore to 4 m × 4 m nearshore, providing high resolution in the area of interest.
- **Non-erodible layers** representing existing seawalls, bulkheads, and groins.
- **Morphological acceleration:** A morphological scale factor of 4 was applied, allowing 29.5 days of simulation time to represent approximately 118 days of sediment transport.

1.2 Boundary conditions

Analysis of buoy data from NDBC 44063 identified three dominant wind and wave approach directions: 45°, 195°, and 310° (nautical convention). The corresponding wave heights, wave periods, and wind speeds associated with each directional bin were extracted and used to define the model boundary conditions for each simulation run. These values are summarized in Table 1.

Table 1 Wind and wave boundary conditions

Wind and Wave Direction (Nautical Conv)	Wave Period (seconds)	Wave Height (m)	Wind speed (m/s)
45	2.34	0.22	4.6
195	2.61	0.20	4.5
310	2.42	0.15	5.1

1.3 Existing conditions

The existing-conditions simulation serves as a baseline reference for evaluating the performance of proposed structural alternatives. It is important to note that the model has not been calibrated against observed sedimentation data. However, the relative differences between alternatives remain informative for comparative analysis.

Under existing conditions, the model predicts sediment accumulation within the channel. The volume of sediment deposited within the channel footprint (shown in Figure 1) is summarized in Table 2.



Figure 1: Project shoreline with the sediment volume area in red

Table 2: Baseline sediment volumes from the model

Wind Direction	Baseline Sediment Volume (m^3)
45	0.07
195	30.95
310	18.43

1.4 Alternatives

Two groin configurations were evaluated for their ability to reduce sediment transport into the navigation channel:

- **Alternative 1 – One Groin:** One groin installed on the north side of the channel.
- **Alternative 2 – Two Groins:** Groins installed on both the north and south sides of the channel.

The groin configurations are illustrated in Figure 2.



Figure 2: One groin and two groin configurations

1.5 Results

The sediment volume deposited within the channel under each alternative is presented in Table 4, and the corresponding percent reductions relative to baseline conditions are summarized in Table 3. The spatial distribution of sediment accumulation for each scenario is shown in Figure 3.

Under existing conditions, sediment erodes from all banks adjacent to the channel and is transported into the channel. The most significant source of sediment influx is concentrated near the southern point, which acts as the primary hotspot for channel infilling.

Table 3: Sediment volume results

Wind/Wave Direction	Current (m^3)	One Groin (m^3)	Two Groins (m^3)
45	0.07	0.01	0.0002
195	30.95	26.10	5.33
310	18.43	7.14	0.65

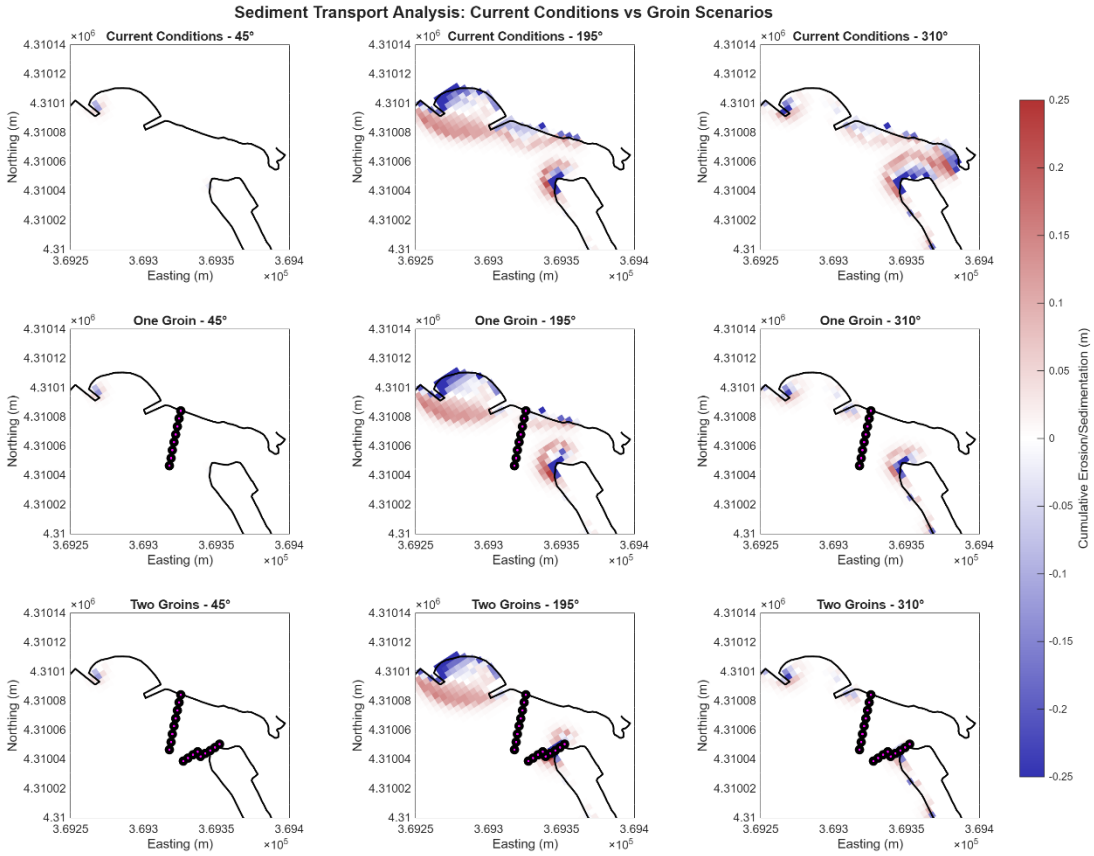


Figure 3: Sediment transport results map comparison

Table 4: Percent sediment accumulation reduction between different scenarios

Wind/Wave Direction	Reduction with One Groin (%)	Reduction with Two Groins (%)
45	83	99
195	15	82
310	61	96
Weighted Average	31	87

The one groin configuration achieves a weighted-average reduction of 31% in channel sedimentation, with the greatest effectiveness observed for the 45° (83%) and 310° (61%) wave directions. However, it provides only a 15% reduction for the 195° direction, which is the dominant contributor to channel infilling. The two groin configuration yields an 87% weighted-average reduction, with reductions exceeding 80%

across all three wave directions, indicating substantially improved performance in mitigating sedimentation from all approach angles.

Appendix E Assumptions

Rock Structure Assumptions:

- The breakwater, rock sill, and rock groin crest elevations are set at 1.72 ft NAVD88, which is the Mean High Water (MHW) elevation plus the 2050 Sea Level Rise (SLR) prediction.
- Submerged breakwater crest elevations are set at -0.55 ft NAVD88, which is the MLW (MLW) elevation.
- Proposed breakwaters are placed 50 feet channel ward of the MHW line, per Maryland State Programmatic General Permit-6 (MDSPGP-6) requirements. The depth applied is important in developing assumed structure heights and associated material costs. Toe elevations vary between the shorelines with
    - -2.25 ft referenced to the North American Vertical Datum of 1988 (NAVD88) at Quiet Waters Retreat and the Entrance to Harness Creek, and
    - -4.5 ft NAVD88 at the Harness Creek Inlet Shoreline.
- It is assumed rock sills will be placed with the structure toe at the MLW line at approximately -0.55 ft NAVD88.
- The depth at the toe of the groins varies between -2 to -3 ft NAVD88. An average depth of -2.5 ft NAVD88 was used for calculations.
- The rock structures are trapezoidal shaped with side slopes of 2H:1V.
- The rock structures shall be composed of Class II Riprap, which has a d50 of 14 inches, per Maryland Department of Transportation (MDOT). This is consistent with the rock structures existing along the Quiet Waters Shoreline. It is assumed that the rock sills, breakwaters, and rock groins shall all be composed of the same size rock.
- Bedding stone shall be the American Association of State Highway and Transportation Officials (AASHTO) #57.
- The breakwater lengths and gaps between breakwaters were determined using ratios from the Virginia Institute of Marine Science (VIMS) Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments (2017). The Mb:Gb is 1:1.65, where Mb is the distance offshore and Gb is the breakwater gap distance. The Lb:Gb is 1:1.4, where Lb is the length of the breakwater.
- The rock sill lengths and gaps were determined using the onsite rock sills. The Gb:Lb is 1:7.2.
- The rock groins lengths were determined using the average length of the existing wooden groins footprint at the entrance to Loden Pond.

Living Breakwater Assumptions:

- It is assumed that Mini Bay Balls will be used for the Boat Rental Shoreline and Wildwood Trail Shoreline. It is assumed that Supra Reef Balls will be used for the Entrance to Harness Creek and the Harness Creek Inlet Shoreline.
    - Mini Bay Balls are 2.42 ft in diameter with a height of 1.58 ft.
    - Supra Reef Balls are 5.42 ft in diameter with a height of 4.25 ft.
- Reef balls shall be placed at a maximum distance of 50 feet channel ward of the MHW line, per Maryland State Programmatic General Permit-6 (MDSPGP-6) requirements.
- It is assumed that ExoFlex Oyster Bags from Natrx are used within Loden Pond. Natrx bags each hold 5 gallons of shell and are 20 in (length) by 12 in (width) by 6 in (height).
- Gabion baskets are assumed to be 6 ft (length) by 2 ft (width) by 2 ft (height) segments tied into V and W formations. Burlap bagging is used within the gabions to secure the oyster shell.
- Coir logs are assumed to be 10 ft long with a 1 ft diameter.

Plantings:

- The following ratios of plant types are used:
    - Quiet Waters Retreat (Segment B):
        - 50% high marsh
        - 50% low marsh
    - Quiet Waters Retreat (Segments C-F):
        - 40% high marsh
        - 40% low marsh
        - 20% brush
    - Loden Pond:
        - 50% high marsh
        - 50% low marsh
        - SAV in deeper water areas
    - Boat Rental Shoreline (Segment A):
        - 50% high marsh
        - 50% low marsh

- Fill is assumed in all areas for proposed plantings except for the SAV areas.

Stantec

Stantec is a global leader in sustainable engineering, architecture, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

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