AtkinsRéalis

**Final Report**

Florida Department of Environmental Protection

March 2024

AtkinsRéalis Job No. 100084049

# COASTAL CONSTRUCTION CONTROL LINE (CCCL) COASTAL ARMORING POLICY STUDY

# Notice

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## Client signoff

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# Executive Summary

**Introduction**

The Department contracted with AtkinsRéalis to study the current regulatory requirements and policies for coastal armoring and suggest changes that could improve regulatory consistency, maintain public beach access, reduce the number of variances for armoring, and minimize impacts to endangered and threatened marine turtles. There are several areas within the regulatory program that may be appropriately addressed by updating the current regulatory framework to bring the statutes and rules up to date with the trend in coastal conditions. These areas include:

- considering sea level rise (SLR) and resilience in structure design and siting,
- evaluating the use of required minimum structural design criteria for armoring,
- studying the 250 ft length maximum gap size requirement,
- assessing the feasibility of allowing for the proactive installation of armoring structures, and
- evaluating the potential creation of an acceptable seaward line of coastal construction for armoring along discrete segments of coastline.

This study did not consider armoring as an element of the Department's beach management funding assistance program pursuant to Sections 161.088 and 161.091, F.S.

Investigation methods used in this study included conducting a literature review, data analysis, and stakeholder interviews. The literature review summary and interview questions with responses are included as appendices.

**Summary of Study Findings and Recommendations**

Sea Level Rise and Resilience Considerations in Armoring Design and Policy

Increased rates of SLR and flood resilience were not a consideration at the time the armoring statutes and rules were developed and as such, they do not provide a means to proactively address SLR or future conditions. This is oftentimes in conflict with engineering recommendations as well as local governments requiring the inclusion of SLR in design and siting. Recommendations to consider SLR and resilience in armoring design and policy include:

- Select a specific SLR projection estimate and apply it consistently across all facets of the CCCL program, including design and storm erosion models.
- Update storm surge values now and at regular intervals in the future (e.g., every 10 years) by incorporating SLR as well as increases in storm intensities and frequencies, to assess the risks more accurately for coastal areas.
- Develop a standardized approach for integrating projected sea level rise into storm erosion models and hydrographs.
- Establish a method to consider SLR when assessing structure eligibility. Proposed changes to 62B-33.002(12) F.A.C. "Eligible Structures" are detailed.
- Incorporate SLR into minimum design standards (Section 5.2.3) to ensure long-term sustainability and resilience.

- Allow reconsideration of wall height to incorporate SLR for requests for seawall reconstruction. Proposed changes to rule 62B-33.002(27) F.A.C. “Major Reconstruction” and 62B-33.002(31) F.A.C. “Minor Reconstruction” are detailed.

Minimum Design Standards and Considerations for Armoring

Many common seawall failure issues could potentially be mitigated through the implementation of baseline design standards. The Florida Building Code and local building ordinances do not address specific design criteria for seawalls, underscoring the essential role and necessity of the CCCL program policies and regulations. Specifying a statewide standard for use of a cantilever wall versus a tie-back wall is impractical as cantilevered walls are not always viable, especially in Southeast Florida where large dunes are prevalent. Design standards developed will need to navigate this challenge. Recommendations towards minimum design standards and considerations include:

- Proposed changes to rule 62B-33.0051(2)(b)(1) F.A.C. are detailed to take into account SLR, material service life, scour depth, drainage behind the armoring structure, and return sections to prevent flanking.

- Proposed changes to rule 62B-33.0051(2)(b)(3) F.A.C. are detailed regarding level of protection.

Gap Size

The prevalent theme throughout the study was that the 250 ft limitation set by the “gap rule” seems arbitrary and should be revised. Recommendations to address gaps and the “gap rule” include:

- The Strategic Beach Management Plan (SBMP) may authorize gaps of larger than one property to be filled. This would require modification to Statute.

- Modify the criteria for qualifying for armoring using the “gap rule”. Proposed changes to 62B-33.0051(1)(a) 3. F.A.C. are detailed.

Proactive Armoring

The armoring program tends to operate reactively to address immediate issues like coastal erosion and damage and, on an individual, permit-by-permit basis. It is important for armoring solutions to include the use of materials and designs resilient to future climate impacts and coastal changes, as well as being mindful of their impact on the surrounding ecosystem. Recommendations towards proactive armoring include:

- Update the storm for which vulnerability is evaluated to be the 25-year return period event coincident with the establishment of critically eroded designations around the State. Proposed changes to 62B-33.002. (59) F.A.C. are detailed.

- Do not require vulnerability criteria be met for coastal armoring to protect public infrastructure. This would require modification of Chapter 161.085 (2) F.S. Proposed changes to 62B-33.0051 (1) (a) 2. F.A.C. are detailed.

Siting (to minimize sea turtle impacts)

While there are no prescriptive standards for siting except for the generalized “armoring shall be sited as far landward as practicable” and “avoid significant adverse impacts to marine turtles,” the data analysis indicated the Department has been consistent in the siting of armoring permits with respect to the CCCL and eligible structures’ foundations. When conducting the stakeholder interviews, the need for improved transparency in site planning with

FWC was emphasized. The common perception among many of the interviewees was that FWC's definition of sea turtle nesting habitat is ambiguous and lacks a consistent standard. It is recommended that an easily accessible and comprehensively detailed informational sheet be created, officially approved by the FWC and made readily available to all applicants. This document should establish a protocol for the regular review and update of the informational sheet to ensure it remains relevant and incorporates any changes in environmental conditions, legal requirements, or best practices.

Line of Coastal Construction for Armoring

A uniform line of coastal armoring for siting of future seawalls could offer more regulatory certainty for both the Department and coastal property owners while avoiding impacts to sea turtle nesting habitat and minimizing impacts to critical beach-dune natural resources. Through the course of the study, several options were considered including a regional, county, and site-specific lines of construction. The number of variables and unknowns makes a regional approach impractical, and a county-wide approach is similarly impractical for most locations. These variables and unknowns include, but are not limited to, variability in coastal geographies, differing environmental impacts, administrative complexity, and limited flexibility and potential for overgeneralization. As such, recommendations are focused on site-specific applications of a uniform line of coastal armoring. A site-specific approach allows for the accounting of the unique physical and environmental features.

**Conclusion**

The Study concludes with recommendations for future study for several areas where further study could be considered for the advancement and refinement of coastal armoring strategies. The recommendations aim to address the complexities of coastal armoring and its impact on the environment and property. By pursuing these suggested areas of research, more effective, sustainable, and environmentally sensitive coastal management strategies could be developed.

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# ABOUT

Florida Department of Environmental Protection (FDEP) engaged AtkinsRéalis to review certain aspects of Florida's Coastal Construction Control Line (CCCL) program with respect to coastal armoring and suggest changes that could improve regulatory consistency, maintain public beach access, reduce the number of variances for armoring, and minimize impacts to endangered and threatened marine turtles. The results are contained herein.

# 1. Introduction

## 1.1 Background

Florida has approximately 1,350 miles of open coast shoreline and has the third largest coastal population within the U.S. with approximately 40% of the state's 15.2M people living in coastal communities. This, coupled with Florida's extensive barrier island systems and low topographic elevations, makes it one of the most uniquely challenged states in terms of coastal protection, management, and regulation in the U.S. Coastal armoring refers to the construction of structure(s) to protect coastal properties (i.e., those on the open coast) from erosion and storm damage. In Florida, coastal armoring is regulated by the Florida Department of Environmental Protection (FDEP) and local government. The FDEP oversees the Coastal Construction Control Line (CCCL) program, which sets guidelines for construction and development activities along the state's sandy beaches and dune systems, including the use of coastal armoring.

Section 161.085, Florida Statutes (F.S.), is the state’s policy on rigid coastal armoring for coastal CCCL permits, pursuant to 161.053, F.S. The statute was enacted in 1995 and amended in 2009 to add requirements for sand-filled geotextile containers as another type of armoring structure. Section 62B-33, Florida Administrative Code (F.A.C.) codifies the statutes into the rules that the Florida Department of Environmental Protection (FDEP or “Department”) follows. In the roughly 28 years since the initial statutes were developed, Florida’s beaches have experienced numerous coastal storm and erosional events after which the Department authorized armoring installations under emergency orders and variances to the existing armoring rules. More segments of Florida’s coast have experienced erosion since the development of the armoring rules and statutes and the underpinning guidance for armoring regulations warrants review and updating. A new look at Florida’s coastal armoring policies can provide a proactive approach that accomplishes important state objectives: incorporating the planning, design, and construction of rigid coastal structures into a comprehensive beach management program providing effective regulatory certainty and conservation of coastal resources and responding to the beachfront property owner’s interests in coastal resilience.

## 1.2 Study Purpose

In February 2023, the Department contracted with AtkinsRéalis to study the current regulatory requirements and policies for coastal armoring and suggest changes that could improve regulatory consistency, maintain public beach access, reduce the number of variances for armoring, and minimize impacts to endangered and threatened marine turtles. There are several areas within the regulatory program that may be appropriately addressed by updating the current regulatory framework to bring the statutes and rules up to date with the trend in coastal conditions. These areas include:

- considering sea level rise (SLR) and resilience in structure design and siting,
- evaluating the use of required minimum structural design criteria for armoring,
- studying the 250 ft length maximum gap size requirement,
- reviewing the integration of protecting other pertinent structures necessary for the occupation of habitable structures,
- assessing the feasibility of allowing for the proactive installation of armoring structures, and
- evaluating the potential creation of an acceptable seaward line of coastal construction for armoring along discrete segments of coastline.

This study did not consider armoring as an element of the Department's beach management funding assistance program pursuant to Sections 161.088 and 161.091, F.S.

The Scope of Work included review of pertinent structures as part of this study as stated in the bullet item above. During meetings the Scope of Work was modified to exclude pertinent structures. The study does not include any further discussion on this topic.

## 1.3 Study Scope

For the purposes of this study, the term coastal armoring is limited specifically to the use of seawalls, and the terms coastal armoring and seawalls may be used interchangeably.  As provided by the Department, the following are the subjects of interest and focus for this study.

### 1.3.1 SLR and Resilience Considerations in Armoring Design and Policy

Increased rates of SLR and flood resilience were not a consideration at the time the armoring statutes and rules were developed. Local governments are increasingly requiring the inclusion of SLR in design and siting, which, at times, can be contrary to the State's rules requiring certain criteria be met for cap elevation and siting, as examples. The CCCL program desires to provide guidance to local governments and armoring applicants on how and when to incorporate SLR and resilience into their project's design and siting. Additionally, SLR projections and timeframes used by other Florida agencies will be reviewed to provide a recommendation to the armoring program as it relates to new and reconstructed structures.

### 1.3.2 Minimum Design Standards and Considerations for Armoring

The CCCL armoring program does not include minimum design standards for seawall and return wall designs except to state in 62B-33.0051(2)(b)3., F.A.C. that, "All armoring shall be designed to remain stable under the hydrodynamic and hydrostatic conditions for which they are proposed. Armoring shall provide a level of protection compatible with existing topography, not to exceed a 50-year design storm." The Florida Building Code and local building codes do not incorporate considerations for these types of structures into their codes.  The Department desires consideration of if and how to incorporate minimum design standards for seawall and return wall designs into the armoring program.

### 1.3.3 Gap Size

A gap exists when unarmored property (or properties) sits between armored sections of the coastline. Existing Florida regulations allow for a permit to be issued to 'close the gap" if the gap is less than or equal to 250 feet. This assumes that an open gap in an otherwise continuous armored shoreline will experience increased erosion as a result of the adjacent armoring. Conversely, it assumes that closing a 250-foot gap will not result in impacts to the coastal system regardless of the length of the adjacent armored sections. The Department is interested in studying the effects of non-continuous walls where a gap exists in an armored section of coastline with a specific focus on the relationship with the length of the gap, length of adjacent continuous walls, and effects on the properties within and adjacent to the gap. The Department desires consideration of if and how to modify gap size criteria to allow for functional, continuous armored shoreline.

### 1.3.4 Proactive Armoring

Currently under 62B-33.0051(1)(a)2.a. F.A.C., if a property is not vulnerable at the time of the permit application but, “If it is projected that the eligible structure will become vulnerable at some future date which falls within the authorized time limit of a permit, then the permit shall authorize the construction of armoring once the anticipated site condition changes occur and the structure becomes vulnerable.” The existing coastal armoring statutes and rules do not provide a means to proactively address SLR or future conditions since a property must be “vulnerable” to qualify for armoring installation.  The Department desires consideration of if and how to incorporate proactive armoring into the armoring program.

### 1.3.5 Siting (to minimize sea turtle impacts)

Considerations with respect to impacts to sea turtles 62B-33 F.A.C. provides that impacts to sea turtles and sea turtle nesting habitat are to be considered during the evaluation of CCCL permit applications. The Department consults with the Florida Fish & Wildlife Conservation Commission (FWC) on review of permit applications for armoring to evaluate a project’s potential impacts on sea turtles. FWC advises FDEP as to appropriate permit conditions to minimize impacts. The Department may condition the nature, timing, and sequence of construction to provide protection to nesting sea turtles, hatchlings, and their habitat. If FWC determines that an Incidental Take may result from a project, FDEP must recommend denial of the permit application per Chapter 379.2431(h), F.S. A “Take”, as defined under Section 7 of the Environmental Species Act (ESA) ESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" of a protected species, in this case sea turtles.  “Incidental take” is further defined as an unintentional, but not unexpected, taking of the species.   As a part of this study, the Department desires a literature review of current research on the impact of seawalls on sea turtles’ nesting activity and nesting habitat including a critical analysis of the effects of the proposed policy changes recommended in this study.  The existing requirement that armoring shall be sited as far landward as practicable to minimize adverse impacts while still providing protection to vulnerable structures was not a subject of this study, apart from the impacts to sea turtles as just described.

### 1.3.6 Line of Coastal Construction for Armoring

One concept for study relates to the feasibility of establishing a relatively uniform alignment of coastal armoring, sited as far landward of the beach and dune system as is practicable. A uniform alignment of coastal armoring may provide more effective coastal protection from an engineering perspective. In addition, an established line of construction for coastal armoring could offer more regulatory certainty for both the Department and coastal property owners while avoiding impacts to sea turtle nesting habitat and minimizing harm to critical beach-dune natural resources. The Department desires consideration on the suitability of incorporating a line of coastal construction for armoring.

# 2. Literature Review

AtkinsRéalis performed a literature review to examine the current state of research, policy, and regulation related to the use of coastal armoring (seawalls) on the open coast. By synthesizing and analyzing relevant studies, this review aims to identify the findings, trends, and gaps in the literature according to the following research categories:

1. **Other State Rules & Policies:**  Existing rules and policies from the relevant agency that governs coastal construction (if one exists) in the following states: 1) South Carolina (SC); 2) Texas (TX); 3) Virginia (VA); 4) North Carolina (NC); and 5) California (CA).

2. **Published and Professional Association Research:** Published and professional association research using to the following keywords, and combinations of key words: coastal armoring, coastal structures, return wall, erosion, seawall, bulkhead, retaining wall, open coast, sea level rise, resilience, marine turtle, sea turtle, habitat, impact, mitigation, proactive armoring, design standard, policy, and siting.
3. **Federal Documentation:** Documents, using the same key words as above, from the following Federal agencies: 1) National Oceanographic and Atmospheric Association (NOAA); 2) Federal Emergency Management Agency (FEMA); 3) United States Fish and Wildlife Service (USFWS); and 4) United States Army Corps of Engineers (USACE).
4. **Florida County and Municipalities:** Local codes and policies in the following Florida Municipalities relevant to armoring on the Atlantic and Gulf of Mexico coasts: 1) Miami-Dade County; 2) Palm Beach County; 3) Walton County; 4) Sarasota County; 5) Brevard County; and 6) Volusia County.
5. **Florida Rules, Statues, and Policies:** Rules, Statutes, and policies for the State of Florida related to coastal armoring.
6. **Florida Fish & Wildlife Conservation Commission (FWC) (Turtles):** Studies by the FWC related to armoring and effects on marine turtles.

General findings by research category are summarized below. General findings specific to the study areas (e.g., SLR, design standards, gap size, etc.) are described in Section 5 “Findings and Recommendations.” Appendix A provides a summary of each document reviewed.

## 2.1 Other State Rules & Policies

The following states were scoped to be reviewed to identify their rules and policies from the relevant agency(ies) that governs coastal construction: SC, TX, VA, NC, and CA. Three additional states were ultimately included in the literature review including: Washington (WA), Oregon (OR) and Hawaii (HI). Of these States, South Carolina, Virginia, and North Carolina have current statutes that prohibit new coastal armoring from being constructed on the open coast. In Texas, coastal armoring is prohibited by local government and private entities, although retaining walls are permittable under certain conditions. State and Federal agencies are exempt from this prohibition and may utilize coastal armoring to protect critical infrastructure (e.g., Texas Department of Transportation (TxDOT) and USACE). In California, coastal armoring is discouraged but permittable, and requires mitigation for adverse impacts.

## 2.2 Published and Professional Association Research

A literature review of available published and professional association research was completed and the articles were organized and reviewed based on topics. Topics included coastal processes, protective armoring, regulation and policy, sea level rise, sea turtle impacts, wall design and standards, and others. Findings showed that earlier research was focused on the coastal processes and interactions with seawalls. Changes in design regarding seawall siting, depths, and end design have evolved through the years as a result of better understanding of coastal process and sea level rise. Sea turtles and impacts to their nesting and hatching capabilities due to seawalls is also discussed with some species being impacted more than others. Regulations and policies were reviewed along with other documents that were identified as useful literature. The documents include several studies pertaining to public perception, economic benefits, and demographics of people who reside along the coast.

## 2.3 Federal Documentation

Documents from relevant Federal agencies (FEMA, NOAA, USACE, and USFWS) were identified and reviewed using the same keywords used above for published and professional research. A general summary of the content contained by agency is shown in the following paragraphs.

### 2.3.1 FEMA

For coastal flood protection structures (e.g., armoring) to be recognized by FEMA, sufficient evidence must be provided that adequate design, construction, and maintenance have been undertaken to provide reasonable assurance of durable protection from the base flood. Specific requirements are detailed including design water levels, wave heights and periods, wave forces, freeboard, toe protection, backfill protection, structural stability, material adequacy, and plan alignment. In addition, FEMA requires an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent to, the protected area when considering requests for flood map revisions based upon new or enlarged coastal flood control structures.

### 2.3.2 NOAA

No specific data or information on coastal armoring was found; however, NOAA has published SLR scenarios up to year 2150 by decade and advise incorporating SLR estimates into design and development.

### 2.3.3 USACE

The Coastal Engineering Manual (CEM) (EM 1110-2-1100) and the Design of Coastal Revetments, Seawalls and Bulkheads (EM 1110-2-1614) provides engineering and design guidance for coastal armoring (USACE, 2002) (USACE, 1995).

### 2.3.4 USFWS

The literature generally encourages the use of living shorelines over “hard” shorelines in estuarine environments; however, no relevant information or discussion was found related to the use of armoring on the open coast.

## 2.4 Florida County and Municipalities

Local codes and policies relevant to armoring on the Atlantic and Gulf of Mexico coasts were identified and reviewed for the Florida municipalities of 1) Miami-Dade County; 2) Palm Beach County; 3) Walton County; 4) Sarasota County; 5) Brevard County; and 6) Volusia County.

### 2.4.1 Miami-Dade and Palm Beach Counties

The open coast shorelines in Miami-Dade County and Palm Beach County are primarily limited to the local municipalities (e.g., cities and towns). No specific rules, regulations, or policies for seawalls on the open coast were found within those county municipal codes. Several local municipalities (e.g., cities and townships within Miami-Dade and Palm Beach Counties) were reviewed, with coastal armoring being permittable, and generally equal to or less restrictive than F.S. and F.A.C.

### 2.4.2 Walton County

Walton County was similarly found to be generally equal to or less restrictive than F.S. and F.A.C.

### 2.4.3 Volusia County

Coastal armoring rules, regulations, and policies for Volusia County, which has an established "bulkhead line" appears to be similar, if not slightly more restrictive than, than F.S. and F.A.C.

### 2.4.4 Brevard and Sarasota Counties

Brevard County and Sarasota County's regulations and policies are considerably more restrictive than F.S. and F.A.C. In unincorporated Brevard County, no new rigid coastal armoring or shoreline hardening structures shall be permitted except under specific emergency provisions. In Sarasota County, a "variance" is required for every application for coastal armoring. Furthermore, Sarasota requires a coastal armoring structure to be within the "public interest" and further restricts coastal armoring for the protection of (1) public infrastructure or (2) when the Board determines that the coastal armoring is necessary to protect property rights.

## 2.5 Florida Rules, Statues, and Policies

Coastal armoring is regulated by the FDEP via the CCCL program, which sets guidelines for construction and development activities along the state's sandy beaches and dune systems. Florida's rules, statutes and policies related to coastal armoring are summarized below.

### 2.5.1 State Policy

The state recognizes the need to protect private structures and public infrastructure from the effects of coastal erosion. Beach nourishment, dune restoration, the landward relocation of structures, and coastal armoring are all effective strategies to mitigate the effects of coastal erosion. Coastal armoring, however, may negatively impact the integrity and natural functioning of the beach and dune system, and it may also increase the vulnerability of adjacent un-armored properties to storm damage. Due to the significant potential impacts associated with coastal, minimum siting and design criteria apply.

### 2.5.2 Florida Statutes

Florida State law requires property owners to obtain permits from the Department for any construction seaward of the CCCL, defined as the land that is subject to 100-year storm surge, storm waves, or other unpredictable weather conditions (161.041, F.S., Permits required) and (161.053, F.S., Coastal construction and excavation; regulation on county basis). The state acknowledges the need to protect both private structures and public infrastructure from the adverse effects of coastal erosion. It emphasizes that this protection is essential until broader, region-wide erosion control measures are implemented. To this end, the state grants permits for coastal armoring structures, such as seawalls, under specific conditions and requirements. These are detailed in section 161.085 of the Florida Statutes, which covers Rigid Coastal Armoring Structures. This policy is a temporary solution to protect private and public properties from erosion until more comprehensive regional erosion reduction strategies are in place. Any application for permit or other type of approval for an activity that affects marine turtles, or their nests or habitat shall be subject to conditions and requirements for marine turtle protection as part of the permitting or approval process (379.2431, F.S., Florida's Marine Turtle Permit Act).

### 2.5.3 Florida Administrative Code

To obtain authorization for coastal armoring, the armoring must be for the purpose of protecting an “eligible” structure and said eligible structure must be determined to be “vulnerable” (62B-33.0051, FAC, Coastal Armoring and Related Structures). “Eligible Structures” are located partially or wholly seaward of the CCCL and include private “non-conforming” habitable structures (habitable structures on a foundation not designed to withstand undermining by storm erosion; other major non-habitable structures whose failure would damage a habitable structure; and significant public infrastructure (62B-33.002(12), FAC). The eligible structure must also be “vulnerable” to damage from a 15-year return interval storm, with the vulnerability analysis considering the effects of shoreline change rates, natural physical features, and existing manmade structures (62B-33.002(39), FAC). Armoring may be authorized, irrespective of eligibility and vulnerability criteria, to close a gap of not more than 250 ft between adjacent armoring under certain conditions (62B-33.0051 (1)(a)(3), FAC). Design & Siting Criteria require the armoring be sited and designed to minimize adverse impacts (both physical and environmental), maintain lateral public access, and be appropriately designed for the established design storm event (62B-33.0051(2), FAC).

## 2.6 FWC (Sea Turtles)

Studies from FWC related to armoring and effects on marine turtles were identified and reviewed. Most of the literature found is published by FWC’s Fish and Wildlife Research Institute (FWRI). The Institute has ongoing studies on the impacts of “barriers to nesting” which includes, among many other barriers, coastal armoring. Generalized conclusions by FWRI include:

- Seawalls are the most common potential barriers in all but the northwest region, where sand fences were most common.
- The threat for nesting sea turtles posed by seawalls may lie in a reduction of nesting habitat, in an elevation of the physiological cost of nesting, and in displacement of turtles into nesting habitat that is sub-optimal.
- Overall, there are fewer successful nesting emergences in front of the various armoring structures than in the non-walled “natural” areas.
- The problems associated with coastal armoring and nesting marine turtles are complex and span many disciplines of knowledge, all of which must be integrated.

## 2.7 Literature Review Summary of Findings

Florida has perhaps the biggest challenge with regulating coastal development, including coastal armoring, with the largest shoreline in the continental U.S. (1,350 miles) and the third largest coastal population (15.2M) in the U.S. (behind only California and New York) (NOAA 2023).

### 2.7.1 SLR and Resilience Considerations in Armoring Design and Policy

In reviewing the policies and regulations of other coastal states during the literature review, California is perhaps the most proactive and vocal on the need to incorporate SLR into planning and design. Melius and Caldwell (2015) noted that local governments in California lacked reliable, adequate scientific and legal information to guide their decision-making with respect to coastal armoring, and they further lack financial support and regulatory incentives to appropriately consider sea level rise and related coastal hazards in their infrastructure and coastal land-use planning. They further suggested that it is essential to require sea level rise in erosion rate calculations, mean high tide line determinations, setback determinations, and develop standard transferable methodologies for factoring sea level rise in to hazards analysis. About the same time, the California Coastal Commission adopted the "Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits" (2015, Rev 2018) to acknowledge and address sea level rise in planning and permitting decisions using the best available science to determine locally relevant and context-specific sea level rise projections for all stages of planning, project design, and permitting reviews, among other goals (California Coastal Commssion, 2018).

By 2016, California produced a "Statewide Sea Level Rise Vulnerability Synthesis" which presented key statewide findings on vulnerability to inform sea level rise planning and preparedness. The result was "county level snapshots" to describe sea level rise vulnerability, local planning efforts and management priorities at the local levels (California Coastal Commission, 2016).

Most recently, the California Coastal Commission developed the "Sea Level Rise Planning Guidance (latest revision 2021)" which requires a hazards analysis for new development, including coastal armoring. The hazard analysis, must include (California Coastal Commission, 2021):

- Use of the most current 'best available science' on sea level rise projections and impacts at the time of development application. The document discusses using worst case scenarios for critical infrastructure, and lesser scenarios for individual developments.
- Evaluation for sea level rise impacts over a time period appropriate to the planning project type. Currently this time period is recommended at 50-100 years.
- Analysis of all relevant hazards including but not limited to wave run-up, tidal inundation, storm flooding, groundwater change, and short- and long-term erosion, as all is influenced by sea level rise.
- Evaluation of the foreseeable effects that the transportation infrastructure will have on communities, vulnerable populations, and coastal resources over time (including in terms of impacts on public access for all types of coastal users, shoreline dynamics, natural landforms, natural shoreline processes, beach widths, wetlands, other shoreline habitats seaward and inland of the transportation infrastructure, public views, and cultural and historical resources) as project impacts continue and/or change over time, including in response to sea level rise.
- A Coastal Hazards Monitoring Plan.
- Mitigation for impacts on all coastal resources. Mitigation shall minimize impacts to the extent feasible and fully compensate for impacts that remain; mitigation shall address impacts that will occur over the full life of the structure, but may be assessed in appropriate increments, rather than being required entirely up front.

In reviewing peer-reviewed publications, Headland, Trivedi and Boudreau (2011) suggests an Adaptive Management Approach to incorporating SLR into the design of coastal structures. For example, they propose an initial seawall design to accommodate a mid-level SLR scenario over a shorter period (say 20 years), with the design being adaptable to increase the level of protection as needed in the future. The Adaptive Management Strategy will define specific triggers for action based on the observed changes in sea level.

When investigating Federal documentation, NOAA estimates that by 2050, the expected relative sea level (RSL) will cause tide and storm surge heights to increase and will lead to an overall shift in U.S. coastal flood regimes, with major and moderate high tide flood events occurring as frequently as moderate and minor high tide flood events occur today (NOAA, 2022a). Without additional risk-reduction measures, U.S. coastal infrastructure, communities, and ecosystems will face significant consequences. The NOAA SLR scenarios have been widely used in the development of state (e.g., Florida and Virginia) and local agency adaptation plans (e.g., Pensacola, Florida, and Portland, Maine), and processes for anticipating and managing future coastal risks.

There are currently no policies or regulations related to SLR and flood resilience considerations for coastal armoring in the State of Florida's rules, statutes, and policies. Consequently, they lack mechanisms for actively addressing SLR or future environmental conditions. This often leads to a mismatch with engineering guidelines and local government mandates that require the incorporation of SLR considerations in design and planning.

While not specifically related to, or required for coastal armoring, the State has recently adopted the "SLIP Rule" (Section 161.551, F.S. and 62S-7, FAC) which requires state agencies, municipalities, counties, special districts, authorities, or other corporate bodies of the state, which commission or manage a construction project within the coastal building zone using funds appropriated from the state to conduct a sea-level impact projection ("SLIP") study. SLIP stands for Sea Level Impact Projection study. The SLIP study must take into account potential sea-level rise and increased storm risk during the expected life of the coastal structure or 50 years, whichever is less, and to the extent possible, account for the contribution of sea-level rise versus land subsidence to the relative local sea-level rise. The SLIP studies are to be based the NOAA Intermediate-High SLR projections (Florida Department of Environmental Protection, 2021b). The requirements of the SLIP study are very similar to California's Sea Level Rise Planning Guidance described above. Specifically, the requirements of the SLIP study are:

- A systematic, interdisciplinary, and scientifically accepted approach in the natural sciences and construction design in conducting the study.
- An assessment of the flooding, inundation, and wave action damage risks relating to the coastal structure over its expected life or 50 years, whichever is less.
- Consideration of potential sea-level rise and increased storm risk during the expected life of the coastal structure or 50 years, whichever is less, and to the extent possible, account for the contribution of sea-level rise versus land subsidence to the relative local sea-level rise.
- Provide scientific and engineering evidence of the risk to the coastal structure and methods used to mitigate, adapt to, or reduce this risk.
- Use and consider available scientific research and generally accepted industry practices.

  Provide the mean average annual chance of substantial flood damage over the expected life of the coastal structure or 50 years, whichever is less.
- Analyse potential public safety and environmental impacts resulting from damage to the coastal structure including, but not limited to, leakage of pollutants, electrocution and explosion hazards, and hazards resulting from floating or flying structural debris.
- Alternatives for the coastal structure's design and siting, including discussion of how such alternatives would affect the potential public safety and environmental impacts assessed in the study, as well as the risks and costs associated with maintaining, repairing, and constructing the coastal structure.

Overall, the literature review solidifies the need to incorporate SLR in planning and design of coastal armoring, by considering SLR including erosion rate calculations, surge estimates, wall hight, level of protection, etc.

### 2.7.2 Minimum Design Standards and Considerations for Armoring

When considering the minimum design standards for seawalls, design life is a key consideration. The design life includes the structural life of the materials (sometimes referred to as "service life") and the functional life (i.e., the ability of the structure to effectively mitigate the impacts of coastal hazards, such as storm surges and erosion, over a specified period of time). The functional life includes consideration of the "level of protection" (i.e., the design storm(s) for which the structure is designed to withstand).

The literature review on the minimum design standards for seawalls required by various states and local Florida municipalities revealed a diverse range of approaches. Some regions lack specific minimum (or maximum) standards altogether while others refer to general "industry guidelines" providing a broader framework without detailed specifications. An example of the latter is in the current regulations for the State of Florida where rule 62B-33, F.A.C. requires an engineer to design seawalls in accordance with the USACE CEM (EM 1110-2-1100), or other similar professionally recognized publications for the functional life of the structure (State of Florida, 2023b). At present, Florida does not specify a minimum standard for the service life. However, there are also regions with more detailed seawall design requirements, including specifications for wall height, the materials used, and the depth of penetration into the ground. An example is the Town of Palm Beach, which specifies a minimum top of wall and penetration depth  (Town of Palm Beach, 2023).  Little was found in the way of service life, except in California were there is discussion in the literature of the “economic life” of development which was initially stated as 30-50 years (long enough to pay off a mortgage plus some margin), but today is generally assumed to be 75-100 years  (Hanak & Moreno, 2008).  This variability at the state and local levels highlights a lack of uniformity in seawall design standards, reflecting differing local needs, environmental conditions, and regulatory approaches to coastal management.

In peer-reviewed literature, most of the discussion on minimum design standards was focused on the prediction of scour levels to ensure adequate pile embedment. Flocard et al (2015) estimates, ”34% of seawall failures occur as a direct result of erosion of beach or foundation material, and that scour is at least partially responsible for a further 14%.” Nielsen (2023) presents a new equation to predict scour levels for seawall design based on the theory that toe scour is a function of the nearshore incident wave energy. The equation was calibrated with results from several moveable bed model studies covering a large range of scales.  Numerous other studies debate the cause of localized scour at seawalls, but the consensus appears to be that a good rule of thumb is to estimate the design scour depth at a vertical wall as approximately equal to the nonbreaking wave height that can be supported by the water depth at the structure, as adopted by USACE CEM (EM 1110-2-1100).

Another potential point of failure which could benefit from a minimum design standard is the use of return walls to prevent flanking. Literature is sparse on this topic; however, Balaji et al (2017) discusses the effects of seawall construction along the coast of Fansa, South Gujarat, India. A numerical model was used to estimate the wave parameters along the selected coast, the results of which are subsequently utilized in an analytical model (parabolic shape model) to predict the end-wall effect. The results of the analytical model were validated by a remote sensing–based analysis; however, the methodology does not yield a “rule of thumb” or easily adoptable general approach to estimating flanking at other sites. Recommendations for return walls are generalized, and are summarized by Walton and Sensabaugh (1979) to include: taking into consideration shoreline recession due to storms and the anticipated increase in recession rate due to the constructed seawall; the crest elevation of the seawall is equated to the “after storm” elevation; and return wall should extend into the dune beyond the established “after storm” elevation to account for anomalous effect on adjacent non-seawall conditions.

In general, the USACE CEM (EM 1110-2-1100) is widely accepted in the industry with design standards for seawalls including scour, wave height and wave forces.  Other design resources found in federal literature include FEMA’s Guidelines for Flood Risk Analysis and Mapping of Coastal Structures and FEMA’s Coastal Construction Manual.  FEMA requires adequate design, construction, and maintenance to provide reasonable assurance of durable protection. FEMA requires an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent to, the protected area when considering requests for flood map revisions based upon new or enlarged coastal flood control structures.

In summary, seawall design standards exhibit significant variability across different states and localities, with some areas lacking specific guidelines while others adhere to general industry frameworks or detailed specifications. This diversity in standards reflects the varying local needs and environmental conditions. A major focus in the literature is on predicting scour levels to ensure adequate pile embedment, as erosion and scour contribute substantially to seawall failures. The USACE CEM, recognized for its comprehensive guidelines on scour, wave height, and forces, is a widely accepted industry standard, similar to FEMA's requirements for coastal structure design, construction, and maintenance to mitigate flood risks. However, there's a notable lack of standardized approaches for preventing seawall flanking, with generalized recommendations underscoring the importance of accounting for shoreline recession, storm impacts, and the strategic placement of return walls in seawall construction.

### 2.7.3 Gap Size

In Florida, armoring may be authorized, irrespective of eligibility and vulnerability criteria, to close a gap of not more than 250 ft between adjacent armoring under certain conditions, as adopted by both Florida Statutes and Florida Administrative Code. This ”close the gap” allowance for armoring was added to the Florida Statutes in 1999. The reasoning behind the selection of 250 ft specifically for gap width is not known by Department staff or stated in literature.

There was very limited information and documentation in the literature related specifically to the evaluation of gap size and related impacts for unarmored sections of shoreline cited between two adjacent armored sections. The findings of flanking, as described in the prior section, may be useful to the discussion.

### 2.7.4 Proactive Armoring

The installation of armoring in a proactive manner, that is implemented prior to an immediate need, was not found to be explicitly discussed in the literature review. However, Irish et al (2013) (Irish, Lynett, Weiss, Smallegan, & and Cheng, 2013) focused a research study on an unknown century old stone seawall, known as Bay Head Dune, and its response to Hurricane Sandy. Results were compared to a control setting, being a nearby natural beach known as Mantoloking. The response of the Bay Head Dune wall draws parallels to proactive armoring.

Storm flood elevations and the beach settings were similar in both locations. However, erosion and damage to oceanfront homes were drastically different in the two locales studied. In Mantoloking, widespread significant over wash eroded almost the entire dune and split the barrier island into three main parts which led to breaching of the barrier spit in several locations. In contrast, while some areas in Bay Head Dune over washed, no breaching occurred.

The authors used simulations with a Boussinesq-type model to quantitatively assess the protective effect of the Bay Head Dune seawall. They found that the seawall reduced the average wave force acting on the landward oceanfront homes by more than a factor of two. Similarly, erosive flow velocities over the dunes in Bay Head Dune were reduced, with respect to those in Mantoloking.

### 2.7.5 Siting (to minimize sea turtle impacts)

As described in Section 2.6, FWC has conducted studies, primarily through FWRI, on the impact of coastal armoring on marine turtles. These studies have principally focused on obstructions to nesting habitat created by barriers, such as seawalls. The literature did not specifically address the optimal siting of seawalls but was focused rather on estimating and documenting the impacts of walls on sea turtles in general, as opposed to “natural” shorelines.

### 2.7.6 Line of Coastal Construction for Armoring

There was not much in the literature specific to the establishment of lines of construction for coastal armoring. The literature research did yield a few Florida municipalities, including the Town of Palm Beach and Volusia County, that have established their own line of coastal construction. This line is sometimes referred as the “bulkhead line” and is used to establish the location and alignment of existing and future seawalls.

The findings of the literature review were used to inform the remainder of the study. A more detailed summary of the literature reviewed is provided in Appendix A.

# 3. Data Analysis

The purpose of the data analysis was to identify trends related to the impacts of historical armoring projects permitted by the Department. AtkinsRéalis' methodology consisted of reviewing and tabulating relevant datasets obtained from FDEP, as well as interpreting aerial imagery acquired from FDEP, FDOT, and AIRBUS. The study locations selected were South Ponte Vedra (SPV) in St Johns County and Casey and Manasota Keys in Sarasota County. These study locations were chosen based on multiple factors including shoreline conditions and the prevalence of armored and unarmored shoreline segments.

An analysis was conducted at each study location to identify trends for the following factors under review by the policy study:

1. Gap Size: Assessment of the length of gaps between existing armoring structures.
2. Uniformity and Consistency of Siting: Evaluation of the alignment and conformity of armoring structures with the CCCL and protected structures.
3. Frequency of Return Wall Usage: Analysis of how often return walls (walls perpendicular to the shoreline) were utilized.
4. Location of Return Wall Siting Relative to the Line of Construction: Examination of the positioning and length of return walls relative to the line of construction.

An analysis was conducted for the following but no meaningful results were ascertained within the limits of this study's scope. The later section on the summary of findings will discuss what additional analysis and information is needed to produce meaningful results.

5. Erosional Effects or Impact on Adjacent Properties: Investigation into erosional effects or impacts observed on neighboring properties.
6. Circumstances: Consideration of specific circumstances, such as armoring structures sited further seaward than adjacent structures or segments of shoreline where multiple structures become vulnerable.

The resulting dataset consists of Geographic Information System (GIS) shapefiles and data tables for the seawalls and locations analyzed. The methodology was developed and documented so that it can be replicated in the future and at varying locations throughout the state.

The paragraphs below provide a detailed description of the methodology, analysis approach, and findings derived from studying the effects of armoring along the Florida coast.

## 3.1 Data Gathering and Compilation

This section provides descriptions of the data gathered and compiled for this study. FDEP provided GIS and other files related to armoring including work conducted under the 2012 Florida Beaches Habitat Conservation Plan (HCP) Armoring Study (Coastal Tech, 2012). AtkinsRéalis downloaded relevant CCCL permitting records and GIS data including the CCCL line, parcel data and county line limits from publicly available sources. In addition to these datasets, historic aerials were also retrieved. All available data was reviewed and compiled within the ArcGIS Pro database. This approach assisted in efficiently visualizing the data and reviewing the historical progress of armoring the shoreline.

### 3.1.1 Habitat Conservation Plan Data

The Florida Beaches HCP Armoring study was completed in 2012 and commissioned by FDEP with support from a Habitat Conservation Planning Assistance Grant provided by the U.S. Fish and Wildlife Service. The report identified existing armoring structures and conducted storm erosion modeling to identify future (25-yr outlook) armoring needs statewide. The inventory of existing and future armoring structures was delivered as GIS database, documenting the conditions as of August 1, 2011.

AtkinsRéalis utilized the Florida Beaches HCP Armoring study report and data as a starting point for data analysis. While information from the Florida Beaches HCP Armoring study was employed, the current study did not update the Florida Beaches HCP Armoring Study datasets, nor check their accuracy. Instead, the data aided in developing a better understanding of the seawalls constructed on the Florida beaches within the specific study locations.

### 3.1.2 FDEP Permitting Records

FDEP catalogs all permitting activity through an online databased known as Oculus. AtkinsRéalis downloaded a summary list of 1,891 permit authorizations (original and modifications) issued by FDEP since 1979 for shoreline armoring (seawalls only). For the study areas, the Final Order permit document for each seawall contained details on the dimensions, siting, configuration, and construction of the wall. In addition, data retrieved from permits was incorporated into GIS point shapefiles and included the following details:

- Approximate location
- Permit number, type, and status
- Summary report
- Issued and expiration dates
- Structure descriptions
- Owner name
- Property address

### 3.1.3 GIS Datasets

In addition to the Florida Beaches HCP Armoring study GIS database and FDEP Permitting records, AtkinsRéalis retrieved the CCCL and the FDEP Range Monuments. The following lists the primary and support data and sources used in this study:

- Master Existing Armoring – HCP Armoring Report (2012)
- Master Future Armoring – HCP Armoring Report (2012)
- Master Potential Gap – HCP Armoring Report (2012)
- FDEP Permits – FDEP Oculus (Accessed July 2023)
- CCCL – FDEP's Map Direct (Accessed July 2023)
- Range Monuments – FDEP's Map Direct (Accessed July 2023)
- County Parcel Data – County Property Appraiser Websites (Accessed July 2023)
- County Line Limits – U.S. Census Bureau; Data.Gov (Accessed July 2023)

### 3.1.4 Aerial Photography

Historic and recent aerial photography sources were compiled from FDEP's Collection of Aerials and Shoreline Trends System (COASTS) and FDOT's Aerial Photography Archive (APLUS). A third source, AIRBUS, was also used to review recently installed seawalls on Manasota Key (FDEP, 2023a) (FDOT, 2023) (AIRBUS, 2023).

These aerial photography sources provided a comprehensive set of imagery for the study to identify, analyze and interpret historical and recent seawall construction and conditions along Florida's coastline. Table 1 provides the sources and dates for the aerials retrieved.

**Table 1. Sources and dates for aerial photography (sorted by study site location)**

| Study Site | County | FDEP | FDOT | AIRBUS |
|---|---|---|---|---|
| South Ponte Vedra | St. Johns | - | 2008, 2010, 2014, 2016, 2019, 2021 | - |
| Casey Key | Sarasota | 2007, 2010, 2011 | 2005, 2009, 2011, 2014, 2017, 2020 | - |
| Manasota Key | Sarasota | 2007, 2010, 2011 | 2005, 2009, 2011, 2014, 2017, 2020 | 2023 |

## 3.2 Analysis of Selected Seawalls

This section details the process of site selection, creation of the data catalog, and the analysis of selected seawalls for factors under review by the policy study. ArcGIS Pro was utilized to review and consolidate the data associated with the seawalls. By leveraging the capabilities of this software, AtkinsRéalis was able to efficiently manage collected data for a more in-depth understanding of the armoring and its associated factors.

### 3.2.1 Site Selection

AtkinsRéalis conducted a review of three segments of shoreline, including one in St. Johns Count, along South Ponte Vedra Beach (from R-88 to R-96), and two in Sarasota County, along Casey Key (from R-92 to R-101) and Manasota Key (from R-169 to R-176). These locations, determined to be critically eroded by the states Strategic Beach Management Plan, were selected in collaboration with FDEP.

These sites represent segments of shoreline with varying physical characteristics (elevations, etc.) as well as differing strategies for coastline management. St. Johns County allows seawall construction and conducts beach and dune restoration and nourishment projects. Whereas Sarasota County adopts a more conservative approach with stricter regulations on shoreline protection using hard structures and conducts limited beach nourishments in select locations within the county. The Casey Key study area has not historically been restored except for small, individual property dune projects. The same applies to Manasota Key except for a small portion of the study area which was nourished in 2020 (R-173.4 to R-177.5).

### 3.2.2 South Ponte Vedra

Located on the Atlantic coastline, South Ponte Vedra is in St. Johns County and has experienced high erosion with the passing of Hurricanes Matthew (2016), Irma (2017) and Ian/Nicole (2022) resulting in the erection of many new armoring structures. Following Hurricane Matthew, the number of permitted seawalls increased from 52 to 240 in the previous 10 years along the county's entire coastline. The focus area selected for this study was between R-88 to R-96 on approximately 1.6 miles of shoreline. A dune and beach restoration project was conducted in the focus area to repair the beaches damages caused by Hurricane Matthew. The location was selected based on the composition of parcels with and without armoring, and variations in siting of the armoring (i.e., in line vs offset from neighboring armoring). A total of 45 permits (69 authorizations including permit for seawall modifications) were reviewed across 96 parcels along this stretch of coast.


Figure 1. St. Johns County Study Limits

### 3.2.3 Casey Key and Manasota Key

Located on the Gulf of Mexico's coast in Sarasota County, segments of Casey Key and Manasota Key, were selected for analysis. Like St. Johns County, since 2016, Sarasota County coastline saw a large increase in permitted seawalls from 19 to 114 in the previous 10 years. The segments of shoreline selected for the focus area of this study was between R-92 to R-101 for Casey Key and R-169 to R-176 for Manasota Key, approximately 1.8 and 1.0 miles of shoreline, respectively. These locations were selected based on the density of armoring permits. A total of 25 permits were reviewed across 114 parcels along this stretch of coast.

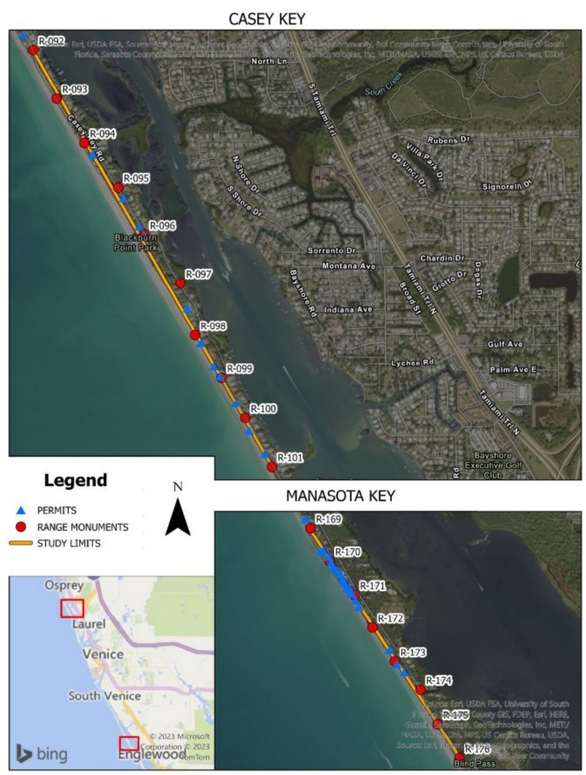


Figure 2. Sarasota County Study Limits

## 3.3 Data Catalog

A comprehensive spreadsheet was created to capture and organize data for the study sites. This spreadsheet served as a central repository and provided a structured framework for subsequent analysis. Each item was carefully defined to ensure clarity and consistency throughout the assessment process. Additionally, the data sources were documented for proper referencing and traceability. Table 2 provides a breakdown of the information gathered through the cataloguing effort.

**Table 2. Data elements captured in the data cataloging effort.**

| Data Set | Definition | Data Source |
|---|---|---|
| **Permit #** | Permit number | Permit |
| **Permit Issue Date** | Date permit issued | Permit |
| **County** | County | Permit/GIS |
| **Municipality** | Name of municipality (Town, City, N/A, etc.) | Permit/GIS |
| **R-Monument** | Location of R-Monument to nearest tenth (i.e., R10.5) | Permit/GIS |
| **Aerial Date** | New line in attribute table for each aerial. | GIS |
| **Managed Beach/Dune** | Is the beach managed with sand placement or dune projects? | FDEP BIPP SBMP |
| **Wall Type** | Cantilevered or Tie-Back | Permit |
| **Foundation Type** | Slab on Grade or Pile Supported | Permit |
| **Wall Material** | Steel, Vinyl, Wood, Composite, Other | Permit |
| **Height of Wall** | Height of wall above 0.0' NAVD | Permit |
| **Depth of Wall** | Depth of wall below 0.0' NAVD | Permit |
| **Length of Wall – Permit** | Length of wall | Permit/GIS |
| **Length of Wall – Cumulative** | Length of walls in continuous line of construction (multi-parcels) | Permit/GIS |
| **Repaired or Modified** | Has the wall been modified or repaired since original permit? | Permit |
| **Wall Visibility** | Is the wall visible in the aerial | GIS |
| **Wall Condition** | Intact or visibly damaged? | GIS |
| **Parcel** | Does the wall span one parcel or multiple? | Permit/GIS |
| **Return Wall** | Is a return wall present? | Permit/GIS |
| **Return Wall Length** | Return wall length | Permit/GIS |
| **Return Wall to Foundation** | Distance from the landward end of return wall to the foundation | Permit/GIS |
| **Emergency Permit** | Was the wall permitted under an Emergency Order? | Permit |
| **Variance** | Is a variance associated with permit? If yes, what type? | Variance List |
| **Adjacent to Gap** | Is the wall adjacent to a gap or non-armored parcel? | GIS |
| **Gap Size** | Length of Gap, if applicable | GIS |
| **Erosion Left** | Is there erosion to the property to the left when looking at the wall from the beach? Scale of 0 to 5 with 0 being no erosion noticed and 5 being most erosive witnessed within study. | GIS |
| **Erosion Right** | Is there erosion to the property to the right when looking at the wall from the beach? Scale of 0 to 5 with 0 being no erosion noticed and 5 being most erosive witnessed within study. | GIS |
| **Wall Siting Left** | Is the wall sited in line with neighboring wall or offset seaward? Negative value indicates offset is landward, 0 indicates walls are in line, Positive value indicates offset is seaward – Measured as compared to adjacent wall located on left when looking at the wall from the beach | Permit/GIS |
| Table 1**Table 2. Data elements captured in the data cataloging effort.(Continued)** | | |

| Data Set | Definition | Data Source |
|---|---|---|
| **Wall Siting Right** | Is the wall sited in line with neighboring wall or offset seaward? Negative value indicates offset is landward, 0 indicates walls are in line, Positive value indicates offset is seaward – Measured as compared to adjacent wall located on right when looking at the wall from the beach | Permit/GIS |
| **Distance: CCCL to Wall** | This is the distance measured from the CCCL. Is this needed? Does this help establish or analyze anything with respect to line of construction, etc.? | GIS |
| **Distance: CCCL to Foundation** | This is the distance measured from the CCCL to the Seaward Edge of Foundation | GIS |
| **Distance to Local Bulkhead Line** | If a "Bulkhead Line (BL)" has been established locally, provide the distance from the wall to the bulkhead line. "Bulkhead line" is a general term. The line may officially be called something else. Negative value indicates BL is landward, 0 indicates wall is in line with BL, Positive value indicates BL is seaward. | GIS |
| **Notes/Observations** | General observations that may be relevant. | Permit/GIS |

A crucial aspect of the data gathering process focused on the data in the permits. These sources were highly valuable as they provided the most up-to-date information on seawall construction. It was essential to review permit modifications, as they could significantly impact the understanding of the armoring's condition. By including the permit data, the analysis aimed to capture the most recent changes and developments related to the seawalls.

GIS enabled the integration and analysis of various spatial data, including viewing historic aerial imagery and measurements. Historic aerial imagery played a crucial role in capturing relevant information about seawall construction and previous gaps in seawalls that have been closed. However, it's important to note that the accuracy of measurements derived from aerial imagery was subject to the quality and resolution of the imagery available. For example, if the permit did not contain the length of the return wall or the distance from the CCCL to the home's foundation, these measurements were taken from clues in the aerial photography and, while they may not be as accurate as on the ground measurements, they are useful estimates for the study. Considering the inherent limitations of estimated measurements, AtkinsRéalis made a diligent effort to utilize the best available aerial imagery for data extraction and took great care in interpreting the imagery to ensure that the measurements derived from it were as reliable and precise as possible.

## 3.4 Trend Analysis

The trend analysis aimed to gain deeper insights into the impacts of seawalls on the coastal system and to evaluate patterns or variability in the data that may influence future permit decisions or policy changes. The trends that were reviewed and discussed herein include gap size, uniformity, and consistency of siting relative to the CCCL, frequency of return wall usage, location of return wall siting relative to the line of construction, erosional effects or impact on adjacent properties, and additional circumstances like individual structures sited further seaward than adjacent structures and segments of shoreline where multiple structures become vulnerable.

### 3.4.1 Gap Size

A gap exists when an unarmored parcel(s) sits between armored sections of the coastline. Florida Statutes Section 161.085 allows for a permit to be issued to 'close the gap' if the gap is less than or equal to 250 feet. This assumes that an open gap in an otherwise continuous armored shoreline will experience increased erosion because of the adjacent armoring. Conversely, it assumes that closing a 250-foot gap will not result in significant impacts to the coastal system, regardless of the length and alignment of the adjacent armored sections. Table 3 below details the number of gaps and the length ranges associated with the gaps remaining.

**Table 3. Gap size widths located within the study areas.**

| Gap Size (FT) | | | |
|---|---|---|---|
| **Length (ft)** | **SPV** | **Casey Key** | **Manasota Key** |
| **<=75** | 5 | - | - |
| **75-250** | 6 | 2 | - |
| **250-500** | - | - | 1 |
| **500-750** | - | - | - |
| **750-1000** | - | - | - |
| **>1000** | 3 | 8 | 2 |
| **Total** | **14** | **10** | **3** |

In assessing how the "gap rule" has been applied in recent years, a review of permits and aerial imagery (current and historic) was used. South Ponte Vedra has an average parcel width of 75 feet, where in recent years 12 seawalls appear to have been authorized using the "gap rule." In contrast, in Sarasota County where the average parcel width is considerably larger, no permit authorizations using the "gap rule" were identified.

### 3.4.2 Uniformity and Consistency of Siting Relative to the CCCL

FDEP is tasked with ensuring that armoring is sited as far landward as practicable and designed to minimize adverse impacts. The objective of this analysis was to identify consistencies in siting the seawall relative to the CCCL and property foundation. Distances between the seawall and the foundation of the protected eligible structure were reviewed to assess whether seawalls were positioned as far landward as feasible using scatter plot diagrams of the distances compared to the permit issuance date. Linear trendlines were also generated to determine the Coefficient of Determination. The following distances were depicted in each chart:

- Distance from CCCL to Seawall (FT)
- Distance from CCCL to Foundation (FT)
- Distance from Seawall to Foundation (FT) (Distance from CCCL to Seawall – Distance from CCCL to Foundation)

Figure 3 through Figure 5 depict the scatter plots for South Ponte Vedra, Casey Key, and Manasota Key, respectively. The findings reveal notable differences between the data for seawalls in South Ponte Vedra and Sarasota County. It is important to note that the characteristics of each location are different and this analysis compares data from within each location. The analysis in not intended to compare the different locations with each other.

In the South Ponte Vedra data, the trendline showed a well-scattered distribution of data (non-correlated). Upon closer examination, while the general trend for the distance from the CCCL to the seawall remained consistent, newer foundations are being constructed closer to the CCCL over time. Consequently, this results in larger distances between the foundation and the seawall. Given the substantial number of seawalls established in St. Johns County, the line of coastal armoring is essentially established, and it is reasonable to assume that future seawalls will be sited and authorized along this alignment.

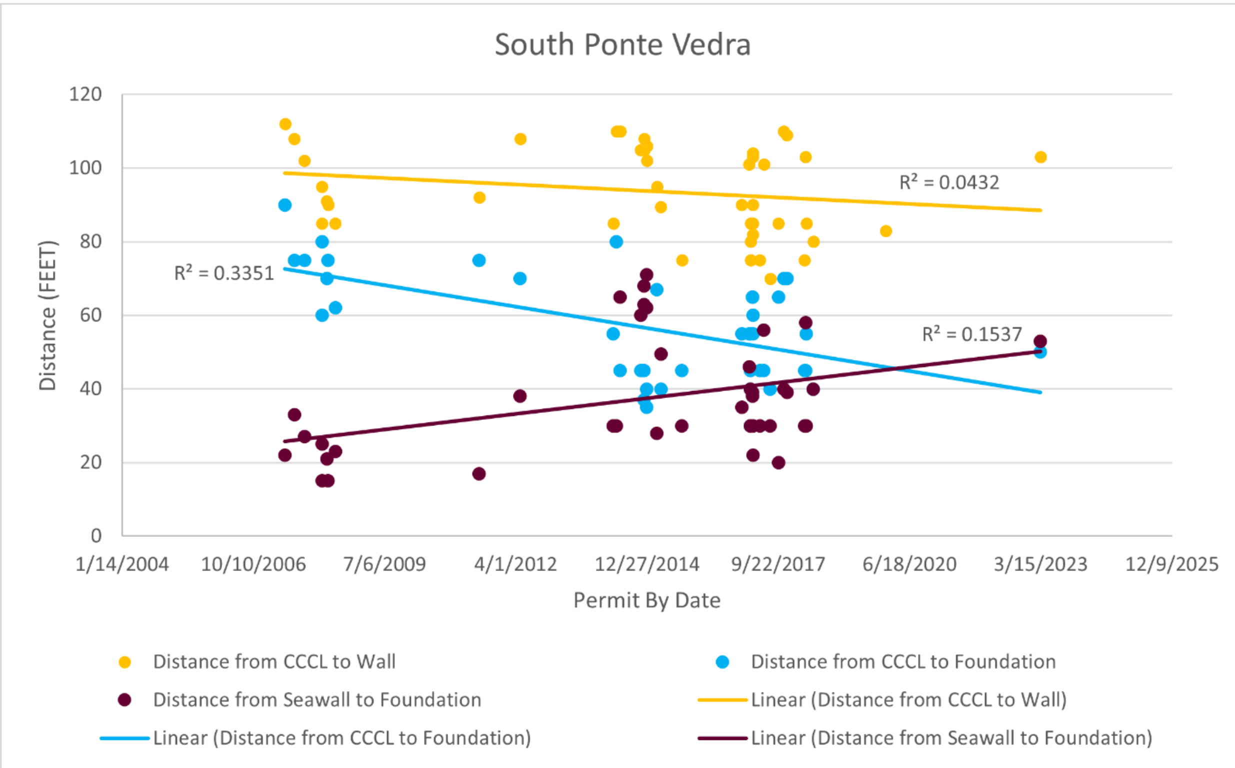


**Figure 3 South Ponte Vedra Distances Vs Permit by Date Scatter plot**

The analysis for Casey Key and Manasota Key exhibited a different trend. Casey Key exhibited relatively constant distances from the CCCL to the seawall and from the CCCL to the foundation. However, in Manasota Key, a lapse in time between authorized permits from 1984 to 2022 resulted with the inability to determine a suitable trend. Furthermore, distances from the seawall to the foundation remained consistent for both study areas, with average distances of 19 and 28 feet, respectively. This suggests that seawalls are being consistently sited in Casey Key relative to the CCCL and in Manasota Key relative to the distance from foundations.

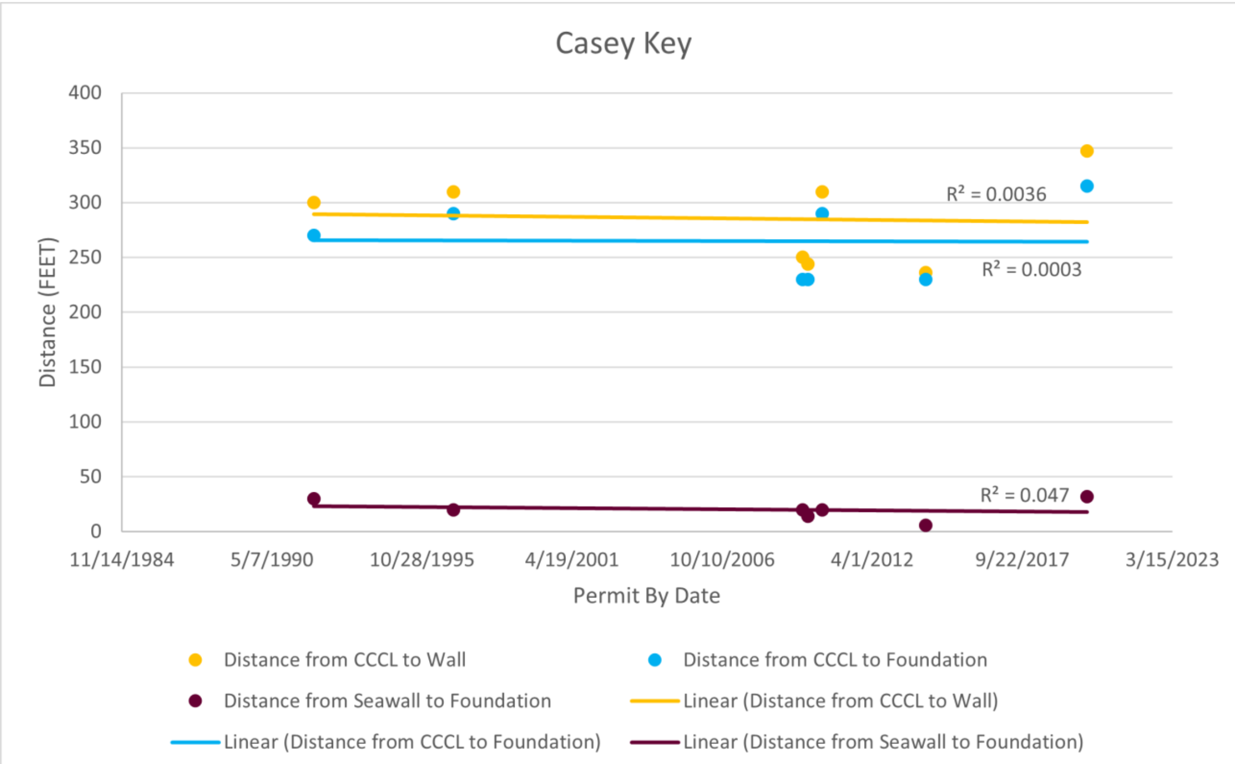


**Figure 4 Casey Key Distances Vs Permit by Date Scatter plot**

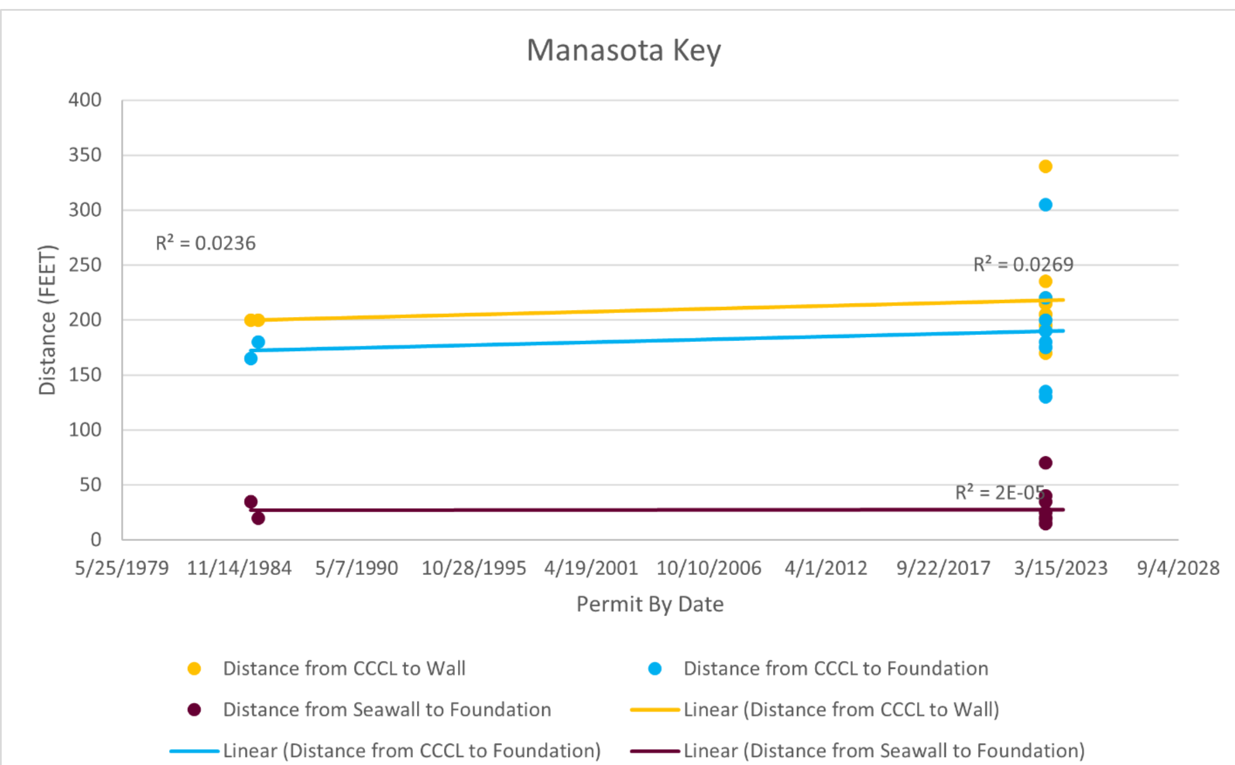


**Figure 5 Manasota Key Distances Vs Permit by Date Scatter plot**

Lastly, data related to the range and average distances per studied area were tabulated, as shown in Table 4 below. The findings indicate that the average distances from the CCCL to seawalls and/or foundations identified along the South Ponte Vedra beach were closer to the CCCL than those observed along Casey Key and Manasota Key. However, distances between the seawall and the foundation were found to be greater in South Ponte Vedra than in Casey Key and Manasota Key.

**Table 4. Siting of Seawall in Relation to CCCL and Foundation**

| Location | Distance (FT) CCCL to Wall | | | Distance (FT) CCCL to Foundation | | | Distance (FT) Seawall to Foundation | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg. | Min | Max | Avg. | Min | Max | Avg. |
| South Ponte Vedra | 70 | 112 | 94 | 35 | 90 | 57 | 15 | 71 | 37 |
| Casey Key | 225 | 347 | 278 | 215 | 315 | 259 | 6 | 32 | 19 |
| Manasota Key | 170 | 340 | 215 | 130 | 305 | 187 | 15 | 70 | 28 |

## 3.4.3 Frequency of Return Wall Usage and Relationship to Foundation Location

Return walls are secondary walls located either perpendicular to or at an angle from the ends of the primary seawall with the purpose to assist in anchoring and stabilizing the seawall and prevent flanking. While the construction of return walls is encouraged, it is not currently mandatory as part of the CCCL permitting process. AtkinsRéalis documented the presence of return walls, their lengths, and their distances from the foundation of the protected structure as seen Table 5 and Table 6 below.

Analysis revealed that most seawalls within South Ponte Vedra have a return wall. A total of 13 permitted seawalls with return walls consisted of multiple parcels (per permit) and 14 seawalls allocated to single property permits. Specifically, permits with multiple parcels included four (4) permits with a return wall on both the north and south sides of the seawall and nine (9) permits with a return wall on one side. Some permits revealed that due to the tie-in of an existing seawall, a return wall was only needed one side. However, most of the seawalls with one sided return walls were left undetermined about why the second return wall was not constructed. Single property permits consisted of nine (9) permits with return walls on both the north and south sides of the seawall and five (5) with a return wall on one side. Only 18 permits did not have return walls, with seven (7) permits associated with multiple parcels per permit and 11 for single property permits. Lastly, out of the 27 permits with return walls, 10 of the return walls were situated adjacent to either an existing (6 occurrences) or pre-existing (4 occurrences) gap.

The analysis for Casey Key and Manasota Key combined revealed that a total of seven (7) out of 15 permitted seawalls included return walls. Among four (4) permitted seawalls associated with multiple parcels per permit, only one had a return wall on one side of the seawall. Other six (6) single property permits included return walls, with three (3) having return walls on both sides of the seawall and three (3) having a return wall on only one side.

For a more comprehensive understanding, Table 5 shows the frequency of return wall usage tabulated to indicate the number of seawalls with return walls and those without. Additionally, the lengths of return walls and their distances from the foundations were recorded for South Ponte Vedra, Casey Key, and Manasota Key and are presented in Table 6. Lengths were measured from the landward end of the return wall to the closet portion of the foundation of the protected structure.

**Table 5. Return wall frequency for each study location.**

| Location | Return Wall | |
|---|---|---|
| | Yes | No |
| South Ponte Vedra | 27 | 18 |
| Casey Key | 3 | 7 |
| Manasota Key | 4 | 1 |

**Table 6. Return wall length and distance to structure foundation for studied limits.**

| Site | | Return Wall Length (FT) | | Return Wall to Foundation (FT) | |
|---|---|---|---|---|---|
| | | NORTH | SOUTH | NORTH | SOUTH |
| South Ponte Vedra | Min | 2 | 4 | 10 | 10 |
| | Max | 45 | 60 | 40 | 30 |
| | Avg. | 16.7 | 18.4 | 25.3 | 19.2 |
| Casey Key | Min | 27 | 12 | 0 | 0 |
| | Max | 27 | 25 | 0 | 0 |
| | Avg. | 23 | 17.3 | - | - |
| Manasota Key | Min | 30 | 11 | 30 | 30 |
| | Max | 30 | 60 | 30 | 30 |
| | Avg. | 30 | 33.7 | 30 | 30 |

Further analysis of the return walls lengths and their location to the foundation were reviewed. The return wall length was compared to the distance from the seawall to the foundation to better understand their relationship. Most of the return walls for South Ponte Vedra were found to be installed less than the distance between the structure's foundation and the seawall. As for Casey Key and Manasota Key, return walls were installed further landward than the structures foundation in some locations. Figure 6 depicts the scatter plot of the return wall length as a percentage of the distance from the foundation to the seawall for South Ponte Vedra, Casey Key, and Manasota Key. Additionally, Table 7 provides range and average of the return wall length as a percentage of the distance from the foundation to the seawall. A value of 0% represents no return wall, where as a value of <100% indicated that it has a return wall length less than the distance between the foundation and the seawall, and a value >100% indicates that it has a return wall length greater than the distance between the foundation and the seawall.

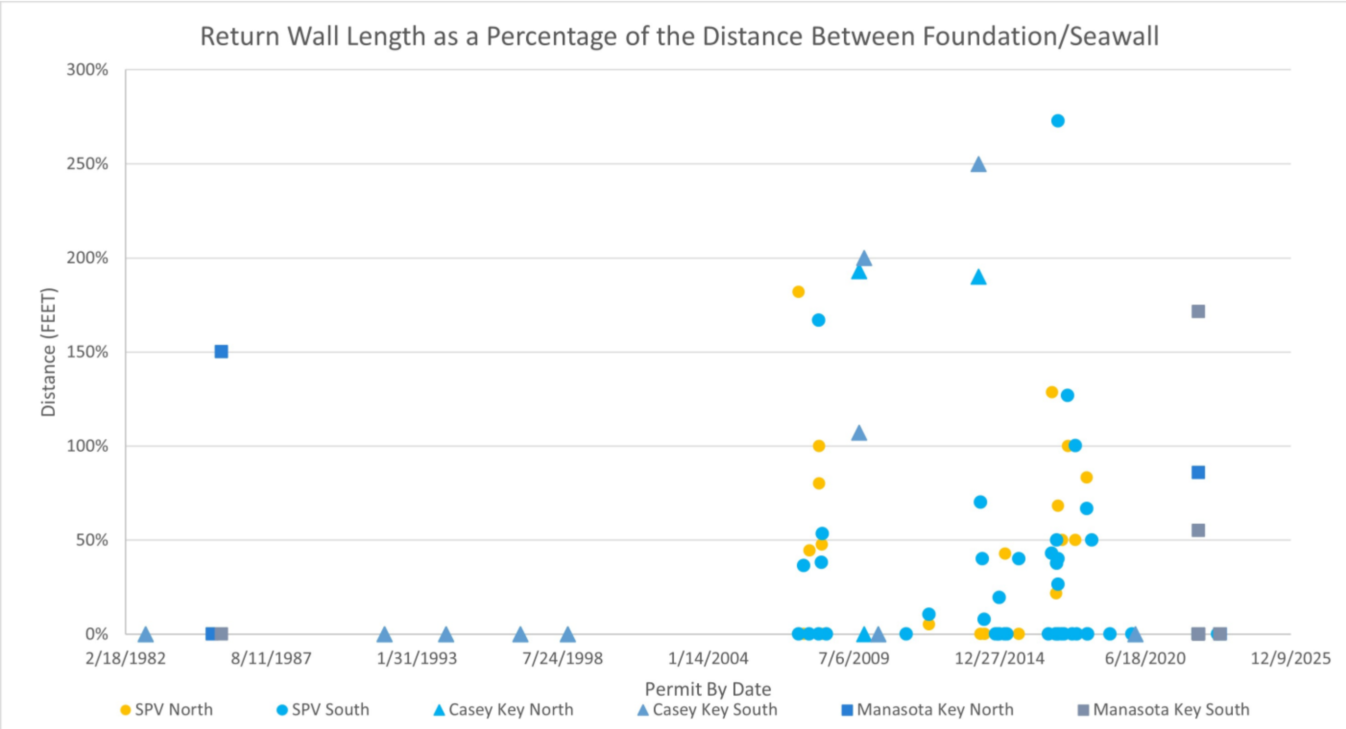


**Figure 6 Return wall length as a percentage of the distance from foundation to seawall.**

**Table 7. Return wall length as a percentage of the distance from foundations to seawall.**

| **Site** | | **% Return Wall Length to Foundation** | |
|---|---|---|---|
| | | **NORTH** | **SOUTH** |
| **South Ponte Vedra** | **Min** | 5% | 8% |
| | **Max** | 182% | 273% |
| | **Avg.** | 63% | 65% |
| **Casey Key** | **Min** | 190% | 107% |
| | **Max** | 193% | 250% |
| | **Avg.** | 191% | 186% |
| **Manasota Key** | **Min** | 86% | 55% |
| | **Max** | 150% | 171% |
| | **Avg.** | 118% | 104% |

### 3.4.4 Erosional Effects or Impact on Adjacent Properties

One aspect of review focused on examining the potential erosional effects or impacts on adjacent properties resulting from the presence of seawalls. However, due to limitations available in aerial imagery to view changes in elevation, the timing of the images, and extended durations between aerial surveys, AtkinsRéalis was unable to analyze erosional patterns or influences between the installed seawalls and their impacts on neighboring unprotected shorelines.

To gain a more conclusive understanding, additional data involving more frequent and clear aerial imagery combined with reviews of field observations and/or survey data would be required to develop well-supported hypotheses regarding the effect of seawalls on adjacent properties in these study areas. The scope of this study did not include a review of this level.

## 3.5 Permit Issuance and Variances

### 3.5.1 Permit Issuance

Permits issued were tallied by County using data from the publicly available Oculus database as of June 2023 (Table 8). In the 19.5 years of the record, an average of 54 permit authorizations were issued annually for seawalls. Notably, the state average for the initial 10 years was 30 permits per year, but in the subsequent 9.5 years, it surged 210% to 93 permits annually. This spike seems linked to the aftermath of multiple significant storm events, beginning with hurricane Matthew in 2016. Since 2004, 42% of all authorizations issued by the State were in Volusia and St John's Counties post-2016. Including Sarasota County, these three counties account for 53% of all authorizations issued.

### 3.5.2 Variances

**Variances related to coastal armoring were downloaded from Oculus (as of July 2023) and were reviewed for content and trends. A total of nine (9) variances were identified with six (6) related to eligibility (i.e., need to protect a conforming structure), two (2) were related to level of protection (i.e., roadways were FDOT requested to use a 100-yr design storm), and one (1) was related to pertinent structures (i.e., need to protect a conforming wastewater treatment plan). These variances are summarized in**
Table 9.

**Table 8. List of Permits Issued 2004-Present (FDEP, 2023b)**

| County | # Armoring Permits | % of State Total | # Armoring Permits | |
|---|---|---|---|---|
| | | | 2004-2015 | 2016-6/2023 |
| Bay | 1 | 0.1% | 0 | 1 |
| Brevard | 14 | 1.3% | 12 | 2 |
| Broward | 3 | 0.3% | 2 | 1 |
| Charlotte | 26 | 2.5% | 5 | 21 |
| Collier | 16 | 1.5% | 6 | 10 |
| Duval | 5 | 0.5% | 5 | 0 |
| Flagler | 13 | 1.2% | 3 | 10 |
| Franklin | 25 | 2.4% | 15 | 10 |
| Gulf | 4 | 0.4% | 3 | 1 |
| Indian River | 18 | 1.7% | 12 | 6 |
| Lee | 19 | 1.8% | 8 | 11 |
| Manatee | 17 | 1.6% | 16 | 1 |
| Martin | 18 | 1.7% | 16 | 2 |
| Monroe | 13 | 1.2% | 4 | 9 |
| Okaloosa | 10 | 0.9% | 4 | 0 |
| Palm Beach | 112 | 10.6% | 70 | 42 |
| Pinellas | 12 | 1.1% | 3 | 9 |
| Sarasota | 139 | 13.2% | 25 | 114 |
| St. Johns | 295 | 27.9% | 55 | 240 |
| Volusia | 264 | 25.0% | 54 | 210 |
| Walton | 33 | 3.1% | 33 | 0 |
| **Total** | **1057** | | **351** | **700** |
| **Average** | **54/yr** | | **29/yr** | **93/yr** |

42% of State total (2004-present) is from St Johns & Volusia, 2016-Present

53% of state total (2004-present) is from Sarasota, St Johns & Volusia, 2016-present

Notes: 1) Modifications to prior permit authorizations were not included. 2) major storm events impacting Florida during this time included (H. = hurricane):

- 2022 – H. Ian and H. Nicole
- 2020 – H. Sally
- 2018 – H. Michael
- 2017 – H. Irma
- 2016 – H. Mathew and H. Hermine
- 2005 – H. Dennis, H. Katrina, H. Wilma
- 2004 – H. Charley, H. Ivan, H. Frances, H. Jeanne

**Table 9. List of Variances (FDEP, 2023b)**

| Received Date | Permit Number | County | Variance description |
|---|---|---|---|
| 06-08-2015 | CH000597 AR V | CHARLOTTE | Variance for protection of a conforming structure in an area under Emergency Order (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure." ) |
| 08-18-2022 | CO1168 AR V | COLLIER | Variance for major reconstruction (replacement) for eligibility and conformity of structure. Home at the site had been demolished with coastal armoring remaining and a new home to be built. (62B-33.002(12)(b)1., 62B-22.002(39), and 62B-33.0051(1)(a)1., F.A.C.) |
| 10-19-2022 | CO001151 AR V | COLLIER | Variance for major reconstruction (replacement) of a seawall to protect a conforming structure (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure.") |
| 07-27-2023 | CO001218 AR V | COLLIER | Variance for major reconstruction (replacement) of a seawall to protect a conforming structure (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure." |
| 07-27-2023 | CO001219 AR V | COLLIER | Variance for major reconstruction (replacement) of a seawall to protect a conforming structure (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure." |
| 09-06-2017 | IR000952 AR V | INDIAN RIVER | Variance for protection of a conforming structure which is highly vulnerable to a 15-yr storm event (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure.") |
| 06-11-2020 | IR000999 AR V | INDIAN RIVER | Variance for protection of a conforming structure which is highly vulnerable to a 15-yr storm event (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure.") |
| 04-13-2021 | PB001285 AR V | PALM BEACH | FDOT requested a variance to allow for a revetment reconstruction design based on 100-yr surge for roadway protection (62B-33.0051(2)(b)3., F.A.C. Armoring shall provide a level of protection compatible with existing topography, not to exceed a 50-year design storm.) |

| | | | |
|---|---|---|---|
| 07-08-2021 | PB001285 AR V | PALM BEACH | FDOT requested a variance to allow for a wall design based on 100-yr surge for roadway protection (62B-33.0051(2)(b)3., F.A.C. Armoring shall provide a level of protection compatible with existing topography, not to exceed a 50-year design storm.) |
| 11-09-2022 | PB1424 AR V | PALM BEACH | Variance for major reconstruction (replacement) from the requirement that the property be unarmored for armoring to be authorized when a gap exists between a line of rigid coastal armoring that is continuous on both sides of the property (62B-33.0051(1)(a)3, F.A.C.) |
| 12-15-2022 | PB1399 AR V | PALM BEACH | Variance for major reconstruction (replacement) and limits on the level of storm design (exceed 50-yr) (62B-33.002(27) and 62B-33.0051(2)(b)3, F.A.C. "the proposed armoring is for the protection of eligible infrastructure." |
| 06-05-2015 | SJ001206 AR V | ST. JOHNS | Variance for protection of a conforming structure which is highly vulnerable to a 15-yr storm event (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure." Protection needed for pertinent structure (wasterwater treatment)). |
| 11-07-2016 | SJ001281 AR V | ST. JOHNS | Variance for protection of a conforming structure where foundation was exposed following storm event (62B-33.0051(1)(a)(1), F.A.C. "the proposed armoring is for the protection of an eligible structure.") |

# 3.6 Data Analysis Summary of Findings

In summary, the trend analysis delved into several aspects including gaps in seawall construction, return wall frequency, and siting relative to the CCCL. Despite some limitations in data and imagery, the study provided valuable insights that can inform coastal management strategies. The summary of results revealed notable differences between the two counties. This divergence may be attributed to the differing armoring policies enforced by each county and/or the different characteristics of the two coastal and dune systems; St. Johns County allows for more property armoring while Sarasota County adopts a more conservative approach, and St. Johns County has higher elevations with the CCCL being more seaward.

St. Johns County has established a consistent armored shoreline that has provided an opportunity to assess the effects of such structures on the beach environment. The “gap rule” was used an estimated 12 times in recent years to permit a seawall to close the gap of less than 250 ft in the South Ponte Vedra study area. Of note, the parcel width in South Ponte Vedra averages 75 ft. Due to the extensive armoring that occurred in recent years in South Ponte Vedra, only two gaps remain, one of which is less than 250 ft and the other greater than 1,000 ft in length.

The well-established (uniform) line of constructed seawalls along South Ponte Vedra shoreline is likely a driving force in the siting of new walls. Return walls were identified on the majority of permitted seawalls, in 27 of the 45 permits reviewed. The length of most return walls installed was less than the distance between the structure's foundation and the seawall.

Sarasota County presented limited information regarding gap sizes due to the low number of permitted armored structures. Among the data reviewed, no authorizations related to closing a gap of less than 250 ft were found in recent years in the Sarasota County study areas. At present, only two gaps of 250 ft wide or less remain. All other gaps remaining in the study area were larger than 1,000 ft. Seawalls in Sarasota County were found to be constructed as far landward as possible with respect to the foundation of the structure being protected. Their sparse availability allowed to flexibility in the seawall alignment to conform with the CCCL and the structures subjected to be protected.

The low number of permitted seawalls made it difficult to analyze return walls; however, about half of the permits for seawalls did also have an associated return wall.

The following factors were reviewed but no real meaningful trends were identified as a result of limitations in available aerial imagery that could observe the changes in elevation, timing, and duration between aerial surveys.

1. Erosional Effects or Impact on Adjacent Properties: Investigation into erosional effects or impacts observed on neighboring properties.

2. Circumstances: Consideration of specific circumstances, such as armoring structures sited further seaward than adjacent structures or segments of shoreline where multiple structures become vulnerable.

To gain a more conclusive understanding, additional data involving more frequent and clear aerial imagery combined with reviews of field observations and/or survey data would be required to develop well-supported hypotheses regarding the effect of seawalls on adjacent properties in these study areas.

# 4. Stakeholder Interviews

To gather insights on the current CCCL armoring guidelines and obtain stakeholders' perspectives on the program's future, a series of interviews were conducted. In consultation with FDEP, six (6) interviewees were selected from a range of backgrounds in coastal armoring and beach management, including consultants and local municipalities and independent interest groups. The interviews were carried out in June 2023.

A list of open-ended questions was prepared by AtkinsRéalis then reviewed and approved by FDEP. These questions were sent to the interviewees in advance of the interview and included:

1. Describe your experience or role related to 1) coastal armoring and 2) beach management (engineer, consultant, scientist, regulator, etc.)
2. What do you see as the main concerns with Florida's current approach to regulating and managing coastal armoring? What is working well?
3. What is your experience with property owners and their concerns about coastal erosion? How do property owners view the permitting process?
4. Describe examples of challenges you have faced when permitting armoring structures in the CCCL program.
5. What conflicts between local regulation and CCCL armoring regulations have you experienced?
6. What is your experience and perspective on emergency permitting, or under Emergency Orders, for armoring structures? Please share any lessons learned or modifications you would suggest for future storms.
7. What is your experience with armoring structures and their interaction with engineered beach and dune projects?
8. How can Florida better regulate and manage armoring as part of a broader set of strategies for responding to sea level rise and coastal hazards.
9. Are there other modifications to the CCCL armoring program that you would suggest?
10. Please provide any other comments or suggestions for consideration.

AtkinsRéalis, joined by representatives from FDEP, conducted the interviews with the intention of facilitating open and honest dialogue. The responses received through these interviews are summarized herein, organized by the study's focus areas which are:

- Sea Level Rise and Resilience Considerations in Armoring Design and Policy
- Minimum Design Standards and Considerations for Armoring
- Gap Size
- Proactive Armoring
- Siting and Design Considerations with respect to impacts to sea turtles
- Line of Coastal Construction for Armoring

Additional topics of discussion, with feedback from the stakeholders, include:

- Emergency Orders
- Integrated Beach Management
- Other

# 4.1 Sea Level Rise and Resilience Considerations in Armoring Design and Policy

## 4.1.1 Seawall Resilience

The interviewees noted that as-built records of seawalls often do not exist, which means the condition and design remain largely unknown until there is exposure or failure. This is further complicated by the lack of efficient inspection methods leaving many homeowners unaware of the condition of their existing seawall. The integrity of the walls is driven in large part by the unseen such as tie-rods, the depth of the wall, and other structural features, make assessment quite challenging. The interviewees further remarked that current regulations focus primarily on the installation of new seawalls, lacking provisions for regular maintenance. This can lead to catastrophic failures when seawalls malfunction due to a lack of maintenance. Furthermore, current regulations are seen as a hinderance to effective maintenance and improvements. Interviewees generally perceive the process for reconstructing or replacing existing seawalls as overly restrictive, if not altogether prohibited under current rules. Even though a seawall may have been in place for a long time, obtaining permission for its repair or reconstruction can be daunting. It was frequently mentioned that the environmental impacts of these older seawalls have already been accounted for, given their longstanding presence in the coastal system.

## 4.1.2 Sea Level Rise (SLR)

In general, the interviewees agreed that the existing statutes, rules, and their implementation are not keeping pace with SLR. They emphasized the importance of incorporating SLR considerations into storm frequency assessments to gain a clearer understanding of vulnerability. It was recommended that the CCCL program take into account SLR when assessing eligible structures and when setting design standards to ensure long-term sustainability and resilience. A common misconception found during the interviews regarded the available data used in the storm surge modeling. Another concern raised is the current absence of a universally accepted method for integrating projected sea level rise into storm erosion models and hydrographs. This gap leads to considerable uncertainty in predictions. One interviewee proposed that the FDEP should choose a specific SLR projection estimate and consistently apply it throughout the CCCL program, spanning its designs, models, and other related areas.

While local governments have instituted minimum wall height regulations that factor in SLR for intracoastal waterways, no such measures are in place for seawalls on the open coast. Furthermore, many local comprehensive plans do not sufficiently address the challenges posed by SLR. This oversight has been perceived by interviewees as a noticeable lack of acknowledgment by local leadership concerning this crucial matter.

# 4.2 Minimum Design Standards and Considerations for Armoring

## 4.2.1 General

Current regulations stipulate a maximum design, but most interviewees believe a minimum design standard would be more appropriate. At present, there are varying design standards for major reconstruction, gap closure, and new construction. Interviewees strongly feel that this inconsistency should be addressed. Furthermore, the interviewees are of the opinion that these minimum standards should consider SLR, suggesting the adoption of a standard SLR estimate. There is a recognized need to develop design standards that cater both to protective value, like design storms, and design life, which would account for the materials used and the overall robustness. A significant question that emerged is whether walls should be constructed to endure a series of events or just a single event. Another challenge was noted with respect to the varying conditions around the state. For example, cantilevered walls are not always viable, especially in Southeast Florida where large dunes are prevalent.

The Florida Building Code does not offer a minimum standard for seawalls. The interviewees noted that in many instances, local government and building officials lack the necessary education or experience to properly review armoring applications. Yet, these officials frequently find themselves answering queries from residents about the procedures and best practices for building, permitting, and erecting coastal armoring systems.

During their discussions, the interviewees reflected on several case studies detailing seawall failures following storm events, many of which were related to toe failure due to insufficient embedment depth.

One interviewee suggested new seawall authorizations should be conditioned with the obligation to place sand as needed at the end of the wall to mitigate potential erosive end effects.

## 4.2.2 Reconstruction

The interviewees agreed that reconstruction authorizations should consider allowing the permittee to propose a revised top of wall elevation to incorporate SLR.

## 4.2.3 Return Walls

The consensus among the interviewees was that there is limited engineering guidance available concerning the length, alignment, specifically curvature, and siting of return walls, particularly when determining their proximity to eligible structures versus property lines. Moreover, for stretches of continuous armoring that span multiple properties, there is a clear need for guidance or regulation on how often return walls should be installed. In numerous situations, the decision on the usage and length of return walls is driven more by economic factors than engineering considerations.

# 4.3 Gap Size

All the interviews indicated that a modification of the Gap Rule is necessary. The prevalent sentiment was that the 250 ft limitation set by the Gap Rule seems arbitrary. Some interviewees proposed that the gap length be confined to the parcel length(s), while others felt that it should be determined by a ratio of the gap length to the armored shoreline in the area. Several participants recommended removing the requirement for an eligible structure when it comes to reconstruction, replacement, or closure of a gap. Furthermore, many found it restrictive that the current Gap Rule mandates the gap to remain unarmored, especially in cases where an existing wall, which would otherwise qualify for a gap closure, requires reconstruction.

## 4.4 Proactive Armoring

Overall, the general sentiment among the interviewees is that new armoring in Florida has been infrequent in recent years, with exceptions following two major storm events on the East Coast. These events led to a surge in the demand for armoring, particularly in St. Johns County and Volusia County.

The armoring program, in the eyes of the interviewees, tends to operate reactively and on an individual basis. One participant remarked on the inefficacy of waiting until a structure is vulnerable to a 15-year event, describing this strategy as being in a constant "crisis mode". They suggested this reactive approach might not be the best way to support property owners and ensure resilient and sustainable protection. Another interviewee emphasized the need for a long-term vision, suggesting a 30–40-year plan for the coastal armoring program, and observed that the proactive nature of the beach management currently differs from that of armoring.

Finally, feedback from property owners consistently highlighted the urgency of erosion issues. Many feel that local governments either are not taking sufficient action or are not proceeding quickly enough with beach projects. Consequently, property owners in these affected areas are often the ones taking the initiative to pursue armoring.

Regarding the rule stipulating that armoring cannot be permitted if there is an already funded beach nourishment project, the interviewees pointed out situations where this might not be the most logical approach. For instance, they suggested that roadways might require the protection of armoring as a last line of defense, especially in areas where the width of nourished beach is limited due to factors like nearshore hardbottom.

## 4.5 Siting (to minimize sea turtle impacts)

Siting discussions were related to the minimization of impacts to nesting sea turtles.  Several interviewees emphasized the need for improved transparency in site planning with the FWC. They asserted that the data FWC relies on for decision-making should be readily available for review. A common perception among many of these interviewees is that the FWC's definition of sea turtle nesting habitat is ambiguous and lacks a consistent standard. There is a concern that the FWC has been altering designs or prompting engineers to do so based purely on environmental reasons without considering engineering aspects. Due to these concerns, some interviewees recommend that the FDEP assume FWC's responsibilities for sea turtle protection during the permitting process. Additionally, a recurring issue discussed by several interviewees was the challenge of completing the construction of armoring projects within the constraints of the sea turtle nesting season due to the limited timeframe.

## 4.6 Line of Coastal Construction for Armoring

The interviewees generally agreed that a seawall/bulkhead line is a great idea in certain localities before emergency situations exists.

## 4.7 Other

Other comments received from the interviewees encompass a range of issues and included:

- The average ownership period for coastal properties is approximately 10 years, with a noticeable gap in awareness among the public and potential buyers regarding coastal challenges. This is exacerbated by a lack of below grade inspection services for seawalls. Most property owners and the general public lack sufficient information about the CCCL armoring requirements and often underestimate the complexity and time needed to obtain a permit.
- While local codes and the CCCL program are largely in sync in Southeast Florida, they diverge when it comes to reconstruction. However, no such conflicts are evident between local regulations in Northeast Florida and CCCL regulations.
- New Smyrna Beach operates with its distinct coastal control line, which is notably more stringent. Due to its geographical positioning, no coastal armoring permits can be granted as there are not any structures that qualify, i.e., those seaward of the State's CCCL. Meanwhile, in Volusia County, there is a mandate for a continuously maintained dune (at least 4 ft high) accompanying any local seawall application, a rule that has been in place since the 1990s. However, this stipulation is often postponed for up to three (3) years for new projects. In certain situations, especially where the dune's width is compromised due to the mean high water location, enforcement is challenging. In such instances, the County permits property owners to contribute to a dedicated fund intended for future restoration.
- One interviewee emphasized that the State should respect existing local regulations. The State's role should be to outline the basic criteria.
- Brevard County stands out; its comprehensive plan for unincorporated areas bars coastal armoring along the open coast shoreline, with sand-filled geotextile containers being the lone exception. Furthermore, Brevard County runs a dune restoration program on its coastlines. As an informal approach, they frequently deposit "extra" sand next to seawalls to counteract end effects. Conversely, the City of Satellite Beach permits rip rap but disallows seawalls. This presents a dilemma as there is a prevailing perception that FWC leans more towards seawalls than sloped structures due to the larger space required for the latter, which could potentially encroach on nesting habitats. After the hurricanes in 2004, several projects employing sand-filled geotextile containers were initiated, with a condition to consistently maintain a sand cover. A considerable number of these were later dismantled by owners, mainly due to the high costs of sand coverage. Lastly, Brevard County enforces a setback, which is 25 ft landward of the old CCCL. All construction activities seaward of this demarcation are prohibited, with the sole exception being sand placement.
- State armoring regulations currently mandate evidence ensuring that a seawall will not negatively affect neighboring properties. Proof is difficult and subjective.
- Emergency Orders (EO)

- Owing to the uncertainties associated with EOs and the efficiency of CCCL application processing, consultants indicated they often prefer pursuing a full permit rather than installing seawalls under an EO. There is a recognized need for the FDEP to educate the public and property owners about EOs as well as regular CCCL armoring applications. Smaller local communities in particular lack the necessary expertise and resources to navigate the EO process, suggesting a need for better coordination and support to these governments during the EO process.

- Regarding the EOs issued after hurricane Ian and hurricane Nicole in 2022, several perspectives emerged. On one hand, the FDEP's public awareness and involvement about EOs during that storm season was seen as unparalleled and highly effective. However, concerns arose about the potential waiver of both state and local requirements for armoring. Many viewed EO authorizations as too limiting, indicating a need for more comprehensive options for temporary stabilization.

- Challenges faced during EOs include the challenging task of obtaining surveys that meet the CCCL program requirements quickly and in large quantities. The scarcity of surveyors exacerbates this issue. Some proposed that the state conducts a survey to input into models, making it easier for homeowners' post-storm. There is also a potential for repurposing Light Detection and Ranging (LiDAR) data for use as site surveys. Many property owners were unfortunately exploited by contractors and consultants, especially in EO contexts, following these storms. The process was further slowed by the difficulty in securing engineers/contractors and then obtaining adequate plans for permitting. After permits were secured, contractors faced material procurement delays for both short-term and long-term protection. Costs for materials, labor, and beach-compatible sand soared, with some reports indicating a doubling or tripling year on year. One interviewee remarked, "It remains unclear to me if FDEP is allowing a less expensive backfill material behind newly constructed seawalls. This point has been a recurring topic of discussion and might need clarification. While the impacts of supply chain disruptions and inflation are widely recognized, I believe their influence on our recovery efforts cannot be overemphasized."

- Integrated Beach Management

  - A healthy beach and dune system in front of coastal armoring is essential to beach management, leaving armoring as a last line of defense. Some individuals interviewed proposed that the CCCL program should work more closely with the Beaches & Ports program in short- and long-term strategies for comprehensive beach management. To truly minimize the use or impact of armoring on beach dynamics, the State must step up its efforts in long-term beach maintenance. One interview referenced the area adjacent to Ponce Inlet as a good example of effective beach management on an armored shoreline where armoring served as a last line of defense during hurricane Nicole. The interviewees pointed out that seawalls do not necessarily preclude or discourage beach management via sand placement. Places like Jupiter Island, Palm Beach, and Cocoa Beach illustrate this — their shorelines are heavily armored, yet they maintain robust beach management programs.

  - If beaches are left undernourished, armoring becomes a necessity. One interviewee referenced Singer Island as an example of this. Here, a large portion of the shoreline had to be armored due to undernourishment. While Singer Island has a two-decade history of beach management, the amount of sand they can use is limited because of the nearshore hardbottom. This hardbottom issue is not unique to Singer Island; it is prevalent in many parts of Southeast Florida. It dictates how much sand can be placed, often necessitating more armoring. Several interviewees suggested that the State consider methods to strike a balance between armoring and the potential harm to hardbottom from sand placement.

- In Brevard County, as one interviewee pointed out, the region boasts a healthy beach and dune system overseen by the County. Notably, seawalls are banned in the unincorporated parts of the County.

- A challenge arises in areas that are not eligible for beach management funds from the State or local governments. Here, property owners typically opt for armoring, primarily because self-funded nourishment or restoration projects tend to be significantly pricier and more complex to execute than armoring.

- Interviewees mentioned it is important to ensure the public are educated and understand that armoring is primarily used to protect structures and infrastructure, rather than to safeguard the beach and dune system. Another interviewee suggested a practice of "pre-fills" or depositing sand next to seawalls. Lastly, while retreating is not the sole solution, interviewees recognized it should be integrated into the conversation surrounding long-term beach management.

# 5. Findings and Recommendations

The recommendations provided herein aim to adapt to the evolving use and application of armoring since the initial implementation of relevant statutes and rules originally established in the 1990's. The purpose of these recommendations is to assist the Department in developing policies, rules, or other mechanisms that consider current physical and environmental and enhance regulatory certainty for CCCL armoring applicants. Regulatory certainty is defined as ensuring fairness and transparency in the armoring criteria, which translates to predictability and consistency in permitting requirements.

## 5.1 SLR and Resilience Considerations in Armoring Design and Policy

### 5.1.1 Current Policies and Regulations

There are currently no policies or regulations related to SLR and flood resilience considerations for coastal armoring in the State's rules, statutes, and policies.

### 5.1.2 Study Findings

Increased rates of SLR and flood resilience were not a consideration at the time the armoring statutes and rules were developed and as such, they do not provide a means to proactively address SLR or future conditions.  This is oftentimes in conflict with engineering recommendations as well as local governments requiring the inclusion of SLR in design and siting.

### 5.1.3 Recommendations.

1. Select a specific SLR projection estimate and apply it consistently across all facets of the CCCL program, including design and storm erosion models. Projections to consider are the Intergovernmental Panel on Climate Change (IPCC) RCP4.5 (global) or NOAA Intermediate-High (location specific) projection. Florida SLIP studies have the NOAA Intermediate-High projection as incorporated into rule (62S-7) and therefore could be readily applied for coastal armoring as well.
   - Proposed rule language to be added to <u>62B-33.002 Definitions. "Sea Level Rise" is the long-term increase in globally averaged mean sea level" based on the NOAA intermediate-High projection as referenced in 62S-7.012, FAC or as otherwise modified or adopted by State.</u>
2. Update storm surge values now and at regular intervals in the future (e.g., every 10 years) by incorporating SLR as well as increases in storm intensities and frequencies, to assess the risks more accurately for coastal areas.
3. Develop a standardized approach for integrating projected sea level rise into storm erosion models and hydrographs.
4. Establish a method to consider SLR when assessing structure eligibility. Proposed rule changes include:
   - 62B-33.002 (12) "Eligible Structures" are public infrastructure and private structures qualified for armoring as follows:

(a) Public infrastructure includes those roads designated as public evacuation routes, public emergency facilities, bridges, power facilities, water or wastewater facilities, other utilities, hospitals, or structures of local governmental, state, or national significance.

(b) Private structures, located partially or wholly seaward of the coastal construction control line, include:

1. ~~Non-conforming~~ Major habitable structures,

2. Major non-habitable structures which are not expendable,

3. Expendable major structures which are amenities necessary for occupation of the major structure; and,

4. Expendable major structures whose failure would cause an adjacent upland non-conforming habitable structure or major non-habitable structure, which is not expendable, to become vulnerable.

(c) Eligible structures do not include minor structures.

- Incorporate SLR into minimum design standards (Section 5.2.3) to ensure long-term sustainability and resilience.

5. Allow reconsideration of wall height to incorporate SLR for requests for seawall reconstruction. Proposed rule changes include:
    - 62B-33.002 (27) “Major Reconstruction” is the complete or partial replacement or rebuilding, to its original level of protection, of a significant portion of an existing armoring structure which has failed or deteriorated. When assessing the original level of protection, the Department will take into account variations in storm conditions and the impact of sea level rise.
    - 62B-33.002 (31) “Minor Reconstruction” is the routine repair of an existing, functional, and intact armoring which is necessary to maintain the structural and functional integrity of the structure as originally designed and includes: repair or replacement of caps, return walls, tiebacks, individual sheet piles, and armor stone. When assessing the original level of protection, the Department will take into account variations in storm conditions and the impact of sea level rise.

# 5.2 Minimum Design Standards and Considerations for Armoring

## 5.2.1 Current Policies and Regulations

Current regulations do not stipulate basic design criteria for wall and return wall other than specifying “All armoring shall be designed to remain stable under the hydrodynamic and hydrostatic conditions for which they are proposed.” Additional, existing rules dictate “Armoring shall provide a level of protection compatible with existing topography, not to exceed a 50-year design storm.” However, when design standards are mentioned in the rules, the language that does existing, albeit vague, is specific to design storm events (i.e., level of protection), but does not consider service life (i.e., material robustness). Furthermore, there are inconsistent design standards for major reconstruction, gap closure, and new construction.

Rule 62B-34, FAC (General Permits), which is not the focus of this study but is related, defines "Certified Armoring" as a manmade structure designed, constructed and maintained to survive the effects of a 30-year storm and provide protection to existing or proposed upland structures from erosion, wave attack, and current action associated with that event, and certified by a professional engineer registered in the state of Florida to meet the criteria specified in subparagraphs 62B-33.024(4)(a)1. through 4., F.A.C.

### 5.2.2 Study Findings

The collapse of numerous seawalls has been attributed to toe failure (scour at the base of the wall) resulting from inadequate embedment depth, a concern frequently highlighted in interviews, observations by AtkinsRéalis professionals, and Department inspections. Additional modes of failure can include flanking (i.e. scour around the seawall leading to undermining and eventual structural failure), structural failure (e.g. inadequate materials, poor construction, or design flaws leading to cracks, bulging or collapse), material breakdown (corrosion, fatigue, or debris impacts), overturning, overtopping (loss of soil, tie-back anchor failure), sliding, and/or seepage. Many of these issues could potentially be mitigated through the implementation of baseline design standards. The Florida Building Code and local building ordinances do not address specific design criteria for seawalls, underscoring the essential role and necessity of the CCCL program policies and regulations.

The establishment of minimum design criteria for both level of protection and service life is imperative, including the effects of SLR. The minimum design standards and associated rule language should be developed to eliminate inconsistences in their application for major reconstruction, gap closure, and new construction.

Specifying a statewide standard for use of a cantilever wall versus a tie-back wall is impractical as cantilevered walls are not always viable, especially in Southeast Florida where large dunes are prevalent. The design standards developed will need to navigate this challenge.

### 5.2.3 Recommendations

*6.* Establish minimum design standards for coastal armoring. Proposed rule changes include:

- 62B-33.0051 Coastal Armoring and Related Structures. (2)(b)(1). Coastal armoring structures shall be designed for the anticipated runup, overtopping, erosion, scour, and water loads of the design storm event. Design procedures are available in the latest edition of the Department of the Army Corps of Engineers' Coastal Engineering Manual (EM 1110-2-1100), or other similar professionally recognized publications.

  <u>a) At a minimum, the design must take into account potential relative local sea-level rise during the expected life of the coastal structure or 30 years, whichever is less, and, to the extent practical.</u>

  <u>b) Materials must provide for a minimum service life of at least 30 years.</u>

  <u>c) At a minimum, the design must assume a scour depth of the most conservative case of at least equal to the anticipated height of the wave at the structure in</u>

accordance with EM 1110-2-110, or other similar professionally recognized publications.

d) Must provide for adequate drainage behind the armoring structure to maintain structural integrity, with no alternation of drainage patterns in the seaward direction.

e) Must provide return sections to prevent flanking. The appropriate length of the returns must be developed using SBEACH-32 or similar professionally accepted numerical model to assess the shoreline recession expected for the design storm event.

- 62B-33.0051 Coastal Armoring and Related Structures. (2)(b)(3). All armoring shall be designed to remain stable under the hydrodynamic and hydrostatic conditions for which they are proposed. Armoring shall provide a level of protection compatible with existing topography, and a minimum 15-yr storm event, whichever is less. The level of protection shall not to exceed a 50-year design storm, except for public infrastructure.

# 5.3 Gap Size

## 5.3.1 Current Policies and Regulations

Armoring may be authorized, irrespective of eligibility and vulnerability criteria, to close a gap of not more than 250 ft between adjacent armoring under certain conditions.

## 5.3.2 Study Findings

The prevalent theme throughout the study was that the 250 ft limitation set by the “gap rule” seems arbitrary and should be revised.

## 5.3.3 Recommendations

7. Consider that the SBMP may authorize gaps of larger than one property to be filled.
    - Statute will need to be modified to include language regarding the SBMP.
8. Modify the criteria for qualifying for armoring using the “gap rule”. Proposed rule changes include:
    - 62B-33.0051(1)(a) 3. A gap exists, that does not exceed ~~250 feet~~ one (1) property between a line of rigid coastal armoring that is continuous on both sides of the ~~unarmored~~ property. For a gap greater than one property, the applicant may demonstrate that the unarmored gap is detrimental to their eligible structures using professionally accepted analysis and certified by a licensed professional engineer. In consideration of closing a gap of larger than one property, all properties within the gap must apply. Such adjacent armoring shall not be deteriorated, dilapidated, or damaged to such a degree that it no longer provides adequate protection to the upland property. The top of the adjacent armoring must be at or above the still water level, including setup, for the design storm of a 15-year return interval storm plus the breaking wave calculated at its highest achievable level based on the maximum eroded beach profile and highest surge level combination. The adjacent armoring must be stable under the design storm of 15-year return interval storm, including maximum localized scour with adequate penetration,

and must have sufficient continuity or return walls to prevent upland erosion and flooding under the design storm of 15-year return interval storm. Such installation shall:

a. Be sited no farther seaward than the adjacent armoring;
b. Close the gap between the adjacent armoring;
c. Avoid significant adverse impacts to marine turtles;
d. Not exceed the highest level of protection provided by the adjoining walls; and,
e. Comply with the requirements of Section 161.053, F.S.

## 5.4 Proactive Armoring

### 5.4.1 Current Policies and Regulations

In general, the existing coastal armoring statutes and rules do not provide a means to proactively address SLR or future conditions since a property must already be "vulnerable" to qualify for armoring installation. There is one exception whereby rule 62B-33.0051(1)(a)2.a. F.A.C., allows for armoring to be authorized if a property is not vulnerable at the time of the permit application but, "If it is projected that the eligible structure will become vulnerable at some future date which falls within the authorized time limit of a permit, then the permit shall authorize the construction of armoring once the anticipated site condition changes occur and the structure becomes vulnerable."

### 5.4.2 Study Findings

The armoring program tends to operate reactively to address immediate issues like coastal erosion and damage and, on an individual, permit-by-permit basis. This reactive approach has become more inefficient and ineffective over time in supporting property owners with ensuring resilient and sustainable protection, while also proactively considering longer-term protection of coastal infrastructure and environmental sustainability.

It is important for armoring solutions to include the use of materials and designs resilient to future climate impacts and coastal changes, as well as being mindful of their impact on the surrounding ecosystem. The ultimate goal is to strike a balance between safeguarding properties and conserving the natural coastal environment.

### 5.4.3 Recommendations

*9.* Update the storm for which vulnerability is evaluated to be the 25-year return period event coincident with the establishment of critically eroded designations around the State. Proposed rule changes include:

   - 62B-33.002. (59) "Vulnerable" is when an eligible structure is subject to either direct wave attack or to erosion from a ~~15~~25-year return interval storm which exposes any portion of the foundation. Vulnerability will be determined by using the methodologies referenced in subparagraph 62B-33.0051(1)(a)2., F.A.C., or the "SBEACH-32 Users Interface Manual "dated January 10, 1996 http://www.flrules.org/Gateway/reference.asp?No=Ref-12082, "SBEACH Report 1"dated July 1, 1989, http://www.flrules.org/Gateway/reference.asp?No=Ref-12083, "SBEACH Report 2" dated

May 1 1990, http://www.flrules.org/Gateway/reference.asp?No=Ref-12084, “SBEACH Report 3” dated May 1,1993, http://www.flrules.org/Gateway/reference.asp?No=Ref-12085, “SBEACH Report 4” dated April 1, 1996, http://www.flrules.org/Gateway/reference.asp?No=Ref-12086, and “SBEACH Report 5” dated August 1,1998, http://www.flrules.org/Gateway/reference.asp?No=Ref-12087 by the U.S. Army Corps of Engineers, which is hereby adopted and incorporated by reference, and which may be obtained at the following web address: www.dep.state.fl.us/beaches.

10. Do not require vulnerability criteria be met for coastal armoring to protect public infrastructure. This would require modification of Chapter 161.085 (2) F.S. Proposed rule changes include:
    - 62B-33.0051 (1) (a) 2. The structure to be protected is vulnerable, except for the protection of public infrastructure. The determination of vulnerability will be made utilizing the dune erosion model contained in the report entitled “Erosion due to High Frequency Storm Events,” by the University of Florida, dated November 22, 1995, which is incorporated herein by reference. Where direct application of the model shows that the structure to be protected is not vulnerable, but the construction otherwise meets the requirements of this rule chapter, an applicant may further demonstrate vulnerability by taking into account the effects of shoreline change rates, natural physical features, and existing manmade structures in accordance with the following circumstances:

# 5.5 Siting (to minimize sea turtle impacts)

## 5.5.1 Current Policies and Regulations

Siting, as discussed herein, is related to the minimization of impacts to nesting sea turtles. Current rules require that “armoring shall be sited as far landward as practicable” and “avoid significant adverse impacts to marine turtles.” As a matter of policy, the Department consults with FWC on review of permit applications for armoring to evaluate a project’s potential impacts on sea turtles. FWC advises FDEP as to appropriate siting and permit conditions to minimize impacts. Such permit conditions may influence the nature, timing, and sequence of construction to provide protection to nesting sea turtles, hatchlings, and their habitat. If FWC determines that Take may result from a project, FDEP must recommend denial of the permit application per Chapter 379.2431(h), F.S., unless otherwise covered by an Incidental Take Permit.

## 5.5.2 Study Findings

While there are no prescriptive standards for siting except for the generalized “armoring shall be sited as far landward as practicable” and “avoid significant adverse impacts to marine turtles,” the data analysis indicated the Department has been consistent in the siting of armoring permits with respect to the CCCL and eligible structures’ foundations. When conducting the stakeholder interviews, the need for improved transparency in site planning with FWC was emphasized. The common perception among many of the interviewees was that FWC’s definition of sea turtle nesting habitat is ambiguous and lacks a consistent standard.

### 5.5.3 Recommendations

11. Create an easily accessible and comprehensively detailed informational sheet. This document should be officially approved by the FWC and made readily available to all applicants. Establish a protocol for the regular review and update of the informational sheet to ensure it remains relevant and incorporates any changes in environmental conditions, legal requirements, or best practices. At a minimum, the information sheet should provide:
    - An unambiguous definition of the term "as far landward as practicable" as it relates to the protection and conservation of sea turtles. This definition should incorporate various scenarios and examples to ensure thorough understanding.
    - Introduce a set of clear, measurable criteria or parameters that can be used to assess whether a proposed activity or construction meets the standard of being "as far landward as practicable." These parameters should consider other environmental, logistical, and safety aspects in addition to sea turtle protection and conservation aspects.
    - Incorporate visual aids, diagrams, or maps where possible to visually depict what "as far landward as practicable" looks like in different contexts and geographical areas.
    - Provide a step-by-step guideline that applicants can follow to ensure their plans or actions comply with the principle of being "as far landward as practicable." These guidelines should include tips for assessment, planning, and modification of plans where necessary, and contact information for pre-application consultations.

## 5.6 Line of Coastal Construction for Armoring

### 5.6.1 Current Policies and Regulations

For the purposes of this study, a "line of coastal construction for armoring" is defined as uniform alignment of coastal armoring, sited as far landward of the beach and dune system as is practicable. In general, the existing coastal armoring statutes and rules do not specifically address a "Line of Construction" although as a matter of policy FDEP considers the alignment of seawalls in the nearby vicinity when evaluating CCCL applications. The Department has a similar policy when siting the seaward edge of foundation for general CCCL permits.

In some areas of the state, a "General Permit (GP) Line" has been established to expedite authorization of construction seaward of the CCCL which meet certain criteria. Rule 62B-34 (5) defines "First Line of Construction" as a reasonably continuous and uniform line formed by the seaward limit of the foundations or exterior walls of habitable major structures in the immediate area, provided those structures have not been unduly affected by erosion. Decks, balconies, non-habitable major structures, minor structures, armoring and other similar structures shall not be used to determine the line of construction.

### 5.6.2 Study Findings

Once established, a uniform line of coastal armoring for siting of future seawalls could offer more regulatory certainty for both the Department and coastal property owners while avoiding impacts to sea turtle nesting habitat and minimizing impacts to critical beach-dune natural resources. Through the course of the study, several options were considered including a regional, county, and site-specific lines of construction. The number of variables and unknowns makes a regional approach impractical, and a county-wide approach is similarly impractical for most locations. These variables and unknowns include, but are not limited to, variability in coastal geographies, differing environmental impacts, administrative complexity, and limited flexibility and potential for overgeneralization. As such, the recommendations below are focused on site-specific applications of a uniform line of coastal armoring. A site-specific approach allows for the accounting of the unique physical and environmental features.

### 5.6.3 Recommendations

*12.* The Department and coastal property owners would benefit from a basic understanding of line of coastal armoring criteria (e.g. "policy" or guidelines); however, no changes to the formal rules and regulations is warranted at this time. A policy to define the "area of influence", similar to the method described in the 30-yr erosion projection rules, which reference "the zone spanned by three adjacent Department reference monuments on each side of the site. A lesser or greater number of reference monuments can be used as necessary to obtain a rate representative of the site, and a rationale for such use shall be provided."

## 5.7 Recommendations for Future Study

In conclusion, the research conducted thus far has illuminated several areas where further study could be considered for the advancement and refinement of coastal armoring strategies. Here are the key recommendations for future investigations:

1. The limitations in studying gap size effects due to the small sample areas and analysis methods suggest a need for more detailed investigation. Future studies could include post-storm aerial or video analysis, particularly in areas with failed adjacent walls and/or numerical and/or physical modelling (e.g., Delft3D or GenCade).
2. Expand data analysis to include survey/elevation data and greater geographic extents to understand the effects of gaps and walls on sediment transport mechanisms. This could lead to a conceptual model relating seawall and site characteristics to effects on properties.
3. Conduct a photogrammetric analysis to understand the historical evolution of seawalls, especially in areas like Palm Beach County, to glean insights into the impacts of armoring.
4. Study the wave-climate-driven concept in new regulations on gap size and adjacent property impacts, as proposed by (Sylvester, 1985). This approach should consider local wave climates and their impact on shoreline behavior in gaps between seawalls.
5. Currently, no design criteria exist to suggest the optimal length of return walls to prevent flanking. Future studies could utilize numerical models (e.g., Delft3D or GenCade) and/or analyse and utilize dune recession data from SBEACH reports, to update the figures and estimates produced (Walton & Sensabaugh, 1979).
6. A more rigorous study on the impacts of isolated seawalls on stretches of un-armored shorelines could be explored as well as a detailed engineering erosional analysis of effects of seawalls that account for levels of background and natural erosion progressions.
7. Consider the use and requirement of the modeling of longshore-transport-induced erosion impacts in demonstrating the vulnerability of a structure (i.e. not just SBEACH for cross-shore transport).

Require the applicant to demonstrate any longshore-transport-induced erosion will not endanger neighboring properties (both degree and extent of any seawall-induced erosion).

8. Incorporate seawall locations and details into the FDEP GIS database to include at a minimum – wall location, length, embedment elevation, material, top of wall elevation, installation date, and permit number.
9. In an effort to increase transparency with FWC/sea turtle siting decisions, provide historical turtle nesting locations and details in GIS.
10. After storms it is difficult for homeowners to contract a surveyor capable of providing a survey as required for CCCL permitting. Recommend that the Department provide post-storm survey data, possibly through LiDAR or other methods, that is acceptable for use in CCCL permitting and available for public use and download.

These recommendations aim to address the complexities of coastal armoring and its impact on the environment and property. By pursuing these suggested areas of research, we can develop more effective, sustainable, and environmentally sensitive coastal management strategies.

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# APPENDICES

# Appendix A. Literature Review Summary

# APPENDIX A: LITERATURE REVIEW SUMMARY

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# 1. OTHER STATE RULE AND POLICIES

The following states were scoped to be reviewed to identify their rules and policies from the relevant agency(ies) that governs coastal construction: SC, TX, VA, NC, and CA. Of these States, South Carolina, Virginia, and North Carolina have current statutes that prohibit new coastal armoring from being constructed on the open coast. In Texas, coastal armoring is prohibited by local government and private entities, although retaining walls are permittable under certain conditions. State and Federal agencies are exempt from this prohibition and may utilize coastal armoring to protect critical infrastructure (e.g. TxDOT, USACE). In California, coastal armoring is discouraged but permittable, and requires mitigation for adverse impacts. Florida has perhaps the biggest challenge with regulating coastal development, including coastal armoring, with the largest shoreline in the U.S. (8,436 ft) and the third largest coastal population (15.2M) in the U.S. (behind California and New York).

Annotation of the literature reviewed follows.

## 1.1 California

(State of California, 2023)

California Coastal Act allows armoring structures if existing coastal development is in jeopardy of being lost to erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. **Section 30235**

The reconstruction or repair of any seawall (is expempt); provided, however, that the reconstructed or repaired seawall is not seaward of the location of the former structure. **Section 30212(4)**

Armoring is permittable and may represent a reasonable short- to mid-term adaptation strategy. This may be especially true for protection of existing critical infrastructure where the armoring is the least environmentally damaging alternative within the context of phased adaptation responses.

Model policies in Appendix B generally emphasize the need to engage in proactive adaptation measures in order to avoid the need for hard shoreline protection.

Nature-based adaptation strategies (i.e. “gray” hybrid shore protection) can enhance the resilience of California’s transportation infrastructure from sea level rise and other coastal impacts while at the same time ensuring that coastal resources are protected, maintained, restored, or enhanced.

Recognizes high-energy wave environments along much of the coast could challenge the effectiveness of nature-based adaptation strategies, particularly those that do not include any armoring. Nature-based adaptation strategies may also require a larger footprint or a greater upfront investment than more traditional armoring.

Hazard Analysis guidelines:

- Use the current 'best available science' on sea level rise projections and impacts at the time of development application. Discusses using worst case scenariso for critical infrastructure, and lesser for individual developments.
- Sea level rise impacts shall be evaluated over a time period appropriate to the planning  project type.
- Analyze all relevant hazards including but not limited to wave run-up, tidal inundation, storm flooding, groundwater change, and short- and long-term erosion, all as influenced by sea level rise.
- Evaluate the foreseeable effects that the transportation infrastructure will have on communities, vulnerable populations, and coastal resources over time (including in terms of impacts on public access for all types of coastal users, shoreline dynamics, natural landforms, natural shoreline processes, beach widths, wetlands, other shoreline habitats seaward and inland of the transportation infrastructure, public views, and cultural and historical resources) as project impacts continue and/or change over time, including in response to sea level rise.
- Requires a Coastal Hazards Monitoring Plan.
- Mitigation for impacts on all coastal resources shall be required. Mitigation shall minimize impacts to the extent feasible and fully compensate for impacts that remain; mitigation shall address impacts that will occur over the full life of the structure, but may be assessed in appropriate increments, rather than being required entirely up front.

### (UCSB, 2023)

No new or relevent information in this document.

### (California Coastal Commission, 2021)

"The goal of this Guidance is to promote resilient coastal infrastructure and protection of coastal resources by providing local governments, asset managers, and other stakeholders with policy and planning information to help inform sea level rise adaptation decisions that are consistent with the California Coastal Act. The Guidance addresses two main types of critical infrastructure: transportation and water."

### (California Coastal Commssion, 2018)

Property owners may argue that they have a right to protect threatened structures even if they have waived rights to shoreline armoring under the Coastal Act, but a recent federal court of appeal ruling casts significant doubt on the existence of any common law right to attempt to fix an ambulatory shoreline boundary through artificial structures such as seawalls (United States v. Milner). In addition, a California case has held that a homeowner did not have a fundamental right to build a new revetment to protect his home from coastal hazards; rather, any right to build such a structure was subject to legitimate regulation under the Coastal Act (Whaler's Village Club v. Cal. Coastal Comm'n).

Suggests that local governments could also downzone areas vulnerable to sea level rise to reduce densities and limit development expectations, and they could manage nonconforming structures in order to bring them into conformance with policies within a reasonable period of time.

“Navigating the balance between coastal resource protection and private property rights will require careful consideration of relevant precedent, nexus and rough proportionality, background principles of property law, and distinguishing government takings from takings by the forces of nature.”

Identifies planning steps as:

1. Determine a range of sea level rise projections relevant to LCP planning area/segment using best-available science.
2. Identify potential physical sea level rise impacts in the LCP planning area/segment, including inundation, storm flooding, wave impacts, erosion, and/or saltwater intrusion into freshwater resources.
3. Assess potential risks from sea level rise to coastal resources and development in the LCP planning area/segment, including those resources addressed in Chapter 3 of the Coastal Act.
4. Identify adaptation measures and LCP policy options to include in the new or updated LCP, including both general policies and ordinances that apply to all development exposed to sea level rise, and more targeted policies and land use changes to address specific risks in particular portions of the planning area. See policies F.1 to F-9 below.
5. Draft updated or new LCP for certification with California Coastal Commission, including the Land Use Plan and Implementing Ordinances.
6. Implement the LCP and monitor and re-evaluate strategies as needed to address new circumstances relevant to the area, including updating policies to address changed circumstances through future LCP amendment.

Policies F.1 through F.9 can help achieve Coastal Act consistency in areas where shoreline protection that would alter the natural shoreline may be needed now or in the future.

- **F.1 Shoreline and Bluff Protective Devices.** Shoreline protective devices, including revetments, breakwaters, groins, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes, shall be permitted when required to serve coastal-dependent uses or protect existing principal structures or public beaches in danger from erosion, when designed to eliminate or mitigate adverse impacts on local shoreline sand supply, and when there is no less environmentally damaging alternative, unless a waiver of rights to shoreline protective devices applies on the property.
- **F.2 Prioritization of Types of Shoreline Protection Shoreline** - protective devices shall only be permitted if no other feasible, less environmentally damaging alternative, including but not limited to relocation of the threatened development, beach nourishment, non-structural drainage and native landscape improvements, or other similar nonstructural options, can be feasibly used to address erosion hazards and to minimize risk of flooding and provide structural stability.
- **F.3 Siting and Design to Avoid and to Mitigate Impacts**
- **F.4 Repair and Maintenance of Shoreline Protective Devices**
- **F.5 Evaluation of Existing Shoreline Armoring** - Applications for new development or redevelopment on property that is protected by existing shoreline protective devices shall not rely on the existing device for protection.
- **F.6 Shoreline Armoring Duration** - Shoreline protective devices shall only be authorized until the time when the existing principal structure that is protected by such a device: 1) is no longer present; 2) no longer requires armoring; or 3) is redeveloped.
- **F.7 Shoreline Armoring Mitigation Period** - As a condition of approval for new, redeveloped, or non-exempt repairs to shoreline protective devices, require mitigation of

impacts to shoreline sand supply, public access and recreation, and any other relevant coastal resource impacts in 20-year (or smaller) increments, starting with the building permit completion certification date.

- **F.8 Shoreline Armoring Monitoring and Mean High Tide Line Surveys** - As a condition of approval for new, redeveloped, or non-exempt repairs to shoreline protective devices, require a monitoring plan to identify the impacts of the shoreline armoring on the surrounding area and determine when a shoreline protective device is no longer needed for protection.
- **F.9 Limits on Future Shoreline Armoring** - As a condition of approval of a coastal development permit for new development or redevelopment on a beach, shoreline, bluff, or other area subject to coastal hazards, applicants shall be required to acknowledge and agree that no bluff or shoreline protective device(s) shall ever be constructed to protect the approved development, including if it is threatened with damage or destruction from coastal hazards in the future.
- **F.10 Bulkheads for Waterfront Development.**
- **F.11 Emergency Permits.**

(Reiblich, Hartge, & Sito, 2018)

No new information.

(California Coastal Commission, 2016)

Most of the work to date has been focused on gaining a more detailed understanding of sea level rise vulnerability at the local level. This document attempts to synthesize the various data and information including:

- A Statewide Sea Level Rise Vulnerability Synthesis which presents key statewide findings on vulnerability to inform sea level rise planning and preparedness.
- County-level Snapshots (County Snapshots) which describe sea level rise vulnerability at a county scale, local planning efforts underway, and discussion of Coastal Act resource management priorities.
- Four Local Coastal Program Case Studies which highlight examples of how the Coastal Commission, local governments, and other stakeholders are working collaboratively to address sea level rise in LCPs.

Despite many miles of existing armoring, erosion will continue to threaten existing developed areas in vulnerable communities, and this threat will increase with rising sea level. Beyond this statement, the document does not delve further into (proactive) measures or policies to address the issue.

(Melius & Caldwell, 2015)

80% of the CA coast is eroding. Approximately 10% of the CA coast is armored, 33% for southern CA.

References an article by Nick Kraus to make the statement "Put simply, when placed on an eroding or retreating beach, armoring structures will cause that beach to narrow and eventually disappear."

"Many armoring structures are installed with little to no analysis of the impacts they will have on the beach, ecosystems, or neighboring properties because property owners wait to apply for permits until there is an imminent emergency, at which time armoring structures may be installed without substantive review."

"Local governments lack reliable, adequate scientific and legal information to guide their decision-making with respect to coastal armoring; they also lack financial support and regulatory incentives to appropriately consider sea level rise and related coastal hazards in their infrastructure and coastal land-use planning."

How does California currently regulate and manage coastal armoring? Governed primarily by California Coastal Act but also the state Constitution and additional portions of the Public Resources Code.

California Coastal Act allows armoring structures if existing coastal development is in jeopardy of being lost to erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply.

Coastal Commission's current practice of imposing a "no future armoring" condition upon newly proposed shoreline development limits the number of properties eligible for armoring. In addition, new development contains minimum setbacks to ensure that new development will be safe (from erosion and wave attack) for its entire "economic life," usually for 50 to 100 years. This economic life assumption is based in part upon erosion rate calculations. There has been no consistent method for considering sea level rise in erosion rate and setback determinations.

The Coastal Commission requires in-lieu mitigation fees for impounded sand and lost recreation value to help mitigate the adverse impacts from armoring.

Redevelopment and nonconforming use provisions (e.g. allow owners to rebuild up to 50% of their structure without having to conform to current setback and other zoning requirements) help perpetuate the status quo of armoring. This means that many structures will likely need to be protected by seawalls past the end of their economic life once the original setback is no longer sufficient.

"Local governments need better information and support to improve decision-making on sea level rise and coastal armoring."

"Property owners lack Incentives and adequate mechanisms to pursue non-armoring responses to coastal hazards."

"Coastal armoring has been a standard response to coastal hazards threats for some state-owned lands and property. This is in part because coastal roadways and other coastal infrastructure were installed largely without sea level rise in mind and will need to be either relocated or protected. For example, Caltrans "has traditionally based infrastructure plans and designs on historical rates (rather than projected rates) of coastal erosion."

"This reactive approach leads to inconsistency in policy application across the state and unpredictability for all involved, including Coastal Commission staff, commissioners, other state and local agencies, permit applicants, and the public."

Relevant Recommendations: Require consideration of sea level rise in erosion rate calculations, mean high tide line determinations, setback determinations, and develop standard transferable methodologies for factoring sea level rise into hazard analyses.

(Hanak & Moreno, 2008)

"Fortunately, California already has a set of policies and institutions that aim to balance the competing objectives for coastal development. Measures such as "no further armoring," which limits the rights of landowners to put in new protective devices, greater setbacks for new development, and planned relocation of stretches of the coastal highway, reflect the fruits of this policy focus."

Initially, planned structure life was typically 35 to 50 years – long enough to pay off a mortgage plus some margin. Coastal managers found that people wanted homes to retain value for longer periods, requiring a longer planned structure life. Today, the Commission generally applies a 75 to 100-year life to new development within its jurisdiction. Most LCPs now also use 75 to 100 years, although some of the older ones still incorporate a 50-year standard.

The application of any forward-looking policy will be limited unless local governments elect to incorporate the improved methodologies into their updated LCPs. At present, the Commission has no legal authority to require local governments to update these plans considering new scientific information or changed circumstances.

Since the late 1990s, the Commission has generally attempted to manage property owner expectations with the application of a "no further armoring" condition on permitted development. Under this approach, permits for new structures include a prohibition against future armoring (or no expansions to the existing armoring). The approach is applied through case-by-case reviews of individual permits. Since it is not the result of a change in law, it could be modified by future commissions.

"To date the restriction has not been subject to legal challenges, although exemptions have been granted. However, when high value property is threatened by more severe or more frequent storms, it may still be difficult for the Commission to resist granting exemptions, even if they conflict with other coastal management goals."

Recognizes alternate forms of coastal protection, such as beach nourishment and living, are not always physically feasible, and that retreat faces significant financial and political hurdles to the extent that they are perceived as conflicting with private property rights.

(Stamski, 2005)

The Monterey Bay National Marine Sanctuary (MBNMS) developed an action plan with the goal of developing and implementing a proactive, regional approach to address coastal erosion and to minimize the negative impacts of coastal armoring on a sanctuary wide basis.

Southern Monterey Bay Coastal Erosion and Armoring Workgroup was created to study a specific sub-region and this report documents the existing conditions of this geographic area to be considered by the workgroup in developing ways to address erosion.

It is noted in the report that "The lack of development along much of southern Monterey Bay provides the Monterey Bay National Marine Sanctuary and other agencies with an ideal, and increasingly rare, opportunity to be proactive in terms of land use development." However, details of the action plan are not provided.

## 1.2 North Carolina

(Town of Duck, 2022)

No new or relevant information. Remove from list.

(A.R. Siders, 2020)

The full-text of this publication was not available; however, the abstract was reviewed.

"This article provides an exploratory statistical analysis of three adaptation measures (shoreline armoring, property acquisitions, and beach nourishment) and their deployment with respect to metrics of risk exposure, socioeconomic markers, and critical infrastructure in North Carolina."

Based on the abstract, the publication does not appear to be relevant as it appears to be focused on socio-economic impacts as opposed to physical effects of shoreline armoring.

(General Assembly of North Carolina, 2011)

North Carolina Legilsation – Limitations on Erosion Control Structures – enacted 2011.

North Carolina prohibits new coastal armoring (seawalls, revetments) on the open coast. Temporary sandbags are permitted for emergency protection. **113A-115.1.b.**

Renewals of coastal armoring permits issued before 1995 can be authorized if it can be demonstrated that there is no practical alternative to replacing the structure that will provide the same or similar benefits and the footprint is not changed. **113A-115.1.c**

Terminal groins are listed as permittable erosion control structures, with a maximum of 6 allowed to be authorized statewide, to protect structuers and infrastructure threatened by erosion. Mitigation, including continued beach fill, is required. **113A-115.1.d/f**

## 1.3 South Carolina

(S.C. Department of Health and Enviormental Control, 2023)

Background - SC Coastal Zone Management Act (CZMA) 1977-1988, limited beachfront jurisdiction, seawalls routinely permitted. In 1988, the South Carolina Beachfront Management Act was enacted by the South Carolina General Assembly. Among the findings, a statement includes "the use of armoring in the form of hard erosion control devices such as seawalls, bulkheads, and rip-rap to protect erosion-threatened structures has not proven effective, has given a false sense of security, and in many instances, has increased the vulnerability of beachfront property to damage from wind and waves while contributing to the deterioration and loss of the dry sand beach." The Beachfront Management Act then established eight state policies to guide the management of ocean beaches. These include a plan for retreat over a 40-year timeline in combination with beach nourishment, and the "severe restriction" of erosion control structures (armoring).

In 2018, the Beachfront Management Reform Act, was signed by Governor Henry McMaster. The Act replaced the 40-year policy of retreat and established a new policy of beach preservation.

2023 - DHEC OCRM convened a South Carolina Beach Preservation Stakeholder Workgroup to identify recommendations for beach preservation. This report summarizes the findings and recommendations of the workgroup.

They recognized the challenge along developed shorelines of balancing coastal development with protecting the natural processes associated with the beach and beach/dune environments and indicated that there needs to be a variety of beach preservation approaches available to address these challenges.

The Workgroup recommends that the term "Beach Preservation" be defined as: "maintaining the natural processes and functionality and benefits of the beaches and the beach/dune system critical areas to support storm protection, habitat, tourism, public access, recreation opportunities, and aesthetics.

The workgroup concluded beach nourishment, inlet management, sand dune restoration (including sand fencing and native vegetation), and the conservation of undeveloped shorelines are coastal management approaches that should be used for beach preservation. The Workgroup also discussed several other approaches, including the landward movement and/or removal of structures wherever necessary or feasible, the maintenance of existing groins, and projects designed to increase the amount of sand or provide for the natural migration and dispersion of sand within the nearshore system.

They further concluded that shore-parallel erosion control structures do not support beach preservation.

Current statute prohibits new erosion control structures from being constructed within the beach/dune system (seaward of the State's jurisdictional setback line). Existing erosion control structures seaward of the setback line that are destroyed more than 50% (above grade) cannot be repaired and must be removed.

(S.C. Department of Health and Enviormental Control, 2023)

No relevant information. Remove from list.

(State of South Carolina, 2022)

Title 48 Chapter 39 of SC Code of Regulations (Coastal Tidelands and Wetlands).

The department shall have the authority to remove all erosion control structures which have an adverse effect on the public interest. **SECTION 48-39-120(c)**

The use of armoring in the form of hard erosion control devices such as seawalls, bulkheads, and rip-rap to protect erosion-threatened structures adjacent to the beach has not proven effective. These armoring devices have given a false sense of security to beachfront property owners. In reality, these hard structures, in many instances, have increased the vulnerability of beachfront property to damage from wind and waves while contributing to the deterioration and loss of the dry sand beach which is so important to the tourism industry. **SECTION 48-39-250(5). Legislative findings regarding the coastal beach/dune system.**

No new erosion control structures or devices are allowed seaward of the setback line except **SECTION 48-39-290(2). Erosion Control Structures (seawalls)**:

(i) structures or devices to protect a public highway that existed on June 25, 1990; and
(ii) shoreline perpendicular wingwalls that extend landward at a ninety-degree angle from the ends of existing erosion control structures or devices that are consistent in height and composition with the existing erosion control structures to which they are attached subject to any special conditions imposed by the department.

Erosion control structures or devices which existed on the effective date of this act must not be repaired or replaced if destroyed:

(i) more than eighty percent above grade through June 30, 1995.
(ii) more than sixty-six and two-thirds percent above grade from July 1, 1995, through June 30, 2005.
(iii) more than fifty percent above grade after June 30, 2005.

(South Carolina Floodwater Commission, 2019a)

No new information.

(South Carolina Flood Water Commission, 2019b)

No new information.

(South Carolina Flood Water Commission, 2019c)

No new information.

(South Carolina Coastal Information Network, 2010)

Final Report of the Shoreline Change Advisory Committee (2010); Technical resource and policy analysis document that examines challenges and opportunities associated with coastal management of beachfront and estuarine shorelines.

"The state's retreat policy does not provide for the immediate, active relocation of structures from the beach/dune system; however, by gradually eliminating erosion control structures, it ensures abandonment of property to allow the natural, inland migration of a healthy beach/dune system, if or when renourishment becomes unsustainable for a specific area or community."

The Committee identified four broad goals for improved shoreline management in South Carolina.

- Goal 1, “Minimize Future Risks to Beachfront Communities,” proposes solutions to limit future exposure to losses of infrastructure, properties, and economic and natural resources that rely on a healthy beach/dune system; and to reduce the need for erosion control solutions.
- Goal 2, “Improve the Planning of 1 Beach Renourishment Projects,” presents opportunities for improved coordination and decision making with regard to renourishment projects and other “soft” solutions to beach erosion.
- Goal 3, “Limit the Use of Hard Stabilization Structures,” reinforces existing prohibitions on seawalls and revetments, and recommends improved guidance for the siting, design, and use of groins, breakwaters, and temporary structures.
- Goal 4, “Enhance the Management of Sheltered Coastlines” presents parallel issues facing estuarine and sheltered coastlines of South Carolina, and policy and management recommendations for addressing those issues.

(State of South Carolina, 1978)

DHEC Chapter 30 of SC Code of Regulations (Coastal).

Seawalls and Bulkheads - damage to seawalls and bulkheads must be judged on the percentage of the structure remaining intact at the time of the damage assessment. Erosion control structures or devices must not be repaired or replaced if destroyed:

(i) more than eighty percent above grade through June 30, 1995;
(ii) more than sixty-six and two-thirds percent above grade from July 1, 1995, through June 30, 2005;
(iii) more than fifty percent above grade after June 30, 2005. See R.30–14(D)(3)(c).

Revetments - must be judged on the extent of displacement of the stone, effort to return this stone to the pre-storm event configuration of the structure or device, and the ability of the revetment to retain backfill material at the time of the damage assessment. **30–1. Statement of Policy.(d)(17)c-d.**

The (South Carolina Beachfront Management) Act bans the future construction of seawalls, limits the size of buildings within the predicted erosion zone and adopts a policy of retreat away from the erosional beach. **30–21.A Beachfront Management Plan.**

The (South Carolina Coastal) Council does not have the authority to permit any new seawalls or other erosion control devices within the 40-year setback zone. This prohibition will limit the nature of development in these areas. **30–21.C.1.c Beachfront Management Plan.**

(London, et al., 2009)

This is a study by Clemson University funded by SC DHEC.

Part 1 of the study included interviews administered to nine “innovative” states on shoreline management. Those states were deemed innovative using a combined assessment of the legal analysis of the statutes, rules, regulations, and plans (where available), the survey responses, and primary sources. – Hawaii, Maine, Maryland, New York, North Carolina, Oregon, Rhode Island, South Carlina, and Texas

Eight of the nine states have a regulatory setback based on either erosion rates or distance measures. In general, it is felt that setbacks have failed to meet initial expectations due to variances at the local level and because 30 or even 40 years is not enough of a buffer. As an alternative to standard setbacks, one or more states is using one of the following tools: designation of erosion hazard areas, delineation of low/high risk zones, banning infrastructure provision in high-risk areas, and developing guidelines for local erosion response plans. Rolling easements are utilized in some form in six of the nine states.

Part 2 of the study assessed the effectiveness of beachfront management in South Carolina in avoiding losses associated with shoreline change.

Part 3 includes the findings from focus group meetings with South Carolina coastal communities on current and future South Carolina coastal management.

## 1.4 Texas

(Texas' Office of Secretary of State, 2015)

Erosion response structure – A hard or rigid structure built for shoreline stabilization which includes, but is not limited to, a jetty, groin, breakwater, bulkhead, seawall, riprap, rubble mound, revetment, or the foundation of a structure which is the functional equivalent of these specified structures. **31.1.15A §15.2.34**

Retaining wall – A structure designed to contain, or which primarily contains material or prevents the sliding of land. Retaining walls may collapse under the forces of normal wave activity. **31.1.15A §15.2.65**

Erosion response structures (e.g. seawalls) are prohibited. Retaining walls are permittable under certain conditions. Local governments shall not issue a permit or certificate allowing construction of an erosion response structure. **31.1.15A §15.6.c**

Prohibits maintenance or repair of an existing erosion response structure on the public beach or the enlargement or improvement of a structure within 200 ft landward of the vegetation line. In addition, maintenance or repair is prohibited if more than 50% is damaged. Exceptions include when failure to repair will cause unreasonable hazard to critical public infrastructure, or when failure to repair will cause unreasonable flood hazard to the habitable structures due to adjacent erosion response structures. **31.1.15A §15.6.d**

(Texas' Office of Secretary of State, 2009)

Federal, State, County and Municipalities within Texas are not prevented from erecting or maintaining erosion response structures. **Sec 61.022, Texas Natural Resources Code**

Federal, State, County and Municipalities within Texas are not prevented from erecting or maintaining erosion response structures (Sec 61.022, Texas Natural Resources Code). Of note, however, is the State's Coastal Erosion Planning and Response Act (CEPRA) prohibits funding of "hard" structures on or landward of a public beach. **Sec. 33.603.d, Natural Resources Code**

(Buckingham, 2023)

The GLO is working to promote the use of living shorelines as alternatives to traditional, hard shoreline stabilization techniques.

(Bush, 2019)

Defines “responsible development” as Proposes proactive, resilient planning opportunities in coastal communities. Identifies projects to support communities’ current needs while considering future conditions.  Described as “societal resiliency”.

- Erosion Response Plans
- Large-Scale (Regional) Drainage Projects or Studies
- Utility Planning
- Critical Facility Planning
- Setbacks

## 1.5 Virginia

(Virginia Marine Resources Commission, 2022)

Virginia Code of Regulations, Barrier Island Policy (Regulation 4 Vac 20-440-10 Et Seq)

Permits for coastal development are reviewed and issued by the Marine Resources Commission.

No permanent structure, other than those already specifically allowed by law or provided in subdivision C 2 b below for purposes of permanent access, will be permitted seaward of the crest of the coastal primary sand dune. **Regulation 4 Vac 20-440-10.C.5**

Relocation of structures (habitable). Once local mean high water approaches a structure to within 10 times the average recession rate, a plan for its movement/relocation must be submitted for review. No movement or relocation will be permitted without the written permission of the commission. **Regulation 4 Vac 20-440-10.E.1.c**

(Virgina Department of Conservation and Recreation, 2021)

This is a great document and very nicely done, but not much relevance to the coastal armoring policy study.

42% of public respondents believe their community would benefit from structural shoreline protection, including floodwalls, levees, or tide gates.

## 1.6 Washington

(Washington Department of Fish and Wildlife & Washington Department of Natural Resources, 2021) –

Reducing armor impacts on Puget Sound shorelines, approx. 29% is armored, goal is to remove shoreline armor and/or preserve unarmored stretches.

This Implementation Strategy identifies four strategies:

1. Incentive's strategy: Improve and expand incentives and education for residential property owners to support their efforts to remove hardened shoreline or protect unmodified shorelines.
2. Regulatory strategy: Increase and improve regulatory implementation, compliance, enforcement, and communication to increase habitat protection and improve opportunities for the restoration of shoreline processes and habitat.
3. Design and technical training strategy: Increase and improve coastal processes-based design and technical training to continue to expand technical solutions and capacity.
4. Planning strategy: Improve long-term strategic planning to support and connect regional and local partners to develop integrated habitat restoration and protection, transportation, and infrastructure improvement plans.

(Coyle & Dethier, 2010)

This document reviews existing literature that assesses the role of shoreline armoring in impacting nearshore processes. It began as a synthesis of background material for the Shoreline Armoring Working Group (SAW), an outgrowth of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP).

Discusses armoring on the Puget Sound (estuarine) shoreline, not open coast.

No new or relevant findings, conclusions, or recommendations; however, some good framing and phrasing of the issues.

"The majority of shoreline development is in the form of residential housing. In attempts to protect eroding properties, the typical reaction to coastal hazards is the construction of seawalls, bulkheads, revetments, or other hardened structures. Currently, approximately one third of the Puget Sound's shoreline is armored."

"The perception of increased security they elicit, however, needs to be balanced against the environmental problems that they may cause."

"Generalizing about armoring impacts is very difficult because physical (morphological and hydrodynamic) responses depend on the setting: types of sediment, beach morphology, position in a drift cell, and local wave and current regimes."

Armoring impacts may occur via combinations of at least five distinct mechanisms: encroachment, land-beach disconnection, sediment impoundment, active erosion, and passive erosion.

"Shoreline armoring is increasing worldwide with expanding coastal populations and development, especially in urban areas. Concerns about predicted sea level rise will increase the demand for coastal erosion-control, and thus the demand for more armoring. At the same time, sparse but increasing evidence suggests that armoring may have undesirable effects on nearshore ecosystems, on both geomorphological and ecological processes."

## 1.7 Oregon

(Beasley & Dundas, 2018)

“Working Paper: Do not cite without permission”

Research funded by NOAA National Centers for Coastal Ocean Science Competitive Research Program.

The study aims to identify and quantify the determinants of shoreline armoring for the Oregon Coast.

The state of Oregon has 360 miles of coastline along the Pacific Ocean across seven coastal counties. “Goal 18” prohibits an Oregon property owner from receiving a coastal armoring permit unless the property was developed prior to January 1st, 1977. Under Goal 18, approximately 50% of the 9,500 coastal parcels in Oregon are eligible for armoring. Of the eligible parcels, only 1 out of 4 have exercised the option to install protective structures. An additional 3,300 parcels retain the option for future armoring under current legislation.

Permitting and installation of protective structures is managed through a variety of departments. The Oregon Department of Land Conservation and Development (ODLCD) monitors eligibility by parcel. The Oregon Parks and Recreation Department (OPRD) maintains a database of coastal structures and ultimately is responsible for permitting. The process of installing a beachfront protective structure is comprised of informal and formal components. Informally, a landowner(s) may initiate contact with local government officials to determine likelihood of approval. The landowner(s) then initiates a formal application and hires a geologist for a parcel inspection. The parcel inspection will include the geologist’s recommendation for structure type, location, and dimensions. This information is processed through a formal review, where permits are granted. If unexpected storm damage occurs, an emergency permit may be temporarily granted provided the landowner would have the right to install shoreline armoring. Emergency permits must receive retroactive approval, or the landowner is forced to remove the structure. In addition to emergency permits, the state has granted several overrides to existing eligibility requirements. These exceptions are generally infrequent and related to community-level concerns, not individual parcels.

Select findings:

- Increasing setback distance is also associated with a lower likelihood of armoring.
- If a direct neighbor armors, it is associated with nearly a 5% increase in the likelihood of armoring.
- Beyond neighboring parcels, the ability to join a coalition is associated with a 1% increase in the likelihood of armoring. The only other significant variables are short term erosion rates and distance to a beach access.
- In the 25-year period between 1990 and 2014, approximately 10% of eligible parcels converted to armoring.
- An increase in the parcel-level erosion rate by 1 foot per year leads to a 2% greater likelihood of armoring installation, all else equal.
- Policy based on individual decision making (e.g. armoring) may lead to drastically different outcomes of those that predominantly work on community-wide decision making (e.g. beach nourishment).

# 2. PUBLISHED AND PROFESSIONAL ASSOCIATION RESEARCH

Atkins completed a literature review of available published and professional association research. Articles were organized and reviewed based on coastal processes, protective armoring, regulation and policy, sea level rise, sea turtle impacts, wall design and standards, and others. Findings showed that earlier research was focused on the coastal processes and interactions with seawalls. Changes in design regarding seawall siting, depths, and end design have evolved through the years as a result of better understanding of coastal process and sea level rise. Sea turtles and impacts to their nesting and hatching capabilities due to seawalls is also witnessed with some species being impacted more than others. Regulations and policies were reviewed along with other documents that were identified as useful literature. Findings documents several studies pertaining public perception, economic benefits, and demographics of people who reside along the coast.

Annotation of the literature reviewed follows.

## 2.1 Sea Turtle Impacts

(Sella, et al., 2023)

Study goes into investigating the gap between properties with coastal armoring structures and how the importance lies with sea turtle nesting. Results are compared to natural beach conditions.

Analyzed loggerhead marine turtle nesting patterns and reproductive success to determine if urban pocket beaches represent preferred nesting habitat along armored coastlines. The authors also determined if nests at urban pocket beaches are more likely than nearby armored and unarmored beaches to be inundated from wave runup, which could alter the incubation environment and nest productivity of marine turtles.

Linear extent of urban pocket beaches in Florida was identified, then loggerhead marine turtle nesting success, nest density, and hatching success was compared between urban pocket beaches with armoring and beaches without armoring.

To quantify the number of urban pocket beaches in Florida and their extent, the authors first identified locations where coastal armoring exists along the coast. To do this, they used coastal permitting data from the Florida Department of Environmental Protection (data collected from March 7, 1980, through May 31, 2019 from http://geodata.dep.state.fl.us/), along with the most recently available images from Google Earth Pro (2018–2019) to determine whether or not urban pocket beaches (i.e., beaches up to 1 km in length with armoring on adjacent beaches (Young and Carilli, 2019) existed adjacent to permitted beach armoring.

Modeled differences in wave runup exposure at these beaches under current conditions (2016–2019) without and with tropical storms and future (2060) intermediate-low and high sea level rise scenarios.

Nesting density in pocket beaches were similar to nearby beaches without armoring. However, female turtles were more likely to nest in urban pocket beaches compared to adjacent armored areas, and pocket beach nests had a higher hatchling success rate than unarmored and armored beaches.

Models suggest that exposure to wave runup varies by geographic location, but overall pocket beaches provided viable nesting habitat in all areas surveyed.

(Hirsch, toonder, Reilly, Hoover, & Perrault, 2022)

Objectives were to (1) examine nest density, nesting success, washout rates, and hatching and emergence success at hard-armoring sites in comparison to a control area and (2) characterize impacts of obstructions encountered by sea turtles nesting in northern Palm Beach County, Florida.

Results indicate that the hard-armoring site showed significantly lower nest density for green turtles and nesting success for loggerheads and green turtles in comparison to a control area. Additionally, nesting success for loggerheads and green turtles that encountered hard armoring structures was significantly lower in comparison to those that encountered no obstructions or other obstructions (e.g., beach furniture, walkovers, escarpments, etc.).

Green turtles showed the most significant differences between the two sites, likely a result of their typical nest site selection favoring the upper portions of the beach, crawling further distances from the high-water line than loggerheads or leatherbacks.

Study covered a 2.97 km stretch of beach in Palm Beach County (Tequesta, Coral Cove, and Jupiter Inlet Colony Beaches). This area is recognized as the highest density of loggerhead sea turtle nest in the western hemisphere.

Surveys were conducted during nesting season from 2013-2021.

(Fuentes, et al., 2020)

Study to understand how sea turtle may respond to climate change such as sea level rise and loss of habitat. Modeling of the geographic distribution of climatically suitable nesting habitat for marine turtles in the USA under future climate scenarios, identified potential range shifts by 2050, determined impacts from sea-level rise, and explored changes in exposure to coastal development as a result of range shifts.

Climate data from the WorldClim global climate database (www.wordclim.org).

Marine turtle distribution under current climatic conditions.

For all three species, precipitation, seasonality, and isothermality were the most important variables.

Housing density (Online Resource 4) was predicted to increase on average by 89% in high climatically suitable areas for loggerhead turtle nesting habitats particularly in south Florida and Edisto Island in South Carolina.

(Sella & Fuentes, 2019)

This study examines the spatial and temporal exposure of 203 marine turtle nesting grounds in Florida to coastal modifications. For this, we used coastal permits issued from 1985 through 2016 as a proxy for coastal modifications. To test the suitability of the permit database as a proxy for coastal modification, 34 marine turtle nesting beaches in the Florida Panhandle were ground-truthed to determine the presence of coastal modifications and their correlation with issued permits. The modification types analyzed were:

- construction landward of dune
- construction in dune
- construction on beach
- construction in water
- beach armoring
- other shoreline stabilization
- beach sand placement
- beach cleaning
- dune vegetation planting
- sand fencing
- special events, and
- stormwater outfall.

Permit information was obtained from the Florida Department of Environmental Protection database, where coastal permits issued throughout the 26 coastal counties in Florida are kept. The database was accessed on March 15th, 2017 (http://geodata.dep.state.fl.us/)

A positive correlation between year and permitting numbers was found (linear regression). Beach cleaning, beach sand placement, coastal construction in dune, coastal construction landward of dune, dune vegetation, sand fences, and special event permits were affected by year showing an increase in permits over time. Beach armoring, coastal construction in water, coastal construction on beach, dredging, other shoreline stabilization, and stormwater outfalls did not show a trend of permit distributions over time.

Majority (93.5%) of marine turtle nesting beaches in Florida were exposed to coastal modifications. Of the high-density nesting beaches for each of the three main species of turtles nesting in Florida, thirty-six percent had high or very high exposure to coastal modifications and twenty percent had low or no exposure to coastal modification.

(Hirsch, Kedzuf, & Perrault, 2018)

Study is on alternatives to shoreline protection other than rock revetments of seawalls. Study proposes the use of geotextile container to supplement a dune’s core. Finding showed that neither loggerhead nor green turtle nesting success was significantly different after the installation of the geocore; however, when analyzing loggerhead crawls that came to within 5 meter of the geotextile bags, nesting success decreased. Neither hatching nor emergence success was significantly different after the installation of the geocore for either species. Our results suggest that geocores may minimally affect loggerhead and green turtles and provide a suitable restoration technique for homeowners facing beach erosion

Study occurred in Juno Beach, FL. Only one control and impact location was recorded between 2010-2017. Geocore was approximately 150.5 meter long.

(Coastal Technology Corporation, 2012)

Report is focused on the potential take of Federal and State listed species that inhabit the beaches for nesting, foraging, and other activities.

Study documents

1. Known location and type of armoring in Florida's coastal counties.
2. The expected location of future armoring during the next 25 years.

Study methodology for existing structures:

- Use of aerial imagery (FDEP and FDOT source)
- Review of FDEP permitting records
    - Beaches and Coastal Management System – Integration (BCMSi) database
    - Captured permit filed through August 1, 2011
- When possible, used local government records.
    - Lee and Volusia County had information in the property appraiser's files regarding the presence or absence of existing armoring. Walton County had a GIS shapefile locating existing armoring which was developed as part of an HCP developed for the county. In 1987, Palm Beach County developed an armoring inventor (Olsen, 1987). This information was cross-checked with the aerial interpretation and FDEP permitting records.
- ID four structure types – seawalls, bulkheads, revetments, and geotextile sandbags
    - Note that seawalls vs bulkheads were dependent on the structure location. (IE front of seaward toe of dune (seawall) vs behind seaward toe of dune (bulkhead)).

Study methodology for future structures:

- Utilized FDEPs representative profiles of each county.
- Applied SBEACH to estimate limits of erosion with a 15-year storm based on UF Report "erosion due to High Frequency Storm Events".
- Dune bluff recession rate of 1 foot per year was estimated for the next 25-years.
- The likely future limits of erosion at the representative profiles were superimposed upon georectified aerial photography and linearly interpolated between the representative profiles.

Inlet, vulnerable public roads, and more dynamic areas were considered in future structure evaluation.

Appendix contains a vulnerability analysis of each coastal county.

Summary of the number of structures along the Florida coast at the time of the study was conducted.

(Rizkalla & Savage, 2011)

Study conducted on a control (non-armored beach), a seaward seawall (7 years review), and landward seawall (3-year review) in Vero Beach.

Seaward wall had <5m of dry beach

Landward Wall had <20m of dry beach

The southeastern United States hosts the largest assemblage of loggerhead sea turtles (Caretta caretta) in the western hemisphere, with approximately 90% of nesting occurring on Florida beaches (Ehrhart, Bagley, and Redfoot, 2003; Weishampel et al., 2003)

25% of Florida coast is 'armored'.

Nesting activity was recorded between March and October 2003–2009 during morning surveys under Florida's Statewide Nesting Beach Survey program. Emergence, nest density, and nesting success between the seaward wall and unarmored beach were compared using paired t-tests. Chi square tests were applied to look for differences between nest and false crawl density on an annual basis, and for paired comparisons between the seaward wall, landward wall, and unarmored beach for data collected from 2007–2009.

(Kittinger & Ayers, 2010)

The Coastal Zone Management (CZM) Act was enacted in 1972, largely due to increased recognition of the need to manage coastal environments in a more holistic manner. Study is focused on Hawaii and North Carolina and the similarities and differences among their CZM program. Article goes into detail on the impacts on the states CZM program. However, the coastlines of HI and NC are significantly different from Florida, thus not providing an apple to apples comparison.

Emergence, nesting density, and nesting success were found lower in front of seaward seawall compared to control beach. Hatching success showed no difference between the seaward wall and control site.

The landward wall found no difference in nesting density compared to the seaward seawall.

The data presented here indicate that seawalls impact loggerhead sea turtle nesting by reducing nesting success and increasing the likelihood of nests being washed away during storm events. Fewer animals emerged in front of the seaward wall and there were fewer nests, but it remains unclear by what mechanism turtles detect appropriate nesting habitat.

Only one survey of the beach was completed in 2006. Writer claims further investigation into beach morphology and its impact to sea turtles' decision of location could provide further results.

Writer claims that visual representation may play a factor in turtle emergence. The study documents that the first season of the installed landward seawall with a constructed vegetated dune in front resulted in a 40% decline in turtle emergence and a 50% decline in the number of nests.

## 2.2 Design Guidance & Minimization of Physical Impacts

(Nielsen, 2023)

This paper presents a new equation to predict scour levels for the design of seawall footings.

A new method to determine design scour levels for dune revetments and seawalls is presented. The method is based on the thesis that toe scour is a function of the nearshore incident wave energy and was calibrated with results from several moveable bed model studies covering a large range of scales.

The method determines scour levels to a still water level datum defined at the incident wave-breaking location. Therefore, the method incorporates many more parameters than those that pertain to existing methods including tidal stage, storm surge, wave setup, wave period, and seabed slope.

The method assumed that the scour level was a function of the incident wave energy and was calibrated and verified with results from several various moveable bed model studies undertaken over a large range of scales. The method yielded scour levels to a SWL datum at the wave-breaking location comprising tide, storm surge, and wave setup. Scour depth was based on wave period, hence, estimates of nearshore wavelength, with the pre-existing depth at a distance of ½ nearshore wavelength in front of the structure assumed to be a surrogate for the breaking wave height.

(Hosseinzadeh & Ghiasian, 2022)

Document reviews of the current state-of-the-art in concrete seawalls focusing on design aspects including wave loading and innovative seawall designs, ecological considerations, and durability aspects. Different conventional seawalls and their advantages and disadvantages are reviewed.

Focuses on concrete seawalls, specifically, loading considerations, ecological performance, material durability, and innovative designs. Challenges that limit the performance of concrete seawalls and innovations that enhance performance are highlighted.

**Load Considerations** - hydrostatic, hydrodynamic, and wave loads

"Common design guidelines and standards for seawalls include Coastal Engineering Manual (CEM), Shore Protection Manual (SPH), ASCE standards, and FEMA publication manuals."

**Ecological Considerations**

A major reason for the poor ecological performance of seawalls is that seawalls truncate the intertidal zone and are less structurally complex than the natural communities replaced.

An effective solution for restoring the habitat of marine organisms and to potentially increase abundance and diversity populations is to design structures using natural materials or structures that emulate the physical properties of natural structures. Fishes and benthic invertebrates populate and interact in greater numbers on materials with rugose and irregular surfaces rather than a smooth, flat wall.

Negative impacts on marine ecosystems due to concrete seawalls occur due to a variety of reasons: truncation of the intertidal zone, reduced surface complexity, reduced vertical and horizontal extent, increased turbidity, and coastal eutrophication.

**Durability of Concrete Seawalls**

Details the use of concrete and the chemical natures that impact concrete durability.

**Innovative Seawall Design**

Example of one of the seawall alternatives. Other options are discussed.

(Burke-Flask, Stark, & Rodriguez-Marek, 2021)

Paper expands on the implications of sea level rise and provides an outlook on how sea level rise might impact future projects and drive trends in coastal geotechnical practice.

- Enhanced coastal erosion,
    - Alternatives – Beach Nourishments and Beach Dewatering
- Frequent high tide flooding (impact road base and reduces life of road)
    - Alternatives – Composite, Nondeteriorating material used in roadways.
- Groundwater rise And Saltwater Intrusion.
    - Alternatives – Installation of barriers (seawalls, cement grout, bentonite)

(Ding & Kim, 2019)

Study goes into detail of littoral transport. It does not discuss shoreline structures other than stating the GenCade software take into account engineering structures and engineering activities (dredging/beach nourishments).

Document is very technical in their research and could be used to support how sediment transport occurs.

(Beuzen, et al., 2018)

The study was designed to investigate the effects of contrasting types of seawalls (reflective-impermeable versus dissipative-permeable) on beach profile response to increased water levels, in the presence of both erosive and accretionary wave conditions.

The results obtained showed that seawalls alter the evolution of the equilibrium profile with rising water level, causing increased lowering of the profile adjacent to the structure. Under erosive wave conditions, modelled profiles both with and without seawall structures in place were observed to translate landward in response to SLR and erode the upper profile.

Erosion demand at the upper beach due to a rise in water level remains similar whether a structure is present or not, but that a seawall concentrates the erosion in the area adjacent to the seawall, resulting in enhanced and localized profile lowering.

Type of structure present (dissipative-permeable versus reflective-impermeable) was not observed to have a significant influence on this response. Under accretive conditions, the preservation of a large shoreface and berm resulted in no wave-structure interaction occurring, with the result that the presence of a seawall had no impact on profile evolution.

(Muller, Figlus, & Vries, 2018)

Not a super helpful document but is supporting document that raising the seawall elevation (by any means) will protect the landward resources it was intended to protect.

Author states the current seawall configuration is insufficient to withstand a 100-year storm. An alternative analysis of utilizing the existing seawall with a sand placement in front and on top of the seawall (dune encapsulation) was modeled in XBEACH. Results found that the increase elevation from the sand placement would help in protecting Galveston Island from a 100-year storm.

This numerical model study gives an insight in the reduction of wave height by a sand cover over a seawall and the corresponding increase in wave-induced setup. The usage of XBeach for these hybrid structure designs showed reliable results with default model values. Overall, larger volumes of sand cover led to increased wave energy dissipation in the approach to the seawall and lower wave heights at the structure. This means that the maximum elevation of the structure can be designed lower in comparison with traditional seawall revalidation proposals. However, due to the gradual wave energy dissipation, increased wave-induced setup is generated, suggesting a higher mean water level at the structure that must be accounted for in the final elevation.

(Florida State University, 2018)

This is a survey and appears it may be relevant to the study; however, the document was not available for review.

(Balaji, Kumar, & Misra, 2017)

Rubble mound revetment backed with a seawall.

Project is focused on flanking more so than the type of wall used.

This article discusses the effects of seawall construction along the coast of Fansa, South Gujarat, India. A numerical model has been used to estimate the wave parameters along the selected coast, the results of which are subsequently utilized in an analytical model (parabolic shape model) to predict the end-wall effect. The results of the analytical model predict a maximum landward erosion of about 20m and an alongshore erosion of 200m on the down-drift side of the seawall. These estimations agree with those obtained by the remote sensing–based analysis, which estimates an erosion of approximately 40m by the year 2014.

(Walling, Herrington, & Miller, 2015)

The research compares the effects of the two different shoreline protection systems employed by each town, and finds that: (1) areas with the rock seawall experienced less erosion behind it but more erosion seaward of it, when compared to sections of shoreline without the rock seawall; (2) for structures with the rock seawall protection, wave impact and scour/HVF predominantly resulted in minor damage, whereas for structures without the rock seawall protection, wave impact and scour/HVF predominantly resulted in severe damage; and (3) the variation in distance to the 0 ft NAVD88 contour caused greater variance in damage levels of wave impact and scour/HVF than the variance in beach protection type.

Document demonstrates similar findings to historical scholarly articles. Does not reference many historical research papers. (i.e. Deans reasoning behind increase erosion to frontal section of seawall due to conservation of matter)

(Jayaratne, Mendoza, Silva, & Garcia, 2015)

The study performs lab tests to further understand scour at seawalls. Supporting documentation but no further advancements.

"Study leads to greater understanding of scour failure of vertical seawalls by means of laboratory-based focused wave groups. Scour characteristics such as depth, extent, and patterns at the berm of seawalls are gathered and compared with the published theoretical models."

(Flocard, Carley, Coghlan, & Cox, 2015)

Document aims to determine the design scour depth for open coast seawalls and what considerations are needed for specific structures.

Australian based document.

"Around 34% of seawall failures arise directly from erosion of beach or foundation material, and that scour is at least partially responsible for a further 14%".

"While it is often said that "seawalls cause erosion", more correctly, "erosion causes seawalls."

Basco and Ozger discuss various applications in coastal engineering and define the seawall trap ratio, WTR as:  WTR = wall trap vol/active sediment vol

Weggel presented six classifications of seawall dependent on their location within the active beach system.

CEM concluded: "…that reflection is not a significant factor in profile change or toe scour. In the field, toe scour is more dependent on local, sediment transport gradients and the return of overtopping water (through permeable revetments or beneath walls) than a result of direct, cross-section wave action… conclusions also negate the common perception that sloping and permeable surfaces produce less effects than vertical, impermeable walls."

CEM suggested as a rule of thumb: "The maximum scour depth at a vertical wall (Sm) is approximately equal to the nonbreaking wave height (Hmax) that can be supported by the water depth (h) at the structure …"

Used SBEACH and XBEACH to model the erosion/scouring along seawalls.

(Feygin, 2012)

This article concentrates on discussion of loads affecting seawalls and on design of a new seawall type, the flexible seawall. Article goes into design elements for the new seawall style.

Discusses Design of Scour Protection

Flexible gabion mattresses or aprons, extending 1.5 times of the significant wave height seaward, provide good and reliable scour protection. Normally a thickness of only 300 to 450 mm (12 to 18 in.) required to resist wave generated uplift forces and retain flexibility (US Army Corps of Engineers 1984).

Bulkheads defined at simple sheet piles that are flexible in soil retaining structures.

Seawalls defined as designed to take additional loads included in hydrodynamic forces.

Conclusion

Flexible seawall systems are extremely efficient when walls are built on the beach with rock formation close to the surface and significant variations in bedrock elevation. Both systems allow great flexibility of construction and benefit from multi-span design approach. Seismic regions need further investigation regarding the type of tiebacks.

(Ismail & El-Sayed, 2011)

A study was conducted to investigate hydrodynamic and sediment transport mechanisms induced by the interaction of seawalls or breakwaters and the incident wave field.

Use has been made of field data of two case studies and the numerical predictions of Genesis.

The analysis of the field data indicated lowering the cross-shore beach profiles, an increase of scour depth and an increase of the longshore sediment transport rate in front of the seawalls followed by downdrift accretion.

Modifications of sediment transport rates are attributed to the generated short-crested wave pattern in front of the seawalls and the modifications of longshore current. Significant component of sediment scour, in front of the seawall, is manifested as an offshore sediment transport current.

(Headland, Trivedi, & Boudreau, 2011)

Since there is not generally accepted, specific guidance on ranges of SLR or management strategies for the future, coastal developments are seeking guidance for an understanding of the issues and associated economic implications and other risks.

Scientific projections, illustrative cases, and the evolving nature of SLR projections are discussed. Implementation strategy that integrates Adaptive Management and a Monitoring Framework based on recent experience in San Francisco Bay.

Adaptive Management Approach: Design for a shorter period (say 20 years) and adapt the design to accommodate SLR over time. Start at initial structure design for existing SLR rate. Observe the SLR to determine how much the structure should be adapted to accommodate SLR Elevation at the end of the period. Repeat observation for successive periods. Evaluate total cost for the adaptive management and compare to cost to structure built in year "1" of scenario. Cost is evaluated using a net present value.

Study provides modeled results and real-world application.

(Headland, Alfageme, Smith, & Kotulak, 2007)

Literature is not too useful for our application. Report goes into detail on the advancement of modeling and applying it to evaluating structural and foundation designs of coastal protection. Document can be used to provide support for how certain structures may react given results of the modeling. However, it is suggested that each project undergo thorough review/modeling.

(Basco D. , 2006)

Document discusses the impact of adjacent beaches, and the different effects seawalls have on adjacent shorelines and beaches. Seawalls play a vital role in protecting infrastructure resources but should not be the sole solution.

The document entitled "Hurricane Protection Project for the City of Virginia Beach by the Army Corps. 2000" May contain some design critical elements. (nucorskyline.com) (Nucor Skyline, 2000). Not reviewed.

Possible Flanking (End-wall scour) mechanisms discussed, Sand Trapping, Rip Current and Seaward Return Flow, Blockage of Littoral Drift (Groin Effect), Headland, Parabolic Bay Beaches, Natural Beach Recover after Storms.

The end wall flanking depth has been found to be correlated to be 10% of the structure's length.

(McDougal, 1996)

An extension of the literature review was completed in 1988. This review continues with research on seawall effects on beaches through 1996. Both literature reviews capture the progression in understanding the coastal dynamics and seawall effect on beaches.

Topics hit are:

- Field Studies
  - Long Term Monitoring
  - Seaward Boundary
  - Statistical Procedures
  - Beach Berm and Foreshore
  - Summer Beach Recovery
  - Scour
  - End Effect
  - Storm assessments
- Lab Studies
  - Scaling Guidance
  - Impact of Seawall
  - Longshore Transport
  - Cross-shore Transport

- Numerical Modeling

Controversy regarding the effectiveness and impacts of seawalls can be eliminated by applying two sets of basic terminology.

- Recognition that seawalls are shore-protection structures and not beach-protection structures.
- Separate the passive erosion, which would occur in the absence of the seawall and the active erosion which is directly attributed to the seawall.

Reflection is probably not a significant contributor to beach profile change or to scour in front of seawalls, at least for the duration of a storm. Experiments still need to be performed to achieve unambiguous resolution of this question.

If the beach profile is close to its equilibrium shape, then the arrival of a storm may not change the profile greatly or cause erosion.

Scour does not necessarily occur at seawalls or may be difficult to predict as not being related to incident wave height. However, the tests of KAMPHUIS are suspect due to the small scale and to the complexity of the initial bottom condition. The maximum scour is expected to occur when the water level is highest (peak surge), because the higher water level can support larger waves.

Sediment can move alongshore past a seawall and a slug of sediment in front of a wall can maintain its form. However, it has not been observed in the field whether the longshore sediment transport rate will match the potential or decrease.

Small-scale physical model results are likely to be misleading and should be considered as yielding qualitative information at best and completely erroneous information at worst.

"For all cases tested, profile configurations with and without a seawall were remarkably similar in overall plan form; this suggests that the major transport process is not significantly influenced by the presence of the seawall."

Under storm waves, seawalls accentuated the erosion trough in the surf zone into a scour hole at the toe of the walls instead of spanning over the swash zone.

Local scour at the walls, was stated to be "severe" in many cases. However, "... the volume of sand retained upland of the structure (which would otherwise be eroded under identical wave conditions without a seawall (DEAN 1986) was found experimentally to be approximately 60' greater than the additional volume eroded at the toe of the structure." In other words, less sand volume was removed from the scour trough than removed from a beach unprotected by a wall.

"Wave reflection, often considered to be a major adverse influence on scour in front of a seawall, did not appear to play significant role" (in beach profile development).

Beaches with walls were recovered with greater sand volumes than the corresponding test cases without walls. BARNETT and WANG state that this result should not be taken to indicate that seawalls promote beach recovery after storms, but that such recovery can occur at beaches fronted by walls.

The present authors note that because the beaches in the tests with seawalls did not erode as much as those without walls, it is probable that recovery proceeded more efficiently for the tests with walls.

(Plant & Griggs, 1992)

The full article was not located; however, the online abstract was reviewed. Abstract indicates that the results were limited due to the mild conditions seen in the study area over the 4-year time study period.

Recognizes rising sea level in 1992.

Recognizes that “coastal planners need qualitative descriptions and models of the effects of seawalls on the coastal environment in order to make intelligent decisions about when and where coastal protection structures are appropriate.”

Provides summary of other Griggs work including Gulf/Atlantic beaches reference.

Of note, a revetment fronts the seawall (located in CA) where the study was completed. Revetments fronting walls are not typical for CCCL permitted seawall structures.

The study stated in the conclusions that most of the conclusions were based on visual observations.

(James F. Tait, 1991)

Document compares the 2-year study of beach responses to seawall along the northern Monterey Bay with other field studies.

“Beach response is the morphological transformation of the beach due to sediment transport”

Type of beach response due to seawalls: Frontal Effect (Scour Trough, Deflated Profile, Beach Cusps), End Effects (End Scour, Upcoast Sand Accretion) and Rip Current Trough. Report goes into detail on each response.

Although not documented, hypothetical effects were discussed in detailed.

An examination of the available literature reveals that little field research has been conducted on the problem of beach-seawall interaction. Those few studies which do focus on the problem of beach response to seawalls indicate that beach response can be variable, and that a number of processes may be at work. Furthermore, the factors that may control the type and magnitude of beach response are numerous and interdependent.

(Griggs G. , Observations on the end effects of seawalls, 1989)

References Kraus’ Literature Review

Study completed a 2 year biweekly to monthly monitoring effort of beach changes in the vicinity of several different types of seawalls in Monterey Bay, California.

The downcoast extent of this impact depended primarily on wave height and wave period or the arrival time of the next wave uprush which tended to override and dissipate the reflected wave. Additional influential factors were the end geometry and permeability of the structure, the angle of wave approach, and tidal stage.

Findings found that only the downcoast return wall showed significant effects.

McDougal conducted a series of small-scale wave tank experiments on the problems of seawall end effects. They concluded that the downcoast or downdrift eroded distance from a seawall is related to the length of the structure, with the alongshore impacts extending for a distance equal to 70% of the structure length.

See citation within the Griggs article for further supporting details on McDougal's findings.

(Barnett, 1988)

Study focused on the investigation of beach profile response to the presence of seawalls and the non-presence of seawall under normal wave interaction. Lab tests were performed with seawalls located three predetermined locations along the beach profile and tests without a seawall for control scenario. Fifteen tests were completed with four different sets of water/bathy conditions.

Overall, the document is technical and a good resource to document the placement of a seawall with respect to beach conditions.

The test results were examined by time-series profile evolution, volume change over profile length, and empirical eigenfunction analysis. For all cases tested, profile configurations with and without a seawall were remarkably similar in overall planform; this suggests that the major transport process is not significantly influenced by the presence of the seawall.

Scour continues to persist with seawalled shorelines. However, findings showed that the volume of sand retained by the seawall was approximately 60% greater than the volume eroded at the toe of the structure as result of scour. Material retained by the seawall would have ultimately been lost under natural beach conditions.

Wave Reflection – nonsignificant role.

Water Depth – Lead contributor to increase in erosion.

Seawalls experience more volume recovery in the vicinity of the structures toe, when compared to the natural profile. However, this is not sufficient evidence to support hardening the coastline.

(Kraus, 1988)

This article is an extended literature review set to capture 100 technical papers on laboratory, field, and theoretical and conceptual studies published through mid-1988. Three objectives:

1. Collect results of well-documented studies
2. Summarize the state of knowledge on the seawall and beach interaction

3. Make recommendation for further study and field monitoring programs

Article attempts to answer the following:

1. What is the maximum scour depth at a seawall and the time scale of its development under given wave conditions, water depth, and reflection characteristics of the wall?
2. Is the amount of sand locally scoured on a seawall-backed profile equal to the amount eroded across the profile on adjacent beaches without structures?
3. Do seawalls accelerate or enhance erosion?
4. Are there systematic patterns of scour or undulatory features of the profile in front of seawalls, and which parameters determine the scour type?
5. Is the recovery pattern different for beaches with and without a seawall?
6. Is the longshore bar system in front of a seawall similar to that along neighboring, unstructured beaches?
7. How does a seawall alter the longshore current and longshore sediment transport rate?
8. Is it beneficial to design seawalls to be "softer," i.e., possess lower reflection coefficients and therefore approach the hydrodynamic behavior of a sandy beach?

Article claims that beaches with or without seawalls are comparable so long as a sufficient sediment supply exists. (Abstract section) However, several types of beach profiles behavior were identified, little quantitative information was found available on the interaction between seawalls and beaches.

In the United States, Virginia Beach (Virginia) is an example of the successful long-term functioning of seawalls and bulkheads (built in sections starting in the 1930's) combined with periodic nourishment and sand bypassing (GOLDSMITH, STURM, and THOMAS, 1977).

Document touches mostly on the impacts of scour through various scenarios in lab and field-testing environment.

"... the primary force of wave action alone does not cause scour in front of vertical walls. However, this force may place the material in sus pension where it may easily be transported by currents which otherwise cause no damage." (Page 7)

Laboratory beach with a seawall installed in the surf zone can respond to accretionary wave conditions as would a beach without the seawall. (Page 7)

The maximum scour depth would have been "about one wave height below low water." (Page 7)

The maximum scour depth to be approximately equal to the incident (deep water) wave height in their laboratory experiments, and they reached the same conclusion based on field observations. (Page 7)

Maximum local scour occurred if a seawall was placed on an equilibrium beach profile in a "critical region" located between about the middle and a point two thirds across the surf zone from the shoreline. After the seawall was moved from the critical region to a position more landward, the formerly scoured region immediately began to fill under wave action. CHESTNUTT and SCHILLER noted that the surf zone width depends, in part, on wave period. Therefore, whether a seawall tends to promote erosion or accretion will depend, in part, on the incident waves, which have seasonal variations in height, direction, and period. MWL is another important factor. (Page 8-9)

On the basis of surveys carried out over 20 years, MacDONALD and PATTERSON (1985) described beach profile change along the beach resort city of Gold Coast, Australia. Change in profiles through time was used to illustrate effects of seawalls, groins, jetties (training walls), and beach nourishment projects. Profile surveys at the seawall Palm Beach (on the Gold Coast) indicated that although beach width has been reduced, profile slope underwent no significant change over the period 1966-1983, and bar position and volume were approximately the same in the 1980 and 1983 surveys. The authors stated that the "gully" in front of the wall often carried a strong longshore current, but they did not make comparisons with currents on neighboring beaches or describe the measurement method. They concluded "Their [seawalls] impact on the beaches is largely dependent on their location on the beach profile. The further seaward they are con structed, the greater their influence and the less likely will a usable beach be maintained in front." (Page 14)

The present review has found that beaches with and without seawalls exhibit similar behavior and variation with regard to short-term erosion and recovery associated with storms and post-storm wave conditions. The main exceptions are: (1) localized beach response at the toe and ends of a sea wall in some instances, (2) denial of the sediment encased behind a seawall to the littoral system that would nourish adjacent beaches, and (3) functioning of a seawall as a groin or jetty to block sediment movement alongshore, in situations where the seawall protrudes into the active surf zone

(Orville T. Magoon, 1988)

Report on reviewing the constructed rubble mound revetments along the shoreline of Santa Cruz County, California.

1950’s USACE study revealed a rubble mound revetment was best suited for the shoreline. Beach nourishment with or without groins was economically infeasible given the current beach morphology contained projecting points/headlands that did not sufficiently capture sand. Structure built was a single armored seawall.

Investigation in 1988 of the revetments revealed that 90% of the structures were in good conditions with majority unchanged from as-built conditions.

(Terchunian, 1988)

The abstract indicates this study is not relevant to this study. Paper speaks to procedure to calculate erosion over time at a site (without seawall) and compare against erosion that a seawall would induce and use this as a decision-making apparatus relating to permitting of seawalls. Permitting of seawalls seems relevant but this paper appears to focus on a very narrow method of evaluation that doesn’t take into account the focus areas of the DEP study.

(Dean, 1986)

The study is technical and apply principles with lab and field data to evaluate the potential adverse impact of shoreline armoring.

Principles:

- 2D situation in nature with wave and sediment condition not conducive to formation of an offshore bar, beach profiles seaward of an armored segment does not depend on the presence of the armoring but depends almost entirely on the equilibrium beach profile vis-à-vis the amount of sand available to form this profile.
- In a two-dimensional situation in nature with wave and sediment conditions conducive to formation of a longshore bar, the additional volumetric scour immediately fronting the armoring will be less than or equal to that volume of material that would have been provided through erosion by that portion of the profile upland of the armoring if the armoring was not present.

Study concludes:

- No factual evidence to support claims that armoring causes profile steepening, increased longshore transport, transport of sand offshore a substantial distance, or delayed post-storm recovery.
- Armored sections of shoreline interaction with littoral system are more geometric or kinematic interaction instead of a dynamic interaction. Interaction is really dependent on the amount of sand in the system.
- Armoring can cause localized additional storm scour, both in front and flanking of the armoring.

A methodology is presented to quantify the potential adverse effects of an armoring installation and appropriate periodic sand additions proposed as a means of mitigation to elevate the installation to one of neutral impact on the adjacent shoreline.

(Clark, 1982)

Reports “intent to present the structural design aspects required in a coastal building code using the code guidelines developed for and specifically applicable to Florida’s coastal communities.”

The major concepts of coastal engineering design which are necessary in a coastal building code include:

1. Zone identification (horizontal and vertical)
    a. Coastal Building Code established by the line of demarcation from a surge and flooding by a 100-year design storm. This includes horizontal and vertical limits.
    b. Horizontal limits are determined based on existing structured shoreline or developed (unstructured) and natural shoreline.
    c. Vertical – Based on the design breaking wave crest height of a 100-year-storm.
2. Foundation design for erosion and scour.
    a. Account for the erosion, scour and loads accompanying a 100-year storm event.
    b. Soil bearings are not to be included.
    c. Additional requirements of foundational design.
3. Storm loading (including wind, waves, hydrostatic, and hydrodynamic loads).
    a. Wind velocities - Follows the National Hurricane Center, University of Florida, and Florida Department of Natural Resources.
    b. Water Related Loads – Department of Navy, Naval Facilities Engineering Command Design Manual NAVFAC DM-26, USACE Coastal Engineering Research Center Technical Paper and Reports, FDNR.
4. Excavations
    a. Account for erosion due to 100-design storm.

The major design considerations for coastal and shore protection structures should include structural siting, foundation (e.g. geotextiles), crest (or cap) elevation, toe elevation, structural slope(s), components as impacted by waves superimposed upon the design storm surge, expected scour, impact on the beach and dune system, and impact on the adjacent properties.

Seawalls, revetments, and rubble mound structures are generally designed for a 20 to 50-year storm event.

Recommended sources from which to base minimum criteria and methodology in the design of coastal and shore protection structures

- The Department of the Army Corps of Engineers Shore Protection Manual,
- Department of the Army Coastal Engineering Research Center Technical Papers and Reports,
- Department of Navy,
- Naval Facilities Engineering Command Design Manual NAVFAC DM-26 and DM-7,
- Florida Department of Natural Resources,
- Division of Beaches and Shores Technical and Design Memoranda.

(Todd L Walton, 1979)

Scour at seawalls may also attribute to the fact that waves are expending their energy on a much shorter section of beach when a seawall is present.

Examples of seawall design

Siting Design Considerations

- Calculating Long term effect to beach profile changes
  - Siting equates to the foreshore and above water portions of the equilibrium beach profile remain constant in shape over a long period of time and shift landward at a rate equal to the long-term annual shoreline recession rate.
  - References using the USACE Shore Protection Manual.
- Calculating Storm effects to beach profile changes
  - Most important design element.
  - Obtain an "After storm" profile after a design storm hits the intended shoreline. Study details how to develop an after-storm profile.
  - Provides a rough location of seawall design where dunes existing, no overtopping of dunes occurred, and where no encroachment to infrastructure occurs.
- Scour
  - Provide calculations to scour. (Page 12/30 of PDF)
- Wave forces
  - Wave forces are based on the methods used in the USACE Shore Protection Manual.

Return Wall Design Length

- Takes into consideration shoreline recession due to storm and the anticipated increase in recession rate dure to the constructed seawall.
- Section indicates that the crest elevation of the seawall is equated to the “after storm” elevation.
- Return wall should extend into the dune beyond the established “after storm” elevation to account for anomalous effect on adjacent non-seawall conditions.

## 2.3 Storm Impacts

(Cheng, 2021)

Tropical Storm Eta impacted the coast of west-central Florida on 11-12 November 2020, and generated high waves superimposed on elevated wave levels for over 20 hours. A total of 148 beach and nearshore profiles, spaced about 300 m (984 ft) apart, were surveyed one to two weeks before and one to eight days after the storm to quantify the beach changes.

(Dally, Crowley, & Hudyma, 2021)

This paper presents pre-storm historic beach conditions, the potential causes and progression of erosional events surrounding Hurricanes Matthew and Irma at three locations in northeast Florida, and an assessment of protection measures implemented by homeowners.  Observations made during field investigations show that bulkheads constructed to protect single or multiple houses exacerbate erosion at the ends of the bulkheads.  This results in both failure of the bulkheads as well as increased erosion for neighboring properties.

Document suggests that unlike undeveloped beaches North of Vilano Beach, which received little damage from the hurricanes. The developed segments of Vilano Beach are the suggested blame. Piecemeal bulkheads appear to do little to protect against erosion.

Bulkheads observed were poorly designed and ill-covered.

(Smallegan, Irish, & Dongeren, 2015)

Study compares the shoreline change responses to Hurricane Sandy of developed and undeveloped barriers islands. Ultimately wanting to evaluate which infrastructures affect the island response the most.

XBeach results indicates the seawall reduces overall island erosion and preserves the dune system in both the ‘developed’ and ‘abandoned’ cases. However, buildings are observed to exacerbate erosion, especially in front of oceanfront buildings where deep scour holes form and destroy the dune system.

Overall, this study shows that, although coastal structures, such as the buried seawall, may benefit the barrier island by reducing erosion, buildings greatly affect the morphological response of the island and can exacerbate erosion in front of oceanfront buildings and between structures.

(Irish, Lynett, Weiss, Smallegan, & Cheng, 2013)

Study focuses on an unknown century old stone seawall (Bay Head Dune) and its response to Hurricane Sandy. Result were compared to a control setting of nearby natural beach (Mantoloking).

Surveyed high water marks and assessed damage, over wash, and breaching in both Bay Head and Mantoloking. We found that flood elevations were very similar, with oceanfront flood elevations, as measured from water lines on the interior of homes.

Erosion and damage to oceanfront homes, however, were drastically different in the two locales. In Mantoloking, widespread significant over wash led to breaching of the barrier spit in several locations. In contrast, while some areas in Bay Head over washed, no breaching occurred.

In Montoloking the entire dune almost vanished, and three major barrier spit breaches were formed.

Using simulations with the Boussinesq-type model, we attempt to quantitatively assess the protective effect of the hidden seawall. With our focus on structural damage, the most appropriate hydrodynamic proxy is momentum flux; for shallow water waves, depth-averaged momentum flux per unit length normal to the direction of wave propagation.

Examining the Bay Head simulations, it is clear that behind the seawall, the wave force potential is reduced by greater than a factor of two if the seawall did not exist, wave-averaged forces on these oceanfront homes would have been twice as large as experienced. Similarly, erosive flow velocities over the dunes in Bay Head were reduced, with respect to those in Mantoloking.

(Tabar, Ketteridge, Lasch, & Jones, 2008)

Report identified 111 structures along the coast of Florida that were impact from the 2004 hurricanes. Pre- and post- hurricane aerial video and photography, post-hurricane site damage assessments, pre- and post-hurricane beach profile monitoring data, and LIDAR data were reviewed through this project. Each of the one hundred and eleven coastal armoring structures had their location, type, material of construction, and approximate level-of-damage, logged in the spatial database.

Three areas of focus with respect to storm data and impact to structures: wind, wave, and water level. Majority of the damage to armored structures observed was a result of wave and surge.

> [in our data analysis effort should we consider review of a statewide bathymetry, wind, wave, surge to understand vulnerability areas? Thinking at a high-level overview of this data with recommendation of areas to be further investigated]

Level of Damage (LOD) assessments were performed on all one hundred and eleven identified armoring structures. LOD is defined for the purposes of this study as the amount of damage the structure received from the storm and was based on several criteria.

Conclusion:

- Unarmored shorelines exhibited larger dune recessions than armored shorelines, where the structure remained intact.
- Increased erosion to unarmored properties in the vicinity of the structure returns was observed, as shown in Figure 6.

- Seaward portions of the profile fronting seawalls and revetments showed more loss in elevation than corresponding unarmored shorelines.
- The slope of the seaward portion of the profile was steepest for seawalls, less steep for revetments, and mildest for unarmored stretches of shorelines.
- The structure has an increased effect on the shoreline with increased length of structure and distance placed offshore, as illustrated in Figure 7.

Report “Seawall Design on the Open Coast” by Walton Jr T.L - The study suggests that the return walls should be equal in length to the recession on a natural beach of the contour elevation equal to the seawall cap elevation.

The Tabar/Lasch study found this claim to under predict the return wall length.

(Jeffrey Tabar, 2007)

Document could not be located for review.

(Gary Griggs, 1995)

Report documents the conditions of the beach adjacent to the Aptos Seascape Seawall (same seawall, fronted by revetment, in other Griggs research) in Monterey Bay. Document captures typical non storm conditions and how they compared to several storm event occurring during 1982, 1983 and 1995, with 1995 being the largest and most frequent storm events.

Profiles of before and after storm events.

Control beaches and seawall beaches had similar responses to the storms during the 1995 winter season.

Seawall experiences accelerated scour but quickly recover following storm events.

(Wang, 1989)

Document captures the impacts to several communities in North Carolina in response to impacts from Hurricane Hugo, September 21, 1989.

Report details the type of structures and impacts results from Hurricane Hugo.

Set Back (Siting) of structure was a key connection to the failure of structure during the Hurricane.

Return walls were under designed.

Overtopping and damaged caps support that the seawall crest elevation was too low for majority of the structures.

“Structures built on open coasts should be designed to avoid water force rather than resisting it.”

Conclusion suggests that structures who experience ‘water force’ should be designed to break away during loading. Structure set back is important to reduce structure vulnerability, construction cost, and damages (Impacts). As a structure is place closer to ‘water forces’ the structure needs to be taller, deeper, and ultimately stronger.

## 2.4 Other

(Siders & Keenan, 2020)

This article provides the foundation for future research into how adaptation decisions are made and trade-offs among adaptation actions considered, whether decisions adequately protect critical infrastructure, and how deployment patterns affect social equity. This article provides an exploratory statistical analysis of three adaptation measures (shoreline armoring, property acquisitions, and beach nourishment) and their deployment with respect to metrics of risk exposure, socioeconomic markers, and critical infrastructure in North Carolina (U.S.).

Evaluates two propositions:

- adaptation measures deployed relative to specific metrics of risk.
- adaptation choice disproportionately correlates with socioeconomic attributes.

Findings support that shoreline armoring correlates with higher home values, household incomes, population density, and low racial diversity.

Property acquisitions are found to correlate with low home values, household incomes, population density, and high racial diversity.

Beach nourishment occurs exclusively in areas with shoreline armoring.

Results find no correlation of adaptation deployment with critical infrastructure.

(Landry, Shonkwiler, & Whitehead, 2020)

Not relevant. Purely economic and focused on NC. NC prohibits armoring. Different scenario in FL and can’t ensure that outcomes would translate to Florida.

(Dundas & Lewis, 2020)

This paper estimates the economic benefits derived from the private option to protect coastal oceanfront land from irreversible loss due to erosion.

Area of focus is Oregon and the Pacific Coast.

The authors estimated private values for a coastal protection option in an empirical setting subject to irreversible loss from coastal erosion and a land-use policy that provides identifying variation in the parcel-level option to invest in protection.

The authors then show that these estimated capitalization effects imply that landowners' subjective annual probability that they will experience an irreversible loss absent the option to protect is between 0.7% and 1.3%

Parcels that are vulnerable to coastal risks (i.e., low elevation and eroding shoreline), the price premium for the protection option is significantly different from zero and can be 13%–22% of their property value.

(Beasley & Dundas, 2019)

This paper fills a gap in economists' understanding of how private adaptation incentives and land-use policies may influence the temporal and spatial pattern of investments to mitigate current and future coastal risks.

(Hill M. K., Monroe, Ankersen, Carthy, & Kay, 2019)

This study explored both Florida coastal property owner's opinions of coastal armoring, and its impact on sea turtles and their nesting habitat. A quantitative survey was administered to beachfront property owners that live within a mile of a protected section of beach (e.g. state park, preserve, wildlife refuge). In total, 373 of 1,274 distributed surveys were returned and analyzed.

(Hill M. , Monroe, Ankersen, Carthy, & Kay, 2019)

Survey conducted of 1274 property owners living within 1-mile of a protected section of sea turtle nesting habitat. Survey focused on the relationship between homeowners' intent located near nesting beaches to engage in coastal conservation easements, the theory of planned behaviors, environmental identity, and relevant demographics.

Traditional land types protected by CEs are forests, wetlands, farmland, and ranches (Byers and Marchetti Ponte, 2005). Thus, typical property interests in a CE include forgoing the right to develop or construct buildings. Some can also be proactive management activities like habitat restoration or the removal of invasive plants or animals.

From these findings, coastal conservation groups desiring to positively influence interest in a CCE specific to protect sea turtle nesting habitat with homeowners living on sandy sea turtle nesting beaches in the state of Florida could consider the following courses of action:

- Engage in effective outreach to enhance understanding of the implications and use of coastal conservation easements.
- Provide training and assistance for landowners to understand the CCE process to enhance individual's perceived control to engage in a CCE while building trust in the organization intending to hold the CCE.
- Focus efforts in geographic areas of the state where understanding and interest are high and best sea turtle nesting habitat exists.

Clearly champion the incentives of participating in a CCE with specific emphasis on obtaining tax deductions; conservation of beach habitat; receiving assistance from a conservation organization; and the involved organization's trustworthiness

(Brandon T. O., 2016)

Article is against armoring of shoreline and make false claims to shoreline structures based on past literature.

Only read abstract. Article does not appear to be helpful other than creating an argument to armor shorelines and how it goes against the Clean Water Act.

This Article explains why Nationwide Permit 13 is unlawful under the Clean Water Act, and how Nationwide Permit 13 acts to encourage coastal development and undermine the adoption of less environmentally damaging erosion control measures, such as living shorelines.

Despite well established and significant environmental harms, the United States Army Corps of Engineers currently authorizes the construction of bulkheads and seawalls up to five-hundred feet in length through a general permit—Nationwide Permit 13—that does not even require property owners to notify the United States Army Corps of Engineers before beginning construction.

(Dugan, Emery, Alber, Alexander, & Byers, 2014)

Document could not be located for review.

(Ariza, Lindeman, Mozumder, & Suman, 2014)

Based on exploratory interviews and literature reviews, a survey instrument was administered that quantitatively queried seven primary stakeholder groups on fundamental issues regarding the management of Florida's beaches. Stakeholders expressed complex opinions including a mixture of both satisfaction and dissatisfaction with management of beaches in the state.

There was a lack of consensus on multiple issues with considerable concern about several management issues including reactive, not proactive approaches, incomplete stakeholder representation and limited control of coastal construction. There were also concerns about the long-term emphasis on engineering (seawalls, groins, and breakwaters) relative to other management options (land use policies). Both political processes and availability of finances were often cited as primary reasons for Florida beach management challenges (39% and 44% of stakeholders respectively). The data also suggested polarization regarding the long-term priorities of beach management in several questions including beach nourishment projects and planning for Sea Level Rise (SLR). Primary elements influencing satisfaction/dissatisfaction were the management of natural resources, politics, institutional coordination, public hearing effectiveness, and control of coastal construction.

Almost all stakeholder groups were critical of the effectiveness of the CCCL and other setbacks in the protection of beaches and dunes. A wide array of inconsistencies in the CCCL program has been detailed by Ruppert (2008) and others. The CCCL program is a seemingly fundamental element of beach management in Florida and influences stakeholder satisfaction, in part, as it implies there is some structure and control of coastal construction in Florida

Most stakeholders reported negative or mixed attitudes on armoring (>75% of respondents). In the case of beach renourishment dredging projects, relatively greater satisfaction was expressed (57%

positive, 43% negative or mixed) but stakeholders were split in terms of absolute numbers (61 positive, 59 negative).

(Ells & Murray, 2012)

Article evaluates the long-term evolution of coastlines (North and South Carolina coast) and how human manipulations (erosion prevention) alters the shoreline progression. This report is covering the coastline on a large-scale perspective. Article could be used to argue or support the use of shoreline stabilization.

(Griggs G. B., 2010)

Report is a good overview of California need for armoring and the challenges that go with armoring from the public perspective. Not a technical document.

Not a whole lot of supporting/conflicting information.

(Humbryd, Irish, Rahony, Alpern, & Rackmales, 2009)

Not relevant to our study.

Study is about the use of a bulkhead that rises/falls with floodwater to prevent overtopping. Finding show under laboratory testing conditions, the structure works within low energy conditions but has not been applied to open coast settings nor has the design been structurally finalized.

Structure is a double sheet pile sandwiching a float unit to rise and lower with flooding.

(Schrieter, Ravell, & Dugan, 2008)

Applicable to this study - ecological effect on soft sediment.

(Griggs., 2005).

Document is subjective and written with some bias.

Article gives example at a high-level overview. Not technical. Focused more on the reasoning behind how armoring has become important due to infrastructure development.

California Coastal Commission is the agency that approves most coastal protection structures proposed on the California coast.

(Hartman, 2002)

The article nor abstract could not be located. Content is unknown. Coastal Engineering: Study Suggests Many Factors Affect Erosion on Beaches with Seawalls (asce.org)

Based on age of article being >20yrs, it is likely that the contents have been updated and are reflected in research conducted in later years.

(Wiegel, 2002)

Seawalls, Seacliffs, Beachrock: What Beach Effects? Part 1 (asce.org)

Document could not be located for review.

(Wiegal R. L., 2002)

Seawalls, Seacliffs, Beachrock: What Beach Effects? Part 2 (asce.org)

Document could not be located for review.

Seawalls, Seacliffs, Beachrock: What Beach Effects? Part 3 (asce.org)

Document could not be located for review.

(Kamphuis, 1997)

Do not need article. Based on the age of the research and the fact that it is model based, it is reasonable to expect that additional modeling has taken place since this effort and will be discussed in later years.

(Hall & Pilkey, 1991)

Article not located, but abstract reviewed and found to be irrelevant to our study.

The researchers measure dry beach width on the New Jersey beaches with a variety of structures and no structures. They concluded that the dry beach width is greater on the beaches with no structures. Downdrift and adjacent impacts are not reviewed. The researchers conclude that this study is a snapshot in time and that results would likely be different depending on timing of beach width measurements. This was not a study that measured the beach width over a time series.

# 3. FEDERAL DOCUMENTATION

Documents from relevant Federal agencies (FEMA, NOAA, USACE, and USFWS) were identified and reviewed using the same keywords used above for published and professional research. A general summary of the content contained by agency is:

- FEMA - For coastal flood protection structures (i.e. armoring) to be recognized by FEMA, sufficient evidence must be provided that adequate design, construction, and maintenance have been undertaken to provide reasonable assurance of durable protection from the base flood. Specific requirements are detailed including design water levels, wave heights and periods, wave forces, freeboard, toe protection, backfill protection, structural stability, material adequacy, and plan alignment. In addition, FEMA requires an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent to, the protected area when considering requests for flood map revisions based upon new or enlarged coastal flood control structures.
- NOAA – no specific data or information on coastal armoring has found; however, NOAA has published sea level rise scenarios to 2150 by decade and advise for incorporating SLR estimates into design and development.
- USACE – The Coastal Engineering Manual (CEM) provides engineering and design guidance for coastal armoring (specifically, seawalls, bulkheads, and revetments).
- USFWS – the literature generally encourages the use of living shorelines over “hard” shorelines in estuarine environments; however, no relevant information or discussion was found related to the use of armoring on the open coast.

Annotation of the literature reviewed follows.

## 3.1 EPA

(EPA, 2004)

EPA established a two-part Coastal Wetlands Initiative. This report focuses specifically on the Gulf of Mexico coastline.

The report identifies shoreline hardening as a stressor to coastal wetlands. It suggests living shorelines as an alternative to hard structures.

## 3.2 FEMA

(FEMA, 2020)

This is an excerpt from FEMA’s Coastal Construction Manual and contains a historical perspective on state and community efforts to conduct erosion studies and develop hazard zone maps. Included herein as a description of the establishment of Florida’s CCCL (100-yr) and 30-yr erosion projection lines. Coastal armoring is not discussed.

(FEMA, 2019)

This guidance document supports the standards related to approving coastal protection structures to be shown as providing protection on Flood Insurance Rate Maps (FIRMs) and outlines methods for analyzing the stability and effects of coastal structures during the 1- percent-annual-chance flood conditions.

For coastal flood protection structures to be recognized by FEMA, sufficient evidence must be provided that adequate design, construction, and maintenance have been undertaken to provide reasonable assurance of durable protection from the base flood. Specific requirements are detailed including design water levels, wave heights and periods, wave forces, freeboard, toe protection, backfill protection, structural stability, material adequacy, and plan alignment.

In addition, FEMA requires an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent to, the protected area when considering requests for flood map revisions based upon new or enlarged coastal flood control structures.

(Battalio, Bromirski, Cayan, & White, 2016)

The document is a technical methods manual written to help planners and engineers adjust FEMA coastal flood maps to account for SLR. The document was commissioned by the California Department of Water Resources and California Ocean Science Trust and is focused on California.

When considering a coastal structure, Figure "3.4 Response to SLR on Armored Backshores with Depth-Limited Breaking Waves" is provided along with the following:

> If a structure is presumed to prevent erosion, the fronting beach is still likely to erode. This will increase the extent of wave runup and overtopping, as indicated in Figure 3.4. The effect can be approximately accounted for by increasing the elevation of runup by 1.5 to 3 times sea level rise, and total water level 2 to 4 times sea level rise. The lateral extent can be extended by shifting the flood hazard zones landward in proportion to the landward migration of the shore fronting the coastal armor. The landward shift can be computed as the projection of historical erosion plus the effect of sea level rise on sandy shores. If the beach width approaches zero, the landward extent of the future V-Zone may need to extend inland based on the increase in negative freeboard.

(FEMA, 2011)

The Federal Emergency Management Agency (FEMA) first published the Coastal Construction Manual (FEMA 55) in 1981. It has been updated multiple times since, with the latest version currently dated 2011. The purpose of the manual is to provide guidance for designing and constructing residential buildings in coastal areas that will be more resistant to the damaging effects of natural hazards.

Section 3.3.4.1 discusses SLR. The publication notes that FIRMs do not account for sea level rise. Relying on FIRMs for estimates of elevations for future water and wave effects is not advised for any medium- to long-term planning horizon (10 to 20 years or longer). Instead, forecasts of future water levels should be incorporated into project planning.

(Federal Emergency Mangement Agency, 2007)

FEMA's Design Guide for Improving Critical Facility Safety from Flooding and High Winds

Results are from the following search of key words: Gap, Open, Coast, Scour, Seawall, Bulkhead.

Document goes into detail regarding flooding and does not pertain to design of shoreline protection. Focuses more on the design and considerations of critical facilities and how the flooding would impact said facilities.

(Jones, et al., 2005)

Existing FEMA guidance for treatment of coastal structures (including seawalls) are not mentioned specifically but should also be considered for flood hazard mapping purposes.  A working group was organized to discuss this topic.

One of the working group discussion topics was "Review Data on the Effects of Coastal Structures on Flood Hazards on Adjacent Properties."  The following paragraphs summarizes this discussion topic.

One of the coastal structure evaluation considerations included in FEMA (1990), FEMA (2002) and FEMA (2003) is adverse impacts. Unfortunately, the level of guidance contained in those documents is inadequate.

Impacts can be divided into erosion impacts and hydraulic impacts. Erosion impacts will include the short- or long-term effects of a coastal structure on the topography of adjacent property. Hydraulic impacts will include such things as wave reflection, concentration of flow, etc.

The working group cites multiple sources of literature with papers and studies related to erosion impacts which "taken as a whole, these studies indicate the erosion effects of shore protection structures on nearby properties will vary, depending on the local coastal processes and morphology, sediment budget, and structure location/characteristics."  The authors divide erosion effects into three general categories:  impoundment (sediment landward of the structure being prevented from eroding and nourishing the beach), and passive erosion (continuation of ongoing shoreline recession, resulting in a narrower beach in front of a structure), and active erosion (postulated erosion and scour due to the presence of the structure).  The authors note the first two are relatively uncontroversial and can be quantified for a site, while active erosion is likely to continue to be a subject of debate in years to come.

The authors further note that while the wealth of literature devoted to erosion effects of coastal structures does not exist for hydraulic effects, the hydraulic effects of many coastal structures can be approximated using the methods of hydraulics, fluid mechanics and wave mechanics, coupled with documents such as the Coastal Engineering Manual. There may be some instances where the hydraulic effects of large structures can be better addressed via numerical modeling, but this is expected to be the exception rather than the rule (at least for the near future).

One of the working group discussion topics was "Review Flooding/Wave Effects Behind Structures." The authors noted the following, which may be of relevance to the Department's coastal armoring study.

The dimensions of a coastal structure should be sufficient to prevent flooding and erosion from occurring landward of the structure during the 1% flood event.

Flooding behind a structure can be caused by overtopping of the shore-parallel section of the structure, or due to overtopping of the shore-perpendicular (return wall) section of the structure.

Erosion behind a structure can be caused by undermining at the structure toe, overtopping, or other structural failures. The erosion can be initiated at or across the shore-parallel or shore perpendicular sections.

FEMA procedures do not establish a minimum coastal structure length required to gain flood hazard mapping credit (either during an FIS or a map revision). However, as a first approximation, a structure length less than twice the mapped overtopping zone width behind the structure was suggested by the authors.

## 3.3 NOAA

(NOAA, 2022a)

This report and accompanying datasets from the U.S. Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force provide 1) sea level rise scenarios to 2150 by decade that include estimates of vertical land motion and 2) a set of extreme water level probabilities for various heights along the U.S. coastline.

By 2050, the expected relative sea level (RSL) will cause tide and storm surge heights to increase and will lead to a shift in U.S. coastal flood regimes, with major and moderate high tide flood events occurring as frequently as moderate and minor high tide flood events occur today. Without additional risk-reduction measures, U.S. coastal infrastructure, communities, and ecosystems will face significant consequences.

The scenarios presented have been widely used in the development of state (e.g., Florida and Virginia) and local agency adaptation plans (e.g., Pensacola, Florida, and Portland, Maine), and processes for anticipating and managing future coastal risks.

(NOAA, 2022b)

Federal agencies have been updating tools with the new sea level rise information and have compiled the tools on this website (portal):

- Sea Level Rise Viewer: Use this web mapping tool to visualize community-level impacts from coastal flooding or sea level rise (up to 10 feet above average high tides).
- Coastal Inundation Dashboard: Inundation Dashboard provides real-time and historic coastal flooding information, using both a map-based view and a more detailed station view.

- Coastal Flood Exposure Mapper: Jumpstart community discussions about local coastal flooding hazards by developing maps that show the people, places, and natural resources at risk.
- Coastal County Snapshots: Turn complex county-level data into easy-to-understand charts and graphics — use this tool to create printable handouts that help articulate your community resilience message.
- Sea Level Trends: This tool measures relative sea level trends, with arrows representing the direction and magnitude of change.

(NOAA, 2022c)

This is a public information sheet identifying the need to assess the impacts of, and identify alternatives to, coastal armoring within Monterey Bay National Marine Sanctuary.

There is no new information in this document. Suggest removal from the list.

(NOAA, 2018)

The purpose of the study is to residents' preferences for shoreline management options in coastal New Hampshire, as well as estimate the costs associated with those options. The results of the study do not appear to have been published yet.

(Lopez, 2015)

This is Chapter 25 (Sea-Level Rise and Species Survival along the Florida Coast) on a book.

The book was unavailable for review; however, an abstract states that the text describes how the Endangered Species Act can plan for species conservation in light of sea-level rise. The Act's Section 4 requirement to designate suitable, unoccupied upland habitat can help in proactively identifying and managing upland habitat for species retreat as rising seas and increasing storms threaten coastal species' habitats. The chapter discusses how Section 7 of the Act ensures that federal agency actions to not jeopardize species or adversely modify their habitats applies to federal programs such as the National Flood Insurance Program (NFIP) and can be helpful in preventing construction in flood plains and species' coastal habitats.

(NOAA, 2010)

This is a suggested framework for state coastal managers to follow as they develop and implement climate change adaptation plans.

When there are no suitable alternatives, future shore protection structures should be designed and constructed to minimize adverse impacts at the site of the structure as well as to the broader coastal system, based on future climate change projections, and so they are flexible enough to allow for modifications. Existing structures will likely require upgrading, replacement, or removal. All structures will require monitoring and maintenance to ensure they continue to function as planned.

Regulations can specify allowable uses, locations, and structures, prohibit new structures, and/or require the removal of existing structures given specified circumstances (e.g., no longer maintained, substantially damaged, need to return land to natural functions, etc.). The size, design, and placement of shoreline stabilization structures can also be regulated to minimize environmental and public access impacts. Regulations that severely restrict the use of shore protection structures or require their removal should also require disclosure of such restrictions in real estate transactions.

(NOAA, 1993)

This is not relevant. It is related to remediation of oil spills.

(O'Neill, 1986)

This Information Bulletin is intended to give coastal landowners, developers, and government officials a means to determine what erosion control alternatives might be applicable to specific situations.

No new information.

## 3.4 USACE

(USACE, 2023)

Public informational website which defines seawalls, bulkheads, and revetments. No relevant information.

(USACE, 1995)

This manual provides engineering and design guidance for seawalls, bulkheads, and revetments.

At a minimum, the design must successfully withstand conditions, which have a 50% probability of being exceeded during the project's economic life.

Failure of the project during probable maximum conditions should not result in catastrophe (i.e. loss of life of inordinate loss of money).

Flank protection – return sections (for sheet pile walls) are generally needed due to the tendency for erosion to continue around its ends.

(Basco D. R., 2006)

Section 3 Shore Protection Projects.

Shore protection projects moderate the long-term average erosion rate of shoreline change from natural or manmade causes.

On historic, eroding coasts, it must be expected that erosion will continue to diminish the width of the buffer strip between armored shoreline and the sea.

Design Life: An estimate of the number of years of useful life of the structure/alternative. Usually 25 to 50 years is employed for well-designed projects. Design life selection includes structural life of materials (structural integrity), functional life (usefulness), technical life (technologically up-to-date), and aesthetics. It does not mean the length of time the project will last in the field.

Long-term, relative changes in sea level can be incorporated into storm surge analysis and the economic design of coastal structures.

Functional design: The functional design of coastal armoring structures involves calculations of wave runup, wave overtopping, wave transmission, and reflection. These technical factors together with economic, environmental, political (social), and aesthetic constraints all combine to determine the crest elevation of the structure.

Dean (1987) critically examined nine commonly expressed concerns about seawalls and adjacent beaches. Conclusions from this analysis were as follows:

Concerns Probably False (or Unknown)

- profile steepening
- delayed beach recovery after storms
- increased longshore transport
- sand transport far offshore
- increase in long-term, average erosion rate

Concerns Probably True

- frontal effects (toe, scour, depth increase)
- end-wall effects (flanking)
- blockage of littoral drift when projecting into surf zone (groin effect)
- beach width fronting armor likely to diminish

Kraus (1988) reviewed over 100 references (laboratory, field, theory, and conceptual studies) to make a thorough examination of the literature. This review and seven companion papers are presented in Kraus and Pilkey (eds. 1988). An updated literature review is found in Kraus and McDougal (1996) who examined 40 additional papers. In general, these extensive literature reviews agreed with Dean (1987) regarding which concerns were probably false and which many are true.

Beach profile change and toe scour during storms and nearshore bar differences have been attributed to seawalls. Conventional wisdom has been that these impacts were due to wave reflection. Kraus and McDougal (1996) studied the field results by Griggs et al. (1997); laboratory work by Barnett and Wang (1998) and Moody and Madsen (1995) and their own research in the SUPERTANK (large scale) seawall tests (McDougal, Kraus, and Ajiwibowo 1996) to conclude that reflection is not a significant factor in profile change or toe scour. In the field, toe scour is more dependent on local, sediment transport gradients and the return of overtopping water (through permeable revetments or beneath walls) than a result of direct, cross-section wave action. Their conclusions also negate the common perception that sloping and permeable surfaces produce less effects than vertical, impermeable walls.

Perhaps the key environmental concern is how a seawall affects a neighbor beach with no armoring. The extent and length of the excess erosion is related to seawall length and is explained in terms of the seawall denying sand to the littoral system (e.g., Dean 1987). However, other mechanisms may be responsible. If the seawall extends seaward, it may act like a groin to cause downdrift impacts.

Plant (1990) and Plant and Griggs (1992) observed rip currents at interior sections and at the ends of armored sections. These rip currents were attributed to wave overtopping, return flows and elevated, beach water tables during storms. They concluded that this mechanism may be more responsible for end-of-wall, flanking effects than the sand trapping theory of Dean (1987).

## 3.5 USFWS

(USFWS, n.d.)

This is a public informational website to influence the use of living shorelines over “hard” shorelines in estuarine environments. Not relevant. Remove reference.

# 4. FLORIDA COUNTY AND MUNICIPALITIES

Local codes and policies in the Florida Municipalities of 1) Miami-Dade County; 2) Palm Beach County; 3) St. Johns County; 4) Sarasota County; 5) Brevard County; and 6) Volusia County relevant to armoring on the Atlantic and Gulf of Mexico coasts were identified and reviewed. The open coast shorelines in Miami-Dade County and Palm Beach County are primarily limited to the local municipalities (i.e. cities and towns). No specific rules, regulations or policies for seawalls on the open coast were found within those county municipal codes. Several local municipalities (e.g. cities and townships within Miami-Dade and Palm Beach Counties) were reviewed, with coastal armoring being permittable, and generally equal to or less restrictive than F.S. and F.A.C. Walton County was similarly found to be generally equal to or less restrictive than F.S. and F.A.C. Coastal armoring rules, regulations and policies for Volusia County appear to be similar, if not slightly more restrictive than, than F.S. and F.A.C. Brevard County and Sarasota County regulations and policies are considerably more restrictive than F.S. and F.A.C. In Sarasota County, a “variance” is required for every application for coastal armoring. Furthermore, Sarasota requires a coastal armoring structure to be within the “public interest” and further restricts coastal armoring to for the protection of (1) public infrastructure or (2) when the Board determines that the coastal armoring is necessary to protect property rights. In unincorporated Brevard County, no new rigid coastal armoring or shoreline hardening structures shall be permitted except under specific emergency provisions.

Annotation of the literature reviewed follows.

## 4.1 Brevard County

(Brevard County, 2022a)

> Policy document. “… the public health, safety and welfare of the inhabitants of the county require the establishment of special construction regulations to allow the beach-dune system to maintain its equilibrium, so as to buffer persons and property from devastation by ocean forces, and the establishment of additional setback requirements to provide that structures located on oceanfront property be set back sufficiently and constructed in a manner so as to provide a useful life thereof, considering the perils of storm and sea.” **62.4206**

(Brevard County, 2022b)

> Seawalls, in general, are governed by Chapter 22. Buildings and Building Regulations.
>
> All alterations and repairs to seawalls where more than 50 percent of the seawall will be repaired or altered shall be considered new construction and shall meet the requirements of this article. Minor repairs not affecting the structural integrity of the seawall may be undertaken without a building permit. Sec. 22-601.
>
> Plans and specifications for seawalls proposed for construction of five feet or less in height on any manmade bodies of water may be designed in accordance with the minimum design criteria

contained in this article. For seawalls exceeding five feet in height, the plans and specifications shall be prepared, signed and sealed by an engineer registered in the state. Sec. 22-602.

The maximum height from top of cap to top of sand bottom of the water side of the seawall shall be five feet. Specifies minimum design standards for siting, piles, caps, and tiebacks. Sec. 22-603.

Coastal armoring on the open coast is further governed by Chapter 62. Land Development Regulations, Article XII Coastal Setback and Control Lines.

… the intent of this article to discourage the further construction of rigid coastal and shore protection structures, while allowing the state department of environmental protection to maintain jurisdiction and control over regulation of such structures. **Sec. 62-4205. Intent**

Rigid coastal and shore protection structures, such as seawalls, bulkheads, revetments, and mound structures, block the movement of sand from the dunes to the beach, thereby preventing the natural renourishment of the sandy beaches. This blockage of sand, coupled with the historical rise in relative sea level, could cause the loss of the natural sandy beaches, if allowed to occur. **Sec. 62-4206 (b) Policy.**

In addition to those permit application requirements and procedures for the issuance of a building permit by the county building official under the provisions of Chapter 22, any person desiring to construct seaward of the established county coastal construction control line shall satisfy … additional requirements. **Sec. 62-4208. Prerequisites for issuance of building permit.**

There is hereby established and exists a county coastal setback line (referred to in this article as the coastal setback line) for all property located within the unincorporated area of the county….also known as the 1981 FDEP Coastal Construction Control Line). **Sec. 62-4210. Coastal setback line established.**

Sandbag systems, beach renourishment projects, beach restoration projects, or to rigid coastal and shore protection structures that are either approved by the Board of County Commissioners in an emergency amendment to the coastal management element of the comprehensive plan or approved by the board of county commissioners for areas north of Patrick Air Force Base (PAFB) as a result of an emergency declared by the board. **Sec. 62-4211(b)(3) Exemptions to coastal setback line.**

Prohibited structures and activities seaward of coastal setback line. **Sec. 62-4212.**

a) No new major habitable or major accessory structures shall be constructed seaward of the coastal setback line.
b) No minor structures which are not pile-supported and elevated to a height sufficient to permit maintenance of dune stabilizing vegetation growing beneath the minor structure shall be constructed seaward of the coastal setback line.
c) All excavations, including the removal or alteration of soil, sand, or vegetation by digging, dredging, filling, drilling, cutting, scooping, or hollowing out shall be prohibited seaward of the coastal setback line. This subsection shall not preclude FDEP permitted sandbag systems for vulnerable structures as defined in section 62-4201, beach renourishment projects, beach restoration projects, or dune restoration projects, nor shall this subsection

preclude rigid coastal and shore protection structures approved by the board under an emergency amendment to the coastal management element of the comprehensive plan.

Permitted structures seaward of coastal setback line. **Sec. 62-4213.**

d) No new rigid coastal armoring or shoreline hardening structures shall be permitted in unincorporated Brevard County south of Patrick Air Force Base (PAFB) property or within the Archie Carr National Wildlife Refuge, unless an emergency amendment to the coastal management element of the county comprehensive plan authorizing the construction of such a structure is approved by the board of county commissioners in accordance with the review procedures applicable to such emergency comprehensive plan amendments as set forth in F.S. § 163.3187(a).
e) North of the PAFB, no new shoreline hardening structures should be permitted unless an emergency exists.
f) Where authorized by an approved emergency amendment to the coastal management element of the comprehensive plan pursuant to subsection (d) above or where an emergency exists pursuant to subsection (e) of this section, a shoreline hardening structure may be approved if the following standards are complied with:
    1) Vertical wood or concrete structures and rock revetments shall only be approved when less structural alternatives, such as beach renourishment, dune restoration, and sandbag systems have been determined not to be feasible.
    2) All shoreline protection measures shall be designed to minimize adverse impacts to the naturally functioning beach and dune system and adjacent properties.
    3) The county may require dune restoration and revegetation as a component of the shoreline hardening approval both landward and seaward of the proposed structure.
    4) All shoreline protection shall be designed and constructed to not impede public access to or along the shore.

# 4.2 Palm Beach County

Open coast shoreline in Palm Beach County is primarily limited to the local municipalities. No specific rules, regulations, or policies for seawalls on the open coast were found within Palm Beach County municipal code, except to define "Coastal local government body" as any local governing body which is duly constituted under the laws of Florida and whose geographical jurisdiction covers, includes, or borders the Atlantic Ocean. Such local bodies include, but are not limited, to coastal counties, coastal municipalities, and special taxing districts.

Many of these codes outline minimum design and siting requirements for seawalls along inland waterways, but not much is provided for seawalls on the open coast. A few of these local municipalities were explored further as follows.

City of Delray Beach

(City Commision of Delray Beach, 2023)

Delray Beach Code of Ordinances, Chapter 10 (Flood Damage Control and Coastal Structures), Article 10.3 (Flood Resistant Development):

> Other development in coastal high hazard areas (Zone V). In coastal high hazard areas, development activities other than buildings and structures shall be permitted only if also authorized by the appropriate federal, state or local authority; if located outside the footprint of, and not structurally attached to, buildings and structures; and if analyses prepared by qualified registered design professionals demonstrate no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to adjacent buildings and structures. Such other development activities include but are not limited to: **Sec. 10.3.7.(g)**
>
> 1. Bulkheads, seawalls, retaining walls, revetments, and similar erosion control structures.

### Town of Palm Beach

(Town of Palm Beach, 2023)

Palm Beach Code of Ordinances, Chapter 62 (Marine Structures), Article II (Article II. Bulkheads, Seawalls And Groins On Atlantic Ocean):

> All bulkheads shall be erected along the Official Ocean Bulkhead and Groin Plat of the Town of Palm Beach, Florida, except where the proposed bulkhead is to be located landward of the bulkhead line or except where the proposed bulkhead is no further than 12 inches seaward of the existing bulkhead. In cases where the proposed bulkhead is further than 12 inches seaward of the existing bulkhead, a variance shall be required pursuant to section 134-201. **Sec. 62-37.**
>
> Sec. 62-38. Construction specifications; fee.
>
> (b) Bulkheads and seawalls. **Sec. 62-38.**
>
> (1) Location and alignment. The east face of bulkheads and the most easterly projection of seawalls shall be on the designated bulkhead line.
>
> (2) Projections. The east face of bulkheads shall be without projections except at the top, where a cap or coping may be used. The transition from the face of the bulkhead to the outer face of the cap or coping shall not be abrupt.
>
> (3) Elevation of top. The top of bulkheads or of seawalls shall be at an elevation not lower than 14.34 feet above mean sea level, National Geodetic Vertical Datum, 1929.
>
> (4) Elevation of bottom. The bottom of bulkheads or of cutoff walls for seawalls shall be at an elevation not higher than 13.66 feet below mean sea level, National Geodetic Vertical Datum, 1929, when it is practicable to penetrate the underlying materials to this elevation. When the underlying material is sand, bulkheads and cutoff walls for seawalls shall have a penetration of not less than 12 feet into the sand.
>
> (5) Tightness. Bulkheads and cutoff walls for seawalls, shall, throughout their length, be impervious to the passage of sand.

(6) Presence of rock. If, in the construction of bulkheads and cutoff walls for seawalls, rock too hard for penetration is encountered, before required penetration has been attained the applicant will be required to give the town council satisfactory proof of its ability to penetrate the rock sufficiently (two-foot minimum) to provide a structure equally as stable as though no rock had been encountered and the structure had been built with the prescribed penetration in sand.

# 4.3 Miami-Dade County

Open coast shoreline in Miami-Dade County is primarily limited to the local municipalities (i.e. cities and towns). No specific rules, regulations, or policies for seawalls on the open coast were found within Miami-Dade municipal code.

A few of these local municipalities were explored further as follows.

### Key Biscayne

(Town of Key Biscayne, 2023)

Key Biscayne Code of Ordinances, Chapter 10 (Floodplain Management), Article III (Flood Resistant Development), Division 7 (Other Development), Sec. 10-99 (Other Development in Coastal High Hazard Areas (Zone V) and Coastal A Zones):

In coastal high hazard areas and Coastal A Zones, Development activities other than buildings and structures shall be permitted only if also authorized by the appropriate federal, state or local authority; if located outside the footprint of, and not structurally attached to, buildings and structures; and if analyses prepared by qualified registered design professionals demonstrate no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to adjacent buildings and structures. Such other Development activities include but are not limited to:

1. Bulkheads, seawalls, retaining walls, revetments, and similar erosion control structures **Sec 10-99(1).**

### City of Miami Beach

(City of Miami Beach, 2020)

City of Miami Beach Code of Ordinances, Subpart A (General Ordinances), Chapter 54 (Floods), Article III (Resilience Standards for Tidal Flood Protection), Chapter 54 (Minimum Elevations within Tidally Influenced Areas):

Establishes minimum elevation for new seawalls (on inland waterways), to ensure shoreline protection structures are designed with application of consistent standards that account for future tidal flood conditions and coastal water levels with predicted sea level rise. **Sec. 54-59. Purpose and intent**

This article is not applicable to oceanfront beaches or shorelines seaward of the Coastal Construction Control Line. **Sec. 54-60. Applicability.**

City of Miami Beach Code of Ordinances, Subpart A (General Ordinances), Chapter 54 (Floods), Article II (Floodplain Management), Division 4 (Provisions for Flood Hazard

Reduction), Chapter 54-51 (Standards for coastal high hazard areas (V-zones) and coastal A zones):

> Discusses coastal construction (namely habitable and non-habitable structures, but not shore protection structures) requirements for construction in coastal high hazard areas.

Specific municipal code related to armoring on the open coast were not found.

## City of Bay Harbor Islands

Similar to City of Miami Beach, municipal code and requirements were found related to coastal construction (namely habitable and non-habitable structures, but not shore protection structures) requirements for construction in coastal high hazard areas. Specific municipal code related to armoring on the open coast were not found.

## City of Bal Harbor

(City of Bal Horbour, 2023)

Sec. 8.5-15. Other development.

City of Bal Harbor Code of Ordinances, Chapter 8.5 (Flood Damage Prevention), Section 15 (Other Development):

> Other development in coastal high hazard areas (Zone V) and Coastal A Zones. In coastal high hazard areas and Coastal A Zones, development activities other than buildings and structures shall be permitted only if also authorized by the appropriate federal, state or local authority; if located outside the footprint of, and not structurally attached to, buildings and structures; and if analyses prepared by qualified registered design professionals demonstrate no harmful diversion of floodwaters or wave run-up and wave reflection that would increase damage to adjacent buildings and structures. Such other development activities include but are not limited to:
>
> 1. Bulkheads, seawalls, retaining walls, revetments, and similar erosion control structures **Sec. 8.5-15(d)(1)**

## City of Sunny Isle Beach

(City of Sunny Isle Beach, 2023)

> Other development in coastal high hazard areas (Zone V). In coastal high hazard areas, development activities other than buildings and structures shall be permitted only if also authorized by the appropriate federal, state or local authority; if located outside the footprint of, and not structurally attached to, buildings and structures; and if analyses prepared by qualified registered design professionals demonstrate no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to adjacent buildings and structures. Such other development activities include but are not limited to:
>
> 1. Bulkheads, seawalls, retaining walls, revetments, and similar erosion control structures **Sec. 161-17.(g)(1) Other development.**

## 4.4 Sarasota County

(Sarasota County, 2023)

Shore Protection Structures adversely affect Coastal Systems and the public's right of access along the Wet Sandy Beach. In order to minimize these adverse effects, a coastal setback variance for a Shore Protection Structure shall not be authorized unless it is found to be within the public interest. A hardening project or Shore Protection Structure that is found to be in the public interest shall not impede lateral public pedestrian access and shall minimize adverse impacts to coastal processes and resources, neighboring properties, and the values and functions of the beaches and dune systems and provide mitigation where determined by the Board of County Commissioners to be appropriate. Permanent disruptions to natural coastal processes and long-term erosion impacts shall be considered in deliberations. **Sec. 54-721**

Sarasota County has established a "Gulf Beach Setback Line (GBSL)" and prohibits construction seaward of this line without a variance. **Sec. 54-723.** The GBSL appears to be set at the FDEP "Old CCCL".

Variances for Shore Protection Structures (e.g. seawalls) requirements:

- Must be found to be necessary to protect property rights and found to be in the public interest pursuant to the Comprehensive Plan. In order for the proposed Shore Protection Structure to be found to be necessary and in the public interest, the request:
  - Does not adversely impede lateral public pedestrian access;
  - Protects upland structures from damage or destruction caused by coastal erosion. In determining whether a shore protection structure is necessary, the following factors are evaluated:
    - Whether buildings, roads, or public facilities have been damaged or destroyed.
    - Whether buildings, roads, or public facilities or infrastructure are directly and immediately threatened.
    - Historic erosion trends.
    - The rate of change in erosion; and
    - Other site-specific conditions, including but not limited to the presence of beach stabilizing vegetation, the height and configuration of the eroded bluff, the distance of structures from the eroding bluff, the potential for adverse impacts to neighboring properties, and the elevation and slope of the beach.
- Follows the principles of avoidance first and then minimization of adverse impacts to Coastal Systems and processes, neighboring properties, and the values and functions of Beaches and Dune Systems; and
- Provides mitigation where determined to be appropriate; and
- The proposed Shore Protection Structure Construction shall be approved only when less structural alternatives, such as and including but not limited to landward relocation or elevation of the upland structure, beach nourishment, dune/native habitat restoration and temporary sandbags have been demonstrated by the Applicant and to the satisfaction of the County determined not to be feasible and practical. Where feasible, alternatives to Shoreline Protection Structures shall be employed.

- The proposed Shoreline Protection Structure may be approved only for: (1) the protection of public infrastructure; or (2) when the Board determines that the Shore Protection Structure is necessary to protect property rights.
- A frangibility analysis for a Shore Protection Structure; and/or an engineering analysis of the structural stability or load capacity of a structure or foundation that has been prepared, signed, and sealed by a qualified professional structural engineer that is registered in the State of Florida. County interpretation of this language in the past has required the seawall to "fail" in a 15-yr storm (Perkinson, personal experience).

Has provisions for "Class I" and "Class II" emergency variances for temporary, emergency shore protection.

## 4.5 Volusia County

(Volusia County, 2023)

Regulates coastal construction activities that effect the beach and dune system and that may degrade its natural processes and functions. All such standards shall meet or be more restrictive than the Florida Department of Environmental Protection (FDEP) standards. Sec. 72-1051.

"Beach and dune permit" is required for armoring. Sec. 72-1053.

Considers the following when evaluating an application for armoring.

In determining whether the project is permittable under the provisions of this article, the EMD shall consider, but not be limited to, the following criteria:

- The necessity to conduct such coastal projects for potential benefits versus adverse impacts to the coastal system to include consideration of the feasibility factors contained in section 72-1056(a)(5) for armoring projects.
- The degree, if any, of interference or reduction of public access along the beach. There should be no loss or reduction to public access to the beach after construction and the impact to public access during construction must be minimized to the maximum extent practicable.
- For armoring projects, the distance (linear feet) of the project from existing adjacent, structurally sound seawall, bulkhead or revetment existing on the effective date of this article to determine if it is located in a predominately natural coastline (PNC) area or a predominately armored (non-PNC) area.
- The ability of armoring to achieve the purpose of stabilizing the upland dune system, thus protecting the upland structure from coastal erosion.
- The condition and design of armoring on either side of the proposed site.

Minimum standards for armoring Sec. 72-1056.

- All coastal armoring permits will be reviewed by the EMD for consistency with the Volusia County Sea Turtle Habitat Conservation Plan (HCP), Incidental Take Permit (ITP), and Division 12 of this article.
- All new and reconstructed armoring structures must be buried with an artificial dune at least four feet above the existing grade, at a slope no greater than three to one, and planted with

# Appendix A. Literature Review Summary

the appropriate native coastal vegetation. Requires maintenance of artificial dune or contribution to a trust if maintenance is deemed not feasible.

- All new and reconstructed dune systems shall be maintained by the property owner as long as the armoring structure is in place.
- The County may also allow for, but is not limited to, consideration of the following factors in determining the feasibility of armoring projects: (A) whether a non-armored project affords similar protections of an armored project, (B) impacts of historical accretion of sand along the beach and dune system, (C) historical tidal influence data, and (D) existing natural dune locations. However, in making a feasibility determination, the EMD will not consider cost, obstruction of view, or ease of access as determinative infeasibility factors.
- New seawalls must be placed at the current line of erosion or in line with adjacent coastal construction, whichever is furthest west.

Volusia County has an HCP for sea turtles (Ecological Associates, Inc., 2022) and an ITP (USFWS, 2020).

## 4.6 Walton County

(Walton County, 2023)

Establishes a Coastal Protection Zone (CPZ), restricts erosion control measures to only those that will enhance and protect the dune system **4.02.02**

Permits for seawalls: In coastal high hazard areas and Coastal A Zones, permitted only if also authorized by the appropriate federal, state, or local authority; if located outside the footprint of, and not structurally attached to, buildings and structures; and if analyses prepared by qualified registered design professionals demonstrate no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to adjacent buildings and structures. **4.09.16.G**

# 5. FLORIDA RULES, STATUES, AND POLICIES

Rules, Statutes, and policies for the State of Florida related to coastal armoring were identified and reviewed. Annotation of the literature reviewed follows.

## 5.1 Florida Statutes (F.S.)

(State of Florida, 2023a)

Florida State law requires property owners to obtain permits from the Department of Environmental Protection for any construction seaward of the coastal construction control line, defined as the land that is subject to 100-year storm surge, storm waves, or other unpredictable weather conditions. **161.041, F.S. (Permits required) and 161.053,F.S. (Coastal construction and excavation; regulation on county basis)**

Policy – The state recognizes the need to protect private structures and public infrastructure from the effects of coastal erosion. Beach nourishment, dune restoration, the landward relocation of structures, and coastal armoring are all effective strategies to mitigate the effects of coastal erosion. Coastal armoring, however, may negatively impact the integrity and natural functioning of the beach and dune system, and it may also increase the vulnerability of adjacent unarmored properties to storm damage. Due to the significant potential impacts associated with coastal, minimum siting and design criteria apply.

The state recognizes the need to protect private structures and public infrastructure from damage or destruction caused by coastal erosion, "until such time as the state takes measures to reduce erosion on a regional basis" for protection of private property and public infrastructure. **161.085, F.S. (Rigid coastal armoring structures)**

- Permits for present installations may be issued if it is determined that private structures or public infrastructure is vulnerable to damage from frequent coastal storms.
- Permits for future installations of coastal armoring structures may be issued contingent upon the occurrence of specified changes to the coastal system which would leave upland structures vulnerable to damage from frequent coastal storms.
- Permits for present installations of coastal armoring may be issued where such installation is between and adjoins at both ends rigid coastal armoring structures, follows a continuous and uniform armoring structure construction line with existing coastal armoring structures, and is no more than 250 feet in length.
- Emergency installation of rigid coastal armoring may be authorized by an agency, political subdivision, or municipality having jurisdiction over the impacted area for the protection of private structures or public infrastructure under certain criteria. The structure is considered temporary and must be removed unless a permit is subsequently issued by FDEP.

(State of Florida, 2023c)

Florida's Marine Turtle Protection Act – 379.2431, F.S.:

- Any application for a Department of Environmental Protection permit or other type of approval for an activity that affects marine turtles or their nests or habitat shall be subject to conditions and requirements for marine turtle protection as part of the permitting or approval process.
- Restricts the timing of coastal construction based on Florida's marine sea turtle nesting season.
- Requires recommendation for denial of permit applications if the activity would result in a "take".
    - "Take" means an act that actually kills or injures marine turtles and includes significant habitat modification or degradation that kills or injures marine turtles by significantly impairing essential behavioral patterns, such as breeding, feeding, or sheltering.

## 5.2 Florida Administrative Code (F.A.C)

(State of Florida, 2023b)

"Rigid Coastal Structures" are characterized by their solid or highly impermeable design or construction. Typically included within this category are groins, breakwaters, mound structures, jetties, weirs, seawalls, bulkheads, and revetments. (**62B-33.002 Definitions)**

A Coastal Construction Control Line (CCCL) Permit is required to construction coastal armoring seaward of the State's CCCL line, generally defined as the land that is subject to 100-year storm surge, storm waves or other unpredictable weather conditions.

To obtain authorization for coastal armoring, the armoring must be for the purpose of protecting an "eligible" structure and said eligible structure must be determined to be "vulnerable". **62B-33.0051 Coastal Armoring and Related Structures.**

"Eligible Structures" are located partially or wholly seaward of the coastal construction control line and include (**62B-33.002(12)**:

- Private "non-conforming" habitable structures (habitable major structures on a foundation not designed to withstand undermining by storm erosion (i.e., shallow pile or slab-on-grade)).
- Other major non-habitable structures whose failure would damage a habitable structure.
- Significant public infrastructure.

The eligible structure must also be "vulnerable" to damage from a 15-year return interval storm. The vulnerability analysis should take into account the effects of shoreline change rates, natural physical features, and existing manmade structures, (**62B-33.002(39))**. 62B-33.0051(1)(a)2, F.A.C. prescribes how vulnerability is determined. If the eligible structure is not currently vulnerable, but it is projected that the eligible structure will become vulnerable at some future date which falls within the authorized time limit of a permit, a permit may be issued authorizing the installation of armoring once the anticipated site condition changes occur (allowing time for construction and appropriate timing to avoid construction during marine turtle nesting season).

Armoring cannot be authorized if a funding and permits are in place for a beach nourishment project in the area scheduled to occur within the next 9 months. **62B-33.0051(1)(b)**

Armoring may be authorized, irrespective of eligibility and vulnerability criteria, to close a gap of not more than 250 ft between adjacent armoring under certain conditions. **62B-33.0051 (1)(a)(3)**

Design & Siting Criteria (**62B-33.0051(2)):**

- Armoring shall be sited and designed to minimize adverse impacts to the beach and dune system, marine turtles, native salt-tolerant vegetation, and existing upland and adjacent structures and to minimize interference with public beach access.
- Lateral public access to be maintained.
- Design for the anticipated runup, overtopping, erosion, scour, and water loads of the design storm event. Design procedures are available in the latest edition of the Department of the Army Corps of Engineers' Coastal Engineering Manual (EM 1110-2-1100), or other similar professionally recognized publications.
- All armoring shall be designed to remain stable under the hydrodynamic and hydrostatic conditions for which they are proposed. Armoring shall provide a level of protection compatible with existing topography, not to exceed a 50-year design storm.
- The construction will not result in a significant adverse impact.
- Armoring construction must be conducted in a way that provides protection to nesting sea turtles, hatchlings, and their habitat, pursuant to s. 379.2431, F.S.

## 5.3 Forms and Publications

(Florida Department of Environmental Protection, 2023)

This document is a short summary of the CCCL program rules and policies. The document summarizes relevant sections of 161 FS and 62B-33, FAC.

(Florida Department of Environmental Protection, 2022a)

This document details CCCL emergency permit requirements for local governments, state agencies, and public utilities engaged in post-storm response and recovery. The document summarizes relevant sections of 161 FS and 62B-33, FAC.

(Florida Department of Environmental Protection, 2022b)

This document details CCCL emergency permit requirements for private property owners and managers engaged in post-storm response and recovery. The document summarizes relevant sections of 161 FS and 62B-33, FAC.

(Florida Department of Environmental Protection, 2022c)

This document details CCCL emergency permit requirements for local governments, state agencies, and public utilities engaged in post-storm temporary coastal armoring. The document summarizes relevant sections of 161 FS and 62B-33, FAC.

(Florida Department of Environmental Protection, 2022d)

This document provides the 100-year combined total storm tide levels are excerpts from reports titled, “Combined Total Storm Tide Frequency Analysis”, prepared for each County with an established Coastal Construction Control Line (CCCL). This information is typically used when setting the first habitable floor elevation for structures.

(Florida Department of Environmental Protection, 2022e)

Emergency Authorization (amended) OGC No. 22-2816 For Repairs, Replacement, Restoration, And Certain Other Measures Made Necessary by Tropical Storm Nicole.

Nothing in here is relevant to the coastal armoring study, except to confirm that an EO was issued and would allow local authority for emergency armoring installations.

(Florida Department of Environmental Protection, 2022f)

Emergency Authorization OGC No. 22-2740 for Coastal Armoring in Volusia County Made Necessary by Hurricane Ian.

The EO waived the following CCCL rules as specified in Rule 62B-26.023, F.A.C. as a result of the storm for a specific geographic area, and for a limited time.

- Rule 62B-33.002(27), F.A.C.; defining the term “major reconstruction” as the complete or partial replacement or rebuilding to the original level of protection of a significant portion of an existing armoring structure which has failed or deteriorated. This waiver omits the reference to the original level of protection to allow for armoring structures to be built to a level other than the original level of protection.
- Rules 62B-33.002(12)(b)1., 62B-33.002(39), and 62B-33.0051(1)(a)1., F.A.C.; requiring that a structure be “eligible” in order to authorize a permit for coastal armoring.
- Rule 62B-33.0051(1)(b), F.A.C.; prohibiting a permit for armoring being issued where a beach nourishment, beach restoration, sand transfer, or other project which would provide protection for the vulnerable structure is scheduled for construction within nine months.
- This Emergency Final Order does not waive the requirement to obtain a permit under Rule 62B-33.0051, F.A.C.

(Florida Department of Environmental Protection, 2022g)

Information related to the Hurricane Ian Emergency Permitting Response for Volusia County.

Nothing in here is relevant to the coastal armoring study, except to confirm that an EO was issued and would allow local authority for emergency armoring installations.

(Florida Department of Environmental Protection, 2022h)

Emergency Authorization OGC No. 22-2602 For Repairs, Replacement, Restoration, And Certain Other Measures Made Necessary by Tropical Storm Ian.

Nothing in here is relevant to the coastal armoring study, except to confirm that an EO was issued and would allow local authority for emergency armoring installations.

(Florida Department of Environmental Protection, 2022i)

DEP Form 73-303 (New 09/22) Emergency CCCL Permit Application. (Application processed pursuant to Rule 62B-33.014, F.A.C.)

(Florida Department of Environmental Protection, 2022j)

This report documents the post-storm beach conditions and coastal impact of both Hurricane Ian and Hurricane Nicole.

H. Ian – 2.9 miles of major armoring damage, 2.9 miles of minor armoring damage.

H. Nicole – 4.4 miles of major armoring damage, 1.2 miles of minor armoring damage.

(Florida Department of Environmental Protection, 2021a)

Public informational document describing post-storm permit procedures for activities seaward of the CCCL. The document summarizes relevant sections of 161 FS and 62B-33, FAC.

(Florida Department of Environmental Protection, 2021b)

Section 161.551, F.S., requires state agencies, municipalities, counties, special districts, authorities, or other corporate bodies of the state, which commission or manage a construction project within the coastal building zone using funds appropriated from the state to conduct a sea-level impact projection ("SLIP") study.

At a minimum, Section 161.151 requires a state-financed constructor's SLIP study to include the following:

- A systematic, interdisciplinary, and scientifically accepted approach in the natural sciences and construction design in conducting the study.
- An assessment of the flooding, inundation, and wave action damage risks relating to the coastal structure over its expected life or 50 years, whichever is less. This assessment must:
- Take into account potential sea-level rise and increased storm risk during the expected life of the coastal structure or 50 years, whichever is less, and to the extent possible, account for the contribution of sea-level rise versus land subsidence to the relative local sea-level rise.
- Provide scientific and engineering evidence of the risk to the coastal structure and methods used to mitigate, adapt to, or reduce this risk.
- Use and consider available scientific research and generally accepted industry practices. Provide the mean average annual chance of substantial flood damage over the expected life of the coastal structure or 50 years, whichever is less.
- Analyze potential public safety and environmental impacts resulting from damage to the coastal structure including, but not limited to, leakage of pollutants, electrocution and explosion hazards, and hazards resulting from floating or flying structural debris.

- Alternatives for the coastal structure's design and siting, including discussion of how such alternatives would affect the potential public safety and environmental impacts assessed in the study, as well as the risks and costs associated with maintaining, repairing, and constructing the coastal structure.

Public Financing of Coastal Construction "SLIP Study Rule" – 62S.7, FAC

Slip study tool https://floridadep-slip.org/AboutSLIPStudies.aspx

(Florida Department of Environmental Protection, 2020a); (Florida Department of Environmental Protection, 2020b); (Florida Department of Environmental Protection, 2020c); (Florida Department of Environmental Protection, 2020d); (Florida Department of Environmental Protection, 2020e); (Florida Department of Environmental Protection, 2020f); (Florida Department of Environmental Protection, 2020g); (Florida Department of Environmental Protection, 2020h)

The Strategic Beach Management Plan (SBMP) are issued by region and overview FDEP's beach management programs, coastal emergency response activities, Florida's 66 coastal barrier inlets, list of beach restoration projects, sand resources, and innovative technologies.

These documents provide estimates of the linear feet of armored shoreline by region.  Other than that, there is no new information, data or policy discussions related to coastal armoring.

(Universty of Florida, 2020)

Website was not accessible.

(McNeal & Brantly, 2019)

A PowerPoint Presentation given at the Florida Shore & Beach Preservation Association (FSBPA) in 2019, summarizing the relevant sections of 161 FS and 62B-33, FAC.

Approx. 400 armoring permits issued since 1985.  Of those, approx. 60% issued since 2009. Of the permits issued since 2009, approx. 40% were in St. Johns County alone.

(Birr, 2019)

Remove from list. This is a website put together by a realtor and/or attorney trying to get business. The information appears correct but can't be sure.

(Florida Department of Environmental Protection, 2018)

DEP Form #73-100 (September 2018) Application For A Permit For Construction Seaward Of The CCCL Or 50-Foot Setback.  (Application processed pursuant to Rule 62B-33.008, F.A.C.)

(Byrne, 2018)

Bryne concludes "The permit data within the spreadsheet discussed below shows that most armoring permits in Florida are for bulkheads (seawalls) constructed from vinyl, wood, and concrete, with some utilizing steel. Most of the walls are built with tiebacks and return walls. Coastal armoring in Florida proves to be consistent with the generally accepted engineering practices and principles."

Based on a review of permit data and aerial imagery in South Ponte Vedra in St. Johns County, the author concludes:

- Distance Seaward of Building – Armoring structures along the study location in South Ponte Vedra were placed between 18.7 and 62.5 feet seaward of their respective upland structure. The armoring distance seaward of upland structures does not appear to show any trend of increasing or decreasing over time.
- The data shows an average return wall length of about 15 feet. There were three outliers of 0, 2, and 4 feet. Depending on the storm assessments for an area, this return wall length may be adequate for property protection. However, in the event of a major storm event, there is potential for properties to face damage if these walls are breached.
- Given the aerial imagery available through ArcMap, data representing the depth and length of adjacent flanking erosion was generally unavailable. The imagery was provided on an annual basis, which meant that often after one wall had been built, the following year's imagery would depict an adjacent wall, therefore offering no flanking erosion data to review.
- Offsetting armoring structures may increase the chances of property damage and flanking erosion, so it is important to ask whether pushing adjacent armoring landward, sometimes just five or six feet, to create a larger nesting ground for marine turtles is worth the risk of potentially greater damage to upland structures. A potential solution, which may reduce the conflicts that occur between homeowners and their neighbors, as well as the FWC, is to establish a standard coastal armoring line.
- Generally, roughly 20 feet between the upland structure and the placement site is needed to bring equipment into the construction zone and to implement a sufficient tieback system. The second factor that goes into placing a wall is the shore-normal width of loss for potential marine turtle nesting habitat. If armoring continues to be placed with lots of curves and offsets, a 20-foot separation may be okay. However, to make walls straight across properties and minimize flanking erosion, seawalls may need to be placed an extra 10-15 feet seaward of the building.

(Florida Department of Environmental Protection, 2017)

This document summarizes and breaks down the State's CCCL program policy and guidelines in layman's terms, summarizing the relevant sections of 161 FS and 62B-33, FAC.

(Florida Department of Environmental Protection, 2017)

This document defines and provides the elevation standards for habitable structures located seaward of a Coastal Construction Control Line (CCCL), and the instructions for completing the CCCL Elevation Certificate required within Section 3109 of the Florida Building Code.

(Florida Department of Environmental Protection, 2016)

This document summarizes and breaks down the State's coastal armoring policy and guidelines in layman's terms, summarizing the relevant sections of 161 FS and 62B-33, FAC.

(Williams, 2013)

This is a letter from USFWS to FDEP re-permitting of coastal armoring structures at Singer Island in Palm Beach County.

Since 2007 (to 2013 when the letter was written), FDEP has issued 9 seawall permits along approximately 1.1 miles of northern Singer Island.

USFWS writes to express concern that FDEP is issuing these permits without requiring the owners to secure an Incidental Take Permit (ITP).

The letter references in the in progress Statewide Beaches HCP, which would cover take of sea turtles for seawall projects.

(Walther, 2013)

This White Paper is to offer guidance to minimize the threat to turtle nesting habitat via the siting of seawalls as may be permitted by FDEP.

The paper discusses the feasible proximity of the wall to the upland structure based on the wall type (e.g. cantilever – 5 feet soil anchors – 5 feet vs. tie-back – 20 feet) for pile-supported structures.

The paper discussed the feasible proximity of the wall to upland structures based on wall type for slab on grade structures (e.g. cantilever – not recommended vs. soil anchors – 5 feet vs. tie-back 20 feet).

To minimize adverse impacts to nesting turtles and the beach-dune system, seawalls should be sited "as far landward as practicable", as required by FDEP rules. Such siting frequently results in seawalls being discontinuous and/or not in a straight line; however, it is not necessary for seawalls to be continuous or in a straight line to yield structurally stable seawalls to protect upland structures and minimize the adverse impacts of seawalls.

(Gregory, Zweig, & Gallagher, 2007)

A University of Florida study on Coastal Armoring Using Geotextile Tube Technology and its Impact on Sea Turtles and their Habitat. Geotubes are governed by Rule 62B-56, FAC and are not part of this study. Remove citation from list.

(PBS&J, 2005)

PBS&J was contracted by FDEP to complete a performance-based evaluation of coastal armoring structures located in Florida counties affected by the 2004 hurricane season. One tropical storm and four hurricanes made landfall in or near the State of Florida during the 2004 hurricane season: Tropical Storm Bonnie and Hurricanes Charley, Frances, Ivan, and Jeanne. The 2004 hurricane season resulted in significant beach erosion and widespread damage to coastal armoring structures throughout the state. As a result, the FDEP received requests for permits to repair approximately 13,284 feet of armoring structures and to build an additional 15,741 feet of new coastal armoring structure statewide.

This study included:

(1) data compilation and cataloging,
(2) performance analysis of selected armoring structures,
(3) an analysis of effects of selected armoring structures on surrounding beaches, and
(4) a comparison of the evaluation results with relevant previously published literature.

Findings and conclusions:

- The majority of failures were caused by undermining at the toe due to insufficient depth of foundation.
- Over wash scour, which eroded backfill from the crest of the structure, and flanking of the return walls, were another repeatedly observed factors leading to damage and failure of armoring structures.
- Unarmored shorelines lost more volume of sand in the landward portion of the profile when compared to armored shorelines.
- The survivability of the structure appears to be most dependent on specific structural information such as the design, the construction method, the age of structure and level of maintenance, and the condition of the beach fronting the structure.
- Increased erosion to unarmored properties in the vicinity of the structure returns was observed.
- Seaward portions of the profile fronting seawalls and revetments showed more loss in elevation than corresponding unarmored shorelines.
- Unarmored shorelines exhibited larger dune recessions than armored shorelines, where the structure remained intact.
- The slope of the seaward portion of the profile was steepest for seawalls, less steep for revetments, and mildest for unarmored stretches of shorelines.
- The structure has an increased effect on the shoreline with increased length of structure alongshore and distance placed offshore.

(Thompson, Lin, & Dean, 1994)

The report summarizes results of wave tank experiments conducted at University of Florida in the early 1990s to compare erosion models and effects of seawalls for the CCCL (i.e. investigating the interaction between the seawall and beach profile in the area adjacent to the seawall).

The modeling calibrates based on seawalls located in Palm Beach County.

This document summarizes the Interim Report #1 which focuses on analysis of sediment size (a "course" profile (median 0.18mm) and a "fine" profile (median 0.09mm). This portion of the study concluded:

- General seaward sediment transport trend for both profiles.
- Similar accretionary trends in front of the seawall prior to peak storm surge elevation for both profiles.
- At peak storm surge elevation, erosion occurred. Erosion trend occurred approx. 36 minutes earlier in the fine profile as compared to the course profile.
- After peak surge, the course profile recovered leaving a higher sand level at the seawall toe than before model surge.
- After peak surge, the fine profile did not recover and the sand level at the seawall toe was lower than before the storm.
- At the seawall toe, the maximum decrease in sand level was 1.3 meters for the course profile and 1.5 meters for the fine profile.

(Charles, Lin, & Dean, 1994)

The report summarizes results of wave tank experiments conducted at University of Florida in the early 1990s to compare erosion models and effects of seawalls for the CCCL (i.e. investigating the interaction between the seawall and beach profile in the area adjacent to the seawall).

This document summarizes the Interim Report #3 which focuses on the effects of time-varying storm surge conditions as well as different wave types (regular vs random). This portion of the study concluded:

- Severe erosion landward of the seawall occurs when water overtops the seawall at times of elevated SWLs. The magnitude of this erosion increases with higher water levels and with longer time durations of elevated water levels.
- If the SWL intersects the sand beach, local accretion occurs and there is no change in the profile landward of the seawall. If the SWL intersects the seawall and the beach is totally submerged, then local scour occurs at the seawall toe and erosion occurs landward of the seawall. The magnitude of this erosion increases with higher water levels and with longer time durations of elevated water levels.
- Overall, it appears wave type has little influence on the resulting profile given the time-varying severe sea conditions modeled in the experiments.

(Lin, Zheng, & Dean, 1994)

The report summarizes results of wave tank experiments conducted at University of Florida in the early 1990s to compare erosion models and effects of seawalls for the CCCL (i.e. investigating the interaction between the seawall and beach profile in the area adjacent to the seawall).

This document summarizes the Interim Report #4 which focuses on the effects of model beach profile responses with and without seawall, and with seawall failure during the peak surge level interval. This portion of the study concluded:

- When a seawall is present in the model, it seems to provide sufficient protection to the model beach profile behind the seawall; however, it induces significant erosion in the area in front of the seawall with scour at the toe, particularly during the peak SWL stage. This significant erosion is caused by the reflect of waves at the seawall.
- When no seawall is present, the erosion can be significant in the area landward of the MSL. Seaward of this erosive area, erosion is quite small.

(Demas, Lin, & Dean, 1994)

The report summarizes results of wave tank experiments conducted at University of Florida in the early 1990s to compare erosion models and effects of seawalls for the CCCL (i.e. investigating the interaction between the seawall and beach profile in the area adjacent to the seawall).

This document summarizes the Interim Report #5 which focuses on the effects model beach profile responses with and without seawall, and with seawall failure during the peak surge level period. This portion of the study concluded:

- Behind the seawall, the depth of scour adjacent to the seawall and the nearby erosion are the least for the highest seawall and the greatest for the lowest seawall. Erosion patterns behind the seawall are observed to be dependent upon initial profile. In front of the seawall, the greatest scour depth occurs for the lowest seawall at maximum surge level.
- In front of the seawall, the trend of erosion depth tends to be greatest for a no failure condition and increases with increasing degree of failure. Behind the seawall, the trend displays that erosion depth is least for the no failure and increases to the condition of total failure.

- Seawall toe protection results in improved model performance with decreased scour in front of the wall.

(Srinivas & Dean, 1994)

A University of Florida study comparing 3 cross-shore erosion models: CCCL, EDUNE and SBEACH using field (Palm Beach County) profiles vs. wave tank tests profiles. This study is not relevant to the coastal armoring policy work.

(Srinivas, Dean, & Parchure, 1992)

A University of Florida study was completed with the aim of simulating the effects of over wash on barrier islands with seawalls and characterizing their response based on wave tank experiments.

With the seawall located at the slope break between the crest and the sloping beach, and the crest of the seawall just submerged in sand, the effects on the sediment transport process were found to be minimal. For the same position for the wall but with the crest of the seawall raised above the ground level, overtopping caused wash over of sand indicating substantial sediment transport in suspension.

Positioning the seawall at the MSL shoreline caused significant scour both immediately landward as well as immediately seaward of the seawall.

The study concluded that seawalls need to be located adequately landward of the shoreline to discharge their function effectively without adverse effect to the beach. In addition, concerns for safety warrant the presence of an adequate buffer-zone between the seawall and upland property.

# 6. FWC (TURTLES)

Studies from the Florida Fish and Wildlife Conservation Commission (FWC) related to armoring and effects on marine turtles were identified and reviewed. Most of the literature found is published by FWC's Fish and Wildlife Research Institute (FWRI). The Institute studies the impacts of "barriers to nesting" which includes, among many other barriers, coastal armoring. Annotation of the literature reviewed follows. General conclusions include:

- Seawalls are the most common potential barriers in all but the northwest region, where sand fences were most common.
- The threat for nesting sea turtles posed by seawalls *may* lie in a reduction of nesting habitat, in an elevation of the physiological cost of nesting, and in displacement of turtles into nesting habitat that is sub-optimal.
- Overall, the authors found there were fewer successful nesting emergences in front of the various armoring structures than in the non-walled "natural" areas.
- The authors notes that problems associated with coastal armoring and nesting marine turtles are complex and span many disciplines of knowledge, all of which must be integrated.

Annotation of the literature reviewed follows.

(FWC, 2023)

This is a very brief public informational website which states that FWC's Fish and Wildlife Research Institute (FWRI) conducts research to assess the extent of coastal armoring structures on marine turtle nesting beaches and the effects of these structures on marine turtle nesting behavior. The site further states that the results will assist marine turtle management staff in efforts to minimize impacts from future coastal armoring construction projects.

No new information.

(Ecological Associates, Inc., 2022)

This is an HCP for seawall turtle commissioned by Volusia County. Does not appear to include authorized take for new construction of seawalls.

"Coastal armoring is known to have both direct and indirect effects on nesting and hatchling sea turtles (National Research Council 1990). In general, the quality of nesting habitat is degraded by the presence of these structures on the beach. Over 21 percent (145 miles) of Florida's beaches are armored (NMFS and USFWS 1991a and b)."

"In Volusia County, it was estimated that as of 2001, there were 132 armoring structures collectively encompassing slightly more than 14 miles of shoreline (Revetments are considered to be an unacceptable form of beach armoring since they take up more space on the beach, are an impediment to pedestrian beach access, and are more vulnerable to storm damage."

"Armoring was responsible for nearly one-quarter of all non-nesting emergences (false crawls) on Volusia County's beaches (in 2020/21)."

“Seawalls can effectively eliminate a turtle’s access to upper regions of the beach/dune system. Consequently, nests on armored beaches in Brevard and Indian River Counties were generally found at lower elevations than those on non-walled beaches. Lower elevations subject nests to a greater risk of tidal inundation and can potentially alter thermal regimes, an important factor in determining the sex ratio of hatchlings (Mrosovsky and Provancha 1989, Mrosovsky 1994, Ackerman 1997, Delpech and Foote 1998). For these reasons, the U.S. Fish and Wildlife Service considers armoring structures to cause take of sea turtles.”

“Where seawalls end abruptly, the corners can develop localized edge effects that also adversely impact downdrift natural beaches.”

Table 29 “Variations in Nesting and Shoreline Armoring Among Beach Management Areas, Volusia County Beaches, 2017-2021” compares nesting success for armored vs unarmored beaches. Natural areas have an average nesting success of approx. 52.59% while armored is 45.25%. There is a transition area with average nesting success of 50.32%.

(USFWS, 2020)

This is an Incidental Take Permit (ITP) issued by USFWS for Volusia County. The ITP covers take associated with emergency shoreline protection. While the ITP does not specifically address take due to armoring under non-emergencies, this is covered in the HCP.

(Witherington, Hirama, & Mosier, Barriers to Sea Turtle Nesting on Florida (United States) Beaches: Linear Extent and Changes Following Storms, 2011)This report is authored by employees of the FWC FWRI. This appears to be an update on an earlier study (Witherington, Hirama, & Mosier, Linear Extent of Coastal Armoring and Other Barriers to Sea Turtle Nesting on the Beaches of Florida USA, 2003).

To assess nesting habitat quality, the authors randomly selected beaches totaling 80.45 km in each of four regions of Florida (northeast, southeast, northwest, and southwest) and surveyed them for potential barriers to nesting during the period of April 2001 to May 2002 (total surveyed coastline 321.8 km). Potential barriers to nesting were found in 78 forms on sampled beaches, including seawalls, revetments, sandbags or tubes, sand fences, access structures, recreational equipment, and buildings.

For all regions, the potential barriers to nesting occupied 18.0% of the total surveyed beach length. The region with the greatest extent of potential barriers was southeast (23.8%), followed by southwest (21.7%), northwest (14.1%), and northeast (12.3%). Seawalls were the most common potential barriers in all but the northwest region, where sand fences were most common.

Following coastal effects from four major hurricanes that made landfall in 2004, the team resurveyed 16 km of beach in each region (total 64 km). They recorded a net reduction of sand fencing in northeast and northwest Florida and a net reduction of revetment rocks in the southwest region due to covering by sand. However, the linear extent of barriers increased in northeast and southwest due to seawall construction and additional sand fencing.

The impacts of these barriers, including seawalls, on sea turtles was not included in the study.

(Witherington, Hirama, & Mosier, Linear Extent of Coastal Armoring and Other Barriers to Sea Turtle Nesting on the Beaches of Florida USA, 2003) (Mosier & Witherington, 2002)

This report is authored by employees of the FWC FWRI.

The authors randomly selected beaches totaling ~24% of the shoreline encompassing four regions of Florida (northeast, southeast, northwest, and southwest) and surveyed them for potential barriers to nesting between April 2001 to May 2022. The barriers included seawalls, anthropogenic rocks, geotextile tubes, sandbags, and sand fences.

For all regions, the potential barriers to nesting occupied 18.0% of the total surveyed beach length and noted approximately 14% of the shoreline contained barriers to nesting. Seawalls were the most common potential barriers in all but the northwest region, where sand fences were most common. The region with the greatest barriers was southeast Florida, followed by the southwest, northwest and northeast. South Florida had four times the linear extent of seawalls in comparison with north Florida beaches.

The impacts of these barriers, including seawalls, on sea turtles was not included in the study.

(Mosier & Witherington, 2002)

This report is authored by employees of the FWC FWRI.

Florida beaches host approximately 95% of all the sea turtle nesting in the continental United States (Turtle Expert Working Group, 1998).

(Mosier, 1998)

The threat for nesting sea turtles posed by seawalls may lie in a reduction of nesting habitat, in an elevation of the physiological cost of nesting, and in displacement of turtles into nesting habitat that is sub-optimal (e.g., a lower beach elevation where eggs would drown; Murphy, 1985).

This study was conducted during the 1999 nesting season comparing the effects of different types of armoring structures, placed on various parts of the beach. The authors objectives were to map and characterize the dune (vegetation, armoring structures, topography) on a two-mile stretch of nesting beach in order to analyze the nesting attempts by loggerhead turtles. These data were used to test the hypotheses that predict nest-site choice and nesting behavior dependence upon dune character (e.g. the presence of armoring)

Overall, the authors found there were fewer successful nesting emergences in front of the various armoring structures than in the non-walled “natural” areas. They report differences in the nesting success on the beaches with walls and no walls ($P < 0.0001$).

The author notes that problems associated with coastal armoring and nesting marine turtles are complex and span many disciplines of knowledge, all of which must be integrated.

(Mosier A. , 1998)

Thesis not available for review; however, is cited in other publications by authors Mosier and Witherington concluding that seawalls were shown to have had detrimental effects on sea turtle nesting.

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# Appendix B. Interview Questions and Response Summary

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# APPENDIX B: INTERVIEW QUESTIONS AND RESPONSE SUMMARY

# INTERVIEW QUESTIONS

**Interview Purpose:** To gain an understanding of stakeholders' perspectives regarding the existing armoring guidelines and how stakeholders view the future of the program.

**Interview Questions:**

1. Describe your experience or role related to 1) coastal armoring and 2) beach management … (engineer, consultant, scientist, regulator, etc.)
2. What do you see as the main concerns with Florida's current approach to regulating and managing coastal armoring? What is working well?
3. What is your experience with property owners and their concerns about coastal erosion? How do property owners view the permitting process?
4. Describe examples of challenges you have faced when permitting armoring structures in the CCCL program.
5. What conflicts between local regulation and CCCL armoring regulations have you experienced?
6. What is your experience and perspective on emergency permitting, or under Emergency Orders, for armoring structures? Please share any lessons learned or modifications you would suggest for future storms.
7. What is your experience with armoring structures and their interaction with engineered beach and dune projects?
8. How can Florida better regulate and manage armoring as part of a broader set of strategies for responding to sea level rise and coastal hazards.
9. Are there other modifications to the CCCL armoring program that you would suggest?
10. Please provide any other comments or suggestions for consideration.

# RESPONSE SUMMARY

In support of the Coastal Armoring Policy Study, interviews were conducted to gain insights into stakeholders' perspectives regarding the existing CCCL armoring guidelines and their views on the future of the program. In consultation with FDEP, six interviewees were selected from a range of backgrounds in coastal armoring and beach management, including consultants and local municipalities and independent interest groups. The interviews were carried out in June 2023.

A list of open-ended questions was prepared by Atkins then reviewed and approved by FDEP. The questions were sent to the interviewees in advance of the interview (attached). Atkins, joined by representatives from FDEP, conducted the interviews with the intention of facilitating open and honest dialogue. The information collected will assist in developing an understanding of stakeholder experiences, expectations, and recommendations to be summarized in a final report.

The responses received through these interviews are summarized herein, organized by the study's focus areas which are:

- Sea Level Rise and Resilience Considerations in Armoring Design and Policy
- Minimum Design Standards and Considerations for Armoring
- Gap Size
- Protection of Pertinent Structures
- Proactive Armoring
- Siting and Design Considerations with respect to impacts to sea turtles
- Line of Coastal Construction for Armoring

Additional topics of discussion, with feedback from the stakeholders, include:

- Emergency Orders
- Integrated Beach Management
- Other

## Sea Level Rise and Resilience Considerations in Armoring Design and Policy

1. Seawall Resilience:
    - As-built records of seawalls often don't exist, so the condition and design are largely unknown until exposure and/or failure. Homeowners are typically unaware of the condition of an existing seawall due to lack of efficient inspection methods. The invisible, and often unknown nature of existing seawalls structure, including tie-rods, depth of wall, etc, pose significant challenges for easy assessment.

- Current regulations only permit initial installation of seawalls, lacking provisions for regular maintenance. This leads to catastrophic failures when seawalls malfunction due to the absence of maintenance options. Current regulations hinder effective maintenance and improvements.
- Interviewees perceive the process for reconstructing or replacing existing seawalls as too restrictive or not allowed under existing rule. Reconstruction or repairs are often necessary but difficult to permit, even if a wall has been in place for a long time. It was noted that impact of these seawalls has already been realized due to the fact that they had been in the coastal system for a while.

2. Sea Level Rise (SLR):
   - In general, the interviewees agreed that statutes and rules, and the implementation of those rules, aren't keeping pace with SLR.
   - It is essential to incorporate SLR considerations into storm frequency assessments to better understand vulnerability.
   - The CCCL program should incorporate SLR considerations into assessments of eligible structures and design standards for long-term sustainability and resilience.
   - While there are minimum wall height regulations (local governments) accounting for SLR in intracoastal waterways, no such provisions exist for seawalls on the open coast.
   - Interviewees suggest that the surge levels used to determine vulnerability are outdated, necessitating updates to accurately assess coastal risks.
   - There is currently no widely accepted procedure for incorporating future sea level rise into storm erosion models and hydrographs, leading to uncertainties in predictions.
   - Many local comprehensive plans inadequately address sea level rise, and interviewees perceive a lack of acknowledgment from local leadership regarding this critical issue.
   - An interviewee suggested FDEP select a SLR projection estimate and adopt it across the board for use in the CCCL program in design, models, etc.

# Minimum Design Standards and Considerations for Armoring

3. General:
   - Current regulation specifies a maximum design but interviewees generally suggested a minimum design standard is more appropriate.
   - There are currently different design standards for major reconstruction, gap closure and new construction. The interviewees suggested this disconnect be resolved.
   - The interviewees suggested minimum standards should incorporate SLR, and further suggested adopting a standard SLR estimate. One interview specifically suggested adopting the IPCC Expected rate.
   - Develop design standards for protective value (i.e. design storm) as well as design life (materials and robustness). Should walls be designed to withstand a series of events or a single event?
   - Oftentimes local government and building officials have no education or experience to review armoring applications. Florida Building Code provides no minimum standard. These same officials

are often fielding questions from residents on how to build, permit, and construct coastal armoring systems.

- Cantilevered walls are not always an option, particularly in SE Florida in areas with large dunes.
- Interviewees discussed case studies of failures following storm events, many of which were related to toe failure due to insufficient embedment depth.
- One interviewee suggested approval of a new wall should come with the obligation to place sand as needed at the end of a wall to mitigate potential erosive end effects.

4. Reconstruction:
   - Reconsider height of wall for reconstruction to incorporate SLR.
5. Return Walls:
   - Very little engineering guidance is available for length, alignment (curvature), and siting (close to eligible structure vs property lines) of return walls.
   - On stretches of continuous armoring spanning multiple properties, guidance and/or regulation is needed on how frequently to install return walls. In many cases, return wall use and length comes down to an economic, as opposed to engineering, decision.

# Gap Size

6. All interviews suggested modification of the Gap Rule is warranted. Generally, the 250 ft limitation in the "gap rule' appears arbitrary. Interviewees suggested changing the size of the gap length.
7. A suggestion for the gap length was to limit it to the parcel length(s)
8. A suggestion for the gap length was to make it a ratio of gap length to the armored shoreline in the area.
9. Several interviewees suggested removing the requirement for an eligible structure for reconstruction/replacement or closure of a gap.
10. Interviewees found it very limiting that the current Gap Rule requires the gap to be unarmored even if the existing wall will be reconstructed and otherwise would quality for a gap closure if the wall did not exist.

# Protection of Pertinent Structures

11. Interviewees recognize the need to protect pertinent structures with armoring (upon meeting established vulnerability criteria). Types of pertinent structures may include septic systems, parking facility, electrical conduit route, and access roads.

**Proactive Armoring**

12. The perception amongst the interviewees is that new armoring in Florida is fairly rare except in the instances of two significant storm events on the East Coast in recent years which have spurred locally widespread needs for armoring in St Johns County and Volusia County.
13. In reference to rule language that armoring cannot be permitted if there is a funded beach nourishment project. The interviewees suggested there are situations where this may not make sense. For example, a roadway should have protection by armoring as a last line of defense. Other

cases this makes sense is areas where nourished beach width is limited (due to nearshore hardbottom or otherwise).

14. The interviewees generally perceived the armoring program as reactive and, on a case-by-case basis.
15. One interviewee stated, “waiting until a structure is at risk from a 15-year event (described as a reactive “crisis mode”) may not be the most effective approach for assisting owners and ensuring the resilient and sustainable protection.”
16. One interviewee suggested planning out the next 30-40 years of the coastal armoring program, noting that CCCL Armoring Proactiveness differs from beach management proactiveness.
17. One interviewee requested to see a statewide map containing layers with critical erosion areas, beach nourishment, and coastal armoring.
18. The general consensus and feedback from property owners is that erosion is critical; however, the local government isn’t doing and/or isn’t moving fast enough with a beach project. Owners in these locations are the ones that typically end up pursuing armoring.

# Siting and Design Considerations with respect to impacts to sea turtle

19. Multiple interviewees suggested there needs to be better transparency for site planning with FWC and stated that the data that FWC uses in decision making should be transparent and easily accessible for review.
20. The perception amongst many of the interviewees is that sea turtle nesting habitat is ambiguously defined by FWC and does not appear to have a set standard. FWC has been modifying designs or forcing engineers to modify their designs, and it's all coming from a completely environmental basis, and there's no engineering being considered. Interviewees suggest FDEP taking over FWC's responsibilities for sea turtle protection during permitting.
21. One interview raised the point that cantilevered walls are not always an option, particularly in SE Florida in areas with large dunes.
22. Multiple interviewees discussed the difficulty completing construction of armoring projects outside of sea turtle nesting season (not enough time).
23. In SE Florida there is oftentimes very limited access for heavy equipment to access the beach and install a seawall.

# Line of Coastal Construction for Armoring

24. The interviewees generally agreed that a seawall/bulkhead line is a great idea in certain localities before emergency situations exists.

# Emergency Orders (EO)

25. Due to the uncertainties with EOs and efficiencies of CCCL application processing, consultants oftentimes will seek a full permit as opposed to installation of a way under the EO.
26. Education by FDEP to public / property owners on EOs as well as regular CCCL armoring applications is needed. In particular, smaller local communities don't have the expertise or resources to navigate the EO process. Suggests improvements in coordination and assistance to local governments during the EO process.
27. During the last EOs issued after H. Ian and H. Nicole in 2022 a few views were shared:
    - Public awareness and involvement by FDEP during the 2022 storm season about EOs was unprecedented and very successful.
    - There was concern that state and local requirements for armoring were all being waived.
    - EO authorizations were restrictive. This suggests more robust options for temporary stabilization measures.
28. Challenges during EOs includes:
    - Biggest challenge during EO permitting is obtaining a survey to meet the CCCL program requirements in an expedited fashion and in bulk. Not enough surveyors to do the work. Would like for a survey to be taken by state to serve as input into model. Difficult for homeowners to obtain survey after storms. LIDAR data can be provided to surveyor to be repurposed for site survey.
    - Many property owners were taken advantage by contractors and consultants, especially during EO situations.
    - The inability for engineers/contractors to be secured and then once secured to produce adequate plans for permitting created a painfully slow process for EO approval.
    - Once permits were obtained, the contractors have experienced delays obtaining materials for both temporary and long-term protection, and reportedly the costs for the materials and labor doubled or tripled year over year. Additionally, the costs of beach compatible sand skyrocketed.
    - One interviewee stated "It remains unclear to me if FDEP is allowing a lesser costly backfill material behind newly constructed seawalls, but that point has been repeatedly discussed and may be worthy of clarification. I know the supply chain and inflation pressures are well known, but the impact they have had on our recovery could not be emphasized enough in my opinion."

# Integrated Beach Management

29. A healthy beach and dune system in front of coastal armoring is essential to beach management, leaving the armoring as a last line of defense. Some interviewees suggested that the CCCL program collaborate more effectively with the Beaches & Ports program. If the goal is to minimize the use of armoring and/or minimize the influence armoring on the beach dynamics, the State needs to improve long-term beach maintenance, making armoring the last line of defense.
        - Adjacent to Ponce Inlet is a good example of a successful beach management program on an armored shoreline. During Nicole, the armoring served a last line of defense.

30. Seawalls do not preclude or discourage beach management (sand placement).
    - Examples: Jupiter Island, Palm Beach and Cocoa Beach where the shoreline is heavily armored but also with healthy beach management programs.
31. If beaches are allowed to be undernourished, there will be a need for armoring.
    - Singer Island is a good case study for a beach which is undernourished, requiring the vast majority of shoreline to be armored. This area has a 20-year beach management program history but they are limited in the quantities of sand that can be placed due to nearshore hardbottom.
32. In many locations in SE Florida, hardbottom influences the amount of sand that can be placed which can increase the need for armoring. The State may consider ways to better balance the use of armoring vs impacts to hardbottom due to sand placement.
33. One interviewee referenced Brevard County, stating that there is a healthy beach and dune system maintained by the County, with a prohibition of seawalls in unincorporated areas of the County.
34. In areas that don't qualify for beach management funding from the State (either due to lack of critical erosion designation, or no public access), owners will pursue armoring mostly because self-financing a nourishment or restoration is more expensive than armoring.
35. It was noted that it is important to keep in mind that armoring is used to protect structures and infrastructure, not to protect a beach and dune system and/or public.
36. On interviewee suggested "pre-fills" or placement of sand adjacent to seawalls as a matter of practice.
37. Retreat is not the only answer but should be a part of the discussion of long-term beach management.

# Other

38. The average ownership period for coastal properties is around 10 years. There is a lack of awareness among the public and buyers regarding coastal issues as well as a lack of inspection services occurring for seawalls.
39. Public / property owners are generally uneducated on CCCL armoring requirements, and underestimate the time and complexity of obtaining a permit.
40. Local codes vs CCCL program mostly congruent in SE Florida except for the reconstruction.
41. No conflicts noted between local regulations (NE Florida) and CCCL regulations.
42. New Smyrna Beach has its own coastal control line, which is more restrictive, and by way of its location no coastal armoring permits can be authorized as there are no eligible structures (i.e. seaward of the State's CCCL).
43. Volusia County requires a perpetually maintained dune (4 ft high) as part of any seawall application at the local level (rule enacted in the 90s). The County oftentimes will defer this requirement for 3 years on new installations, and oftentimes cannot enforce in situations since there is no width for a dune due to MHW location. In the case of the latter, the County allows the property owner to contribute to a county managed fund for future restoration.
44. Interviewee suggested that the State not preempt what the local governments already have in place. State should provide minimum requirements.
45. Brevard County is unique in that the local comprehensive plan for unincorporated county prohibits coastal armoring along open coast shoreline (except sand filled geotextile containers). Brevard County has a program

for dune restoration on county shorelines and as an unofficial policy places “extra” sand adjacent to seawalls to help mitigate end effects.

46. City of Satellite Beach allows rip rap but not seawalls. This creates a challenge as the perception is FWC strongly prefers seawalls over sloped structures due to the larger footprint required (taking nesting habitat) for the latter.
47. Noted that the current State armoring regulations require “proof” that a seawall will not adversely impact adjacent properties, but (very generally) FDEP questions the proof that is provided.
48. After the 2004 hurricanes, a few sand filled geotextile container projects were constructed with a requirement to maintain sand cover. Many of these were subsequently removed by the owners because they were too expense to keep covered with sand.
49. Brevard County has a setback with is 25 ft landward of the old CCCL whereby all construction is prohibited seaward of this line except sand placement.

AtkinsRéalis

Christin Perkinson, PhD, PE, BC CE
**AtkinsRéalis**
3522 Thomasville Road, 5th Floor
Tallahassee, FL 32309

Tel: +1 850 575 1800
Fax: +1 850 575 0105
Christin.Perkinson@atkinsrealis.com