CITY OF CARMEL-BY-THE-SEA
PLANNING COMMISSION AGENDA

Planning Commissioners Mel Ahlborn, Stefan Karapetkov, Michael LePage, Stephanie Locke, Kevin Ruess
Forest and Beach Commissioners Sarah Berling, Kelly Brezoczky, Tamara Michie, Harry Ross, and Neal Rutta

All meetings are held in the City Council Chambers
East Side of Monte Verde Street between Ocean and 7th Avenues

Special Meeting
Wednesday, August 19, 2026
4:00 PM

HYBRID MEETING ATTENDANCE OPTIONS
This meeting will be held in person and via teleconference ("hybrid"). The public is welcome to attend the meeting in person or remotely via Zoom, however, the meeting will proceed as normal even if there are technical difficulties accessing Zoom. The City will do its best to resolve any technical issues as quickly as possible. To view or listen to the meeting from home, you may also watch the live stream on the City's YouTube page at: https://www.youtube.com/@CityofCarmelbytheSea/streams. To participate in the meeting via Zoom, copy and paste the link below into your browser.

https://ci-carmel-ca-us.zoom.us/j/82811967060?pwd=VY1s4zZPAWx18aVIhpI7zJwMDnO2SF.1
To attend Zoom webinar via telephone, dial +1 (669) 444-9171, Webinar ID: 828 1196 7060, Passcode: 001916

HOW TO OFFER PUBLIC COMMENT
The public may give public comment at this meeting in person, or using the Zoom teleconference module, provided that there is access to Zoom during the meeting. Zoom comments will be taken after the in-person comments. The public can also email comments to sgorman@ci.carmel.ca.us. Comments must be received at least 2 hours before the meeting in order to be provided to the legislative body. Comments received after that time and up to the beginning of the meeting will be made part of the record.

CALL TO ORDER AND ROLL CALL

PUBLIC APPEARANCES

Members of the public are entitled to speak on matters of municipal concern not on the agenda during Public Appearances. Each person's comments shall be limited to 3 minutes, or as otherwise established by the Chair. While stating your name is optional, it helps to identify speakers in the meeting minutes. Under the Brown Act, public comment for matters on the agenda must relate to that agenda item, and public comments for matters not on the agenda must relate to the subject matter jurisdiction of this legislative body. Remote or in-person participants who do not comply with the requirements of the Brown Act will be muted.

ANNOUNCEMENTS

CONSENT AGENDA

Items on the consent agenda are routine in nature and do not require discussion or independent action. Members of the Commission or the public may ask that any items be considered individually for purposes of Board/Commission discussion and/ or for public comment. Unless that is done, one motion may be used to adopt all recommended actions.

1) January 29, 2026 Special Joint Planning Commission & Forest and Beach Commission Meeting Minutes

ORDERS OF BUSINESS

2) Review of the Administrative Draft SLR and Coastal Hazards Chapter of the Local Coastal Program (LCP)

FUTURE AGENDA ITEMS

3) Next Regular Meeting of the Planning Commission: August 19, 2026

4) Next Regular Meeting of the Forest & Beach Commission: August 20, 2026

ADJOURNMENT

This agenda was posted at City Hall, Monte Verde Street between Ocean Avenue and 7th Avenue, Harrison Memorial Library, located on the NE corner of Ocean Avenue and Lincoln Street, the Carmel-by-the-Sea Post Office, 5th Avenue between Dolores Street and San Carlos Street, and the City's webpage (http://www.ci.carmel.ca.us) in accordance with applicable legal requirements.

SUPPLEMENTAL MATERIAL RECEIVED AFTER THE POSTING OF THE AGENDA
Any supplemental writings or documents distributed to a majority of the Planning Commission regarding any item on this agenda, received after the posting of the agenda will be available at City Hall located on Monte Verde Street between Ocean and Seventh Avenues during regular business hours.

SPECIAL NOTICES TO PUBLIC
In compliance with the Americans with Disabilities Act, if you need special assistance to participate in this meeting, please contact the City Clerk's Office at 831-620-2000 at least 48 hours prior to the meeting to ensure that reasonable arrangements can be made to provide accessibility to the meeting (28CFR 35.102-35.104 ADA Title II).

CARMEL-BY-THE-SEA
PLANNING COMMISSION

SPECIAL MEETING MINUTES

Thursday, January 29, 2026

CALL TO ORDER AND ROLL CALL

The following Planning Commission members were present: Mel Ahlborn, Erin Allen, Stefan Karapetkov, Michael LePage, and Stephanie Locke
The following Forest and Beach Commission members were present: Sarah Berling, Kelly Brezoczky, Harry Ross, Neal Rutta, and Tamara Michie
The following Commission members were absent: None

PUBLIC APPEARANCES

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The following members of the public appeared before the Commissions: None

ANNOUNCEMENTS

None

ORDERS OF BUSINESS

1) Presentation of the Carmel Beach Adaptation Pathways Report — Sea Level Rise and Coastal Hazard Planning for Carmel Beach

Speakers:
Mary Bilse, Environmental Programs Manager
Anastazia Aziz, AICP Principal, EMC Planning Group
David Revell, PH.D. Principal, Integral
Matthew Jamieson, Sr. Scientist, Integral

Public Comment
None

FUTURE AGENDA ITEMS

2) Next Regular Meeting of the Planning Commission: February 11, 2026

3) Next Regular Meeting of the Forest & Beach Commission: February 12, 2026

ADJOURNMENT

4:53 PM

APPROVED:

_____
Michael LePage, Chair

ATTEST:

_____
Shelby Gorman, Commission Clerk

CITY OF CARMEL-BY-THE-SEA
Planning Commission
Staff Report

August 19, 2026
ORDERS OF BUSINESS

TO:	Chair LePage and Planning Commissioners
SUBMITTED BY:	Mary Bilse, Environmental Programs Manager, Valerie Gaino, Environmental Analyst
APPROVED BY:	Brandon Swanson, Acting City Administrator
SUBJECT:	Review of the Administrative Draft SLR and Coastal Hazards Chapter of the Local Coastal Program (LCP)

Application:	**APN:**
Block & Lot:	
Location:	
Applicant:	**Owner:**

Recommendation:

Receive a presentation from consultants, EMC Planning Group and Integral Consulting, on the Administrative Draft Carmel Sea Level Rise (SLR) and Coastal Hazards Chapter of the Local Coastal Program (LCP) **(Attachment #1**), Provide feedback on the draft addressing adaptation strategies, proposed policies and goals, and make recommendations preliminary to LCP integration.

Summary, Background, and Project Description:

The California Sea Level Rise Mitigation and Adaptation Act of 2021 (SB 1) amended the California Coastal Act to require the California Coastal Commission to incorporate consideration of sea level rise into coastal resource planning and management and to develop recommendations and guidelines for identifying, assessing, minimizing, and mitigating sea level rise within LCPs. SB 1 also established the goal of anticipating, assessing, planning for, and, to the extent feasible, avoiding, minimizing, and mitigating the adverse environmental and economic effects of sea level rise within the coastal zone.

In 2023, the Legislature enacted SB 272, which established a specific requirement that local governments located in the coastal zone develop a sea level rise plan as part of a new or updated LCP. The plan must incorporate best available science; a vulnerability assessment that includes efforts to ensure equity for at-risk communities; sea level rise

adaptation strategies and recommended projects; identification of lead planning and implementation agencies; and a timeline for updates based on changing conditions and projections. The update timeline must also include economic impact analyses addressing, at a minimum, costs to critical public infrastructure and recommended approaches for implementing adaptation strategies and projects. Local governments subject to SB 272 must comply by January 1, 2034.

In 2023, the City, with funding from a California Coastal Commission grant, embarked on a planning initiative to identify the City's vulnerability to coastal hazards and sea level rise and to develop adaptation strategies for each of the three subareas of Carmel Beach.

In 2024, the City received the *Carmel Climate Change Vulnerability Assessment* (**Attachment #1 Appendix A**), prepared by Integral Consulting. The Vulnerability Assessment describes the locations and degree to which Carmel's coastline may be affected by coastal hazards and sea level rise.

A subsequent report, also prepared by Integral Consulting, the *Carmel Adaptation Pathways Report* (**Attachment #1 Appendix B**), identifies the community's adaptation priorities, evaluates potential adaptation alternatives, and defines physical and other decision triggers that can indicate when implementation of particular strategies may be appropriate.

In January 2026, the Forest and Beach Commission and Planning Commission received a presentation on the *Draft Adaptation Pathways Report* and provided comments and suggestions to assist with finalizing the Report.

The City is now using these technical studies and the Adaptation Pathways framework to develop the SLR and Coastal Hazards Chapter (the "Chapter") for integration into the City's LCP. The Chapter is a required deliverable under the California Coastal Commission grant and is currently scheduled for completion in late 2027.

INTENT OF THE HAZARDS CHAPTER

Under the City’s LCP and Implementation Plan (IP), the Chapter is intended to establish a clear and adaptable policy framework for reducing risks from coastal hazards and sea level rise while protecting the recreational, scenic, ecological, cultural, and public access resources of Carmel Beach.

The Chapter will codify the City's goals and policies for addressing coastal hazards and sea level rise. The strategies identified in the *Carmel Adaptation Pathways Report* will be integrated by reference, as appropriate, and will inform implementation of the goals and policies established by the Chapter.

Implementation of the Chapter is supported by the *Shoreline Management Plan* (**Attachment #2**), which includes the Shoreline Emergency Action Response Plan, one of the Chapter 9 appendices **(Attachment #3 and Attachment #4**). These documents

provide implementation, monitoring, and operational guidance that will inform the City's Implementation Plan and Chapter 17 (zoning) of the City's Municipal Code.

Rather than committing the City to rigid timelines, the Chapter establishes a flexible "Adaptation Pathways" framework. This approach allows the City to choose from a variety of adaptation strategies—ranging from immediate fixes to long-term systemic shifts, triggered by specific, observable physical thresholds (e.g., sand depth at ramps, frequency of wave overtopping, or reduction in summer beach width) rather than fixed dates.

The Chapter describes Goals and Policies for the entire beach, and then for each of the three sub-areas: 1) North Beach and North Dunes, 2) Central Beach and Del Mar Dunes, and 3) South Beach and Scenic Road. Once incorporated into the LCP, the City will be able to select from a spectrum of "green to grey" strategies across different time horizons.

Brief Adaptation Strategy Overview

1. Immediate and Near-Term Strategies (0 to 1 ft of SLR): The primary focus in the near term is winter-storm preparedness, preserving the natural character of the beach, and maintaining safe public access.

- **Nature-Based Prioritization:** The chapter prioritizes green strategies, such as developing (or reinstating) an annual beach and dune management program, restoring native dune vegetation to improve sand trapping, and integrating woody debris as dune toe protection.
- **Infrastructure Maintenance:** It emphasizes the repair or replacement of existing accessways such as the Eighth Avenue sand ramp, the coastal access stairways and the Fourth Avenue outfall.

2. Mid-Term Strategies (2 ft of SLR): As sea levels continue to rise, the City will reach critical decision points regarding how to mitigate the loss of the dry sand beach and protect upland infrastructure.

- **Beach Nourishment vs. Hard Armoring:** The City will evaluate the feasibility of larger-scale beach nourishment and/or the extension and elevation of existing coastal armoring (seawalls and revetments).
- **Wave Energy Dissipation:** Alternative hybrid protections, such as nearshore reefs or shore platform enhancements, may be tested to trip waves and reduce scouring.

3. Long-Term Strategies (4 ft of SLR): In the long term, ongoing maintenance of existing infrastructure and armoring may no longer be economically, or physically

sustainable as coastal squeeze drastically narrows the beach.

- **Managed Retreat and Relocation:** Where feasible and consistent with Coastal Act requirements, the Chapter supports planning for the inland migration of the beach and relocation or redesign of vulnerable infrastructure, such as the Del Mar Parking Lot, wastewater conveyance pipes and pump stations. It triggers the potential inland realignment of Scenic Road and the Scenic Pathway.

Staff Analysis:

Staff requests that the Forest and Beach and Planning Commissioners review the Administrative Draft SLR and Coastal Hazards Chapter, discuss its alignment with the community's vision for maintaining the recreational, scenic, and ecological functions of Carmel Beach, and provide suggestions and recommendations for the final draft that will be incorporated into the LCP and IP.

Staff requests the Commissioners evaluate and provide feedback on:

- Existing and proposed monitoring requirements outlined in the Shoreline Management Plan
- Recommended locations within the LCP for the SLR and Coastal Hazards Chapter
- Impactful policies such as coastal overlay zones and real estate disclosures
- Next steps for Chapter refinement

Other Project Components:

ATTACHMENTS:

1. Attachment #1: Administrative Draft_ Carmel LCP Coastal Hazards
2. Attachment #2: Shoreline Management Plan (Appendix A)
3. Attachment #3: Appendices 9.1-9.7 IP (Shoreline Emergency Action Response Plan)
4. Attachment #4: Carmel Beach Area Monitoring Program (cross-sections)
5. Attachment #5: Correspondence

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1.0
Coastal Hazards and Sea Level Rise

1.1 Background and Setting

California's coastal climate is already changing. Statewide monitoring documents rising sea levels along the California coast, warming coastal waters, and increasing variability in storm and wave conditions (CA Environmental Protection Agency 2022). In response to projected sea level rise, the State of California's Ocean Protection Council and Coastal Commission have recommended a framework for coastal planning. The Ocean Protection Council issues the technical guidance on sea level rise science and projections, and the Coastal Commission translates that science into policy guidance for the coastal zone. In 2023, the California Legislature reinforced this framework by passing Senate Bill 272, requiring coastal jurisdictions to plan for and integrate sea level rise and coastal hazards into Local Coastal Programs. The following Sea Level Rise and Coastal Hazards section describes how the City of Carmel-by-the-Sea is meeting that mandate.

In 2023, the City launched the Carmel Adaptation Planning Initiative to assess its vulnerability to sea level rise induced coastal hazards and to develop adaptation strategies. The project's first phase produced the *Carmel Climate Change Vulnerability Assessment* (Vulnerability Assessment; Appendix A). Drawing on the best available science, including the sea level rise projections adopted by the California Ocean Protection Council, the Vulnerability Assessment establishes where and to what degree Carmel's coastline is projected to be impacted. The second planning phase produced the *Carmel Adaptation Pathways* (Adaptation Pathways; Appendix B), which identifies the community's adaptation priorities, evaluates alternative strategies, and defines the triggers that signal when each strategy should be implemented.

For assessment and planning purposes, the Vulnerability Assessment and Adaptation Pathways divide Carmel Beach into three subareas: North Beach and North Dunes, Central Beach and Del Mar Dunes, and South Beach and Scenic Road (Figure 1, Carmel Beach Subareas and Coastal Hazards). Each subarea has a distinct shoreline character, and each faces a different combination of hazards. The goals and policies in this chapter are organized accordingly, beginning with those that apply to the entire beach and followed by subarea-specific direction.

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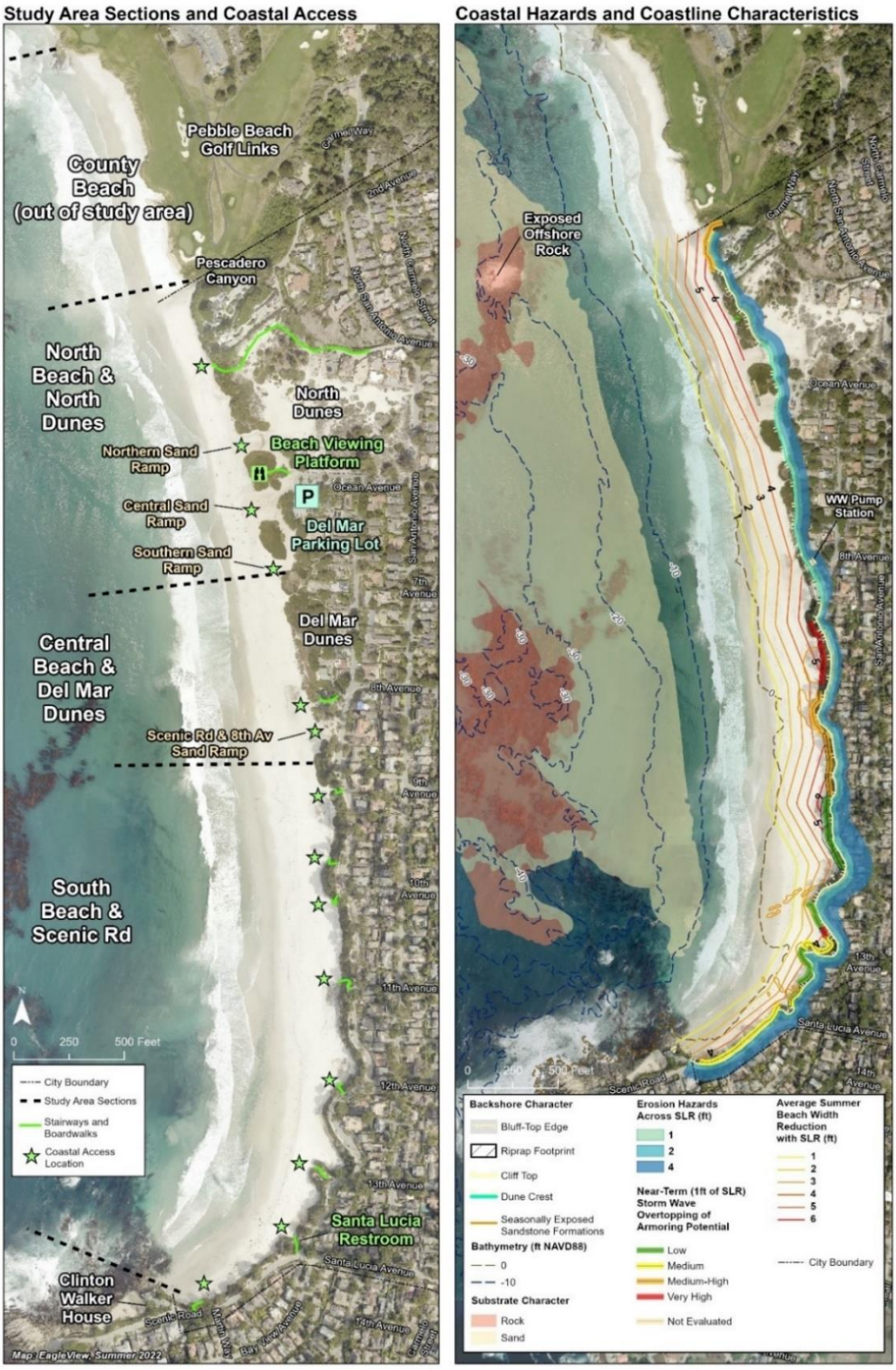
Figure 1 Carmel Beach Subareas and Coastal Hazards



Source: Revell 2026.

Carmel Beach Study Area and Adaptation Pathway Subareas (left); Coastal Erosion Hazard Zones and Areas of Concern for Wave Overtopping and Important Geomorphic Characteristics of the Upland Backshore, Nearshore, and Offshore Regions (right)

During the Carmel Adaptation Planning Initiative, the community identified public access to Carmel Beach and the preservation of its natural character as the highest priorities for sea level rise adaptation. Rather than committing the City to predetermined actions on fixed timelines, the Adaptation Pathways approach organizes strategies around sea level rise horizons and provides observed, measurable conditions that signal when to act. This approach allows the City to track changes as they occur and initiate the next phase of adaptation early enough to mitigate projected damage.

As part of the Carmel-by-the-Sea Local Coastal Program's Land Use Plan, this chapter establishes the City's goals and policies for reducing risk from coastal hazards and sea level rise. The Vulnerability Assessment and Adaptation Pathways report are incorporated by reference and as Appendix A, *Carmel Climate Change Vulnerability Assessment* and Appendix B, *Carmel Adaptation Pathways*. These documents inform the creation and implementation of the goals and policies that follow. The regulatory standards, permit requirements, and adaptation triggers that carry these policies out are set forth in the Implementation Plan.

Carmel Beach's Social, Recreational and Ecological Setting

Community outreach conducted during the Carmel Adaptation Planning initiative confirmed that Carmel Beach's recreational and natural values are integral to the community's identity. The beach is among the most heavily visited coastal destinations on the Monterey Peninsula. In 2024, visitors from across the United States came to Carmel Beach an estimated 1.15 million times (Revell 2025). Nature observation and dog walking are the most common activities among residents and visitors, along with surfing, running, fishing, and beach volleyball. The Scenic Road Pathway carries substantial pedestrian traffic for walking and ocean viewing, while the Del Mar Avenue parking area functions as an informal gathering place for socializing and community events.

The beach's ecological resources are also central to the community's values. The North Dunes support Tidestrom's lupine, a federally and state-listed endangered plant. The California black legless lizard, a state species of special concern, is found in the dune scrub habitat in the North Dunes and along central beach in the Del Mar Dunes. Offshore, the Carmel Bay State Marine Conservation Area lies within the Monterey Bay National Marine Sanctuary and encompasses the coastal waters fronting Carmel Beach (CA Dept. Fish and Wildlife 2026). Those same waters carry a separate designation as the Carmel Bay Area of Special Biological Significance, administered by the State Water Resources Control Board, which affords them heightened protection from waste discharge (State Water Resources Control Board 2012). Sustaining these ecological features will require deliberate planning as sea level rise and related climate-driven changes alter the shoreline. The adaptation measures established in this chapter are intended to operate within natural systems, incorporating nature-based solutions where feasible in order to preserve both the ecological function and the physical character of Carmel Beach.

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Carmel Beach's Geography

Carmel Beach has a largely fixed supply of sand. Its sediment originates primarily from granodiorite formations in the Pacific Grove and Monterey Peninsula area, accumulated over geological timescales. Pescadero Canyon and the beach's sandstone cliffs contribute only a small amount of sediment. Carmel Beach is situated between Arrowhead Point to the north and Carmel Point to the south. These two headlands restrict the movement of sediment into and out of Carmel Bay. Unlike most beaches located on the Pacific Coast, Carmel Beach does not receive significant sediment deposits from inland rivers or transported from adjacent beaches (Patsch & Griggs 2006). Instead, on human timescales, the sand that makes up Carmel Beach remains within Carmel Bay's geography, shifting on and offshore seasonally (Revell 2023).

As a result of this contained system, the width of Carmel Beach has stayed relatively constant over time. Seasonal changes in beach width occur when erosive winter storm waves pull sand into near-shore sandbars and reduce the size of the dry-sand beach. Smaller summer waves redeposit sand back onshore, allowing the dry-sand beach to recover. While more drastic beach narrowing occurs seaward of hardened backshores, there is little evidence of long-term sand volume loss overall on Carmel Beach. Between 1984 and 2021, beach widths averaged 250 feet (Revell 2023).

Projected Coastal Hazards

Planning for Sea Level Rise

California is projected to experience substantial sea level rise over the course of this century, permanently altering the configuration of Carmel Beach and exposing the adjacent built environment to coastal hazards. Carmel Bay's sand volume has remained relatively stable over recent decades, and Carmel Beach retains its sediment rather than losing it to adjacent littoral systems. Nonetheless, rising water levels will reduce the width of the beach substantially. With the backshore held in place by protective seawalls, revetments, and fixed development, the beach will not migrate landward as sea levels rise. This will result in a progressive and permanent narrowing of the dry sand beach, also referred to as coastal squeeze. Intensifying storms and greater variability in water levels and wave energy will accelerate this trend.

The Vulnerability Assessment evaluated potential impacts across sea level rise increments ranging from zero to five feet, measured from a 2020 baseline. Under the projections adopted by the California Ocean Protection Council, one foot of sea level rise is anticipated between 2045 and 2060. At that threshold, the City's coastal infrastructure, built environment, and natural resources will be measurably exposed to the effects of rising water. Absent targeted adaptation, the beach will narrow, and dune and cliff erosion will accelerate near residential development, wastewater infrastructure, public access facilities, and ecological habitat.

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The Vulnerability Assessment projects that Carmel Beach will narrow significantly as sea levels rise. Each foot of sea level rise will move the shoreline fifty to sixty feet landward, assuming the position of the backshore remains unchanged (Revell 2024). By four feet of sea level rise, the Vulnerability Assessment projects that the only continuous stretch of dry sand beach will extend from the North Dunes sand ramps to Pescadero Canyon, with two isolated pockets remaining near Eighth and Eleventh Avenues. At five feet, only a single pocket near the North Dunes and the Fourth Avenue stairway may remain. See Table 1, Impacts of Sea Level Rise on Dry Sand Beach, for the proportion of the historical summer beach projected to remain at each increment of sea level rise.

Table 1 Impacts of Sea Level Rise on Dry Sand Beach

Sea Level Rise (SLR) Scenario	Average Summer Beach Remaining for Carmel Beach (%)
0 ft SLR	100%
1 ft SLR	80%
2 ft SLR	61%
3 ft SLR	41%
4 ft SLR	22%
5 ft SLR	8%

SOURCE: Revell 2024
NOTE: The baseline year for sea level rise is 2020. Summer dry sand beach acreage is representative of the 75th percentile beach width from 1984 to 2021.

The Carmel Adaptation Planning Initiative used these projections to create a strategic framework for adapting to shoreline change over time. The planning team screened and ranked potential adaptation strategies against criteria addressing technical and cost feasibility, regulatory viability, and secondary effects on public access, public safety, and coastal resources. The planning team vetted each strategy through regulatory consultation, City review, and community outreach. That outreach included 307 completed surveys and eight presentations before the City Council and the Forest and Beach Commission. Participants identified the loss of sandy beach, storm-driven cliff and dune erosion, and damage to coastal access stairways and sand ramps as their principal concerns. Respondents also expressed a preference for nature-based approaches over armoring, despite greater familiarity with the latter. The Adaptation Pathways report presents the strategies in three categories: dune and sand management, described as green strategies; engineered protection, described as gray strategies; and managed retreat or relocation. The strategies carried forward into this chapter reflect those priorities.

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The *Carmel Adaptation Pathways* report summarizes the adaptation pathways developed for each subarea of Carmel Beach. These summaries are diagramed later in this section in Figure 4, North Beach and North Dunes Adaptation Pathway, Figure 6, Central Beach and Del Mar Dunes Adaptation Pathway, and Figure 8, South Beach and Scenic Road Adaptation Pathway. The diagrams illustrate how management and adaptation strategies can be sequenced as sea level rise.

The "Phase" column at the left of each diagram identifies time horizons rather than fixed dates. This allows the City to plan according to monitored, observable conditions rather than a predetermined schedule. The phases are summarized in Table 2, Phases of Adaptation by Feet of Sea Level Rise and Estimated Year.

Table 2 Phases of Adaptation by Feet of Sea Level Rise and Estimated Year

Phase	Estimated Sea Level Rise	Estimated Date
Immediate (Current)	0 foot	Base year 2025
Near-Term	1 foot	2045-2060
Mid-Term	2 feet	2060-2080
Long-Term	4 feet	2080-2100+

SOURCE: Revell 2026

The "Strategy" column identifies the adaptation strategies recommended for each phase. The "Trigger(s) to Initiate Strategy" column identifies the observable conditions to be quantified and monitored. When a monitored condition reaches its established threshold, planning for the next phase begins. The "Upfront Cost/Maintain" column indicates the relative cost of constructing and maintaining the strategies associated with that phase.

The timeline graphic at the right of each diagram arrays the adaptation pathway against increasing sea level rise. A solid red line indicates a measure in place and functioning. A black dot marks a trigger, signaling that planning for the next phase should begin. As adaptation measures begin to lose effectiveness (shown by a red square), the timeline incorporates lead time for designing and constructing the succeeding measure, represented by a dotted red line.

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A hypothetical example follows, illustrating how a phased adaptation pathway may be applied to a shoreline asset over time.

A Roadway Adaptation Story

In the hypothetical City of Resilience, Pine Way is a residential street built along a shoreline cliff. Safe vehicle loading requires the road to be set back at least twelve feet from the cliff edge.

Immediate. In 2026, the City measures the setback at twenty-five feet. It adopts a phased adaptation plan keyed to that distance, commits to measuring annually, and stabilizes the cliff face with native vegetation.

Near-Term. Several years later, following modest sea level rise and a severe winter storm that removes five feet of cliff, the setback reaches twenty feet, the established trigger. In response, the City raises the crest of the existing armoring and begins planning its mid-term strategies, which will be costlier to construct.

Mid-Term. Within a decade the setback narrows to fifteen feet. The City installs offshore wave-deflection structures, regularly places sand at the base of the cliff, and begins redesigning the roadway. When the setback reaches twelve feet, Pine Way is reduced to a single, one-way lane.

Long-Term. By 2100 the cliff edge lies one foot from the roadway, which can no longer safely carry vehicle loads. The City closes Pine Way and converts the paved road to a railing-protected pedestrian trail leading to a scenic overlook.

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Building resiliency to sea level rise requires a proactive approach in which the City anticipates future conditions and implements strategies in advance, rather than responding reactively to emerging impacts. Strategies are intended to be combined and phased over time. These strategies should be adjusted in response to changing shoreline conditions and as monitored data and sea level rise research evolves. The goals and policies that follow incorporate the *Carmel Adaptation Pathways* report as the framework for the City's planning and adaptation response to coastal hazards.

1.2 Entire Carmel Beach — Goals and Policies

Carmel Beach, including its dunes, cliffs, shoreline, and the Scenic Road and Pathway, is a valuable coastal resource, and its protection is a matter of public importance. The beach, dunes, and nearshore environment function together as a dynamic natural system that supports recreation, ocean views, coastal habitat, and public access. It is the intent of the Local Coastal Program that the City respond to climate change and adapt to coastal hazard risk in a manner that protects the natural character of Carmel Beach, maintains its recreational and scenic values, protects dune and coastal habitat, and ensures public safety and welfare.

Goals – Entire Carmel Beach

Goal 1.2.1

Preserve Carmel Beach as a coastal resource of local, statewide, and national significance by sustaining its natural character, recreational and scenic value, coastal habitat, and public access as the City adapts to coastal hazards and sea level rise.

Goal 1.2.2

Prioritize early and proactive adaptation strategies that maintain beach access, public safety, and ecological resilience.

Goal 1.2.3

Maintain safe and reliable critical infrastructure serving the City by protecting existing facilities from coastal hazards and by planning for their relocation out of hazard areas as sea levels rise.

Goal 1.2.4

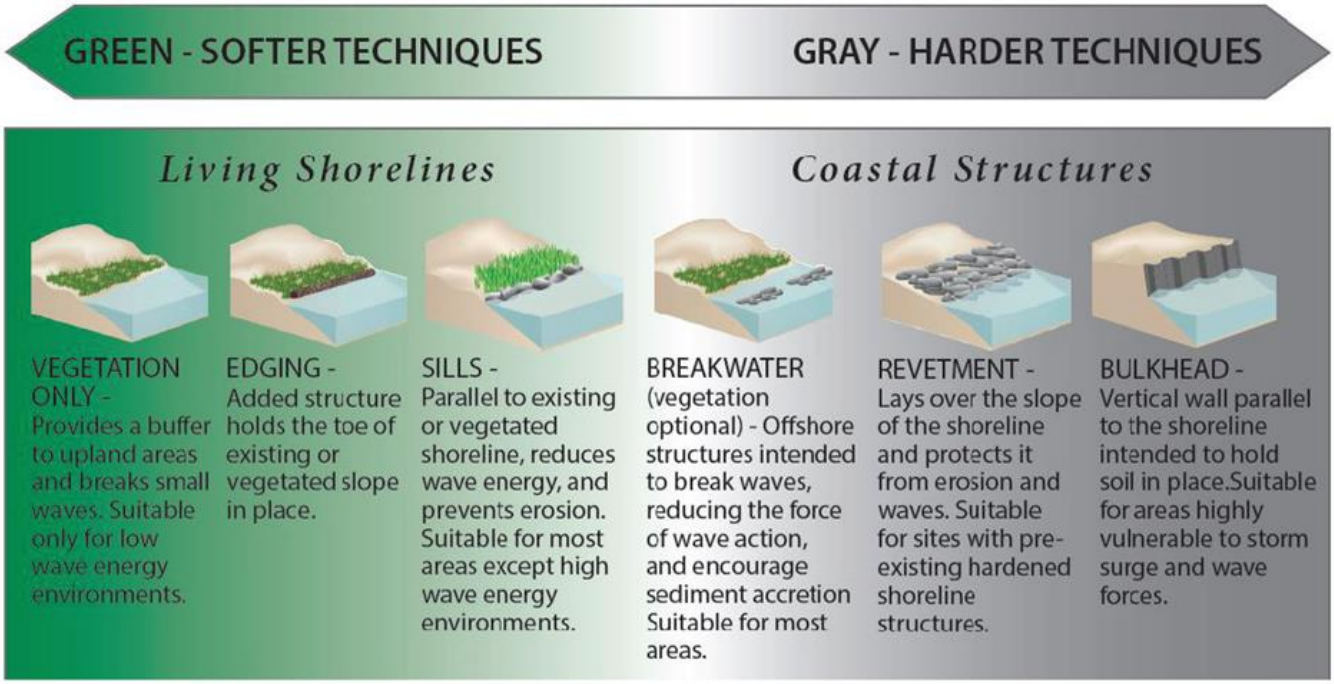
Base long-range infrastructure decisions on exposure to coastal hazards by siting new and replacement facilities outside hazard areas and by favoring nature-based adaptation solutions over hard shoreline armoring (Figure 2, Examples of Shoreline Armoring).

Goal 1.2.5

Minimize coastal hazard risk to life, property, and coastal resources by requiring that new development neither create nor exacerbate coastal hazards and by implementing phased adaptation measures as sea levels rise.

Administrative Draft

Figure 2 Examples of Shoreline Armoring



Source: National Oceanic and Atmospheric Administration 2015

Policies – Entire Carmel Beach

Policy HAZ-1.2.1

Interpretation. In the event of a conflict between the policies of this Coastal Hazards chapter and other policies of the Local Coastal Program, the policies of this chapter shall prevail where necessary to minimize risks to life, property, and coastal resources from coastal hazards.

Areas subject to coastal hazards means those areas projected to be subject to cliff erosion, cliff failure, dune recession, wave uprush, wave overtopping, or coastal flooding, as identified in Appendix A, *Carmel Climate Change Vulnerability Assessment* or in the most current coastal hazard mapping maintained by the City pursuant to HAZ-1.2.2.

Policy HAZ-1.2.2

Best Available Science. In coastal hazard planning, permitting, and policy updates, the City shall use the best available, professionally accepted science regarding sea level rise, coastal erosion, cliff and dune retreat, coastal flooding, and related coastal hazards.

The City shall review and update its mapping of those hazards as necessary, and at a minimum every ten years, based on current guidance, including but not limited to the State of California Sea Level Rise Guidance adopted by the California Ocean Protection Council and applicable guidance adopted by the California Coastal Commission. The mapping shall depict projected hazards through the year

Administrative

2100, shall apply the sea level rise projections and risk aversion criteria recommended in that guidance, shall assume that no shoreline armoring is in place, and shall apply the highest erosion rate assumption carried in the underlying hazard analysis.

Policy HAZ-1.2.3

Adaptive Management. The City shall implement adaptation in phases consistent with the adaptation pathways in Appendix B, *Adaptation Pathways*, initiating each phase when monitoring data indicate that a defined trigger has been reached. The City shall endeavor to sequence adaptation measures so that early phases maintain essential functions at lower initial cost while planning proceeds for the measures that follow. The City may adjust the timing or type of adaptation measures within an initiated phase where site conditions, monitoring data, or best available science and engineering demonstrate that a different approach would better protect public safety, coastal resources, and public access. Any such adjustment shall be documented in the next Annual Monitoring Report.

Policy HAZ-1.2.4

Phased Adaptation Plan. Each Phased Adaptation Plan for an existing structure or asset shall be based on a hazards analysis that evaluates the impacts of sea level rise on the structure or asset using the best available science. The hazards analysis shall incorporate up-to-date risk aversion criteria recommended in the State of California Sea Level Rise Guidance adopted by the California Ocean Protection Council, or in superseding guidance adopted by either the Ocean Protection Council or the California Coastal Commission.

Each Phased Adaptation Plan shall identify a sequence of adaptation measures that respond to the projected hazards. The plan shall identify specific, objective triggers that initiate each phase and require implementation of the adaptation measures associated with that phase. Guiding adaptation triggers and measures are found in Appendix B, *Carmel Adaptation Pathways*. The plan shall be designed to avoid or minimize impacts to coastal access and to environmental, recreational, and public resources over the planning horizon.

Policy HAZ-1.2.5

Nature-Based Adaptation. The City shall give preference to nature-based adaptation strategies, according to the most up-to-date guidance of the California Coastal Commission. Nature-based strategies include, but are not limited to, dune restoration, sand management, and living shoreline techniques. Living shoreline techniques include the placement of woody material and other natural materials to trap sand and protect dune toes from erosion. The City shall incorporate nature-based strategies into its own shoreline projects where feasible.

Policy HAZ-1.2.6

Managed Retreat. The City shall support managed retreat, where feasible, to allow for inland beach migration to sustain lateral beach access over time.

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Policy HAZ-1.2.7

Public Infrastructure. Public infrastructure improvements shall be resilient to coastal hazards and sea level rise impacts. Infrastructure shall be designed for adaptation, including resiliency, redundancy and relocation considerations, incorporating resilient materials and designs appropriate for coastal hazard hardening.

Policy HAZ-1.2.8

Coastal Change Monitoring Program. The City shall maintain a Coastal Change Monitoring Program that tracks shoreline and cliff conditions to inform beach management, maintenance, and adaptation decisions and to determine when adaptation phase triggers have been reached. The Program shall commence no later than one year following certification of this Local Coastal Program amendment and shall track conditions including but not limited to:

- Sand depth at beach access ramps and stairway landings;
- Exposure of bedrock, revetments, and seawalls;
- Dry sand beach width during summer and winter conditions, including beach width available for lateral access;
- Long-term net change in beach sand volume;
- Dune crest and bluff edge location relative to development and infrastructure;
- Frequency of wave runup reaching dune toes or overtopping shoreline protective devices;
- Condition of stormwater outfalls, public accessways, stairways, parking areas, the Scenic Road Pathway, and other public infrastructure in the coastal hazard area;
- Scour at the base of stairways, ramps, and shoreline protective devices; and
- Frequency and duration of wave runup or overtopping that closes an accessway.

The City shall collect shoreline and cliff position data at least twice each year, capturing summer and winter conditions, and following significant storm events. The City shall update the shoreline topographic maps used for decision-making at least every five years or after a significant change in the coastline. The City Administrator, or their designee, shall present a monitoring report to the City Council annually and following any significant storm event that materially changes shoreline conditions. The report shall compare observed conditions against each adaptation trigger established in the Coastal Access Phased Adaptation Plan (per HAZ-1.2.9) and the Critical Infrastructure Phased Adaptation Plan (per HAZ-1.2.10) and state whether the trigger threshold has been reached.

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Policy HAZ-1.2.9

Coastal Access Planning. Within two years of certification of this Local Coastal Program amendment, the City shall prepare and adopt a Coastal Access Phased Adaptation Plan to maintain safe and reliable vertical and lateral public access to Carmel Beach. The Plan shall identify, for each beach subarea and each adaptation phase, the triggers that initiate the phase and the adaptation measures associated with that phase. Triggers shall be specific and objective, shall be measurable through the Coastal Change Monitoring Program, and shall be consistent with the certified triggers established in the City's Implementation Plan. Triggers shall address, at a minimum:

- Dry sand beach width available for lateral access;
- Sand depth at beach access ramps and stairway landings;
- Exposure of bedrock, revetments, and seawalls that obstructs lateral access;
- Scour at the base of stairways, ramps, and shoreline protective devices;
- Frequency and duration of wave runup or overtopping that closes an accessway; and
- Condition of stairways, ramps, landings, and the Scenic Road Pathway.

Adaptation measures may include repair and reconstruction of accessways, sand placement and redistribution to restore ramp elevations, realignment or relocation of accessways, and provision of alternative access where access can no longer be safely maintained at a given location. Sand-related measures shall be implemented through the Beach and Dune Management Program. Measures involving repair, reconstruction, realignment, or relocation of built accessways shall be implemented through the City's capital improvement program and applicable coastal development permits.

The City shall prioritize timely repair of damaged accessways and shall implement improvements that enhance safety while minimizing impacts to coastal resources. Any new shoreline access point shall be sited and constructed to allow for future retreat. The Coastal Change Monitoring Program's annual report shall evaluate each trigger established in the Coastal Access Phased Adaptation Plan and state whether the trigger threshold has been reached.

Policy HAZ-1.2.10

Critical Infrastructure Planning. Within two years of certification of this Local Coastal Program amendment, the City shall prepare and adopt a Critical Infrastructure Phased Adaptation Plan addressing critical infrastructure and related structures vulnerable to coastal hazards. Critical infrastructure has the meaning set forth in the Definitions and Resources section of this chapter, and includes but is not limited to water, stormwater, wastewater, transportation, gas, electric, and communications facilities, public restrooms, and other utilities and public facilities.

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The Plan shall identify, for each asset or group of assets and each adaptation phase, the triggers that initiate the phase and the adaptation measures associated with that phase. Triggers shall be specific and objective, shall be measurable through the Coastal Change Monitoring Program, and shall be consistent with the certified triggers established in the Implementation Plan. Triggers shall address, at a minimum:

- Distance from the cliff crest or dune crest to each asset;
- Elevation of each asset relative to projected total water levels;
- Frequency and duration of wave overtopping at structures fronting critical infrastructure;
- Exposure or undermining of buried conveyance lines and stormwater outfalls;
- Cumulative repair and maintenance cost for each asset within a rolling five-year period; and
- Replacement of, or significant upgrade to, an asset located within a hazard area.

Adaptation measures may include protection in place, elevation of assets, redundancy and resiliency upgrades, realignment or relocation outside the hazard area, and decommissioning and replacement outside the hazard area. Measures shall be implemented through the City's capital improvement program, through agreements with infrastructure providers, and through applicable coastal development permits.

The City shall prepare and maintain the Plan through a collaborative regional process that includes Monterey County, the Carmel Area Wastewater District, California American Water, Pacific Gas and Electric Company, and other affected providers. The City shall identify phased adaptation options before hazard exposure becomes acute.

Policy HAZ-1.2.11

Beach and Dune Management Program. Within two years of certification of this Local Coastal Program amendment, the City shall implement a beach and dune management program to perform sand management, maintenance and nourishment on Carmel Beach. The program shall identify when, where, and how sand management actions may occur based on the triggers and adaptation actions identified in the Coastal Access Phased Adaptation Plan (HAZ-1.2.9) and the Critical Infrastructure Phased Adaptation Plan (HAZ-1.2.10). The program's work plan shall be updated based on the findings in the coastal Change Monitoring Program's annual report. The City may use heavy equipment to redistribute beach sand in accordance with the Program. Sand management activities shall minimize beach encroachment and impacts to public access and shall protect public safety. Actions under the Beach and Dune Management Program may include:

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- Redistribution of sand to maintain sand ramps and dune elevations;
- Restoration and maintenance of dune vegetation and habitat in accordance with the North Dunes and Del Mar Dunes Habitat Restoration Plan, where applicable;
- Repair and sand coverage of exposed revetments;
- Maintenance of the Eighth Avenue emergency vehicle access ramp;
- Improvements to vertical access landings to enhance public safety; and
- Sand supply and nourishment standards and schedules established pursuant to HAZ-1.2.12, including criteria for determining whether material is beach-quality sand compatible with native Carmel Beach sand.

Policy HAZ-1.2.12

Sand Supply and Nourishment. When the Coastal Change Monitoring Program indicates a sustained net loss of beach sand volume or a reduction in the historical average summer dry sand beach width, the City shall evaluate beach nourishment strategies. Where nourishment is feasible, the City shall implement strategies that supplement, maintain, or increase the available volume of sand while minimizing impacts to coastal resources. Nourishment activities shall avoid significant adverse impacts to the Carmel Bay Area of Special Biological Significance, the Carmel Bay State Marine Conservation Area, and nearshore habitat. The City shall establish sand supply and nourishment standards and schedules as part of the Beach and Dune Management Program (HAZ-1.2.11).

Policy HAZ-1.2.13

Shoreline Protection Devices. New shoreline protection devices, or the modification of existing shoreline structures, may be permitted as a short- to mid-term adaptation strategy when:

- The device is required to protect coastal-dependent uses, existing structures, critical public infrastructure, or public beaches in danger from erosion, consistent with Coastal Act Section 30235;
- The device is the least environmentally damaging feasible alternative in the context of phased adaptation, and nature-based adaptation strategies are not feasible;
- Relocation of the protected structure is not feasible within a reasonable timeframe; and
- The device is designed to eliminate or mitigate adverse impacts on local shoreline sand supply.

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Shoreline protection devices include but are not limited to seawalls, revetments, groins, nearshore reefs, and cliff retaining walls. Approval of any device shall be time-limited and tied to the continued existence and function of the structure it protects. The permittee shall maintain an approved shoreline protection device in its permitted condition for the term of the permit, including maintaining sand coverage over revetments.

Policy HAZ-1.2.14

Design of Shoreline Protection. Where a shoreline protection device is permitted, the following design standards shall be conditions of approval:

- The design shall safeguard public access to and along the shoreline;
- The design shall mitigate all adverse impacts to coastal resources;
- The structure shall minimize encroachment onto sandy beach areas;
- The design shall be visually compatible with the natural coastal setting;
- The design shall be compatible with existing shoreline protection device designs and shall incorporate visual mitigation measures, such as a golden granite facing;
- The design shall provide for drainage and scour protection; and
- Revetments shall be designed and sited so that they can be covered and maintained with beach sand.

Policy HAZ-1.2.15

Long-Term Solution. As part of an application for a Coastal Development Permit for a new or existing shoreline protective device, the applicant shall submit a Phased Adaptation Plan identifying a permanent, non-armoring solution, which may include relocation, realignment, or nature-based protection.

The Phased Adaptation Plan shall include a schedule identifying how the applicant will monitor and report changing conditions at intervals not exceeding five years. Each report shall evaluate the device's continued necessity and performance, impacts to public access and shoreline sand supply, and progress toward the permanent solution. The City shall reassess the authorization upon each report and upon redevelopment of the protected structure.

As a condition of approval, the applicant shall accept an obligation to remove the shoreline protective device and restore the affected shoreline to a condition resembling the natural landform, at the permittee's sole expense, upon expiration of the permit term or completion of the permanent solution. Where temporary armoring is approved to protect a structure pending relocation, the armoring shall be removed and the shoreline restored once relocation is complete.

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Policy HAZ-1.2.16

New Development and Redevelopment. An application for a Coastal Development Permit for new development or redevelopment proposed in an area subject to coastal hazards risks at any point over the life of the development, as mapped in Appendix A, *Carmel Climate Change Vulnerability Assessment*, shall include a Phased Adaptation Plan prepared in accordance with HAZ-1.2.4.

The Phased Adaptation Plan's coastal hazards report shall evaluate the site's exposure to coastal hazards over the life of the proposed development, including but not limited to cliff erosion and failure, storm wave overtopping, dune recession, wave uprush, and flooding. The report shall recommend siting and design measures sufficient to avoid or mitigate those hazards over the life of the development, such as finished floor elevations above the projected base flood elevation or increased setbacks. The report shall be prepared and certified by a licensed civil engineer or certified engineering geologist with expertise in coastal processes.

Permit approval shall be conditioned on adherence to the Phased Adaptation Plan and on the financial assurance required by HAZ-1.2.18.

Policy HAZ-1.2.17

Hazard Disclosure. Where a coastal hazards report prepared under HAZ-1.2.16 identifies exposure to coastal hazards over the life of the proposed development, the City shall require, as a condition of approval, that the property owner record a deed restriction against the property. The deed restriction shall run with the land and bind all successors in interest and shall acknowledge the site-specific and project-specific recommendations of the coastal hazards report.

The deed restriction shall state:

- That the property is located in an area subject to coastal hazards, and that the owner assumes all risks and liabilities associated with those hazards;
- That the owner waives any claim of liability against the City for damage arising from coastal hazards;
- That new shoreline armoring is prohibited and that the development approved under this permit is not an existing structure entitled to shoreline protection;
- That if the development becomes threatened by coastal hazards and is no longer safe for occupancy or its intended use, the owner shall remove the development and remediate any resulting debris or nuisance conditions at the owner's sole expense;

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- That the City may not be able to guarantee continued public access to, or the continued availability of infrastructure serving, the property;
- That the boundary between public and private land may shift landward as sea level rises; and
- That approval of development does not authorize development on public trust lands.

Policy HAZ-1.2.18

Financial Assurance for Future Removal and Remediation. As a condition of approval of a coastal development permit for development or redevelopment within an area subject to coastal hazards risks over the life of the development, as mapped in Appendix A, *Carmel Climate Change Vulnerability Assessment*, the City shall require financial assurance, either through bonding, an in-lieu fee, or equivalent security recorded against the property, to fund the future removal of the development and remediation of any nuisance conditions resulting from coastal hazards. This requirement applies to permits for shoreline protective devices, and in that case the assurance shall also fund removal of the device and restoration of the affected shoreline.

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1.3 North Beach and North Dunes — Goals and Policies

The northern section of Carmel Beach provides open recreation space backed by the City's largest dune complex. The North Dunes support Tidestrom's lupine, a federally and state-listed endangered plant, and the California black legless lizard, a state species of special concern. The area's only residential development sits on the northernmost bluffs near Pescadero Canyon, where two homes are protected by private seawalls. A stormwater outfall and seawall are located south of the Fourth Avenue coastal access stairway. The Del Mar Parking Lot and the three sand ramps are among the most heavily used access points on the beach, and the parking lot is the most accessible point for visitors arriving by transit. Four sand volleyball courts, a blufftop viewing platform, and a public restroom make the area a popular destination. The sand ramps are constructed of bulldozed sand over buried drift logs. As erosion scarping becomes more frequent with rising seas, continued sand loss could expose that core and compromise the integrity of the ramps. Historical elevation data show that ramp elevations have already dropped one to three feet since the City's large-scale sand management program ended in the mid-2010s.

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Several facilities in this subarea are already exposed. The stormwater outfall and seawall just south of the Fourth Avenue coastal access stairway are likely subject to erosion under current conditions, and the project's coastal protection assessment identified that seawall as a high priority for repair. The blufftop viewing platform at Ocean Avenue and the Fourth Avenue coastal access stairway are also vulnerable to dune erosion.

As sea levels rise, this dune-backed shoreline will be susceptible to beach narrowing and dune erosion. In the near term, at one foot of sea level rise between roughly 2045 and 2060, the shoreline is projected to recede fifteen to thirty feet, exposing the North Dunes habitat and threatening access at the northern sand ramp unless a consistent sand supply is maintained. Assuming no adaptation measures are implemented, by two feet of sea level rise, the dune-backed shoreline is likely to transform into a cliff-backed shoreline, potentially limiting public access to the beach. At five feet of sea level rise this section is projected to be among the last stretches of Carmel Beach retaining a dry sand beach through the summer months.

The following goals and policies cover the North Beach and North Dunes subarea, extending from the armored properties on the cliffs adjacent to Pescadero Canyon at the northern City boundary, through the unarmored North Dunes and three sand ramps, to the Del Mar Avenue parking lot (Figure 3, North Beach and North Dunes).

Goals – North Beach and North Dunes

Goal 1.3.1

Sustain the recreational and ecological values of North Beach and North Dunes, maintain safe public access to the beach, and adapt the Del Mar Parking Lot as the shoreline recedes.

Goal 1.3.2

Adapt the North Beach and North Dunes section of Carmel Beach consistent with the adaptation pathway shown in Figure 4, North Beach and North Dunes Adaptation Pathway, guided by monitoring and initiated with enough lead time to avoid projected damage.

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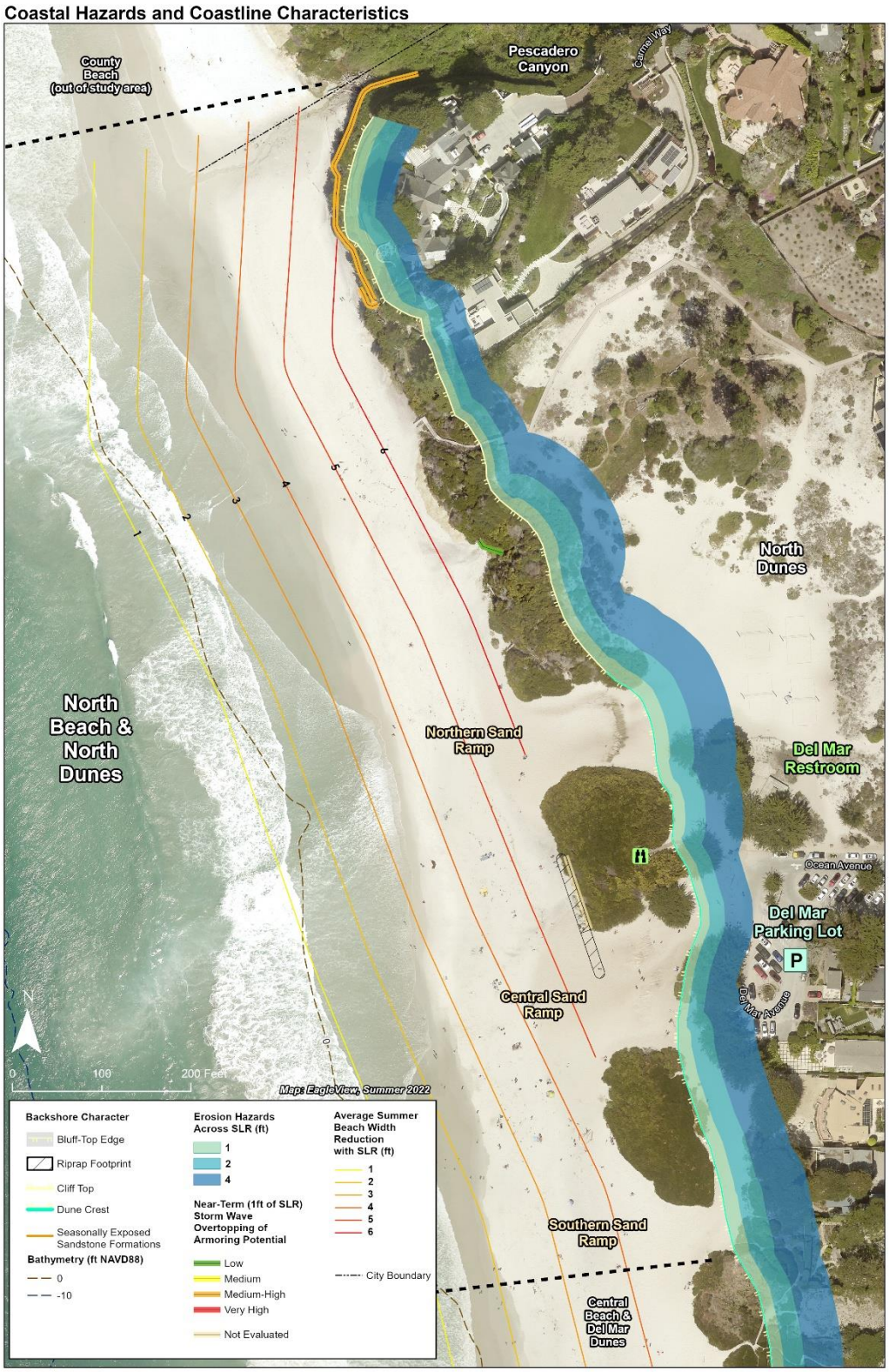
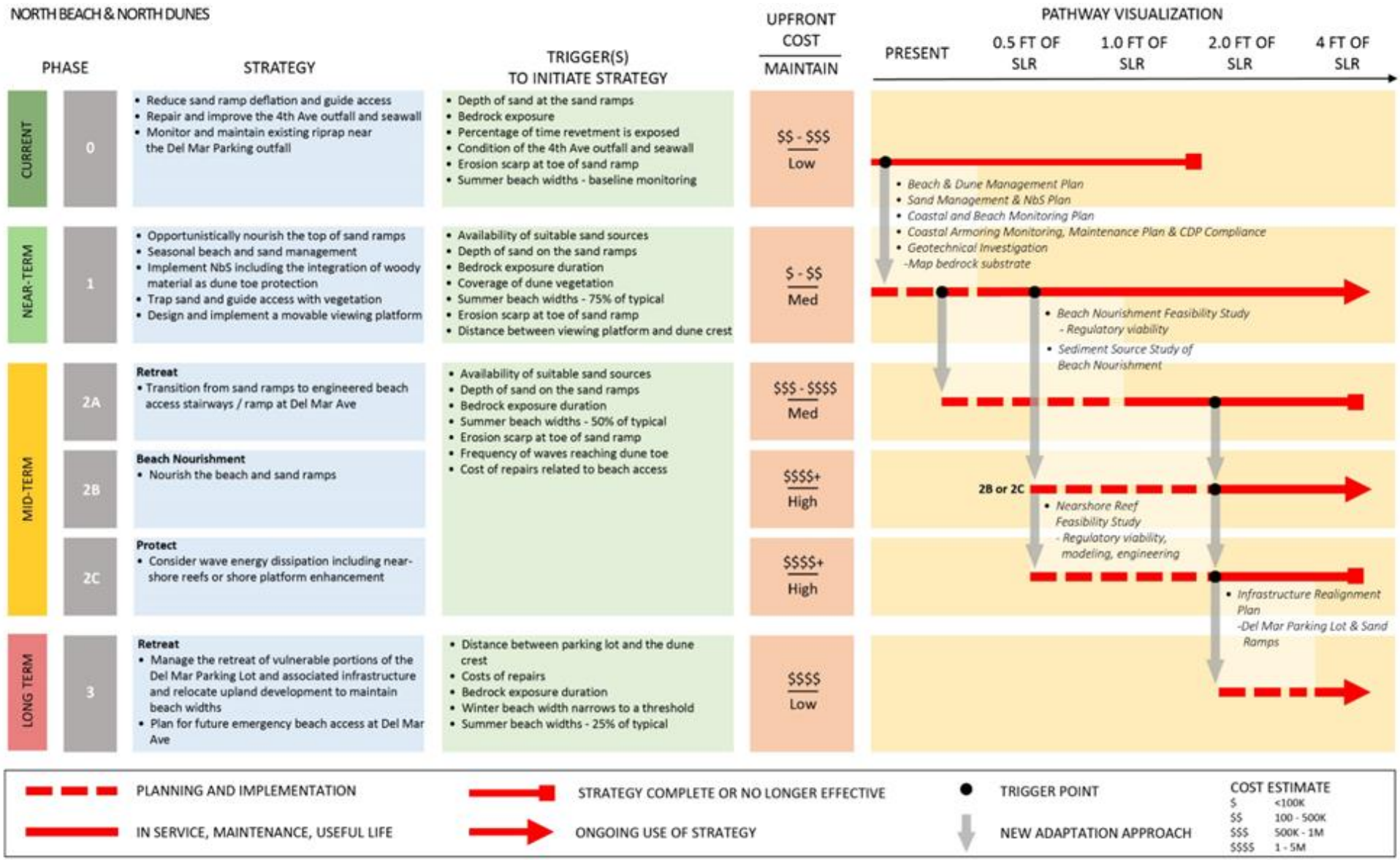
Figure 3 North Beach and North Dunes



Source: Revell, David. *Carmel Adaptation Pathways*. Integral Consulting, Inc., 2026

Figure 4 North Beach and North Dunes Adaptation Pathway



Source: Revell, David. *Carmel Adaptation Pathways*. Integral Consulting, 2026.

Policies – North Beach and North Dunes

Policy HAZ-1.3.1

Sand Ramp Maintenance. The City shall maintain the northern, central and southern sand ramps to ensure safe public access, including maintaining sand cover over exposed sandstone and addressing erosion and deflation of ramp surfaces. Maintenance shall be conducted through the Beach and Dune Management Program (HAZ-1.2.11) and consistent with the Coastal Access Phased Adaptation Plan (HAZ-1.2.9). The City shall prioritize the sand ramps for opportunistic sand placement when compatible material is available.

Policy HAZ-1.3.2

North Dunes Restoration. As part of the Beach and Dune Management Program (HAZ-1.2.11), the City shall restore and expand the North Dunes with native dune vegetation to improve sand trapping, enhance dune stability, and sustain the dunes' function as a natural sand reservoir and erosion buffer. Restoration shall be conducted in accordance with the North Dunes and Del Mar Dunes Habitat Restoration Plan and shall improve habitat for special-status species, including Tidestrom's lupine and the California black legless lizard.

Policy HAZ-1.3.3

Guided Access. As part of the Beach and Dune Management Program (HAZ-1.2.11), the City shall install and maintain fencing, boardwalks, or other low-impact measures where necessary to guide public access away from sensitive dune vegetation while maintaining recreational use. The City shall discourage off-trail use on or over the bluff face by installing landscaping barriers at shortcuts and by promptly restoring damaged landscaping.

Policy HAZ-1.3.4

Del Mar Parking Lot Adaptation. The Coastal Access Phased Adaptation Plan (HAZ-1.2.9) shall address the Del Mar Parking Lot and the public access and recreation facilities it serves, including the sand volleyball courts and blufftop viewing platform. The Critical Infrastructure Phased Adaptation Plan (HAZ-1.2.10) shall address the public restroom and the water storage tanks located near the parking lot, in coordination with the Coastal Access Phased Adaptation Plan. Each plan shall identify the triggers and phased measures applicable to those facilities, including eventual relocation or redesign where erosion makes their current location untenable.

Beginning with the next Capital Improvement Program cycle, the City shall implement early measures to reduce erosion risk to the parking lot and associated facilities, which may include grading, landscaping, and stormwater management to reduce erosional scour.

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Policy HAZ-1.3.5

Fourth Avenue Outfall Improvements. As part of the Critical Infrastructure Phased Adaptation Plan (HAZ-1.2.10), the City shall repair or redesign the Fourth Avenue stormwater outfall to improve drainage performance, reduce the risk of structural failure, and reduce discharge impacts to the Carmel Bay Area of Special Biological Significance. Redesign shall address projected erosion and sea level rise using the risk aversion criteria required by HAZ-1.2.4 and shall be designed to accommodate a future vertical public beach accessway should the nearest sand ramp become unsafe or no longer viable (Figure 4 North Beach and North Dunes Adaptation Pathways, Phase 2a).

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1.4 Central Beach and Del Mar Dunes — Goals and Policies

Central Beach and Del Mar Dunes connect the wide, recreational beaches of the north with the narrower, armored shoreline to the south. The section is characterized by densely vegetated dunes supporting dune scrub habitat. The dunes act as a protective buffer between storm waves and upland development and hold a reservoir of sand that feeds the beach. Private homes sit atop the rear dune and are reached by private coastal accessways. Two coastal access sand ramps lie south of the Del Mar parking lot, and a public stairway and emergency vehicle access ramp are located at Eighth Avenue. Although no riprap is visible, armoring is mapped beneath the dunes at Eighth Avenue in the Shoreline Management Plan.

Erosion is already evident here. Dune scarping was observed during the winter storms of 2022 and 2023, and the dunes near Eighth Avenue eroded thirty feet and formed a fourteen-foot scarp during the 1982-83 El Niño winter. The Eighth Avenue emergency access ramp is currently closed because of erosion damage. A gravity sewer line runs from the Del Mar parking lot to Eighth Avenue just inland of the dune crest. City and private stormwater drainpipes in this section are also exposed to erosion (Revell 2024).

At one foot of sea level rise, between roughly 2045 and 2060, the foredune is projected to recede up to forty feet, threatening the sewer line and destabilizing the sand ramps. At two feet, between roughly 2060 and 2080, the wastewater lift station near Eighth Avenue is at risk of erosion and flooding. At four feet, between roughly 2080 and 2100, three homes near Scenic Road and Eighth Avenue are projected to be exposed to erosion, and under the worst-case erosion scenario a total of eight homes between Eighth Avenue and Ocean Avenue could be threatened (Revell 2024).

The following goals and policies cover the unarmored dunes and private properties extending from the Del Mar Avenue parking lot on the north to Eighth Avenue on the south (Figure 5, Central Beach and Del Mar Dunes).

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Figure 5 Central Beach and Del Mar Dunes



Source: Revell, David. *Carmel Adaptation Pathways*. Integral Consulting, Inc., 2026

Goals – Central Beach and Del Mar Dunes

Goal 1.4.1

Enhance the natural resilience of the Del Mar Dunes, maintain public beach access, and protect critical infrastructure while planning for its eventual relocation out of hazard areas.

Goal 1.4.2

Adapt the Central Beach and Del Mar Dunes section of Carmel Beach consistent with the adaptation pathway shown in Figure 6, Central Beach and Del Mar Dunes Adaptation Pathway, guided by monitoring and initiated with enough lead time to avoid projected damage.

Policies – Central Beach and Del Mar Dunes

Policy HAZ-1.4.1

Dune Restoration. As part of the Beach and Dune Management Program (HAZ-1.2.11), the City shall maintain, restore, and enhance the Del Mar Dunes through native vegetation planting, sand management, and dune stabilization techniques that increase sand retention and ecological function. Restoration shall be conducted in accordance with the North Dunes and Del Mar Dunes Habitat Restoration Plan. The City shall enforce the maintenance of native vegetation and landscaping requirements of private landowners adjoining the dunes.

Policy HAZ-1.4.2

Nature-Based Stabilization. As part of the Beach and Dune Management Program (HAZ-1.2.11), the City shall use living shoreline techniques along the backshore of Central Beach, including placement of woody material to protect the dune toe and vegetation to trap sand, in order to stabilize the Del Mar Dunes and reduce erosion. Driftwood-cored dune construction may be used at the Eighth Avenue sand ramp and other dune-backed locations.

Policy HAZ-1.4.3

Private Property Coordination. The City shall coordinate with owners of private property adjoining the Del Mar Dunes to support dune restoration and proactive adaptation. Coordination shall include sharing results of the Coastal Change Monitoring Program (HAZ-1.2.8) and current hazard projections, providing information on dune-compatible landscaping and invasive species removal, encouraging early preparation of Phased Adaptation Plans under HAZ-1.2.16, and seeking access to private property where necessary to conduct monitoring.

Policy HAZ-1.4.4

Emergency Access. The City shall maintain emergency vehicle access to the beach. The City shall restore the existing sand ramp at Eighth Avenue or establish an alternative alignment where erosion makes the existing location unsafe or infeasible, drawing on the alternatives identified in Appendix B, Carmel Adaptation Pathways. Maintenance shall be conducted through the Beach and Dune Management Program (HAZ-1.2.11), and any re-alignment shall be coordinated with the Coastal Access Phased Adaptation Plan (HAZ-1.2.9).

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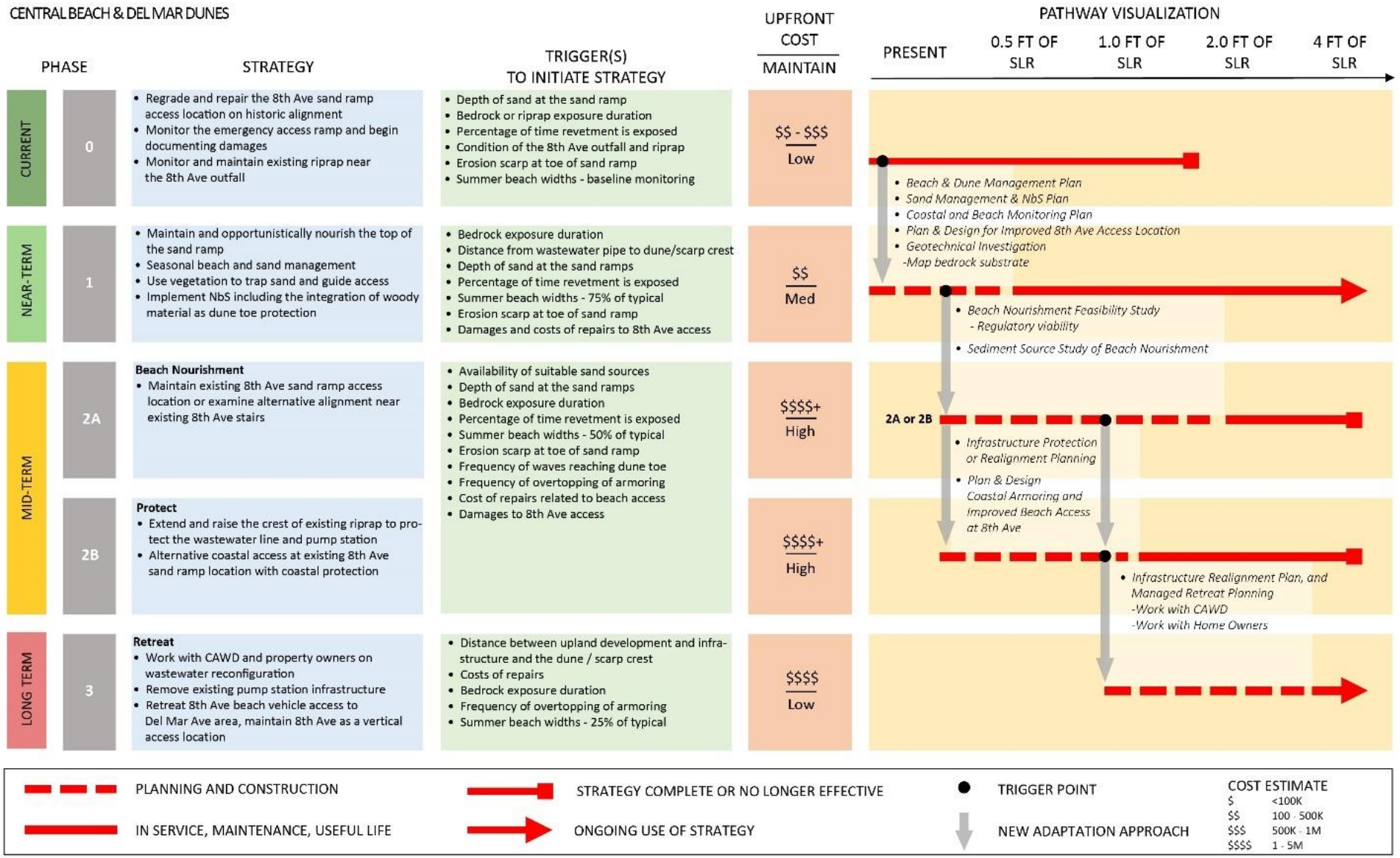
Figure 6 Central Beach and Del Mar Dunes Adaptation Pathway



Source: Revell, David. *Carmel Adaptation Pathways*. Integral Consulting, Inc., 2026.

Policy HAZ-1.4.5

Infrastructure Coordination. As part of the Coastal Change Monitoring Program, the City shall coordinate with the Carmel Area Wastewater District and other infrastructure providers to monitor exposure risks to wastewater infrastructure on Central Beach, including pump stations and conveyance pipelines, and plan adaptation measures where necessary.

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1.5 South Beach and Scenic Road — Goals and Policies

The southern section of the beach is dominated by armored cliff faces, vegetated bluffs, and a narrow sandy beach. Scenic Road and the Scenic Road Pathway wind along the bluffs adjacent to residential development. Scenic Road has carried one-way southbound traffic between Eighth Avenue and Santa Lucia Avenue since the 1960s and was narrowed further in 1988 to provide more space for the Pathway and landscaping. On a typical day, approximately 2,300 vehicles travel southbound along Scenic Road to access ocean views and free street parking. Eight coastal access stairways lead down the cliffs to the shore between Ninth Avenue and Martin Way, and a public restroom is located at Santa Lucia Avenue and Scenic Road. Stormwater outfalls are channeled under Scenic Road and through the seawalls.

The width of the beach varies significantly through the year. In winter, larger waves pull sand offshore, often exposing the underlying shore platforms. These conditions limit lateral access, particularly around the rocky headlands at Tenth, Twelfth, and Thirteenth Avenues. As sand volume decreases, waves reach the armoring structures with greater force, and the resulting currents accelerate scour at the base and along the ends of the seawalls. During high-energy winter storms, waves overtop the seawalls and saturate the cliffs behind them, leaving the bluffs prone to erosion and failure.

Rising sea levels will intensify these processes. Cliff erosion driven by both uphill stormwater runoff and ocean saturation will narrow the distance between the bluff edge and the Scenic Road Pathway and eventually destabilize the ground beneath the roadway and the residences behind it. At two feet of sea level rise, between roughly 2060 and 2080, nearly the entire length of Scenic Road is projected to be exposed to erosion. Most of the underground water and wastewater infrastructure here, including a water main between Eighth and Tenth Avenues, may become exposed. At four feet, between roughly 2080 and 2100, projected cliff retreat reaches up to 150 feet between Tenth and Twelfth Avenues, and 42 oceanfront homes along Scenic Road may be exposed to erosion hazards (Revell 2024).

Critical infrastructure along Scenic Road faces risk from both cliff erosion and wave overtopping. Key assets include the roadway itself, water and wastewater lines, and storm drain outfalls. Damage to these systems can cause service losses that extend well beyond the immediate site, with wide-ranging consequences for public health and safety.

Critical infrastructure is expensive to construct and slow to relocate. Because of the lead time required for planning, funding, and construction, efforts to move it out of hazard-prone areas must begin well in advance of frequent erosion and overtopping. Given the severity of the consequences of failure and the limited adaptability of these systems, the following policies apply a conservative approach, using the high sea level rise scenario recommended by the California Coastal Commission for critical infrastructure.

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The following goals and policies cover the mostly armored cliffs along Scenic Road from Eighth Avenue on the north to Martin Way on the south (Figure 7, South Beach and Scenic Road).

Goals– South Beach and Scenic Road

Goal 1.5.1

For as long as feasible, protect Scenic Road, the Scenic Road Pathway, and the critical infrastructure along them from cliff erosion and wave overtopping, and maintain safe vertical and lateral public access to South Beach.

Goal 1.5.2

Adapt South Beach and Scenic Road in planned phases consistent with the pathway shown in Figure 10, South Beach and Scenic Road Adaptation Pathway, guided by monitoring and initiated with enough lead time to avoid projected damage.

Goal 1.5.3

Relocate critical infrastructure along Scenic Road out of the coastal hazard areas as the primary strategy for protecting that infrastructure. Begin analysis, site planning, and financial planning far enough ahead of hazard exposure to maintain uninterrupted service, public safety, and coastal resources.

Policies– South Beach and Scenic Road

Policy HAZ-1.5.1

Shoreline Protection Maintenance. In addition to the conditions required by HAZ-1.2.14, and in accordance with the phased adaptation in Figure 8, South Beach and Scenic Road Adaptation Pathway, any coastal development permit approved for the repair, maintenance, or improvement of a shoreline protective device along South Beach or Scenic Road shall require incorporation of measures that reduce scour, wave overtopping, or wave energy reaching the backshore. Such measures include but are not limited to wave and current deflectors at access points, raising the crest of existing seawalls, low-crested structures, and nearshore reefs (Figure 9, Illustration of a Submerged Nearshore Reef Structure).

Where feasible, replacement of riprap revetments with soil nail or tie-back walls shall be considered in order to recover sandy beach area.

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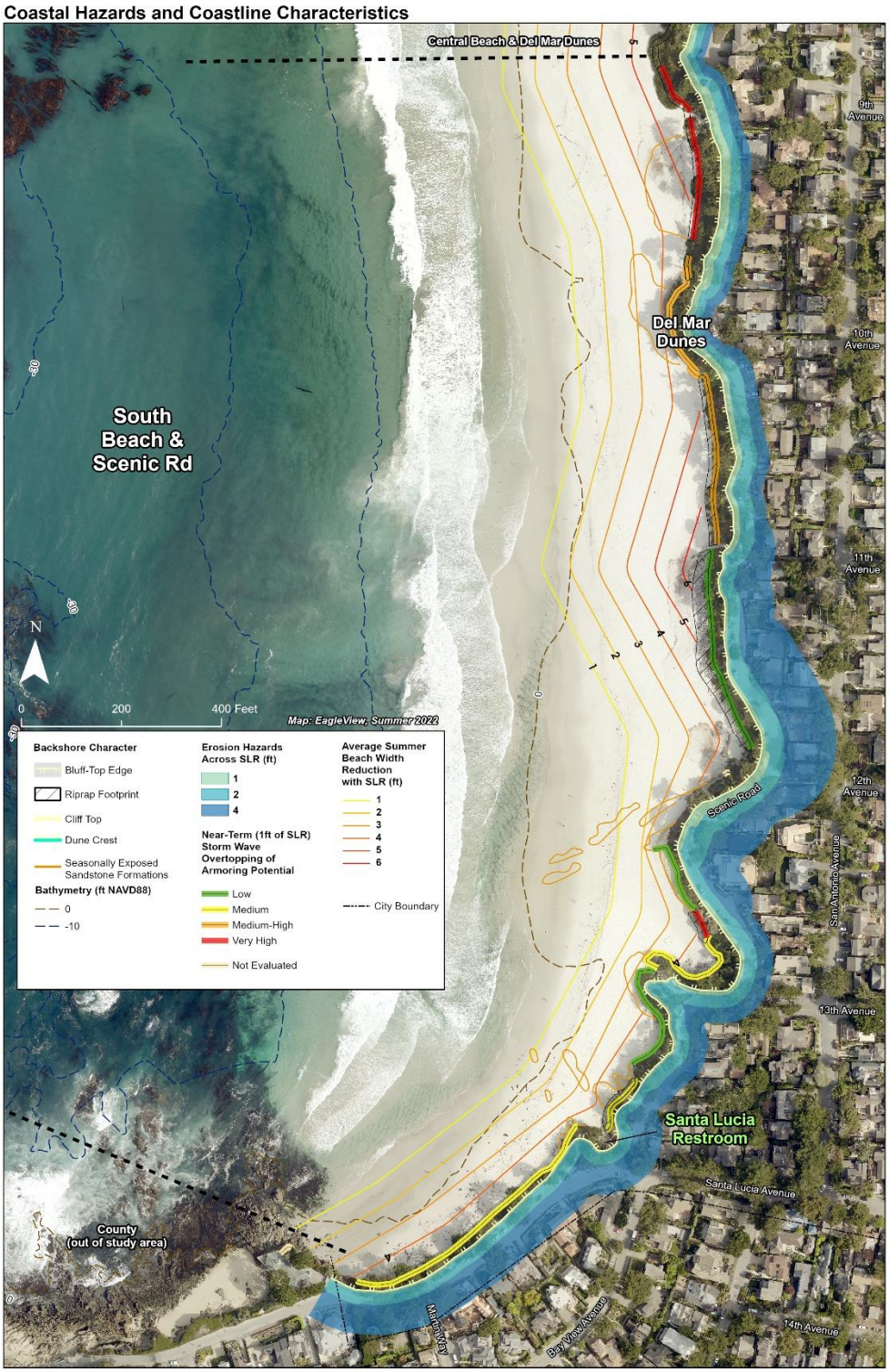
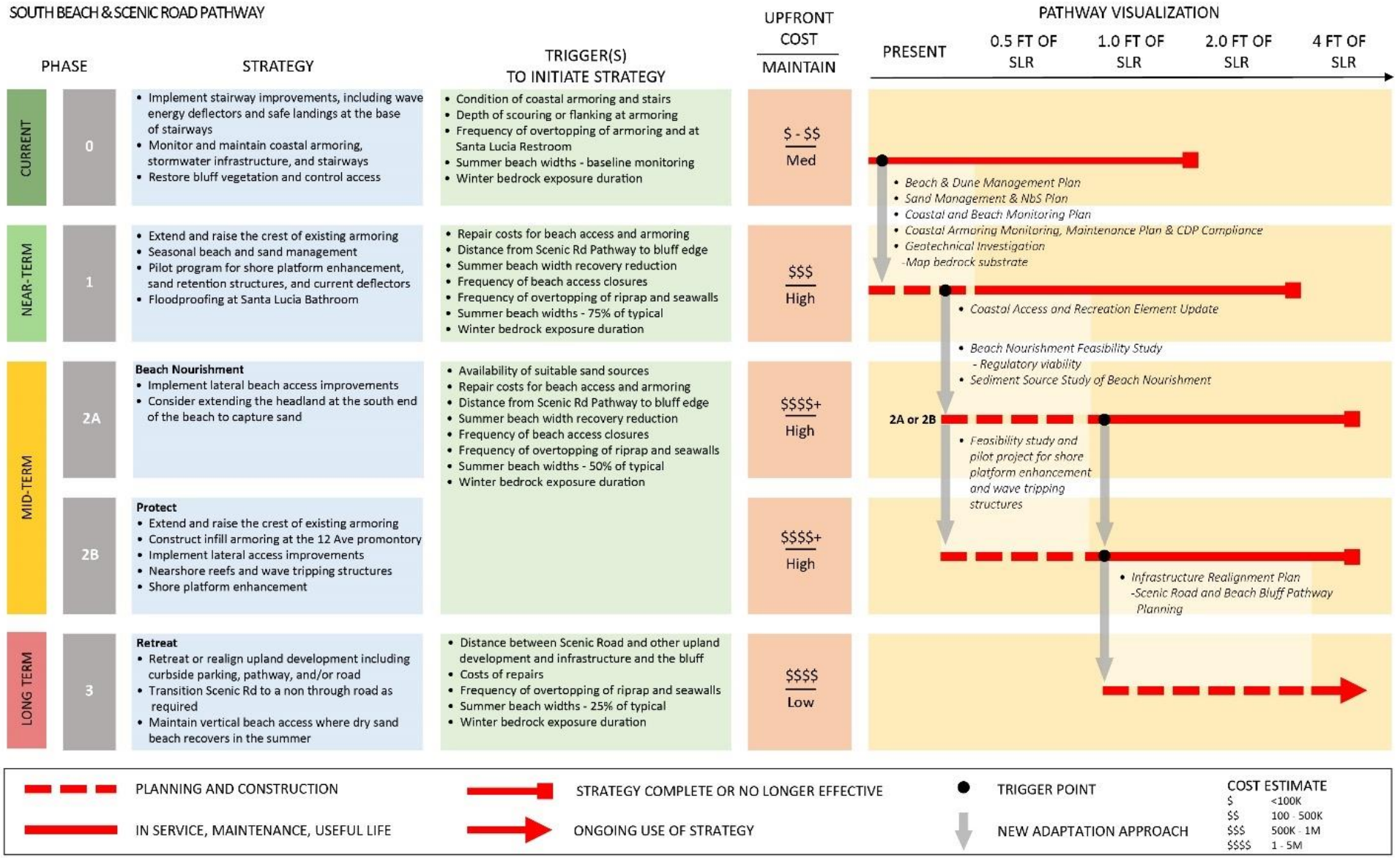
Figure 7 South Beach and Scenic Road



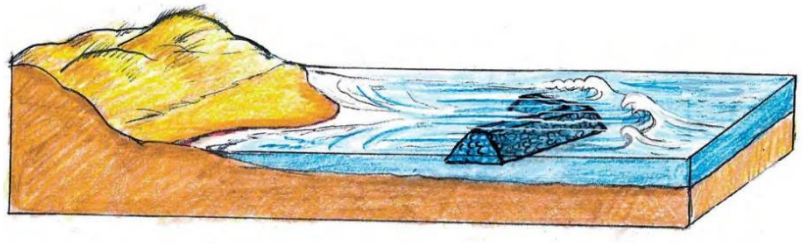
Source: Revell, David. *Carmel Adaptation Pathways*. Integral Consulting, Inc., 2026

Figure 8 South Beach and Scenic Road Adaptation Pathway



Source: Revell, David. *Carmel Adaptation Pathways*. Integral Consulting, Inc., 2026.

Figure 9 Illustration of a Submerged Nearshore Reef Structure



Source: Revell 2026

Policy HAZ-1.5.2

Scenic Road Adaptation. For as long as feasible, the City shall protect Scenic Road and the Scenic Road Pathway from coastal hazards. The Critical Infrastructure Phased Adaptation Plan (HAZ-1.2.10) shall address Scenic Road, identifying the triggers and phased measures that apply, including roadway realignment, lane or parking reductions, conversion to non-vehicular use, and eventual relocation out of the coastal hazard area.

Policy HAZ-1.5.3

Scenic Road Pathway Maintenance. The City shall maintain the Scenic Road Pathway to the maximum extent feasible, ensuring public safety and minimizing impacts to coastal processes. Maintenance does not authorize new shoreline armoring, which remains subject to HAZ-1.2.13 through HAZ-1.2.15. The Coastal Public Access Phased Adaptation Plan (HAZ-1.2.9) shall address realignment or relocation of the Pathway where erosion makes its current alignment unsafe or infeasible.

Policy HAZ-1.5.4

Beach Access. The City shall maintain vertical and lateral public access along South Beach to the maximum extent feasible. The Coastal Public Access Phased Adaptation Plan (HAZ-1.2.9) shall address South Beach access, including maintenance and eventual realignment or replacement of the coastal access stairways, measures to sustain lateral access as the beach narrows and sandstone outcrops become exposed, and identification of locations where access cannot feasibly be maintained.

Policy HAZ-1.5.5

Wastewater and Water Infrastructure. The City shall work with the other responsible providers to plan for phased relocation of existing wastewater and water infrastructure along Scenic Road. Scheduled replacement or significant upgrades shall be treated as an opportunity to relocate. Planning shall begin far enough ahead of projected exposure to allow for design, permitting, funding, and construction. The Critical Infrastructure Phased Adaptation Plan shall establish the triggers and phases that govern relocation, using the distance from the Scenic Road Beach Bluff Pathway to the bluff edge as a primary indicator.

Administrative Draft

Policy HAZ-1.5.6

Infrastructure Development. Where the City finds that development of critical infrastructure cannot feasibly avoid areas subject to coastal hazards, the City shall update the Critical Infrastructure Phased Adaptation Plan to address that infrastructure. In addition to the requirements in HAZ-1.2.4, the Plan shall provide for:

- Regular monitoring of erosion and other coastal hazards at the site, and management of responses to those hazards both on site and off site;
- Identification of how those hazards are affecting, or will soon affect, the operation of the infrastructure;
- Identification of changes necessary to allow continued safe functioning of the infrastructure, including retrofits, upgrades, or relocation; and
- Metrics for assessing site conditions and responses related to flooding and erosion under both typical and extreme storm events, accounting for sea level rise.

The Plan shall also provide for increased frequency of inspection as coastal hazards threaten the integrity of the infrastructure.

Policy HAZ-1.5.7

Public Restroom Facilities. The public restroom at Santa Lucia Avenue is critical infrastructure exposed to cliff erosion and coastal flooding under current conditions. The Critical Infrastructure Phased Adaptation Plan (HAZ-1.2.10) shall treat the facility as impacted in the Immediate phase and shall establish the triggers and phased measures that apply to it. Phased measures shall include floodproofing in the Near-Term phase and relocation or replacement outside the coastal hazard area in the Mid-Term or Long-Term phase. The City shall coordinate these measures with the Coastal Public Access Phased Adaptation Plan (HAZ-1.2.9) so that restroom service to South Beach is maintained as accessways are realigned, relocated, or closed.

Administrative Draft

2.0
Definitions and Resources

The following definitions are based on the California Coastal Commission's resources for Sea Level Rise Adaptation Planning. The California Coastal Commission's *Sea Level Rise Policy Guidance* (California Coastal Commission 2024), *Critical Infrastructure at Risk* (California Coastal Commission 2021), and *Nature-Based Adaptation Strategies* (California Coastal Commission 2026) provide extensive guidance for implementing the Ocean Protection Council's Sea Level Rise Program and the requirements codified in Senate Bill 1 (Atkins, 2022) and Senate Bill 272 (Laird, 2023).

Armoring, hard. Engineered or hybrid features constructed of rock, concrete or other rigid materials that fix the shoreline position and alter the natural shoreline processes, including sediment transport and beach dynamics. This includes but is not limited to seawalls, cliff retaining walls, revetments, riprap, earthen berms, cave fills, groins, or bulkheads.

Armoring, hybrid. Nature-based adaptation strategies that combines fixing the shoreline, such as with a buried revetment or other shoreline protective device, with a nature-based feature to provide ecological or other benefits.

Armoring, soft. The use or construction of nature-based adaptation strategies that avoid fixing the shoreline with hard structures and instead rely on the use of dynamic systems to attenuate coastal hazards, such as dune or wetland restoration, sand replenishment and other systems to buffer and protect coastlines from coastal hazards.

Critical infrastructure. Assets that support societal functions and protect public health, safety and welfare, including but not limited to roads, public restrooms, water, wastewater, drainage, sewers, transportation, stormwater, wastewater, groundwater, wireless transmission systems, telecommunications, and energy assets.

Dry-sand beach. The portion of the beach that is landward of the mean high-water mark.

Development. Synonymous with "development" and "new development" and shall include construction of entirely new structures (whereby the policies apply to the entire new structure), additions to existing structures (whereby the policies apply only to the addition itself).

Erosion, coastal. Can refer to either beach narrowing or cliff retreat. For cliffs, this refers to the long-term loss or removal of land due to coastal or terrestrial processes. For beaches, this may refer to either the long-term, short-term, or localized removal of sediments from the beach.

Existing structure. A structure that existed as of the effective date of the Coastal Act (January 1, 1977) that has not been redeveloped since.

Managed retreat. Adaptation measures or programs that relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. These strategies include land use designations and zoning ordinances that encourage building in more resilient areas or gradually removing and relocating existing development.

Nature based adaptation. A coastal adaptation and/or erosion control method that is comprised of natural and mostly natural elements, which contributes to the persistence and enhancement of coastal processes and ecological benefits while also protecting inshore areas. A broad category of strategies that work with nature to build coastal resilience.

Nourishment. The placement of sand and/or sediment on a beach to offset erosion or increase beach width.

Revetment. A sloped structure of rock or concrete to absorb wave energy and protect landward areas.

Redevelopment. Replacement of 20% or more of an existing structure, either through multiple, smaller sequential renovations or replacements or through a larger, single project renovation. Shall require a Coastal Development Permit and require that the entire structure be brought into conformance with the standards of the City's Local Coastal Program and the California Coastal Act.

Shoreline protective device. A broad term for constructed features that block the landward retreat of the shoreline and are used to protect structures or other features from erosion and other hazards.

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Carmel Climate Change Vulnerability Assessment

A

APPENDIX

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MEMORANDUM

To:	Mary Bilse, Environmental Programs Manager and Robert Harary, Director of Public Works, City of Carmel-by-the-Sea
From:	David Revell, Integral Consulting Inc.
Date:	October 4, 2023
Subject:	Carmel Climate Change Vulnerability Assessment, Shoreline and Beach Change Analysis: Seasonal and Long Term
Project No.:	C3016

EXECUTIVE SUMMARY

Carmel Beach is a 1.25-mile-long pocket beach with sand constrained by two rocky headlands—Arrowhead Point in the north and Carmel Point and an offshore reef in the south. As a large pocket beach, the volume of sand is mostly contained between the headlands, where very little sediment is gained or lost within the system. Sediment movement within the system can occur either north or south (alongshore) or off and onshore (cross shore) based on seasonal changes in wave energy and direction and in response to large storm wave events. Note that the movement of sediment in coastal environments is a dynamic and ongoing process. Sediment transport at Carmel Beach will be influenced by sea-level rise and increased storminess, which are long-term factors influenced by climate change. This report focuses only on typical historical conditions and does not project the potential hazard at Carmel Beach due to climate change. This will occur in future tasks.

The following is a highlight of this study's major findings for shoreline and beach change organized by **long-term historical trends** (decadal scale), **seasonal trends** (monthly to annual scale), **storm impacts** (event specific), and **recovery** (both seasonal and long term).

Long-term Historical Trends

- Over the last 80 years, while there have been many observed changes in dry sand beach widths due to a sequence of storm and recovery events, there is no long-term erosion trend as evidenced by a relatively stable average shoreline position

derived via satellite measurements. This lack of an erosion trend indicates that there has been a consistent volume of sand in this pocket beach at Carmel Bay.

- The stable beach volume in this area is rather unique in California. Most of the other littoral cells (or beach compartments) have a set of sand sources and a sink (like a submarine canyon) where sand is lost from the beach system.
- On average, dry beach widths were narrower south of 8th Avenue, wider in the north by the Pebble Beach Golf Links, and the widest in the dune-backed areas near the Del Mar parking lot.

Seasonal Trends

- The dry sand beach widths change seasonally, where the narrowest beach widths occur in the spring (after winter storm waves move sand offshore) and the widest beach widths occur in the fall (after small summer waves bring that same sand back onshore).
- The highest range in beach widths occurs around the area of 4th Avenue and Pescadero Canyon (around the offshore rock).
- The beach width remains most consistent in the dune-backed areas near the Del Mar Parking lot, presumably as a result of sand being eroded from the dunes and nourishing that portion of the beach.

Storm Impacts

- The biggest storm impacts occur during strong west swells (often El Niño years), which approach the beach straight on. When erosion is highest, dry sand beach widths are the narrowest as most of the sand is moved from the dry sand beach and into nearshore bars. This erosion and sand transport during storms can expose the sandstone bedrock underlying the sand in some areas resulting in challenges to beach access and damaging coastal armoring. When the beach is narrowest, the waves can break closer to shore, overtop the coastal armoring, and lead to erosion of the cliffs and bluffs.
- The most significant observed cliff erosion ranged between 20–40 ft and was observed following the 1982–1983 El Niño in areas where coastal armoring was already in place.

Recovery

- Recovery of the dry sand beach after large storm events can take a few years. The area south of 8th Avenue usually begins recovery earliest but takes the longest to recover.
- Recovery time varies but is related to waves with smaller wave heights and longer periods and coming from both the north and south angles to the beach.

INTRODUCTION

Purpose of this Study

This study is part of the City of Carmel Coastal Engineering and Hazard Assessment and serves as a technical memorandum to complete the deliverable for Task 2 of the Carmel Climate Change Vulnerability Assessment, Shoreline and Beach Change Analysis: Seasonal and Long Term. This technical memo intends to explain the physical processes that lead to seasonal changes in the beach, document the extent of historic erosion, and quantify changes to the shoreline, cliffs, and dunes.

During this task in the project, large ocean swells associated with the energetic winter storms of 2022–23 caused substantial beach scouring. Examples of these hazardous conditions can be seen in Figure 1 below, where scouring made beach access difficult (see Figure 1, left) and portions of the beach became difficult to navigate (see Figure 22, right).

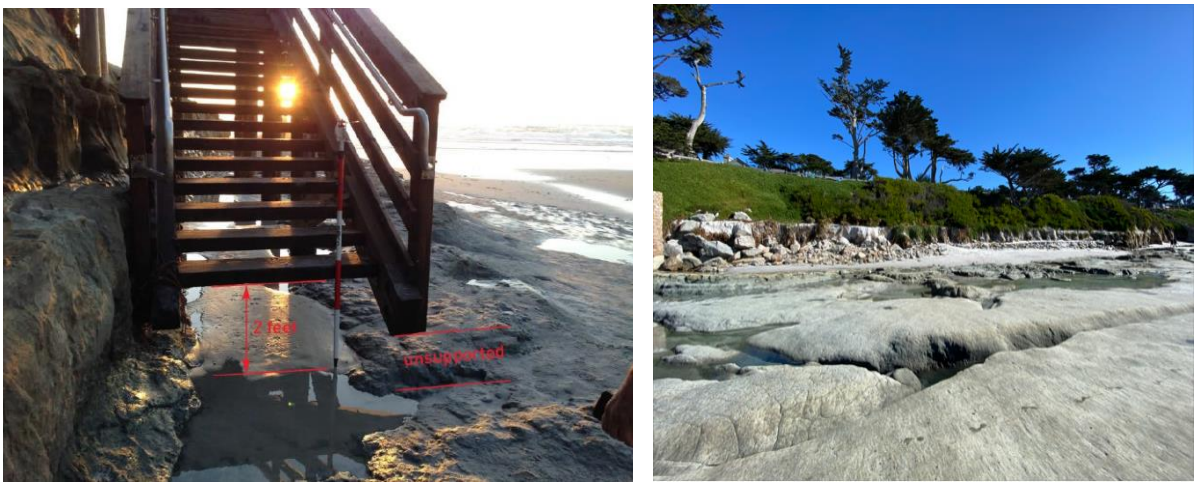


Figure 1. Left, undermined 12th Avenue stairway following the El Niño Winter of 2015–16 (January 24, 2016). Source: Easton Geology (2016)
Right, the beach scoured down to bedrock near 10th and 11th avenues following strong winter storms of 2022–23 (January 30, 2023). Source: HKA (2023).

These storm events highlighted the need to identify priority locations for repairs (see Task 1 report by Haro, Kasunich & Associates, Inc., Carmel Beach Coastal Protection Assessment). As results from Task 1 were presented and the project progressed, some of the key questions being asked by members of the City of Carmel-by-the-Sea for this task included:

- What is the long-term trend in shoreline change, and is there a narrowing of beach widths?
- What changes do large storm events cause?

- How long does the beach take to recover following large storm events?

This study will serve to provide an understanding for how this beach system changes both seasonally and long term, and these findings will inform sea-level rise and coastal hazard modeling efforts for Task 3, Shoreline and Beach Erosion Exposure Modeling, and improve understanding of potential exposure and vulnerabilities to city infrastructure and development for Task 4, Coastal Hazard and Sea Level Rise Vulnerabilities.

Study Area

This study focuses on Carmel Beach within Carmel Bay, illustrated by the brackets in Figure 2. Carmel Beach is a pocket beach extending between Arrowhead to Carmel Points, the city portion of Carmel Beach encompasses the lower three-fourths of this northern pocket beach (from Pescadero Canyon to Carmel Point), with the Pebble Beach section extending north towards Arrowhead Point[1] (see Figure 2). As the city and non-city portions of Carmel Beach form a connected system, the analysis is focused on both portions.

[1] Named for the golf course located just inland of this location and not to be confused with the actual Pebble Beach, a small pocket beach located in the north of Carmel Bay.



Figure 2. Project Study Area.

Beach Sections and Coastal Access

The city beach is a 22.5-acre public park accessed by locals and visitors alike. It is served by an extensive public access system that includes 10 beach access stairways and four sand ramps. Beach access parking is available at the Del Mar Parking Lot (122 spaces), as well as along Scenic Road (127 spaces) and North San Antonio Avenue in the north (10 spaces) (Shonman and D'Ambrosio 2003) (see Figure 3).

The beach sections referenced in this study emerged from the City's Climate Change Vulnerability Assessment report (2021). One of the priorities of this report was to identify how adaptation options and strategies along the coast may vary for four distinct planning areas within the City (see the areas identified in Figure 3). The planning areas identified include:

- Mostly armored cliffs and bluffs along Scenic Road south of 8th Avenue. Henceforth referred to as **Section 1, South Beach** (Figure 4).
- Unarmored dunes along private property between 8th Avenue and Del Mar Parking Lot. Henceforth referred to as **Section 2, Central Beach** (Figure 5)**.**
- Mostly natural, unarmored North Dunes area. Henceforth referred to as **Section 3, North Dunes** (Figure 6).
- Armored private properties on the cliffs at the north end of the City. Henceforth referred to as **Section 4, North Beach** (Figure 7).

For the sake of brevity, each beach section in this memo will be referred to by section number and/or its short name, South Beach, Central Beach, North Dunes, or North Beach. Also included is the beach section north of the City limits, referred to in this study as **Section 5, Pebble Beach** (Figure 8).



Figure 3. Carmel Beach Sections and Coastal Access (left), and Offshore and Nearshore Characteristics (right)



Figure 4. Section 1, South Beach. Source: California Coastal Records Project (2018)



Figure 5. Section 2, Central Beach. Source: California Coastal Records Project (2018)



Figure 6. Section 3, North Dunes. Source: California Coastal Records Project (2018)



Figure 7. Section 4, North Beach. Source: California Coastal Records Project (2018)



Figure 8. Section 5, Pebble Beach. Source: California Coastal Records Project (2018)

COASTAL PROCESSES AND MORPHOLOGY

The coastal zone is influenced by a multitude of marine forces including tides, waves, and wind, and extends seaward to the point at which waves no longer interact with the seabed. This section will provide an overview of the coastal processes that are pertinent to Carmel Beach. Note that Carmel has cliffs, dunes, and beaches that behave differently and quasi-independently.

Coastal processes that create coastal hazards include tides, waves, and related storm conditions. An important measure of coastal hazards is the total water level (TWL) elevation, which is the combined effect of wave run-up height, storm surge, tides, and sea-level elevations (**Error! Reference source not found.**Figure 9). At Carmel Beach, river discharge is not a contributing factor to TWL in the study area as flows from Pescadero Creek are low, and there is very little interaction with Carmel River and San Jose Creek in the southern Carmel Bay beach compartment due to Carmel Point. A combination of large waves occurring at high tides during storm conditions poses the largest potential threat for coastal erosion. Coastal erosion is comprised of both beach narrowing and cliff retreat. Beach narrowing and cliff retreat are two separate processes, but a narrower beach can lead to increased cliff retreat, which is explained further below. In the future, as sea levels rise, both the wave run-up dynamics and the tidal elevations will change, leading to higher TWLs for longer durations, accelerating both beach narrowing and cliff retreat. Each coastal process is summarized in **Error! Reference source not found.**.

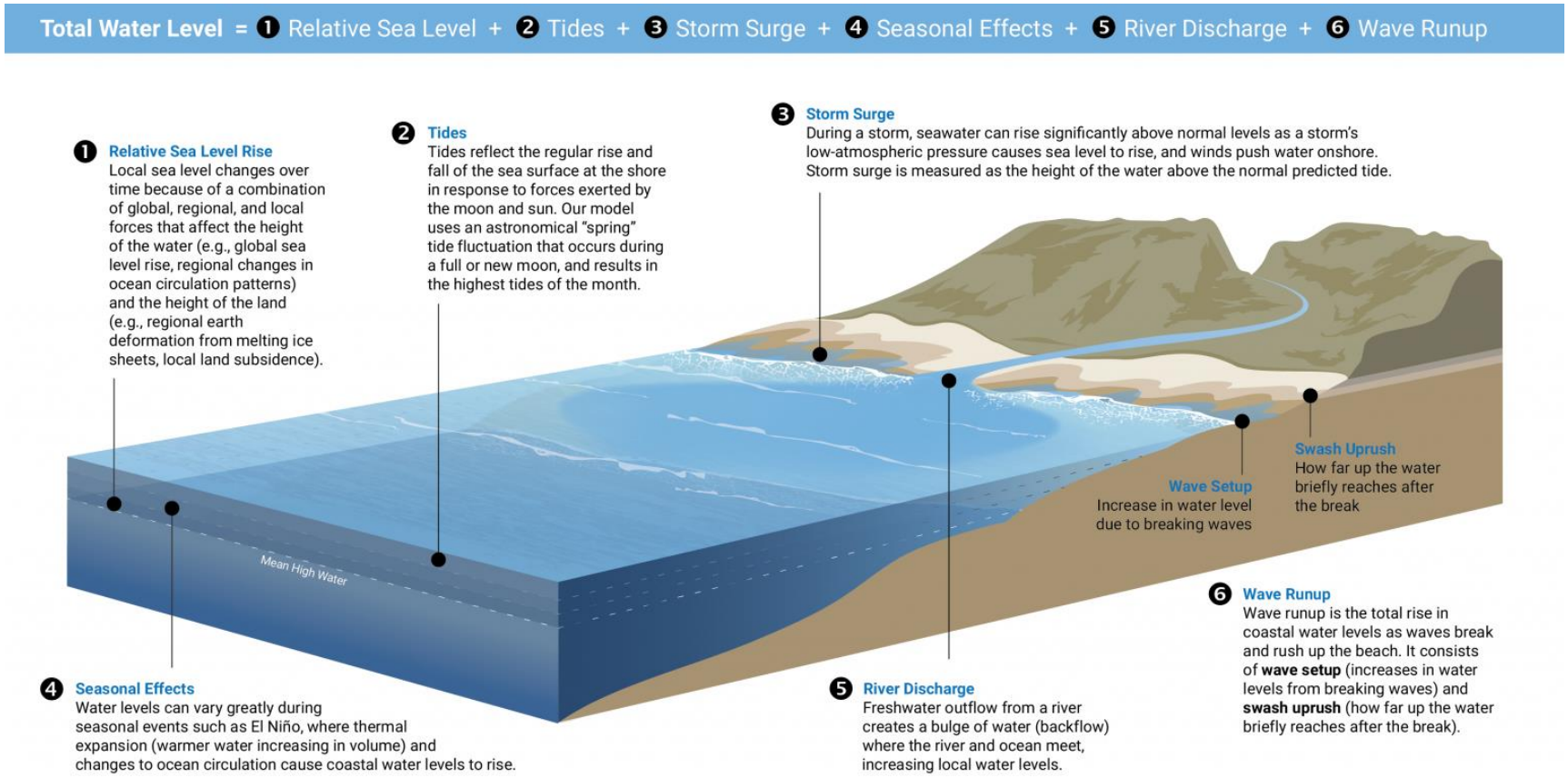


Figure 9. Conceptual diagram of the components of total water level.
Source: Our Coast Our Future Web Platform, Point Blue Conservation Science and USGS (2021).

Tides

Tides in the study area are mixed, predominantly semidiurnal, and are composed of two low and two high-water levels of unequal heights per 24.8-hour tidal cycle. Typically, the largest tide ranges in a year occur in late December to early January when the moon and sun are in alignment and closest in their orbits to the earth. These astronomical high tides are known as “king tides” and often result in coastal flooding unrelated to storm events.

Maximum water levels occur due to astronomical tides, wind surges, wave setup, density anomalies, long waves (including tsunamis), and cyclic El Niño and Pacific Decadal Oscillations. On longer time scales, the tides will reach higher elevations as sea levels rise. The National Oceanic and Atmospheric Administration (NOAA) Monterey tide gauge (Station 9413450) is the closest tide gauge to Carmel with readings extending only to the 1970s, whereas some gauges date back much further. For instance, the San Francisco tide gauges dates back to the mid-1800s. The relative rise in sea level, based on the Monterey gauge, is 1.62 millimeters per year (mm/yr.), based on monthly mean sea level data from 1973–2022, with a 95% confidence interval of 0.70 mm/yr. (Figure 10). This indicates that sea levels have risen 0.3 ft since the early 1970s. These measured local relative sea-level rise trends when compared to the global average provide estimates of land motion. In this case, the land is rising but just not as fast as sea levels.

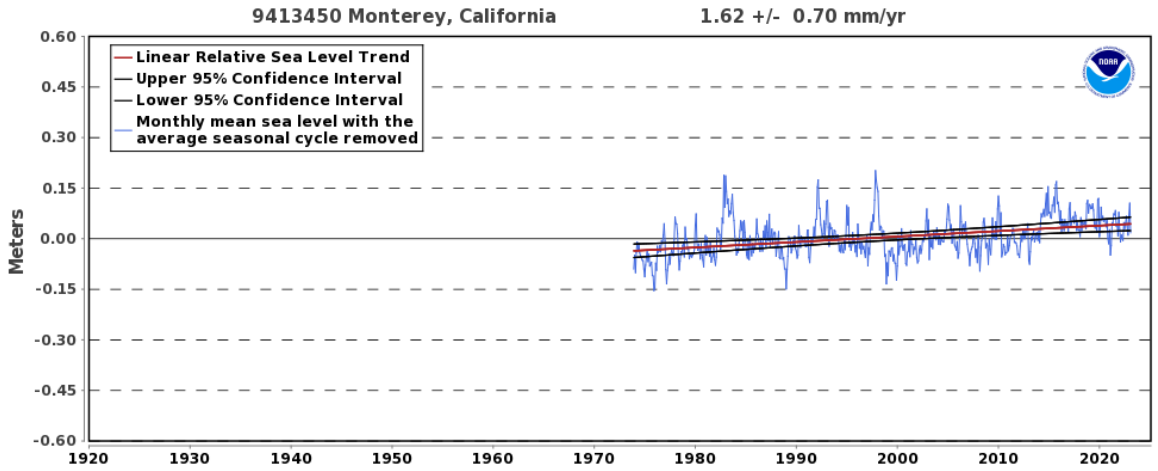


Figure 10. Relative Sea Level Trend for the NOAA Monterey Tide Gauge (NOAA Station 9413450)

Waves

The waves that approach Carmel Beach are characterized by three dominant types depending on their wave source and direction (see **Error! Reference source not f ound.**)**Error! Reference source not found.**. Most wave energy approaches the study site from the northwest and west (Storlazzi and Wingfield 2005) by waves generated by

cyclones in the North Pacific and tends to peak in wave height during the winter months (up to 25 ft). During the summer, southern hemisphere waves produce smaller waves with longer wave periods (greater than 20 seconds). Between April and October, mid-sized and slightly shorter period wind waves also approach Carmel Beach from the northwest (Storlazzi and Wingfield 2005). In general, smaller waves tend to move sand volumes up the beach profile and feed the dry sand beach while larger waves tend to move sand off of the dry sand beach.

The wave climate fluctuates over interannual and longer time periods with ocean-atmosphere oscillations like the El Niño Southern Oscillation (ENSO). These storms tend to follow a more southerly track when El Niño conditions are strongest, resulting in more erosion potential for the study area. El Niño conditions generally occur every three to seven years, with particularly intense events every 10 to 20 years (Storlazzi and Griggs 1998). There are also longer-term climatic oscillations such as the Pacific Decadal Oscillation (PDO). PDO warm phases have been associated with periods of increased storm frequency and intensity, resulting in accelerated erosion rates (Russell and Griggs 2012).

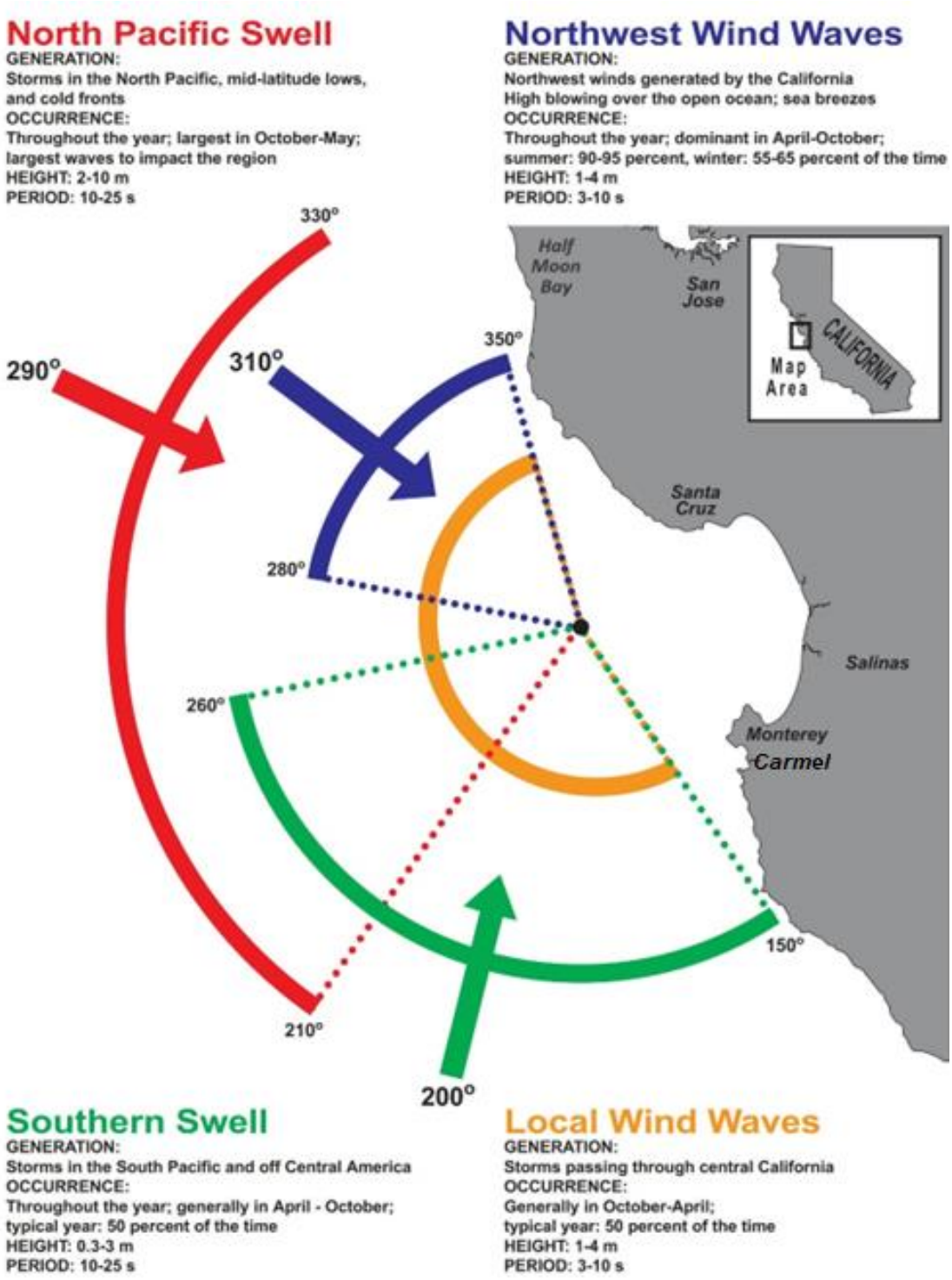


Figure 11. Diagram depicting dominant wave types, directions, and seasons for Carmel Beach and Monterey Bay.
Source: Storlazzi and Wingfield (2005)

FEMA Storm Wave Hazard Zones

The National Flood Insurance Program, administered by the Federal Emergency Management Agency (FEMA), is intended to reduce future flood damage by encouraging local governments to adopt floodplain management regulatory programs. The regulatory Flood Insurance Rate Maps identify base flood elevations according to a 1%-annual-chance TWL elevation at the coast. The base flood elevations are depicted in **Error! Reference source not found.** (right) and vary from 16 to 31 ft. FEMA has d etermined that the highest wave runup extents between 9th and 11th avenues, and this is the one location where FEMA projects that the current 1%-annual-chance wave runup hazards to overtop the crest of the bluff.



Figure 12. City stormwater and water ponding areas (left), and FEMA 1%-annual-chance storm wave flood extent (right). Water ponding locations represent general areas, and were sourced from differences between winter 2009 and summer 2010 digital elevation models, as well as aerial images from 2003–2022.

Geomorphology

Carmel Beach's sediment originates from the granodiorite formations in the Pacific Grove and Monterey peninsula areas. Additionally, there have been minor contributions from sediment deposition at Pescadero Canyon and erosion of the sandstone cliffs in the central and southern regions of the beach. Eventually, sediment is gradually transported southward through a small channel, making its way out towards the Carmel submarine canyon (Storlazzi and Field 2000). Over the course of geological timescales (i.e., millennia), these sources have contributed to the composition of Carmel Beach.

Over the course of human timescales (i.e., decades to centuries), the sediments in Carmel Bay mostly remain between Arrowhead and Carmel points. Unlike most other California beaches that are located on exposed, open coastlines, Carmel Beach is a pocket beach situated between two headlands. On an open, exposed coastline, a beach can receive sediment from adjacent beaches. At Carmel, however, the headlands impede the delivery of sediment into and out of the beach. Therefore, Carmel receives very little sediment via alongshore littoral transport from the beaches north (Monterey Bay) and south (Carmel River State Beach) (see Figure 2. Project Study Area.Figure 2), and the sediment mostly moves in the cross-shore direction seasonally, as explained below.

Beach Dynamics

A beach is not just the dry sand above the waves; it also includes sediment volumes extending until the offshore. Figure 13 illustrates a cross-shore section of the beach, starting inland and extending offshore. Starting inland, the following describes the different portions of the beach cross section:

- **Backshore**: The dry sand beach starts at the toe of a cliff or dune and extends to the highest of high tides (also known as mean higher high hater [MHHW]). In this zone, the sand might build up to form a berm crest. The dominant force that shapes the beach in this zone is the wind, or aeolian forcing.
- **Nearshore**: This nearshore can also be considered the “surf zone.” This zone extends from the MHHW location on the beach to the offshore point where the sand no longer feels the effects of waves. The dominant force that shapes the beach in this zone are the waves. This section also includes the **beachface**, also known as a foreshore, which is the gently sloping part of a beach that is closest to the water's edge. It is the part of the beach that is typically exposed to the daily rise and fall of tides. The beachface is important in this study because this is the zone that the satellite imagery uses to demarcate the shoreline. The nearshore section also includes sandbars, which are berms of sand that are underwater and in nearshore waters.

- **Offshore:** The offshore portion of the beach is in deeper water. The sediment in this portion does not contribute to the beach since the sediment does not feel wave action at this depth. Dominant forces in this zone are ocean currents.

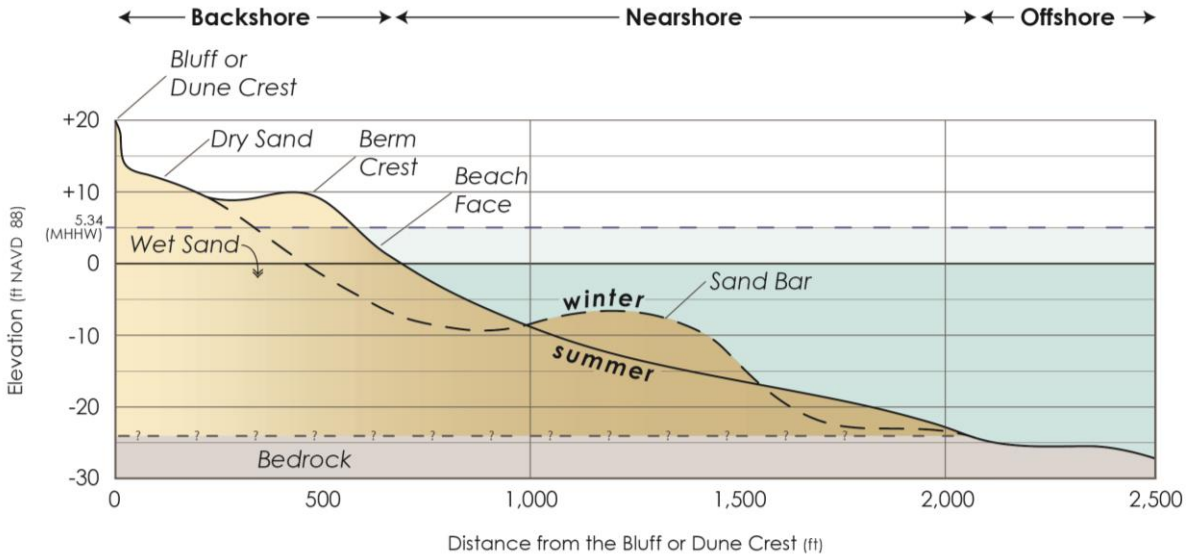


Figure 13. Example of a cross-shore profile showing seasonal change for Carmel Beach. The beach profile changes seasonally with a widening of the beach typically occurring between April and September, and a narrowing of the beach occurring in conjunction with winter storms and large waves, typically occurring in the winter months. The solid black line represents a typical summer profile, with a beach berm forming in spring and summer and a widening of the dry sand beach by as much as 200 ft. The hatched line represents a typical winter profile, with the beach face retreating and a longshore bar developing in the nearshore.
Image adapted from Waves and Beaches by Willard Bascom, 1964 (updated in 2020 by Kim McCoy).

The movement of sediment on and offshore throughout the seasons is influenced by various natural processes, including changes in wave action, tides, and weather patterns. The following is an overview of how sediment can move across the beach profile:

- **Winter season (offshore movement):** During the winter months, storms and strong winds are more common. These weather events generate powerful waves and increased wave energy. Powerful waves can erode the beach face and the backshore, picking up sand and sediment from the beach. Sediment is transported off the beach as the waves carry it away from the shore and onto nearshore sand bars.
- **Spring season (onshore movement):** In the spring, weather patterns often become milder with reduced storm activity. As wave energy decreases, sediment that was transported offshore into nearshore sand bars during the winter begin to

move back toward the shore, which is known as onshore sediment transport. Beaches then experience accretion, where sand is deposited back onto the beachface, widening the shoreline.

- **Summer season (onshore movement and stabilization):** During the summer, waves are typically calmer, and the beach may stabilize as sediment transport slows down. Beaches may reach their widest points during this season, providing ample space for beachgoers and recreational activities.
- **Autumn season (variable conditions):** In the autumn, weather patterns can vary, with occasional storms and changing wave conditions. Sediment movement can be influenced by the specific weather events that occur during this season. Storms can lead to erosion and offshore sediment transport, while calmer periods may promote onshore sediment transport and beach accretion.

Note that the movement of sediment in coastal environments is a dynamic and ongoing process. Sediment transport will also be influenced by long-term factors, such as sea level rise, increased storminess, and changes in the underlying geology. This report focuses only on historical typical conditions, and does not project the hazard of sea level rise and potential erosion in the future.

Cliff Dynamics

The Carmel cliffs are comprised of variable materials, and each material will erode differently depending on its strength and other factors. Three types of material comprise these backshore areas: 1) marine terraces that are generally composed of loose deposits of layered sands, clays, and gravels; 2) dune sands (largely quartz sands) and 3) generally dense sandstone bedrock, often overlayed by deposits of siltstone and claystone (Shonman and D'Ambrosio 2003).

In nearshore waters, sediment pockets overlay and fill areas of sandstone bedrock, which are punctuated by areas of Salinan Block granodiorite (see Figure 3, right). This rock serves as a holdfast for kelp, which is visible in many aerial photos offshore of the South and North Beach areas. Approximately 1,000 ft seaward of the North Beach section near Pescadero Canyon an offshore rock outcrop emerges from the bay, and these rocks can affect wave refraction and breaking wave patterns.

Carmel Beach is backed by sandstone cliffs and sand dunes. The cliff-backed portions make up 64% of the city's backshore and are comprised of sandstone overlayed by loose terrace deposits (see Figure 3, right). The dune-backed portions of the shore comprise 36% of the city's backshore and are comprised of sandstone at an unknown depth and location, overlayed by windblown dune sands and dune vegetation (see **Error! Reference s ource not found.**, which shows the underlying sandstone exposed).



Figure 14. The exposed sandstone formation, indicated in red, located at the central sand ramp near the Del Mar Parking Lot.

Cliff erosion and bluff failures tend to happen more rarely and are episodic in nature. There are different mechanisms for failure or erosion, and these can be divided into two different types. The first type of failure mechanism is driven by coastal forces (i.e., waves and tides), and will be directly related to whether or not the beach is wide or narrow; a wider beach will protect the cliffs and bluffs from wave exposure. The second type of failure is driven by terrestrial forces (i.e., rain, stormwater, groundwater), and is not affected by beach widths. The two types of failures are detailed below:

Coastal-driven failure mechanisms: Powerful waves, especially during storms, can directly impact terraces and cliffs. The force of the waves and the backshore currents that are created can lead to abrasion of the sandstone rock, undercut the base of the cliffs, and lead to failures and collapse of the terraces above. Tides can also contribute to erosion, especially when powerful waves coincide with high tides. At these times, wave runup can exceed the crest elevation of the coastal armoring, and erosive forces can reach the softer terrace deposits and topsoil. The repeated wetting and drying of the materials in the terrace deposits can also lead to weakening over time. Wind-driven spray from breaking waves can further saturate terrace soils and accelerate failures along the bluff face.

Terrestrial-driven failure mechanisms: Other erosive forces include those from subaerial forces including stormwater runoff and focused sheet flow. This is most pronounced during periods of heavy rainfall, which can saturate the topsoil, lead to runoff that can carry away loose sediments and make terrace areas prone to landslides. In addition, the

movement of groundwater within the bluff or terrace can erode materials from within, weakening their structural integrity.

CARMEL BEACH: A BRIEF OVERVIEW AND HISTORY

Carmel Beach is a dynamic landscape featuring a diverse range of cliff and dune formations. These formations have been impacted by human actions that have ultimately shaped the beach into its present state. This section will detail these geomorphic processes and provide an overview of human influences, synthesizing their interplay in the evolution of Carmel Beach.

Figure 15 provides a shore-parallel cross section of the varying vertical cliff and dune formations, as well as a diagram of coastal armoring locations and seasonal beach widths. Along the beach, the contact between the less consolidated softer marine terrace deposits and the dense sandstone basal unit varies but tends to be lower in the Central Beach section between 11th and 8th avenues, and highest in the North Beach and South Beach. Sandstone underlies the terrace for the entirety of the beach, however in the central portion of the beach, remnant windblown Pleistocene sand dunes and dune vegetation overlay the basal sandstone geologic unit (James C. Reynolds and Associates 1986, Shonman and D'Ambrosio 2003).

Since 1958, the City—and to a lesser extent, private homeowners—have built numerous seawalls and riprap revetments to protect portions of the shoreline cliffs and bluffs. Seawalls and revetments protect about 68% of the city's backshore, including a large private seawall in the north and numerous City-maintained seawalls in the south. Riprap revetments can be found throughout the beach, primarily in the wider beach areas in the north of Section 1 as well throughout Sections 2 and 3. The locations and conditions of these are documented extensively in the Task 1 report by Haro, Kasunich & Associates, Inc. (2023). Since the 1960s, the City has often managed sand to improve access along the city's sand ramps and cover the riprap revetments for both appearance and public safety (see Beach Management section below).

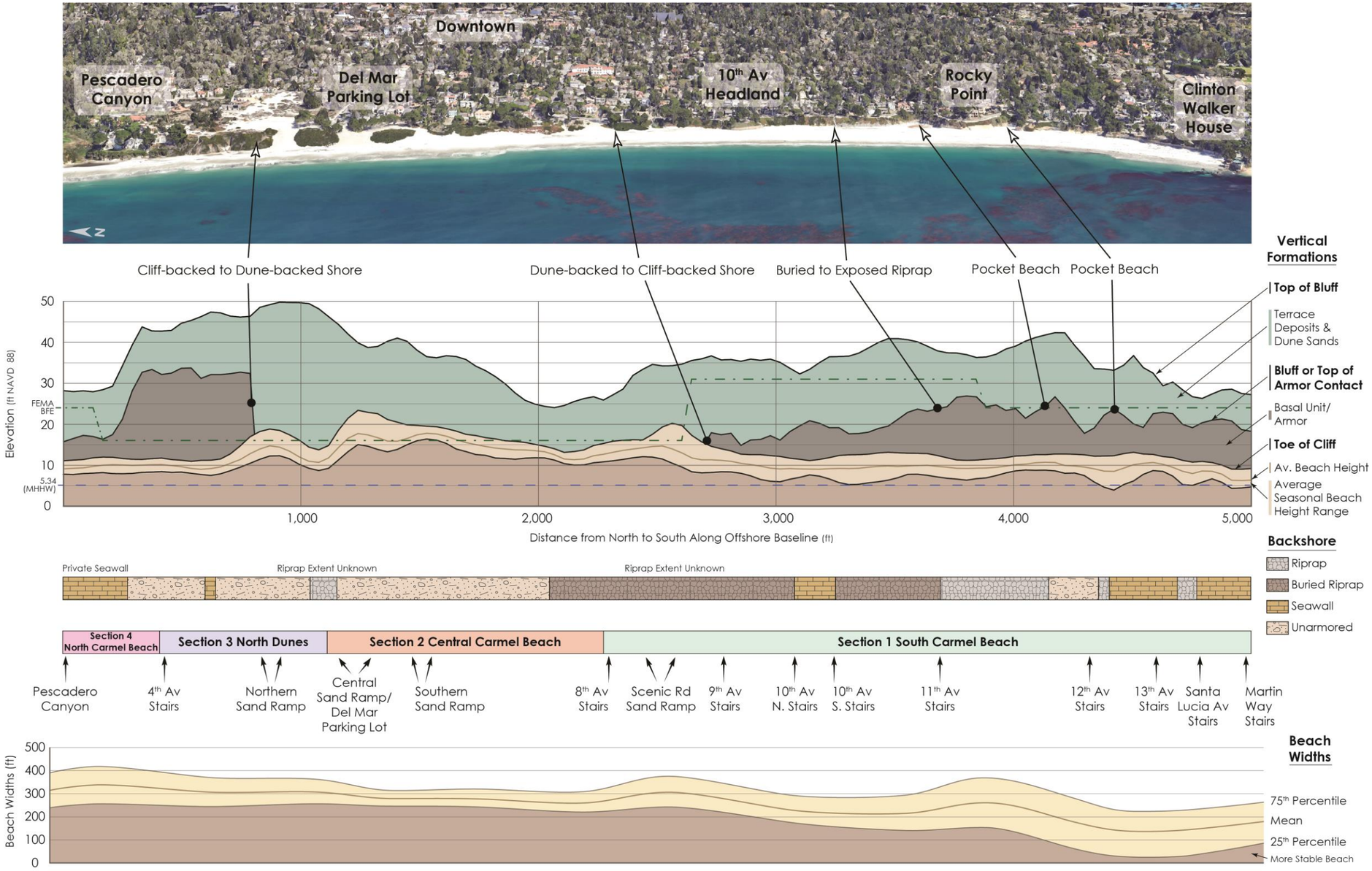


Figure 15. Beach locations (first/top panel), a cross section of the geology (second panel), a depiction of backshore protection (third panel), beach sections (fourth panel), and beach width measurements from CoastSat (fifth/bottom panel). Note that the mean 25th and 75th percentile beach widths are from the entire satellite-derived beach width dataset (years 1984–2021). Approximately half of the linear distance of the city's shoreline protection structures are seawalls; however, as they have been built on many crenulated portions of the backshore, this distribution is not reflected in the figure, which follows a linear path along the foreshore.

Table 1. Beach sections, geomorphology, backshore protection, beach width, and flood height information

Name and Extent	Geomorphology	Backshore Characteristics	Beach Width Range 25th-75th Percentiles	FEMA Flood Elevation
North Beach Pescadero Canyon to 4th Avenue	Sandstone overlayed by terrace deposits up to 45 ft	Private seawall near Pescadero Canyon and unarmored cliffs	Relatively wider beach with some variability 200–400 ft	24 ft (max) 16 ft (min)
North Dunes 4th Avenue to the Central Sand Ramp	Sandstone overlayed by windblown beach sands ranging between 25–50 ft	Mostly unarmored, one sea wall protecting an outfall, and buried riprap	Relatively stable beach 280–310 ft	16 ft
Central Carmel Beach Central Sand Ramp to 8th Avenue	Sandstone overlayed by windblown beach sands ranging between 25–35 ft	Mostly unarmored and some buried riprap (the extent of this riprap is unknown)	Relatively stable beach 280–310 ft	16 ft
South Carmel Beach 8th Avenue to Martin Way	Sandstone overlayed by terrace deposits between 25–45 ft	Mostly armored with riprap and seawalls	The narrowest beach width with the greatest seasonal variability 150–300 ft	31 ft (max) 16 ft (min)

The highest beach widths are found in the central and northern sections of Carmel Beach (between Pescadero Canyon to 8th Avenue), with beach widths of around 300 ft. As higher and wider beaches serve to dissipate storm wave impacts, there is a clear connection between seawall armoring and narrower average beach widths. The average beach width declines south of 8th Avenue, with the lowest average beach width of 100 ft located around the small rocky headland at 13th Avenue. The range of beach widths shows the extent to which seasonal change occurs, indicating that sections that experience the greatest scouring also experience the greatest recovery.

The variability of dry sand beach widths (explained in more detail in the Dry Sand Beach Widths section), is usually due to seasonal changes as opposed to inter-annual changes. The southern section (south of 8th Avenue) has the highest variability in the dataset, with beach widths ranging 175 ft (50–225 ft) between the 25th and 75th percentiles. The northern sections (between Pescadero Canyon and the Central Sand Ramp) also had high variability, generally ranging from 150 ft (between 250–400 ft). The most stable beach

section is found in the largely unarmored dune-backed stretches of the Del Mar and North dunes. The beach widths in these sections usually range approximately 50 ft (between 250–300 ft) between the 25th and 75th percentiles.

Beach Management – Sand Redistribution Program, Beach Berm, and Water Ponding

The city's sand redistribution program has involved bulldozing sand from the lower beach (located above high tide line) to the upper beach and is intended to improve public safety and compensate for sand that is naturally pushed downslope by visitors (see Figure 16). This program has been in place since the 1960s and originally operated below the Del Mar parking lot in late spring/early summer. Starting in 1984, the sand redistribution plan expanded, and sand was also bulldozed to cover the riprap revetments (see Figure 17 as a reference from 2003). The total sand redistribution volume varies between 50–100,000 cubic yards depending on conditions (mild winter requires less sand movement than severe winters) (Shonman and D'Ambrosio 2003).



Figure 16. Active Beach Management near the Del Mar Parking Lot
Source: Coastal Records Project (August 2003)



Figure 17. Beach management with sand bulldozed over the riprap revetments near 13th Avenue
Source: Coastal Records Project (August 2003).

During the spring and early summer, beach-building process lead to the development of a wide sand berm in the foreshore of the beach. Behind this berm, the sand level will typically be lower. Intermittently, and most often during periods of high tide, wave runup can overtop the berm and settle in the lower areas of the back beach. During fall and early winter, stormwater runoff can also create scour pockets near the city's outfalls and rain and stormwater can settle in these lower areas. Figure 12 (left) shows the locations of the city's outfall network as well as the general locations of water ponding.

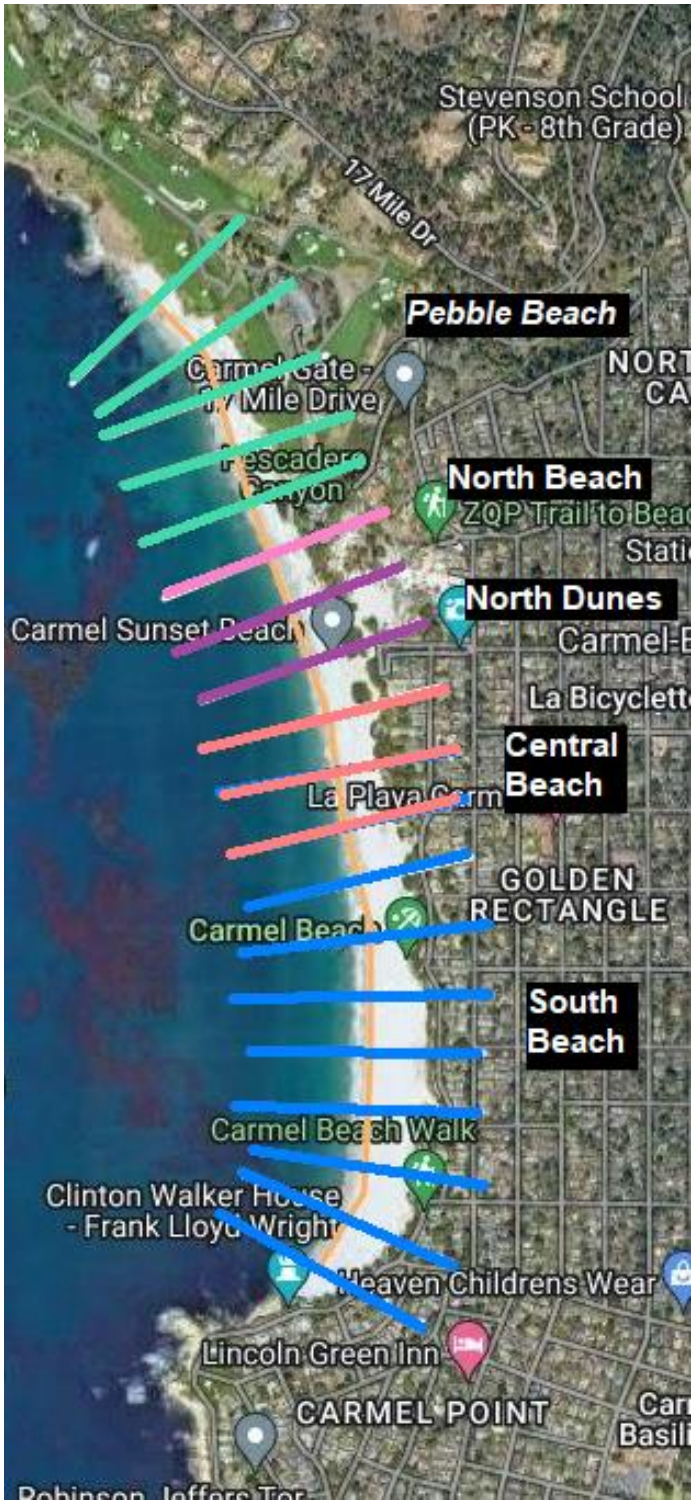
BEACH WIDTH DATA AND ANALYSIS METHODS

This study builds on a large body of work including the City's Shoreline Management Plan (2003), Coastal Access and Recreation Element (2003), Coastal Resource Element (2003), Climate Change Vulnerability Assessment (2021), as well as numerous other studies, including those led by Willard Bascom in 1945–47. This study relies primarily on publicly accessible shoreline position data from CoastSat extending from 1984–2021, digital elevation models from 1997–2018, aerial photos from 1941–2022, as well as storm damage photos and firsthand accounts of city staff and residents.

Datasets

The primary datasets used in this analysis include:

- Waves
    - NDBC Buoy Station 46042 (NOAA)
- Shoreline Position
    - CoastSat shoreline positions ~monthly from 1984–2021 (University of New South Wales and USGS)
    - Aerial photographs from 1941–2022 (numerous sources)
- Elevations
    - Digital elevation models, 8 flights from 1997–2018 (NOAA, U.S. Geological Survey [USGS], FEMA, U.S. Army Corp of Engineers, Association of Monterey Bay Area Governments)
    - Beach profile surveys by Willard Bascom, monthly from 1946–47 (archived and sourced from the University of California, San Diego [UCSD])
- Others
    - Reports, historical photos, winter of 2022–23 field visits.



Dry Beach Change Analysis

Seasonal and interannual beach width trends were assessed using satellite-derived shoreline positions between 1984 and 2021. These approximately monthly shoreline positions were sourced from the CoastSat project; an open-source and joint development effort between the Water Research Laboratory of the University of New South Wales in Sydney, and USGS (Vos et al. 2019). CoastSat extracts shoreline positions from Landsat 5, Landsat 7, Landsat 8, Landsat 9, and Sentinel-2 satellite images with a horizontal accuracy of +/- 10 m (33 ft) and provides the largest repository of historical shoreline positions for Carmel Beach with over 15,000 observation records. CoastSat delineates the shoreline as the wet/dry line in each satellite image (see orange shoreline, **Error! Reference source not found.**). Beach widths, therefore, represent the visible dry sand beach and are representative of the distribution of sand across the entire nearshore profile. This wet/dry line was determined at every time step where there was a non-obscured image (usually due to cloudy or foggy weather) available; about monthly or bi-monthly.

Figure 18. CoastSat transects and groupings based on beach section. Interactive map and data available at: http://coastsat.wrl.unsw.edu.au/

For this study, 18 cross-shore transects were grouped by section: South Beach, Central Beach, North Dunes, North Beach, and Pebble Beach. At each transect, a backshore toe location was determined for the most landward side of the transect, and this toe location was subtracted from the shore position to determine a dry sand beach width for each time step. These dry sand beach widths were then analyzed for overall, seasonal, and interannual trends, and the findings are presented below.

Caveats

The analysis in this report included the years when there was an active sand redistribution program on the City portion of the beach. Therefore, the natural evolution of the beach is not necessarily observed but one that is influenced by the City's redistribution efforts. The sand redistribution program moves sand the lower beach to the upper beach, a process that largely mimics, but speeds up, the natural process of beach width recovery through wind and wave action. The nuances of how this program has influenced the CoastSat shoreline positions cannot be determined. In the data, it may register as the beach building out faster over the long term than it naturally would (i.e., faster recovery rates).

Cliff Erosion Analysis

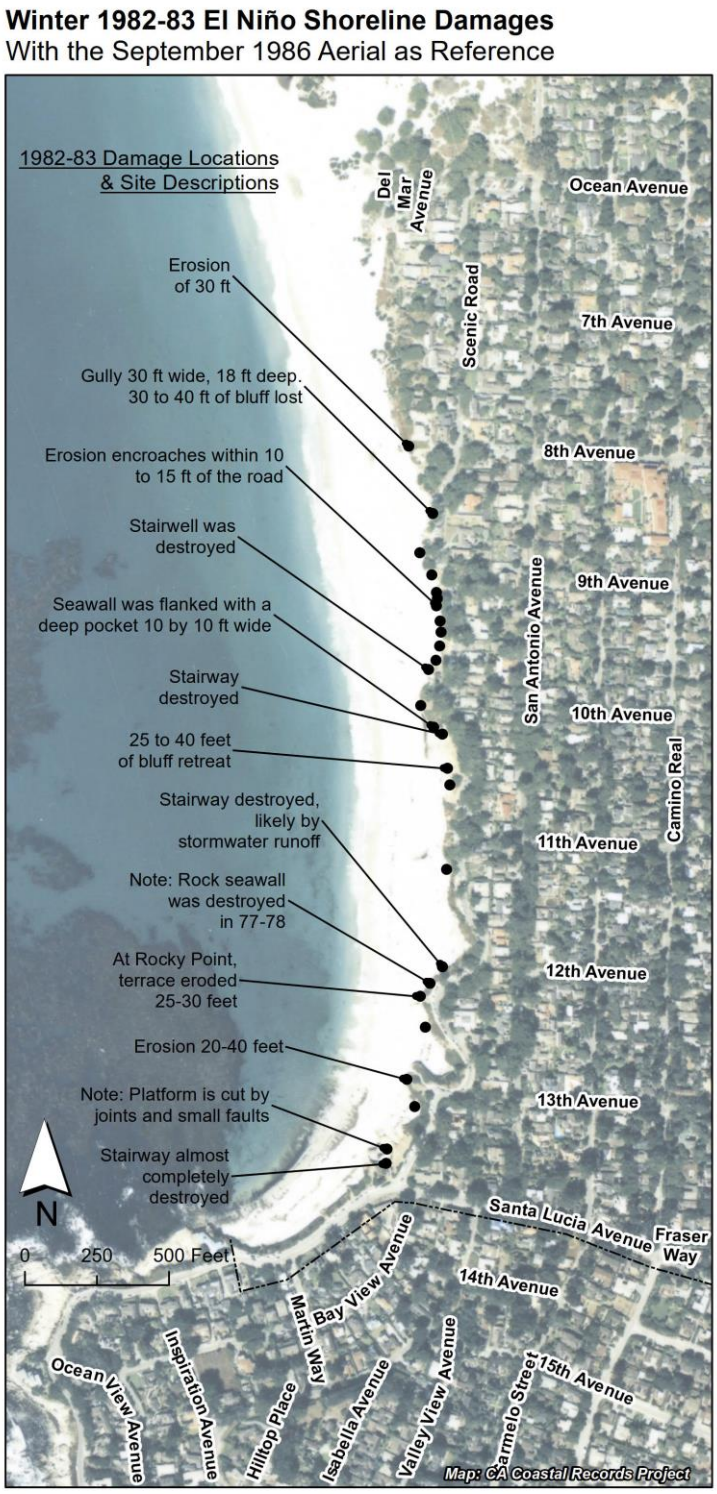
Typically, the evaluation of the long-term trend in cliff erosion is performed by comparing a series of historical aerials and surveys. However, along the City's shoreline, this is made difficult by shoreline protection and recovery efforts including the filling and armoring of eroded areas following storm events. The majority of these occurred following the Carmel Beach Rehabilitation Project (1983–1988), where the City added significant fill material to Carmel's coastal bluffs following erosion events, Scenic Road was repaved, the seaward curb and pedestrian pathway was redesigned (moving the bluff top edge seaward), and the stormwater system was rebuilt and conveyance improved to reduce future erosion (Shonman and D'Ambrosio 2003).

In addition, determining a cliff top position is made difficult due to a lack of georectified and high-resolution historical aerial photographs, as well as obstructions from the dense vegetation along the City's bluffs. However, the unarmored cliffs along the Pebble Beach Golf Links can be used as a proxy for a similar geologic setting, and the results can inform what a long-term erosion rate[2] for the city may have been without human intervention[3].

[2] It is important to note that erosion of an average annual sense can be a bit misleading, since erosion rarely occurs during average conditions, but rather larger failures tend to occur during major storm events.
[3] Cliff face areas along the Pebble Beach Golf Links have been armored as well, however much less so than the city portions of the beach.

The Integral Consulting Inc. (Integral) team analyzed shoreline position change for ~1,000 ft of the largely unarmored cliffs along Pebble Beach, stretching along the 10th fairway to Pescadero Canyon. The team used the Digital Shoreline Analysis System (DSAS) tool from USGS, which enables the calculation of rate-of-change statistics from multiple historical shoreline positions. It provides an automated method for establishing measurement locations, performs erosion rate calculations, and provides the statistical data necessary to assess the robustness of the erosion calculations.

CLIFF EROSION



The cliffs and bluffs along the City's shoreline have endured numerous erosion events, with perhaps the most notable in recent memory being the 1982–83 El Niño winter. As recounted in local media and post-storm surveys, the beach was heavily scoured following a series of storms. This left the bluffs less protected from wave attack and exposed them to considerable amounts of subaerial erosion processes. The City contracted Rogers E. Johnson and Associates to perform a post-storm assessment, and a map of observed damage locations from the assessment can be found in

Figure 19. Winter of 1982–83 shoreline damages. Observations compiled from Rogers E. Johnson and Associates

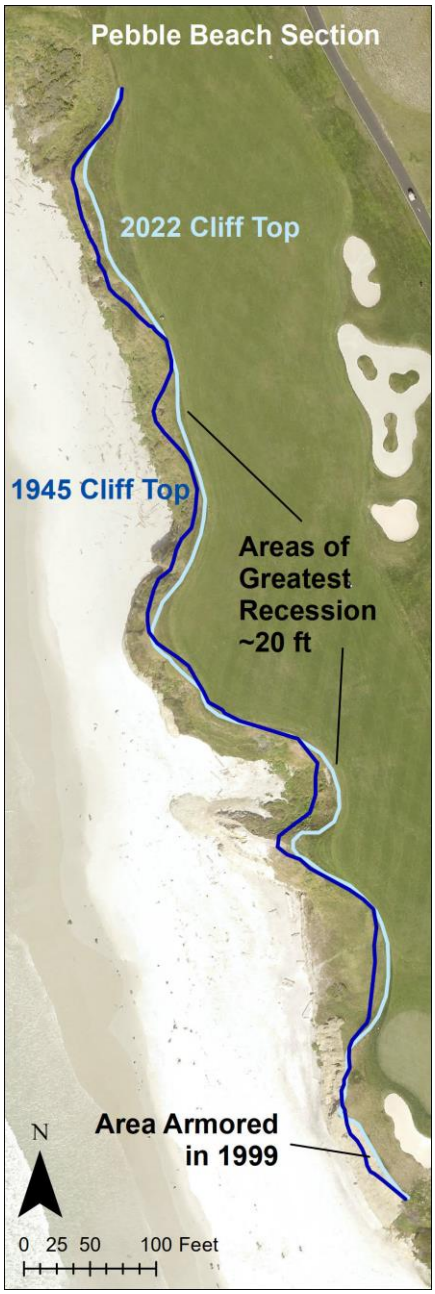


Figure 20. Bluff-top position for the Pebble Beach section along Carmel Beach.

As part of this 1984 assessment, Rogers E. Johnson and Associates calculated the long-term trends in historical erosion between 1908 and 1983. They determined that the northern portion of the beach experienced **4.8 in./yr.** of erosion and the southern portion experienced **3.6–8.4 in./yr.**; with much of this erosion occurring in the winter of 1982–83. This included some major erosion hotspot locations such as 30 ft of bluff loss between 8th and 9th avenues, 25–40 ft of bluff between 10th and 11th Avenue, 20–40 ft of bluff between 9th and 10th avenues, and 30 ft of bluff near Santa Lucia Avenue (Rogers E. Johnson and Associates 1984). It is important to note that the large erosion distances observed during this event occurred on bluffs that already had coastal armoring.

As part of the background investigation, the Integral team reviewed other erosion studies, including the UCSD and Scripps Historical Coastal Erosion Study (Zuzanna and Young 2022) and the USGS Statewide Assessment (Hapke and Reid 2007). The UCSD Scripps Study found negligible (0.0001 in./yr.) erosion between 2010 and 2016, likely due to the very short sample period. The USGS Statewide Assessment is reported for the area from Point Piños to Gorda and shows **11.8 in./yr**. from 1930s to 2002; however, this is for a much wider area of study.

The Integral team used the DSAS tool to determine both an endpoint erosion rate and a linear regression erosion rate for the Pebble Beach section of cliffs. The average bluff top recession from 1945 to 2022 was found to be just over 1 in./yr (as an averaged linear rate), with the greatest erosion occurring at two locations where erosion averaged ~3 in. a year or ~20 ft total (see the areas noted in).

These bluff top erosion rates will be incorporated into the next phase of work projecting future coastal erosion distances exacerbated by sea-level rise.

DRY SAND BEACH WIDTHS: SEASONAL AND STORM EVENT RESPONSE

Seasonal Dry Sand Beach Widths

Analyzing the trends in the CoastSat dataset, the change in dry sand beach widths over time (variability) was mostly due to seasonal, rather than interannual (i.e., between years) changes, with beach widths being the narrowest in the spring months and widest in the fall months (Figure 21). To determine how the beach widths changed throughout the year, the shoreline positions were averaged over each month for all of the years in the dataset, and the results are presented in Figure 21**Error! Reference source not found.**. The sections b etween 4th Avenue and 8th Avenue (North Dunes and Central Beach) were more stable throughout the year than the other sections, since they had more similar winter and summer beach. The ends of the beach, south of 8th Avenue (South Beach) and north of 4th Avenue (North Beach), were the least stable throughout the year, since they had the narrowest beach width in the winter and widest beach width in the summer. The southern section had the narrowest beach widths overall, particularly in the winter season.

Widening and narrowing along the beach happened at different times for different sections of the beach. Both the extreme north (Pebble Beach) and south were more likely to recover earlier in the year, with beach widths widening beginning in late winter (i.e., March), whereas the central areas of Carmel Beach often recovered later in the year, with beach widths widening in the late spring or summer (i.e., June). The first section of the beach that eroded was Pebble Beach; Pebble Beach began to narrow in the late summer.

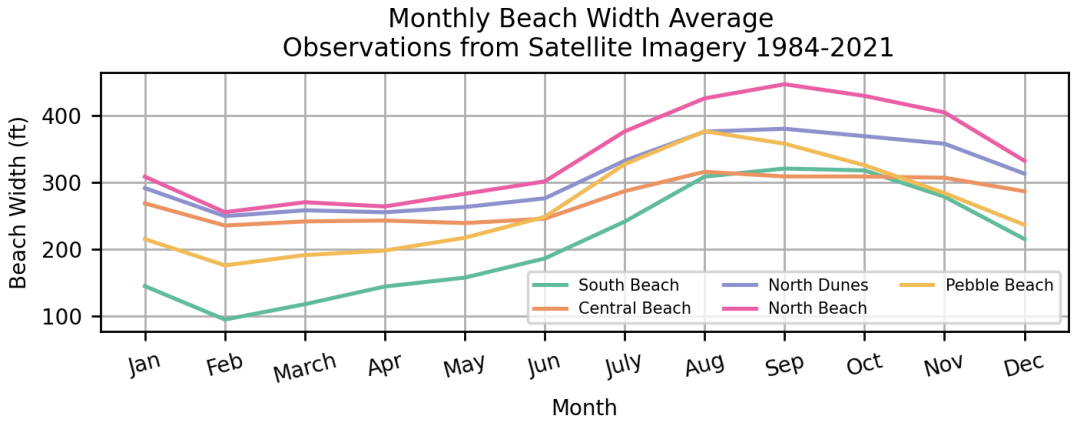


Figure 21. Beach widths were averaged by month for the entire dataset and grouped by beach section. The beach widths show a seasonal oscillation.

Beach Volume Change; Storm Response

During major storms, which are more frequent and intense during El Niño years, large storm wave events can scour and narrow the protective beach. In addition, large storms bring high rainfall, which saturates and weakens coastal bluffs, elevates sea levels causing waves to break closer to shore, and is often accompanied by larger waves leading to more erosion. Storlazzi and Griggs have found that 75% of shoreline erosion and damage has occurred during El Niño winters, and the moderate- to high-intensity El Niños do most of the damage (Storlazzi and Griggs 1998).



Figure 22. In response to winter storms (seen here in 2023), it is common for the steep sand dunes around Del Mar Avenue to scarp on the seaward edge (left), and for scouring to expose the underlying base of sandstone outcroppings (right) and footings of the coastal armoring in the southern areas of the beach.
Source: Integral Consulting (February 1, 2023)

The winter of 1997–98 was a very strong El Niño for California with one of the wettest winters on record. This marks the first major El Niño event where digital elevation surveys are available both pre- and post-storm season. The changes in beach elevation and volumes correspond with the CoastSat dry sand beach width data, with a significant narrowing of areas south of 8th Avenue and much less in the dune-backed Del Mar and North Dunes areas. The North Dunes area even saw some accretion, perhaps explained by sediment eroding from the upland dunes down onto the dry sand beach and foreshore. The maximum scour of sand levels between fall and spring was ~14 ft, with a total of ~300,000 cubic yards of sand moved from the beach into nearshore bars (see Figure 23). By comparison, the City's summer sand redistribution program moves 50,000–100,000 cubic yards of sand depending on conditions (Shonman and D'Ambrosio 2003).

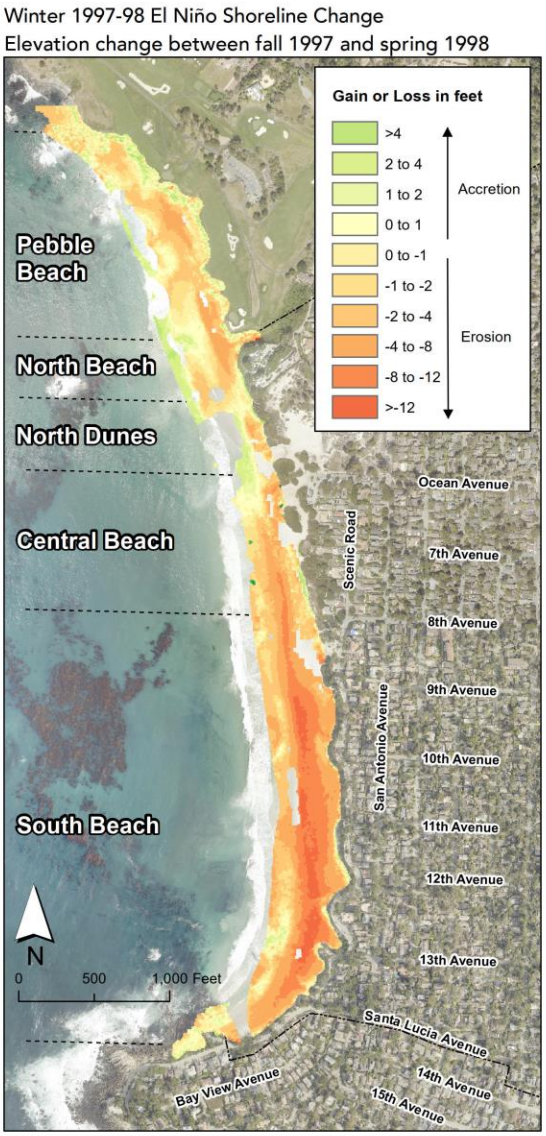


Figure 23. Beach elevation change following the El Niño winter of 1997–98

The beach scouring that occurred in the winter of 1997–98 corresponds with observations and documentation of other El Niño years that have occurred.

Following the 1982–83 El Niño, City staff reported that the level of back beach areas was 4 to 10 ft lower than it normally is in July (Rogers E. Johnson and Associates 1983). In addition, significant erosion took place in the Del Mar Dunes, which led to the placement of engineered revetments, and necessitating the City to restore the dunes to their original size (Shonman and D'Ambrosio 2003).

According to city inspections in January 2016 (another El Niño year), measurements showed that the sand level on the beach along the south side of 12th Avenue had dropped by nearly 6 feet. Sand began to be redeposited at various shoreline sites during February, and this became very noticeable in the coves at 12th and 13th Avenues later in the season (City of Carmel-by-the-Sea 2016).

LONG-TERM DRY SAND BEACH WIDTH CHANGE AND RECOVERY

Overall, while the shoreline was variable both seasonally and in response to large storm events, it showed a mostly stable long-term trend between 1984 to 2021 across all beach sections. To examine any long-term trends in dry sand beach widths, the beach widths were averaged by year, and the results are plotted in Figure 24.

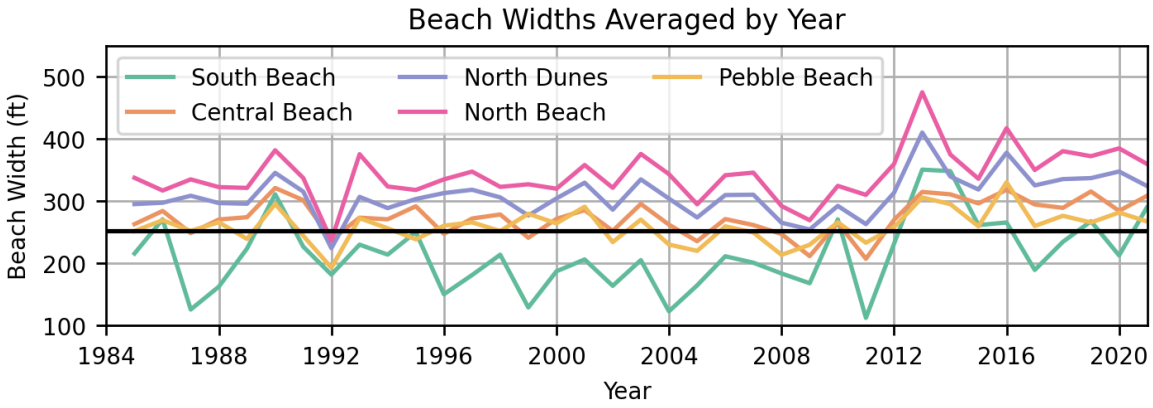


Figure 24. Beach widths were averaged by year for the entire dataset and grouped by beach section. The beach widths are generally stable and deviate about a mean.

The beach widths average about 250 ft without any significant trend (no obvious accretion or erosion) in the 40-year dataset. This provides good evidence that over the last 40 years, the sand volume in the Carmel Bay pocket beach has stayed relatively constant.

Overall, dry sand beach widths are lower for the ends of the beach (Pebble Beach and South Beach), and higher in the central portions, which can also be seen in satellite images of April 1971, October 1976, April 1993, and spring 2006 (Figure 25, Figure 26).

The southern section of the beach has had historically lower beach widths than the other sections, and a particularly good example of a narrow southern beach section can be seen in the spring 2005 image (Figure 26). A particularly narrow beach occurred in 1992 (which is likely related to the 1992 El Niño), and 2009 and 2011, when the beach widths dropped to below average (Figure 26). An example photo of a narrow Carmel Beach can be seen in the spring of 2010 (Figure 25). After 2011, all dry sand beach widths recovered to higher than average, before decreasing after 2013 to below or about average. Example photos of wide beach widths can be seen in September 1986, May 2001, and July 2016 imagery (Figure 25, Figure 26). In recent years, since around 2018, the southern section of the beach has seen wider beach widths than the extreme northern section (Pebble Beach).

Figure 25 and Figure 26 also show that the widest beach widths did not occur in the earliest aerial images of 1941 and 1945, providing additional evidence that sand volumes in Carmel Bay have likely been relatively stable over the last 80 years.

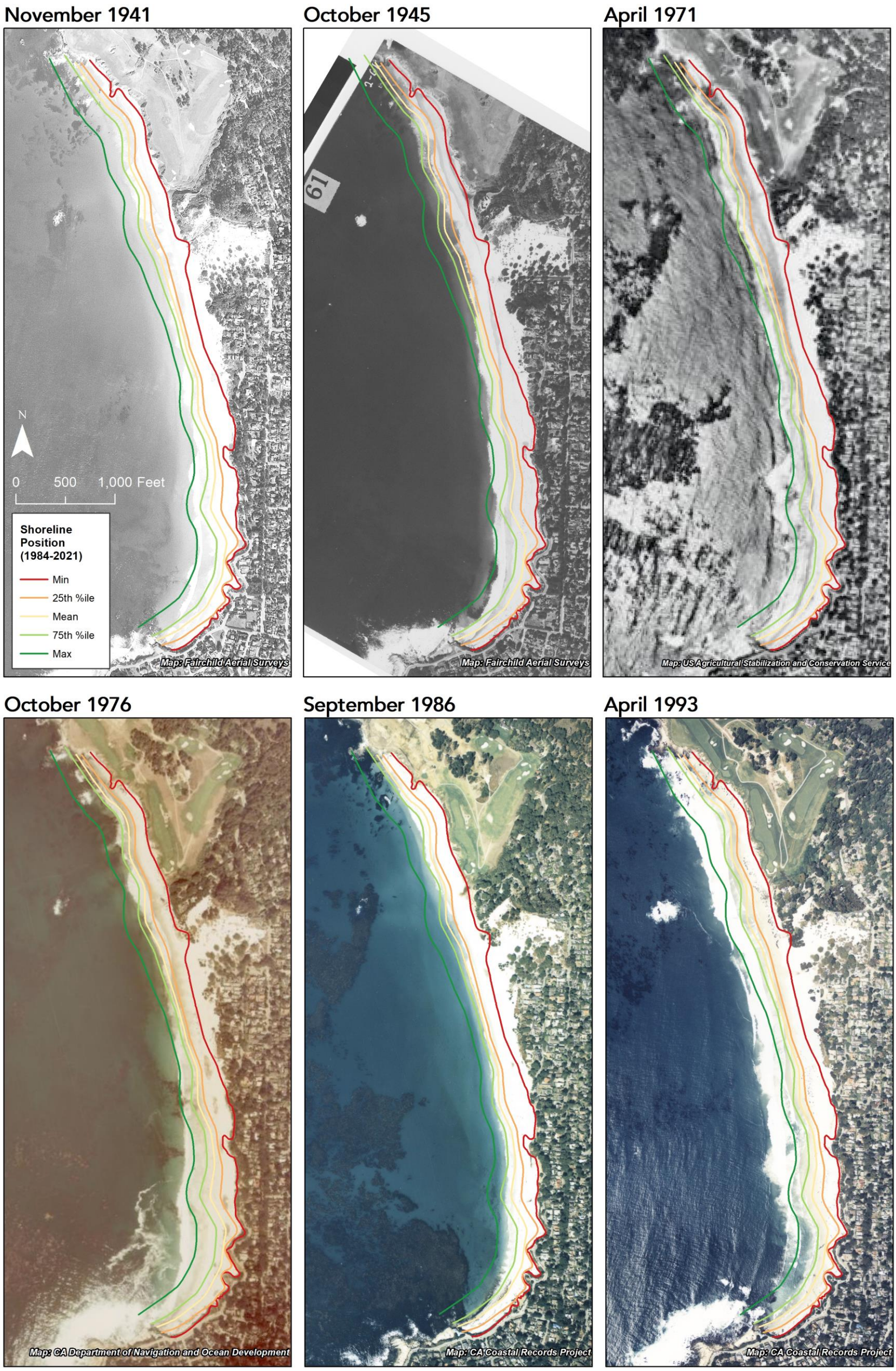


Figure 25. Aerial time series for select years from 1941–1993 with shoreline beach positions from 1984-2021.

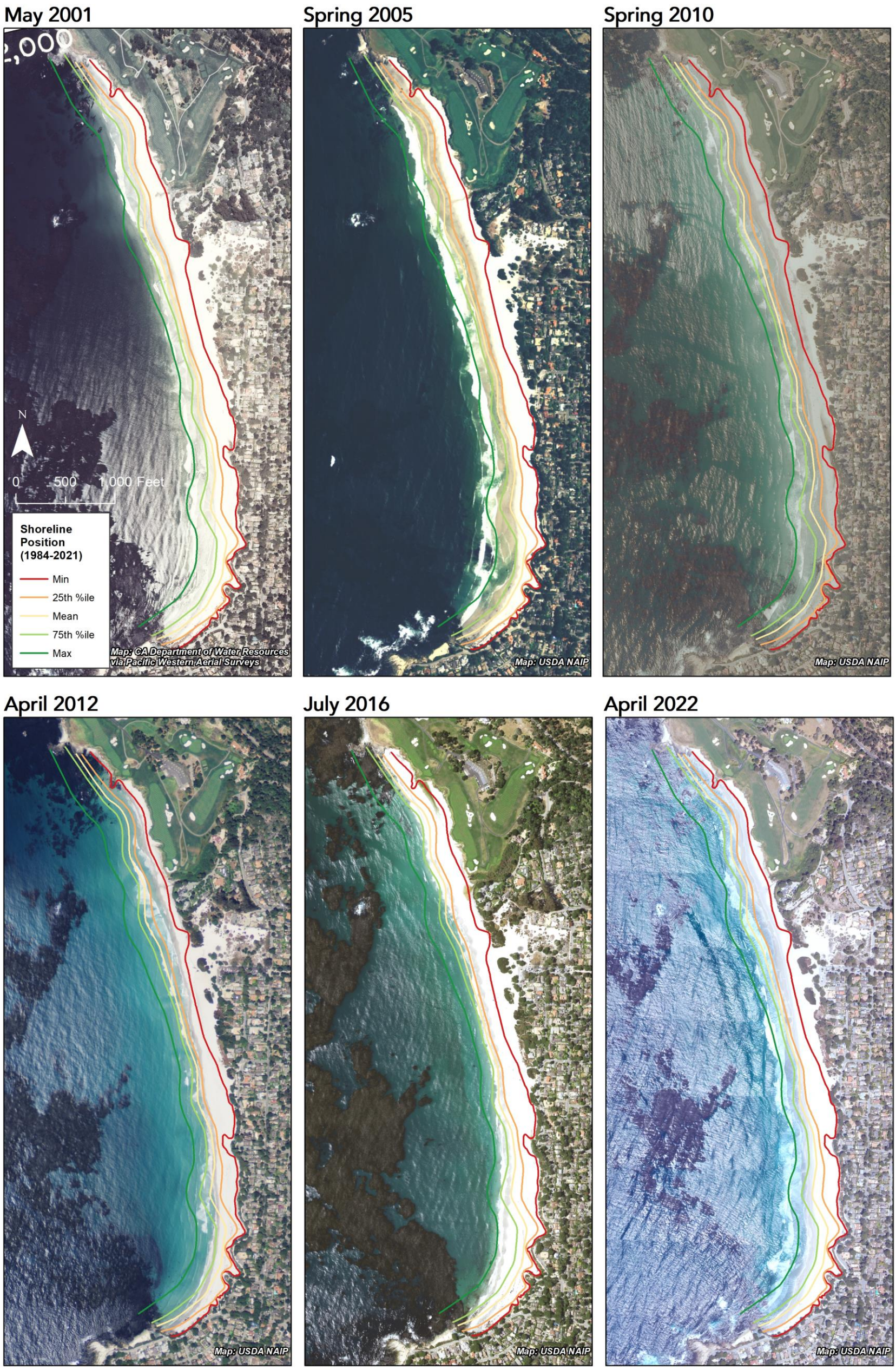


Figure 26. Aerial time series for select years from 2001–22 with shoreline beach positions from 1984–2021.

Beach Width Recovery

Recovery Time Scales and Rates

One of the questions that the Carmel community has been asking, especially after the energetic winter erosion from January and February of 2023, is about the timing of the dry sand beach recovery. To address this question, the recovery time scale was defined annually as the number of days that it took for a beach to build back up from the most eroded position (narrowest beach width) to the most accreted position (widest beach width) for that year. The recovery rate is defined as the speed (measured by the number of days) for the beach to go from narrowest to widest as calculated as the distance the beach recovered divided by the number of days the beach took to recover. Figure 27 shows that higher recovery rates correspond to a lower number of days, meaning that the beach recovered quickly in that specific year. On average, it took the beach ~160 days (about 4 months) at a rate of 1.2 ft/day for the beach to reach its maximum position. Fast recovery rates tended to follow El Niño events, as seen in the years 1993 and 2016, showing that the beach wants to build back up to a mean position.

Interannual recovery for each beach section can also be seen in Figure 24 when beach widths increase. After the 1992 El Niño, beach widths for all beach sections dropped and then recovered the following year (1993), except for the southern portion of the beach. Beach widths for the southern portion of the beach remained narrow until about 2013 when it recovered again. The years 2011–2013 also saw high recovery rates, when beach widths widened until the 2014 El Niño when they narrowed again.

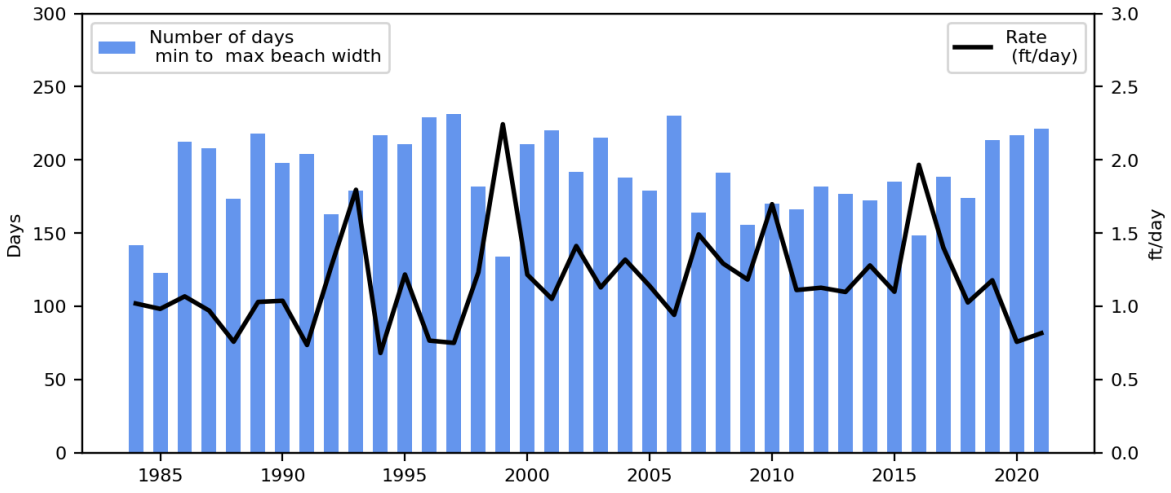


Figure 27. Recovery time scales. Note the sharp peaks in recovery rates around the stronger El Niño years of 1997–98 and 2014–16.

Wave Conditions During Dry Sand Beach Recovery

It is generally understood that beach recovery occurs when waves are smaller and have longer periods. To examine what conditions contributed to high recovery rates, an analysis of the offshore wave conditions that co-occurred with high and low recovery rates was conducted (Table 2). Table 2 divides the wave conditions into three wave directional categories, and then identifies the average wave height and period for each direction. Results show that faster recovery rates corresponded with waves that came from either the north or south and not head-on, and the southern waves have smaller wave heights and longer periods than lower-recovery years. Seasons with lower recovery rates had more waves coming head-on (from a western direction) and larger waves from the north and south.

It appears that a combination of north and south-angled waves, smaller wave heights and longer wave periods are associated with higher recovery rates. However, it is not clear how the relative contributions of the wave direction and smaller wave heights drive physical processes to accelerate recovery rates. A more detailed analysis of recovery events, including spectral information from the wave buoys, and potentially numerical model simulations would be required to determine more specific characteristics and the dynamic details of the recovery process.

Table 2. Wave conditions that co-occur for recovery. Wave data are taken from the Monterey Bay buoy. Each row represents wave information from a different direction. The first row is waves from the northwest/north northwest, the second row is waves from the west. The wave information is the percentage of waves, wave height, and wave period.

	Recovery rate > 1ft/day	Recovery rate 0–1ft/day
Northwest Bin (Waves coming from the north >310 degN)	**13% of waves** Average wave 6.3 ft @ 8.7 seconds	**12% of waves** Average wave 7.2 ft @ 8.7 seconds
West Bin (Waves coming from 240-310 degN, head-on)	**75% of waves** 6.5ft @ 10.8 seconds	**81% of waves** 6.6ft @ 10.7 seconds
Southwest Bin (Waves coming from 180-240 degN, head-on)	**12% of waves** 4.6ft @ 15.5 seconds	**7% of waves** 4.8ft @ 14.4 seconds

CONCLUSIONS

Large storm waves have historically caused dramatic short-term erosion impacts along Carmel Beach that have damaged coastal accessways, narrowed the dry sand beach, and led to the construction of coastal armoring along more than half of the City's backshore. Through analysis of historical reports, aerial and satellite imagery, shoreline position trends, and beach volume changes, Carmel Beach has shown no long-term erosion trend.

This positive finding appears related to a relatively stable volume of sand in this pocket beach constrained in the north by Arrowhead Point, in the south by Carmel Point, and offshore by the granodiorite basal rock.

Based on a 40-year record of approximately monthly shoreline positions, dry sand beach widths vary seasonally and in response to large wave events which narrow the beaches and move sand into nearshore sandbars in the winter and then onshore back onto the dry sand beaches in the summer. An analysis of Willard Bascom's studies on Carmel Beach dating to the mid-to-late 1940s, highlights that this has been occurring for over 80 years.

There has been considerable concern among community members over the future of the dry sand beach and shoreline, especially in response to rising sea levels and potential climate change-induced shifts in weather patterns. Over the short term, the beach will continue to narrow and recover seasonally, and given the stable sand volumes, these seasonal dynamics and storm response and recovery can be expected to continue.

However, as sea levels rise rates accelerate and wave heights increase, various bluff-top and upland resources and infrastructure may be more significantly impacted by erosion, and the narrowing of the beach with additional beach elevation scour caused by more routine interactions with existing coastal armoring may become more frequent and significant.

The extent and potential implications of erosion to Carmel's beaches and bluffs to sea level rise will be explored further in Task 3, Shoreline and Beach Erosion Exposure Modeling. Once this modeling is completed, a vulnerability assessment will be completed to identify potential impacts on the various City assets, infrastructure, and upland development in Task 4, Coastal Hazard and Sea Level Rise Vulnerability.

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

backshore	Extreme inland limit of the beach
basal unit	Lower geologic formation of the cliff (sandstone in Carmel)
bluff	Soft unconsolidated materials found in the marine terrace deposits
bluff contact	Location where the bluff meets the cliff
bluff top	Location where there is an identifiable break from the steeper cliff and bluff to the gently sloping inland areas
cliff	Hard consolidated rock under the bluff
CoSMoS	Coastal Storm Modeling System (USGS)
DEM	Topographic Digital Elevation Model
dry sand beach	The portion of the beach that is landward of the mean high water mark
DSAS	Digital Shoreline Analysis System (USGS)
erosion (coastal)	Can refer to either beach narrowing and cliff retreat. For cliffs, this refers to the long-term loss or removal of land due to coastal or terrestrial processes. For beaches, this may refer to either the long-term, short-term, or localized (see scouring) removal of sediments from the beach.
ENSO	El Niño Southern Oscillation
FEMA	Federal Emergency Management Agency
MHW	Mean high water
MHHW	Mean higher high water
MLW	Mean low water
NAVD 88	North American Vertical Datum of 1988 (NAVD 88). The vertical control datum used for surveying.
NOAA	National Oceanic and Atmospheric Administration
PDO	Pacific Decadal Oscillation
scour (beach)	Process by which waves and currents remove sediment from the beach (usually localized)
shoreline	Typically where water meets the land. In this report, it refers to the wet/dry line

toe of the cliff	Location where the dry sand beach meets the base of the cliff
TWL	Total water level. The combined effect of wave run-up height, storm surge, tides, and sea level elevations
USGS	U.S. Geological Survey

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- Agnes Martelet, Environmental Compliance Manager

MEMORANDUM

To:	Mary Bilse, Environmental Programs Manager and Robert Harary, Director of Public Works, City of Carmel-by-the-Sea
From:	David Revell, Integral Consulting Inc.
Date:	February 20, 2024
Subject:	Carmel Climate Change Vulnerability Assessment, Shoreline and Beach Erosion Exposure Modeling and Coastal Hazard and Sea Level Rise Vulnerability
Project No.:	C3016

EXECUTIVE SUMMARY

Integral Consulting Inc. (Integral) working with EMC Planning and Haro Kasunich and Associates (HKA) have been conducting a Coastal Engineering and Hazard Assessment for the City of Carmel-by-the-Sea (City). The following is a synopsis of the major findings for Task 3, Shoreline and Beach Erosion Exposure Modeling, and Task 4, Coastal Hazard and Sea Level Rise Vulnerability.

The scope of work for Task 3 was to project future beach narrowing and cliff and dune erosion hazard extents with sea level rise. The coastal erosion hazard projections include a future without armoring present and one that considers the effect of the existing City's coastal armoring. The hazard exposure modeling in Task 3 was then used to determine what assets and infrastructure were at risk of coastal erosion in the future under armored and unarmored conditions. The vulnerability assessment evaluated erosion hazard exposure to land use and structures, roads and parking, and infrastructure. The differences between hazard extents and vulnerabilities will be useful in Phase 2 of the project when examining the implications of various adaptation strategies and policy implications.

Beach Narrowing (Task 3)

- It is projected that the width of Carmel Beach will narrow between 50 and 60 ft for each foot of sea level rise. Assuming that the location of the backshore does not change, the following typical summer beach conditions are projected:
  - By 2 ft of sea level rise, lateral access to areas south of the 12th Avenue headland may be obstructed.
  - By 3 ft of sea level rise, the southern end of Carmel Beach south of 8th Avenue is projected to be a series of pocket beaches rather than one continuous stretch of dry sand beach. Only during highly recovered conditions will a dry sand beach remain south of 12th Avenue.
  - By 4 ft of sea level rise, the only continuous dry sand beach remaining will be from the North Dunes sand ramps to Pescadero Canyon. In the south, only two small pockets of dry sand beaches are projected to remain around 8th Avenue and 11th Avenue.
  - By 5 ft of sea level rise, only one pocket of dry sand beach around the North Dunes and the 4th Avenue stairs is likely to remain.

Coastal Cliff and Dune Erosion (Task 3)

- Considering coastal armoring in erosion projections, erosion rates are dampened significantly in the near term; however, with increasing sea level rise, the effectiveness of the armoring is reduced, leading to an acceleration in blufftop erosion above the coastal armoring beyond 1 ft of sea level rise.
- In the armored scenario, the following is projected:
  - By 1 ft of sea level rise, the areas with the greatest threat of erosion are the private oceanfront properties near Pescadero Canyon, the dune-backed shore between 4th Avenue and 8th Avenue, the lower cliffs between 8th Avenue and 11th Avenue, and the unarmored cliffs by 12th Avenue.
  - By 2 ft of sea level rise, erosion rates accelerate as coastal armoring is more likely to be overtopped by larger waves. Areas behind seawalls have projected erosion hazard distances of 20 to 40 ft.
  - By 4 ft of sea level rise the highest erosion distance is projected around 12th Avenue, where a combination of factors related to local geology, wave heights, and lack of armoring yields projections of retreat up to 150 ft. Areas of the north dunes around the Del Mar sand ramp also see higher projections of retreat of up to 90 ft, extending to the volleyball courts.

Vulnerability Assessment (Task 4)

The scope of work for Task 4 was to determine the bluff-top assets and infrastructure potentially exposed to coastal erosion for both armored and unarmored backshore conditions. The vulnerability assessment evaluated erosion hazard exposure to land use and structures, roads and parking, and utility infrastructure. For succinctness, the results of only the coastal armored scenario are presented here. See Appendix A for a full suite of tables for both the armored and unarmored scenarios.

- Currently, all the assets and infrastructure along the beach and bluff including 10 coastal access stairways, the Scenic Road walkway, and the stormwater drainage network are exposed to erosion. The public restroom adjacent to the Santa Lucia Avenue stairs is exposed to erosion and will face increased threat from coastal wave flooding in the future.
- By 1 ft of sea level rise, Scenic Road is exposed to erosion in six locations, largely around 12th Avenue and between 10th and 8th Avenues. A wastewater force main near Martin Way is exposed, as well as a wastewater main between 9th and 10th avenues, and a wastewater main under the dunes between 7th and 8th Avenues. Waves overtopping the bluff are expected to be more likely along the southern seawall between Santa Lucia Ave and Martin Way.
- By 2 ft of sea level rise, nearly the entire length of Scenic Road is exposed to erosion, including most of the underground water and wastewater infrastructure. This includes a water main between 8th and 10th avenues. Waves overtopping the bluffs are expected to be more likely between 10th and 11th avenues.
- With between 2 and 4 ft of sea level rise, 44 homes along Scenic Road and near Pescadero Canyon are projected to potentially be exposed to erosion. One additional water main under Scenic Road south of 13th Avenue is exposed to erosion. One additional wastewater force main is exposed to erosion by 8th Avenue. The Del Mar parking lot is exposed to erosion. Waves overtopping the bluffs are expected to be more likely between 9th and 10th avenues.

INTRODUCTION

Purpose of This Study

This study is part of the City of Carmel Coastal Engineering and Hazard Assessment, and this technical memorandum serves to complete the deliverables for Task 3, Shoreline and Beach Erosion Exposure Modeling, and Task 4, Coastal Hazard and Sea Level Rise Vulnerability. This technical memorandum projects long-term beach, cliff, and dune erosion with sea level rise, as well as summarizes the risk to public and private

infrastructure and assets. The coastal hazard exposure forecasting was completed using a suite of state-of-the-science models for a range of sea level rise horizons considering a variety of assumptions on historical erosion rates and conditions with and without coastal armoring in place. The vulnerability assessment evaluates the spatial intersection between the projected coastal hazards and the locations of bluff-top infrastructure and assets. Results from the vulnerability assessment are summarized by the likelihood of impact across multiple horizons, near-term (1 ft of sea level rise / 2045–2060), medium-term (2 ft of sea level rise / 2060–2080), and long-term (4 ft of sea level rise / 2080–2100) and are presented in the Task 4 Vulnerability Assessment section.

Study Area

This study focuses on the City-owned portion of Carmel Beach from Pescadero Canyon in the north to Carmel Point in the south. Summaries of hazards and vulnerabilities are organized and divided into four sections, which emerged from the City's Climate Change Vulnerability Assessment Report (City of Carmel-by-the-Sea 2021). One of the priorities of this report was to identify how adaptation options and strategies along the coast may vary for four distinct planning areas within the City. Results from the hazards modeling and vulnerability assessment will inform the development of adaptation strategies in Phase 2 of this project.

Study Area Sections

- Mostly armored cliffs and bluffs along Scenic Road south of 8th Avenue. Henceforth referred to as **Section 1, South Beach.**
- Unarmored dunes along private property between 8th Avenue and Del Mar Parking Lot. Henceforth referred to as **Section 2, Central Beach**.
- Mostly natural, unarmored North Dunes area. Henceforth referred to as **Section 3, North Dunes.**
- Armored private properties on the cliffs at the north end of the City. Henceforth referred to as **Section 4, North Beach**.

For the sake of brevity, each section in this memo will be referred to by section number and/or its short name, South Beach, Central Beach, North Dunes, or North Beach.

Within each section listed above, erosion projections were conducted on multiple smaller backshore locations. Each of these subsections was organized by their unique orientation, backshore type (armor or unarmored), and backshore characteristics (dune-backed, cliff-backed, vegetated, unvegetated, etc.). In total, 31 separate backshore areas were used to project location-specific erosion hazard zones.

SEA LEVEL RISE

Global sea level rise is a result of human-caused climate change and is driven by the thermal expansion of ocean water and the melting of terrestrial ice as the Earth warms. Global climate models indicate that California will see significant sea level rise during this century, with the exact magnitude depending on factors such as global greenhouse gas emissions and the Earth's energy imbalance, the rate at which oceans absorb heat, land ice melting rates, movement of land-based ice sheets, and local land subsidence or uplift.

According to California's Office of Environmental Health Hazard Assessment, the central coast of California experienced about 8 in. of sea level rise from 1900 to 2020, and the rate is projected to increase over this century (OEHHA 2022). California Ocean Protection Council (OPC) and California Coastal Commission (CCC) both issued guidance documents that are meant to guide local jurisdictions on sea level rise planning. They are:

- State of California Sea-Level Rise Guidance Year 2018 Update, adopted by OPC in 2018
- CCC Sea Level Rise Policy Guidance, certified by the Coastal Commission in 2018.
- Draft State of California Sea Level Rise Guidance: 2024 Science and Policy Update, released in January, 2024[1]

Based on this guidance, this study evaluated a range of sea level rise projections under high emissions (RCP 8.5) using a 1) median scenario, representing a 50% probability that sea level rise will reach 2.0 ft by 2100; 2) likely scenario representing a 66% probability that sea-level rise will reach 3.0 ft by 2100 and; 3) a medium-high risk aversion scenario representing a 0.5% probability that sea level rise will reach 3.9 ft of sea level rise by 2080 (Table 1 and Figure 1).

[1] In this draft update, some language form the 2018 report have been updated. "Medium-High Risk Aversion" now corresponds to the "High" scenario, and "Likely" corresponds to the "Intermediate" scenario. This updated language corresponds with NOAA's 2022 Global and Regional Sea Level Rise Scenarios for the United States Report.

Table 1. Probabilistic projections for future sea level rise by year for Monterey.

From OPC 2018 Guidance	Sea Level Rise Rate (ft) Range of Projections		
Year	**Median** *50% probability SLR meets or exceeds...*	**Likely** *66% probability SLR meets or exceeds...*	**Medium-High Risk Aversion** *0.5% probability SLR meets or exceeds...*
2020	0 (baseline)		
2040	0.3	0.5	0.7
2060	0.7	1.1	2.1
2080	1.3	2.0	3.9
2100	2.0	3.0	6.4

Source: OPC Guidance (2018). Projected sea levels using the Monterey tide gauge. Values have been adjusted by shifting the baseline year from 2000 to 2020. All sea level rise rates are referenced to high emissions scenarios.

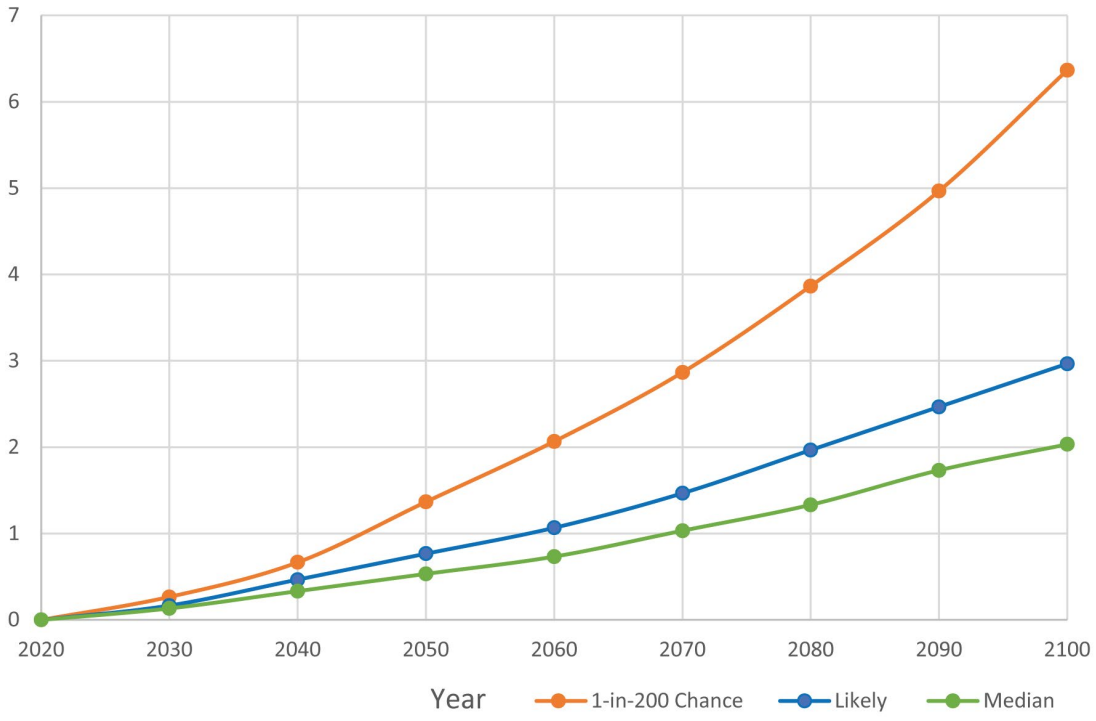

Figure 1. 1-in-200 Chance (Medium-High Risk Aversion), Likely (66% Probability), and Median (50% Probability) rate of sea level rise from 2020 to 2100 under high emissions, based on OPC Guidance (2018, 2024).

COASTAL HAZARDS

This study evaluated the following coastal hazards:

- **Coastal cliff and dune erosion**—includes erosion of the dune-backed areas from 8th Avenue in the south to the volleyball courts in the north, and the cliff-backed sections in the southern and northern sections of the study area.
- **Beach narrowing**—represented by the projected future change in the summer beach widths for each foot of sea level rise.
- **Coastal wave overtopping**—evaluated based on total water level exceedance analysis for above existing coastal armoring and dune and cliff crests along the study area.

Descriptions of these hazards and the forces that influence them are presented below.

Coastal Cliff and Dune Erosion Forces

Coastal erosion is a complex process shaped by various factors resulting in the ongoing retreat of dunes and cliffs. The factors that contribute to erosion encompass marine forces (such as wave energy), terrestrial forces (including rainfall and groundwater flow), and terrestrial conditions (like rock type, grain size, joint density, or the presence of coastal armoring). Together, these elements are the primary influences contributing to coastal cliff and dune retreat.

Two erosion processes occur along the cliff-backed shoreline: the first is erosion of the softer marine terrace deposits (or bluffs) that overlay the sandstone bedrock, and the second involves the long-term erosion of the sandstone bedrock (or cliffs). In conjunction, these processes lead to inland retreat of the bluff-top edge along the cliff-backed shore.

Erosion processes on the dune-backed shoreline are influenced by wind and water, with marine forces such as wave attack being the primary driver of dune crest recession. As waves arrive during winter storms, this wave action can transport sand away from the base of the dune, creating a dune scarp. Over time, a new dune profile will take shape as the slope stabilizes, and accretive forces such as summer waves bring sand to shore and prevailing winds (also known as aeolian transport) bring sand to the dune. If the erosive forces acting upon the dune surpass the constructive accretive forces, the crest of the dune will progressively migrate inland.

Carmel Beach experiences most erosion events in the winter when storms bring intense rainfall and larger waves. During the winter, the sand that is typically on the dry beach during the summer is relocated offshore to form sandbars. For typical winter conditions, these sandbars act as a protective barrier, causing larger waves to break offshore,

dissipating much of their energy before reaching the beach. However, during large storms, there is so much wave energy and elevated water levels that the waves will reach backshore and can contribute to erosion. In a natural, unarmored environment, additional eroded sediment from the backshore would be available to replenish the beach during such events. However, in an armored setting, this source of sediment is not available to counterbalance the increased wave energy.

The erosion forces at work involve a complex interplay of marine and terrestrial factors and conditions. The subsequent sections explore these in more detail.

Marine Forcing

Waves and induced currents are the main primary marine influences on erosion. Elevated wave heights, typically associated with winter storms, contribute to increased run-up and higher total water levels. This results in more wave energy being directed toward the back of the beach. Furthermore, local variability in nearshore geomorphology can concentrate wave energy in specific zones and guide water flow, leading to the acceleration of alongshore currents.

Wave Reflection

Waves that reach the seawalls will reflect off the seawalls and travel seaward. At the seawall, the water particles under the reflected wave will move quickly, mobilize sand, and cause scour at the toe of the structure. The amount of scour is proportional to the height of the wave; the higher the wave, the greater the scour. In Figure 2, waves are crashing into the seawall near Martin Way.



Figure 2. Martin Way Stairs (highlighted in yellow) during the El Niño winter of 2023–24. Source: City of Carmel, January 2024

Wave Overtopping

When wave run-up reaches coastal armoring structures, especially vertical seawalls, it can elevate water levels and create wave splash over the seawalls (Figure 3). This wave splash water, especially when driven by onshore winds, can saturate the bluff terraces behind the wall, contributing to bluff failure and erosion behind the seawalls. As sea levels rise, wave run up elevations reach a point where the water that is overtopping is not just a vertical splash but rather a wave (or “green water”), that has horizontal momentum and can further accelerate the erosion of the bluff above the coastal armoring structures.



Figure 3. Wave overtopping on a Carmel seawall (see arrow). Note the directional wave and splash along the wall. Source: City of Carmel January 5, 2023

Inshore and Backshore Currents

The study by Rogers E. Johnson and Associates (Johnson 1983) detailed a swift inshore current that moves horizontally along the beach, typically heading southward where elevations are lower. Inshore and backshore currents have been observed in recent events, illustrated in Figure 4. In the initial panel, waves collide with the seawall, reflecting away from it. The water, attempting to escape, is directed around the seawall. These currents with high particle velocities can more effectively mobilize sand away from the beach.



Figure 4. Rip currents moving away from the shore in the cove at 13th Avenue. Left, the cove fills with water from broken waves. Right, an alongshore current develops, channeling water out of the cove and along the seawall to the south.
Source: City of Carmel, January 2023

Local Conditions

Outcrops and variability of the backshore will affect how currents develop and where wave focusing occurs. A unique contributing factor for Carmel is the orientation of exposed outcrops of sandstone in the beach area (Figure 5). These outcrops are usually buried by beach sand and are only exposed following significant winter scouring events. The Johnson (1983) study notes that deep channels exist between these outcrops that lie perpendicular to the bluffs. These formations may act to direct and focus water flow toward specific locations on the backshore, producing more severe erosion (Figure 6).



Figure 5. Left: Sandstone outcrop between Santa Lucia Ave and 13th Avenue, winter of 2010. Note the perched beach sand atop the sandstone outcrop to the right (orange circle), an indication of the previous summer's sand levels. Right: A scoured beach in January 2023 near 10th Avenue reveals a channel between sandstone bedrock with a gap oriented at an angle to the backshore. Source: City of Carmel.



Figure 6. Focusing of water flow between the gap in the sandstone formation. This leads to a piling up of water in the gap and subsequently higher erosion. Location: Stairs at northern end of 10th Avenue. Source: City of Carmel, January 2023

Terrestrial Forcing and Conditions

Terrestrial forces include rainfall and groundwater flow, as well as terrain and lithological conditions, including variations in geology, profile elevation, beach slope, folding, faulting, and shoreline orientation. As noted in the Johnson (1983) study, two strong sets of fractures which trend in the northwest direction have allowed waves to selectively attack the backshore along these zones of weakness. This process has helped to form the coves and headlands seen in the southern end of the beach. In addition, there are also anthropogenic factors to consider related to land use patterns, stormwater management, irrigation systems, coastal armoring, and recovery efforts. Human and animal foot traffic along informal shoreline trails, or through vegetated dunes (or bluff-cuts) also contributes to erosion along shoreline bluffs and is a persistent problem for the City (Shonman and D'Ambrosio 2015).

Stormwater Runoff Influence

The City's shoreline is located at the bottom of a hill where stormwater is channeled from the streets above. The City's stormwater discharges onto the beach through 21 outfalls. During the severe El Niño winter of 1982-83, severe winter storms struck Carmel every 10 days, and the heavy rains overwhelmed the City's storm drain system and were a major contributor to bluff-top erosion. Although significant upgrades and improvements to the drain system and catch basins were made between 1983 and 1988 following the El Niño storms, the ability of the stormwater system to channel water effectively will be affected by sea level rise, coastal erosion processes, and increases in high-intensity rainfall events due to climate change (Shonman and D'Ambrosio 2003).

Erosion Response

The erosion response of the cliff-backed bluffs and the dunes and beach are different. Bluff erosion occurs episodically, and the bluff does not recover without intervention. In contrast, the sandy beach will recover between storm events as smaller waves bring sand back to the shore. Given enough time and favorable winds, sand dunes can also recover as the beach sand is blow into the dunes. Predominantly sandy areas, like dunes and the beach, will erode gradually over time, while predominantly rocky areas, like the cliffs and bluffs, will erode episodically over time. Figure 7 depicts the different types of erosion depending on the backshore type.

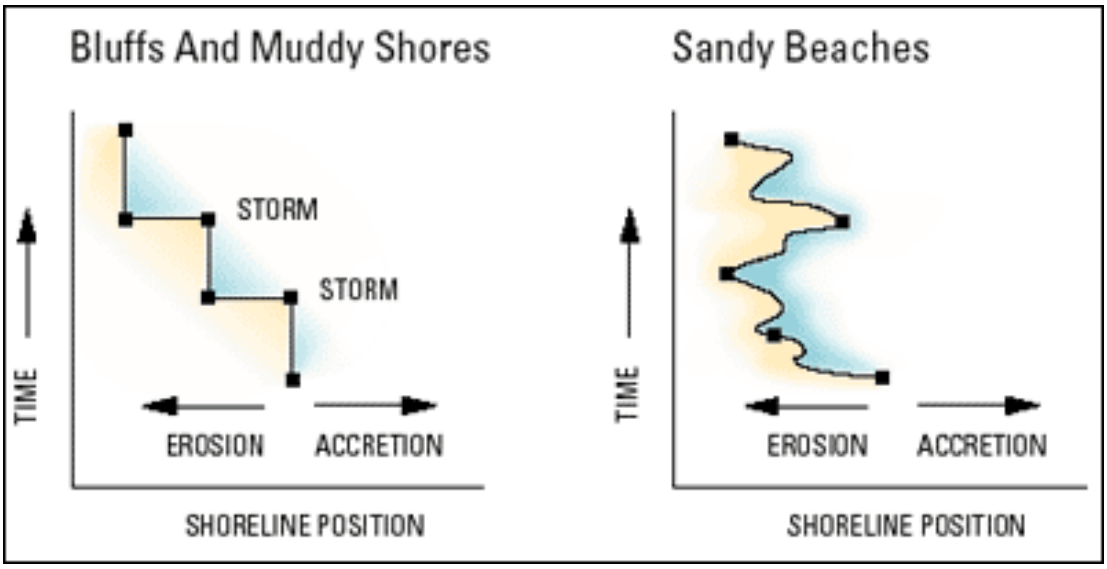

Figure 7. Bluff erosion occurs episodically and only moves inland while sandy beaches can erode during storms and recover during calmer wave conditions time.
Image from the U.S. Geological Survey.

Beach Narrowing

The effect of sea level rise will be the landward migration of the shoreline. On average, Carmel Beach has an offshore slope of approximately 50:1 to 60:1,[2] meaning every foot of sea level rise will result in a 50- to 60-ft landward progression of the shoreline.

It is important to understand that coastal armoring protects what is behind the armor, at the cost of the fronting beach. With increasing sea levels, it is only a matter of time before beaches in front of hard armoring structures will disappear. This is a phenomenon known as coastal squeeze or passive erosion.

Dune Erosion and Scarping

During storm events, the dunes along Carmel Beach can experience substantial erosion. Wave run-up, especially during elevated tides, allows wave energy to reach the backshore and impact the base of the dune. This can result in the removal of sand, leaving a steep dune scarp (Figure 8). The extent of dune erosion at a specific location is influenced by factors such as beach slope, dune vegetation, and, crucially, the location of buried riprap that protects the dune toe from erosion.

[2] From the 15-m isobath to the toe of the cliff, dune, or coastal armor.

Following significant erosion, the recovery of Carmel's dunes occurs gradually, facilitated by smaller waves and wind bringing sand back over an extended period. However, because of the longer recovery time of dune systems, they are especially susceptible to increased storm frequencies and sea level rise. Elevated water levels with sea level rise will allow wave erosion processes to act farther up on the beach profile causing an evolution of the dune profile farther inland.



Figure 8. Dune scarp at Del Mar Sand Ramp. The yellow hatched line represents the previous summer's beach profile. Dune scarping can have a significant impact on beach access. Source: City of Carmel, January 2023

Bluff Terrace Erosion

Bluff terrace erosion is primarily due to two natural processes: 1) wave attack eroding the sandstone bedrock and undermining the bluff, and 2) terrace slumping. Rainfall and saturated soils can cause gullying and slumping that contribute to the recession of the bluff. Slumping can also accelerate erosion of the underlying sandstone during large failure events. Note that as bluffs erode, debris accumulates at the base of the cliff, which can provide some temporary protection from wave attack.

DATA AND ANALYSIS METHODS

This section summarizes this assessment's methodology and approaches for assessing sea level rise and coastal hazard vulnerabilities.

Coastal Modeling Parameters

The extent of coastal erosion is represented as the landward migration of the bluff or dune crest. Coastal erosion is episodic, not constant, making it difficult to estimate the eroded position of the cliff top for any given time and location. This study projects the average retreat rates associated with a series of these episodic events over time to yield projections for the average bluff or dune crest position in the future.

The models for cliff erosion rely on simplifications of reality and relate cliff retreat to factors such as wave impacts, sea level rise, historical erosion rates, and cross-shore profile geometry. Detailed below are the data sets that contributed to these model parameters. The short-term impacts of these seasonal processes vary spatially, and the processes occur across long time scales; thus, they are extremely hard to predict both spatially and temporally.

Coastal models require historical erosion rates to project future erosion rates. They also require additional parameters to determine terrestrial and marine forcing, including the following:

- **Geomorphic:** bluff-top elevation, contact elevation between terrace and cliff, toe elevation, foreshore beach slope
- **Waves**: total water levels.

Determination of Erosion Rates

Location-specific erosion rates are an important factor in determining erosion projections and were needed given the detailed scale of this study. Unfortunately, data were not available to support an accurate location-specific historical erosion rate assessment and literature was cited to determine average erosion rates across the entirety of Carmel Beach. To arrive at a location-specific erosion rates, the average erosion rates from the literature were adjusted to take into account varying local conditions. For a more detailed explanation of average historical erosion rates and maximum observed failure distances, refer to the Task 2 Report: Shoreline and Beach Change Analysis: Seasonal and Long Term.

An upper and lower bound of potential erosion rates were determined to reflect a more likely and worst-case condition and to account for uncertainty in both spatial accuracy and confidence in the cited literature. The Johnson (1983) study documented locations and extents of failures and computed a long-term erosion rate from 1908 to 1982, and determined that the bluffs eroded between 0.3 and 0.7 ft/yr with an average of 0.4 ft/yr. It should be noted that erosion occurs episodically, not on an average annual basis, and

maximum failure distances may reach as far as 30-40 feet, as documented in Johnson (1983) study following the 1982-83 El Niño winter.

To represent a lower bound, this study adjusted the average lower bound to 0.2 ft/yr, which is an average between the erosion rate found for the Pebble Beach Golf Course section of beach (0.1 ft/yr) and the lower bound reported by Johnson (0.3 ft/yr). To represent a worst case, this study used the average of 0.7 ft/yr found by Johnson (1983).

Location-Specific Historical Erosion Rates

To determine site-specific erosion rates for the entire shoreline, the historical erosion rates of 0.2 ft/yr (likely), 0.4 ft/yr (best, representing an average), and 0.7 ft/yr (worst case) were multiplied by an adjustment factor, which was determined based on geological conditions, geomorphic factors, locations with accelerated nearshore currents and historical observations of failures. Projections of erosion using these historical rate assumptions are discussed in the Task 3, Hazard Model Findings section, below.

A site-specific adjustment factor was informed from reports of geological conditions from the Johnson (1983) study, the James C. Reynolds and Associates (Reynolds 1986) soil investigation report noting bluff contact elevations, Carmel Shoreline Assessment Fall 2014 to Summer 2016 (Carmel-by-the-Sea 2016), and from observations made in the field by the Haro Kasunich & Associates, Inc. and Integral team in 2023. These reports and field observations provided a spatially explicit reference for the geological and terrestrial conditions that may contribute to higher erosion rates in certain areas, such as noted locations of jointing, faulting, fractures, and sandstone platforms that may focus wave energy, as well as areas that experience more significant beach scouring. Elements that may inhibit erosion were also factored in, such as the presence of a sandstone platform that may deflect wave energy, a more sheltered shoreline orientation, the presence dune vegetation, and areas that experience less beach scouring. Consideration was also given to the contact elevation of the more erosion-prone terrace deposits. This information was also verified by failure observations that were compiled from site-specific studies, including from Johnson (1983, 1997), and assessments from Shonman and D'Ambrosio (2015). The range of assumed location-specific erosion rates are shown in Figure 9.

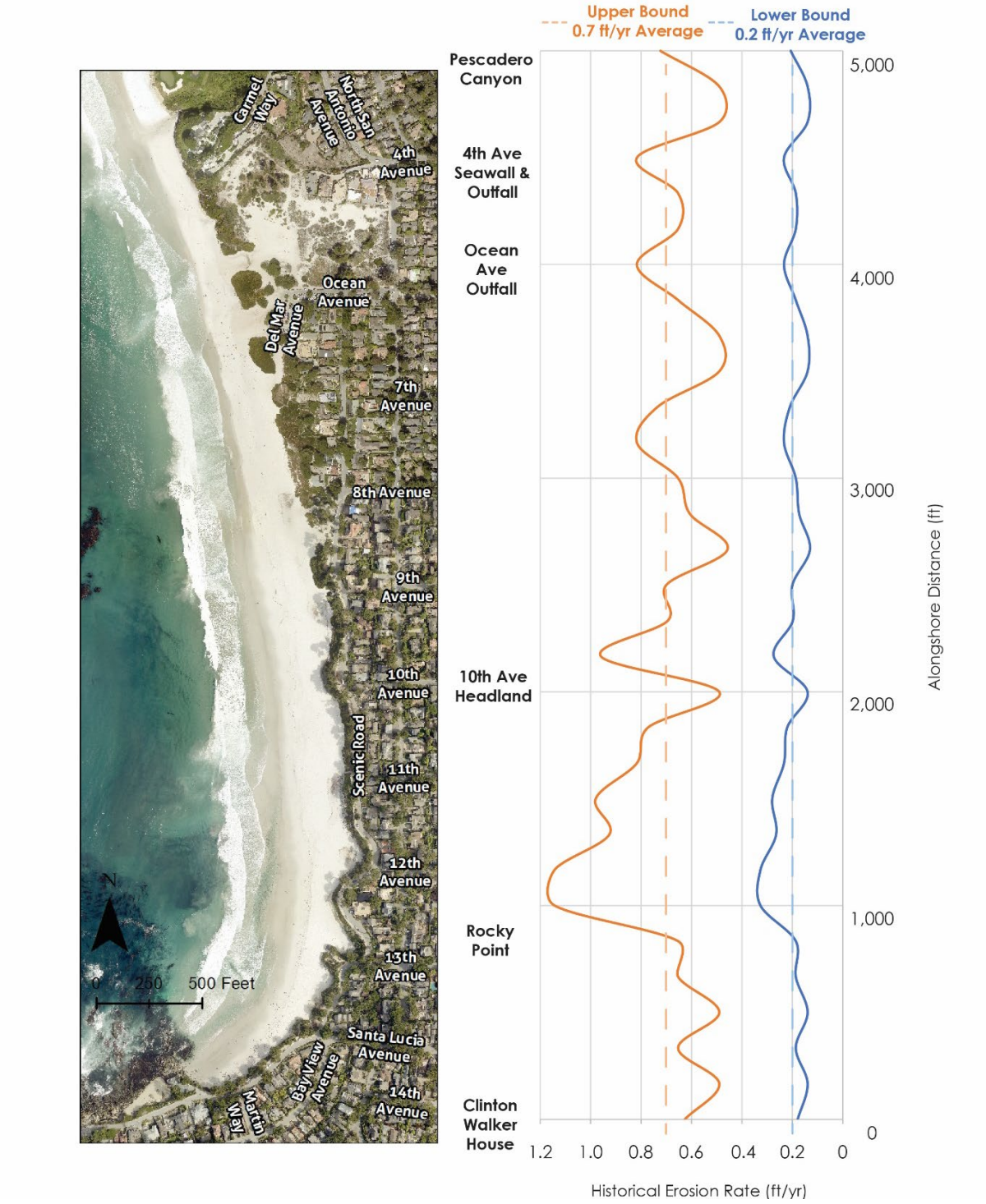

Figure 9. The range of historical erosion rates estimated in this study, which are used to derive future erosion projections by accelerating these rates with sea level rise.

Geomorphic Data (Elevation and Slopes)

Digital elevation models (DEMs) were used to develop cross-shore profiles, which inform the elevations of important cliff and dune features. These data were sourced from the National Oceanic and Atmospheric Administration (NOAA) Digital Coast website and the Association of Monterey Bay Area Governments (AMBAG). Elevation models considered in this study included the following surveys: Federal Emergency Management Agency (FEMA) 2018 (Spring), U.S. Geological Survey (USGS) 2016 (Spring), California ARRA 2010/11 (Winter), AMBAG 2010 (Summer), U.S. Army Corps of Engineers NCMP 2009 (Fall), USGS 1998 (Spring), USGS 1997 (Fall), as well as the USGS CoNED Topobathy from the Coastal National Elevation Database (multiple dates from 2008 to 2015).

Cliff and Dune Feature Locations

Locations of the following cliff features was determined: the toe of the cliff or armoring structure, the top of the armoring structure or the contract between the cliff and the bluff terrace, and the crest of the bluff at the landward edge. These features were manually digitized from high-resolution aerial photographs from EagleView (2022) provided by the City and verified using the 2018 and 2016 lidar DEMs, as well as oblique images from the California Coastal Records Project. The height of all coastal armoring was further verified from site observations as documented in the tables provided in Task 1, Coastal Engineering Assessment.

Cliff Top Elevations

The elevation of the top of the cliff was determined just inland (2 m) of the observed cliff-top location to account for potential positional inaccuracies in the DEMs. Elevations for each transect were determined using available DEMs for each year, and outliers were removed from the data set.

Bluff Contact and Top of Armor Elevations

The contact elevation between the more erosion-resistant sandstone or coastal armoring and the less erosion-resistant terrace was determined using an average elevation from all available data sets while filtering bias errors due to vegetation. The contact elevation was determined manually through interpretation of the change in slope in the DEMs as well as aerial image interpretation. Contact elevation depths were verified with the Reynolds (1986) assessment. Note that the sandstone bedrock dips below an area of dunes at 8th Avenue and reemerges just shoreward of the beach volleyball courts. For the dune-backed sections where the sandstone bedrock is buried by dune sand, a linear interpolation between the known locations of the southern and northern contact

elevations was used. This interpolated location is important because once dune erosion reaches this location, then the erosion processes shift to cliff erosion processes.

Cliff Toe Elevations

The elevation of the cliff or armor toe was determined just seaward (5 m) of the observed toe location to account for seasonal changes in beach elevation, which can affect the horizontal toe position. Toe elevations were determined for both winter/spring and summer/fall. For these modeling purposes, the average winter/spring elevation was used, as this season is typically most erosive, and beach sand levels are the lowest. This elevation was calculated from the average of the three lowest elevations found among the available DEMs. The lowest toe elevations were typically found in the 1998 spring (following the El Niño Winter) and 2010 summer surveys, with the 2016 spring and 2018 spring surveys also contributing.

Nearshore Waves and Total Water Levels

Wave properties, including wave height and period, were derived from unpublished data from the USGS (Hegermiller et al. 2017). The time series of nearshore waves along the central California coast, including hindcasted data for 1980–2010 and projected data for 2010–2100, were developed using downscaled regional models. Each subunit in the study area was linked to a nearshore wave data location, with a total of nine wave data points referenced.

An important measure of coastal hazards is the total water level elevation, which is the combined effect of wave run-up height, storm surge, tides, and sea level elevations. For a more detailed discussion of total water level, please see Integral's Task 2 report, Shoreline and Beach Change: Seasonal and Long Term. For this analysis, total water levels were determined by combining the highest astronomical tide (HAT), CoSMoS Waves, and a wave run-up using the Stockdon et al. (2006) wave run-up equation.

The total water levels were calibrated using FEMA's flood hazard elevation levels by matching the total water level at each transect to the FEMA flood hazard elevation. To ensure the total water levels matched the flood hazard elevation levels, the foreshore slopes of the transects were adjusted. The final range of slopes was between 6/100 and 14/100 (tanβ – 0.06 – 0.14).

Cliff and Dune Erosion Projection Methods

Erosion projections assume that sea level rise will elevate wave energy, intensifying its impact on cliffs, dunes, and armor, and ultimately leading to heightened retreat rates. Peer-reviewed models, described in more detail below, rely on assumptions linking cliff

retreat to sea level rise, wave energy, historical cliff behavior, and cross-shore profile geometry. The CoSMoS cliff forecasting tool relies on five different models from Limber et al. (2018). However, not all models within the CoSMoS cliff forecasting tool were appropriate for the study area. This study used two models hand-picked to match the hard rock geologic conditions of the study area, which are detailed below.

Several different scenarios are modeled: 1) unarmored and armored, and 2) high, medium, and low assumptions on historical erosion rates. The erosion model projects erosion distances at 1-year time steps. Erosion distances are mapped in approximately 20-year time periods: 2020–2040 (0–1 ft sea level rise), 2040–2060 (1–2 ft sea level rise), and 2060–2080 (2–4 ft sea level rise). While period of time is used for the erosion modeling, all results are reported by level of sea level rise.

Exceedance Model (Cliff-backed shorelines with Armoring)

This model uses historical erosion rates to project cliff retreat using methods described in ESA (2016), Revell et al. (2011), and Limber et al. (2018). It presumes that the wave energy reaching the bluff will cause the bluff retreat rate to accelerate beyond historical levels. Wave energy reaching the bluff is modeled as the amount of time the total water level exceeds the contact between the terrace and the sandstone, also called "exceedance hours." With sea level rise, the retreat rate will increase proportionally to the increase in exceedance hours. As total water levels were calculated assuming elevated tides and scoured beach profiles, exceedance hours were divided by 4 to account for hours of high wave run up occurring during high tides in the mixed semi-diurnal tide regime (two high and two low tides of unequal height daily). One erosion hazard zone representing the best estimate of future erosion hazards was developed.

Trenhaile Model (Cliff-backed shorelines without armoring)

This model presumes that the distance between wave breaking and the cliff toe (surf zone length) will drive cliff retreat and is described in Trenhaile (2000) and Limber et al. (2018). A shorter surf zone will increase the wave energy available to reach the backshore, and sea level rise will reduce surf zone length and lead to an acceleration of erosion into the future. Unlike the exceedance model described above, this model does not consider the presence of armoring along the backshore. Three erosion hazard zones representing a range of estimates of future erosion hazards was developed.

Dune Erosion Model (Dune-backed shorelines)

This model was conducted using a geometric model of foredune erosion due to sea level rise (Komar et al 1999, Revell et al 2011). This model projected that the dune would intersect the underlying cemented beach deposits and more erosion-resistant sandstone

between 2045 and 2060 (or one foot of sea level rise). After one foot of sea level rise, the dominant erosion mode was modeled as a hard cliff-back coast (see Trenhaile model, described above).

Beach Narrowing Projection Methods

A Bruun-type model was used to estimate coastal recession by assuming the conservation of sediment and an equilibrium profile shape. [3] This model shifts the beach profile upward and landward by a distance determined by sea level rise and the geometry of the profile. The baseline for a typical summer beach is the 75th percentile beach location as determined from analysis of the CoastSat data record from 1984 to 2021 and is described in more detail in Task 2. For this analysis, it is assumed that the current armored backshore toe of the cliff or dune location does not retreat inland with sea level rise. This model can be considered a “hold the line” scenario and represents what changes to the beach may occur if the coastal armoring is maintained and no additional adaptation strategies are implemented in the future.

Model Caveats and Disclaimer

The cliff erosion model projections show a band of potential erosion. It is highly unlikely that all of this erosion would occur simultaneously, rather multiple cliff failures would occur along the coast in different locations. The cliff erosion models used in this study do not account for the evolution of nearshore slopes over time, including the beach and shore platform, which are likely to evolve as sea levels rise and erosion forcing conditions change. Additionally, the efficacy of coastal armoring over time and when or if failure of these structures will occur is not considered.

Small variations in initial parameter values can lead to significant variations in model predictions as they are multiplied over long time scales. As a result, the uncertainty in erosion rate projections generally increases over time.

Finally, the future holds many uncertainties that may influence erosion, ranging from potential changes in precipitation, temperature, wave climate, frequency and magnitude of precipitating storm events, and anthropogenic contributions and responses to erosion. Due to the highly uncertain nature of these processes, caution should be used with all erosion projections.

[3] The conservation of sediment assumption in the Bruun model was justified in Task 2 findings of a stable sand volume in the nearshore system.

Given these disclaimers, however, all efforts have been made to utilize the best available science and methods and carefully document uncertainties. These results represent the state of the practice in coastal cliff erosion projections.

Vulnerability Assessment Methods

The vulnerability assessment analyzes the spatial intersection (or overlay) of the coastal erosion hazard zones with the assets and infrastructure data sets. The study team overlaid all available parcels, structures, roads, and infrastructure data sets with the coastal erosion hazard zones to quantitatively assess both the number and amount of assets affected. For each resource sector, individual data sets had particular reporting criteria, including number, length, and area affected. Data sets were queried, and summary statistics of assets affected were calculated by sea level rise elevation (see Appendix A for tabular results). Results were collated into tables and are interpreted in the Task 4, Vulnerability Assessment, section below. Because of the sensitive nature of utility and infrastructure data, and to respect the privacy of individual residents and landowners, this study does not map the locations of vulnerable assets.

Asset Data

The study team considered and collected all available geospatial asset data from the City, County, and cross-jurisdictional agencies such as CalAm Water and the Carmel Area Wastewater District. The team obtained the most up-to-date data directly from the source at the time of evaluation and performed quality assurance on the data.

TASK 3 HAZARD MODEL FINDINGS

This section provides the analysis and modeling results in the forms of tables of total water levels with sea level rise by backshore section, maps displaying erosion hazard zone projections, and maps of beach narrowing.

Total Water Level Findings

This section reports the progression of total water levels with sea level rise. High total water levels allow wave energy to reach the backshore, overtop coastal armoring and accelerate erosion, and these values are related to how much erosion accelerates in the erosion scenario with armoring. This analysis assumes that the future wave climate is comparable to the historical wave climate and that total water level changes are based primarily on influences from sea level rise. Modeling of total water levels assumes that current backshore location and height of armoring remain consistent throughout the future, and that no additional adaptation strategies are implemented.

Table 1. The percentage of time total water level exceeds the top of armor or sandstone and terrace contact elevation (left) and if total water levels exceed the crest (right) for each sea level rise level. Green indicates very little (<3%), yellow indicates low (3–10%), orange indicates medium (10–20%), and red indicates high levels of exceedance time (>20%). Areas are listed from south to north.

	Water Levels above the Top of Armoring or Sandstone Cliff *Percentage of days* that the contact elevation is exceeded*			**Water Levels above the Crest of the Bluff or Dune** *Does wave splash exceed crest elevation? (YES or NO)*		
	Sea Level Rise Horizon, feet (years)			Sea Level Rise Horizon, feet (years)		
Location *From south to north*	1 (2045–2060)	2 (2060–2080)	4 (2080–2100+)	1 (2045–2060)	2 (2060–2080)	4 (2080–2100+)
Section 1 South Beach						
Martin Way to Santa Lucia Ave (Seawall)	4%	8%	21%	YES	YES	YES
Santa Lucia Ave to 13th Ave (Seawall)	6%	16%	23%	YES	YES	YES
13th Ave Headland (Seawall)	1%	3%	10%	YES	YES	YES
13th Ave Cove (Seawall)	4%	10%	22%	NO	NO	NO
13th Ave to 12th Ave (Riprap)	22%	25%	25%	NO	NO	NO
13th Ave to 12th Ave (Seawall)	<1%	<1%	2%	NO	YES	YES
13th Ave to 12th Ave (Unarmored Cliff with Riprap around SW Drain)	2%	5%	17%	NO	YES	YES
13th Ave to 12th Ave (Unarmored Cliff)	14%	21%	25%	NO	NO	YES
12th Ave Cove (Unarmored Cliff)	<1%	1%	5%	NO	NO	NO
12th Ave Cove (Revetment)	1%	2%	6%	NO	NO	NO
12th Ave to 11th Ave (Revetment)	1%	1%	4%	YES	YES	YES
11th Ave to 10th Ave (Buried Revetment)	15%	20%	24%	YES	YES	YES
10th Ave Headland (Seawall)	13%	19%	24%	YES	YES	YES
10th Ave to 9th Ave (Buried Revetment)	24%	25%	25%	YES	YES	YES
9th Ave to 8th Ave (Buried Revetment)	25%	25%	25%	YES	YES	YES
8th Ave Stairs (Buried Revetment)	12%	24%	25%	NO	NO	NO
Section 2 Central Beach						
8th Ave (Buried Revetment under Vegetated Dune)	<1%	3%	23%	NO	NO	YES
8th Ave to 7th Ave (Vegetated Dune)	<1%	<1%	4%	NO	NO	NO
7th Ave (Vegetated Dune)	0	0	<1%	NO	NO	NO
Southern Sand Ramp (Dune)	0	0	0	NO	NO	NO
7th Ave to Ocean Ave (Vegetated Dune)	0	0	0	NO	NO	NO

Location *From south to north*	**Water Levels above the Top of Armoring or Sandstone Cliff** *Percentage of days* that the contact elevation is exceeded* Sea Level Rise Horizon, feet (years)			**Water Levels above the Crest of the Bluff or Dune** *Does wave splash exceed crest elevation? (YES or NO)* Sea Level Rise Horizon, feet (years)		
	1 (2045–2060)	2 (2060–2080)	4 (2080–2100+)	1 (2045–2060)	2 (2060–2080)	4 (2080–2100+)
Del Mar Parking Lot (Dune)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Section 3 North Dunes						
Ocean Ave (Buried Revetment under Vegetated Dune)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Ocean Ave (Vegetated Dune)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Northern Sand Ramp (Dune)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Ocean Ave to 4th Ave (Vegetated Dune and Cliff)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Ocean Ave to 4th Ave (Vegetated Dune and Cliff)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Ocean Ave to 4th Ave (Seawall)	**0**	**0**	**0**	**NO**	**NO**	**NO**
4th Ave Stairs (Vegetated Dune and Cliff)	**0**	**0**	**0**	**NO**	**NO**	**NO**
Section 4 North Beach						
4th Ave to Pescadero Canyon (Unarmored Cliff)	**0**	**0**	**0**	**NO**	**NO**	**NO**
4th Ave to Pescadero Canyon (Seawall)	**18%**	**24%**	**25%**	**NO**	**NO**	**YES**

Note: *Percentage of days are tallied by decadal range. The decal ranges used assume a high emissions and medium-high risk aversion sea level rise scenario with 1 ft of sea level rise by the 2040s, 2 ft of sea level rise by the 2060s, and 4 ft of sea level rise by the 2080s.

For the South Beach section, by 1 ft of sea level rise, total water levels during a 100-year storm event are often up to 3 feet or more over the terrace contact elevation. By 2 ft of sea level rise, the total water level is often greater than 5 ft over the crest in most sections.

For the Central Beach section, the total water level is expected to be higher than the crest only at the southernmost areas near 8th Avenue. As elevations rise toward the north, total water levels are not projected to exceed the dune crest or bluff contact elevation by four ft of sea level rise.

The North Dunes and North Beach do not see total water levels higher than the bluff contact or crest elevation except for the low-lying area near Pescadero Canyon. In this area, the total water levels are projected to be 5 ft greater than the top of armor elevation for all sea level rise horizons and projected to be higher than the bluff crest by 4 ft of sea level rise.

Cliff and Dune Erosion Hazard Findings

This section provides maps of the erosion hazard zones (Figures 12 through 16). The maps are organized by the with and without armoring scenarios and split into the north (including the North Dunes, North Beach, and Central Beach), central (including the Central Beach and South Beach), and south (including South Beach) areas. For the with armoring scenario, a range of future erosion probabilities are presented. For the armored erosion projection, only a best estimate scenario relying on a range of erosion baselines and future conditions is presented. For the armored scenario, erosion rates are dampened significantly in the near term due to limited wave splash above the crest of the armoring structures; however, with increasing sea level rise, the effectiveness of the armoring is reduced, leading to more green water horizontal wave run up velocities and an acceleration in bluff-top erosion above the coastal armoring in future.

Hazards Zone Disclaimer

The maps and associated analyses in this section are intended as planning tools to illustrate projected hazard exposure with sea level rise. The contributors and sponsors of this product do not assume liability for any injury, death, property damage, or other effects of erosion or flooding.

Although every effort was made to review all resource sector and infrastructure data used in this study, neither the City nor its consultant, Integral, can verify the completeness of all spatial data. For this reason, we do not accept responsibility for any errors, omissions, or positional inaccuracies. Users of the data displayed in the maps are strongly cautioned to verify all information.

Coastal Cliff and Dune Erosion Projection Without Armoring - North Carmel Beach



Figure 10. Map of dune and cliff erosion for the northern beach. Displays erosion hazards without armoring. Hazard zones represent three bands of certainty, most likely, based on the assumption of a low average erosion rate (0.2 ft/yr), best, based on the assumption of an average erosion rate (0.4 ft/yr), and worst case, based on the assumption of a high average erosion rate (0.7 ft/yr).



Figure 11. Map of dune and cliff erosion for the central beach. Displays erosion hazards without armoring. Hazard zones represent three bands of certainty, most likely, based on the assumption of a low average erosion rate (0.2 ft/yr), best, based on the assumption of an average erosion rate (0.4 ft/yr), and worst case, based on the assumption of a high average erosion rate (0.7 ft/yr).



Figure 12. Map of dune and cliff erosion for the southern beach. Displays erosion hazards without armoring. Hazard zones represent three bands of certainty, most likely, based on the assumption of a low average erosion rate (0.2 ft/yr), best, based on the assumption of an average erosion rate (0.4 ft/yr), and worst case, based on the assumption of a high average erosion rate (0.7 ft/yr).



Figure 13. Map of dune and cliff erosion for the northern beach. Displays erosion hazards with armoring. Hazard zones in areas where armoring is not present rely on the 'without armoring' scenario using the assumption of an average erosion rate (0.4 ft/yr).



Figure 14. Map of dune and cliff erosion for the central beach. Displays erosion hazards with armoring. Hazard zones in areas where armoring is not present rely on the 'without armoring' scenario using the assumption of an average erosion rate (0.4 ft/yr).



Figure 15. Map of dune and cliff erosion for the southern beach. Displays erosion hazards with armoring. Hazard zones in areas where armoring is not present rely on the 'without armoring' scenario using the assumption of an average erosion rate (0.4 ft/yr).



Figure 16. Map of dune and cliff erosion for the entire beach. Displays erosion hazards with armoring. Hazard zones in areas where armoring is not present rely on the 'without armoring' scenario using the assumption of an average erosion rate (0.4 ft/yr).

Beach Narrowing Findings

In response to rising sea levels, Carmel Beach will narrow over time without any additional adaptation strategies (Figures 17 and 18). Beaches with no armoring may migrate landward with sea level rise as cliffs and dunes erode naturally. However, if landward migration is inhibited by armoring, beaches will narrow and likely be permanently inundated (Table 2) at some point in the future. This is a phenomenon known as coastal squeeze or passive erosion. A narrative of beach narrowing can be found below in the Task 4, Vulnerability Assessment section.

Table 2. Typical summer dry sand beach remaining with each foot of sea level rise

Sea Level Rise Elevation (ft)	Acres of Dry Sand Beach (typical summer)	Percentage
0	34.2	100%
1	27.4	80%
2	20.7	61%
3	14.1	41%
4	7.6	22%
5	2.6	8%

Notes: The baseline year for sea level rise 2020. Summer dry sand beach acreage is representative of the 75 percentile beach width from 1984 to 2021.

How to Interpret the Hazard Maps

The maps of beach narrowing with sea level rise represent a typical summer beach. Actual summer beach widths may vary. Beach widths are constrained by the current position of backshore toe and are reflective of a “hold the line” scenario.

Summer Beach Width Change Projection - North Carmel Beach

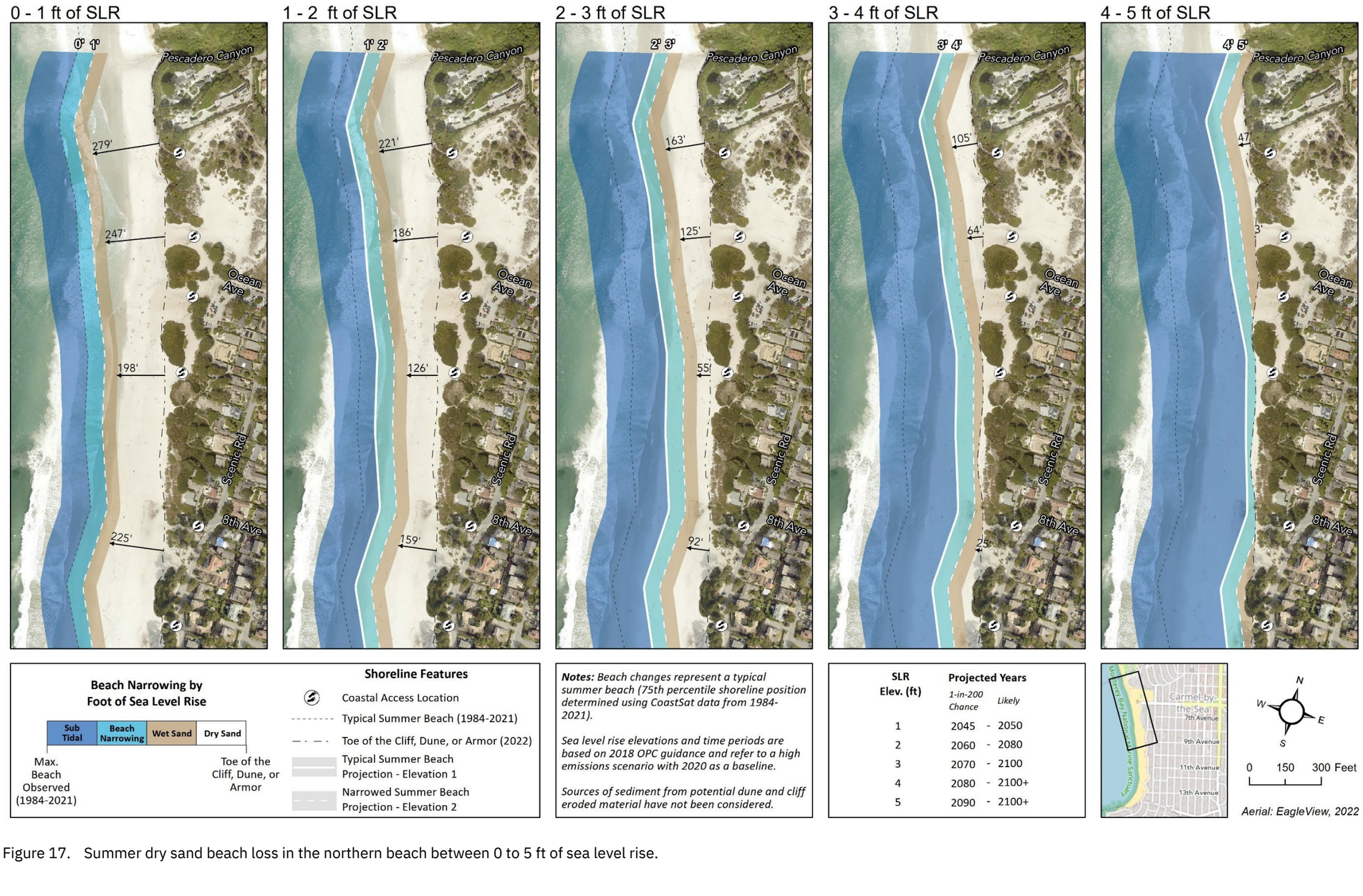

Figure 17. Summer dry sand beach loss in the northern beach between 0 to 5 ft of sea level rise.

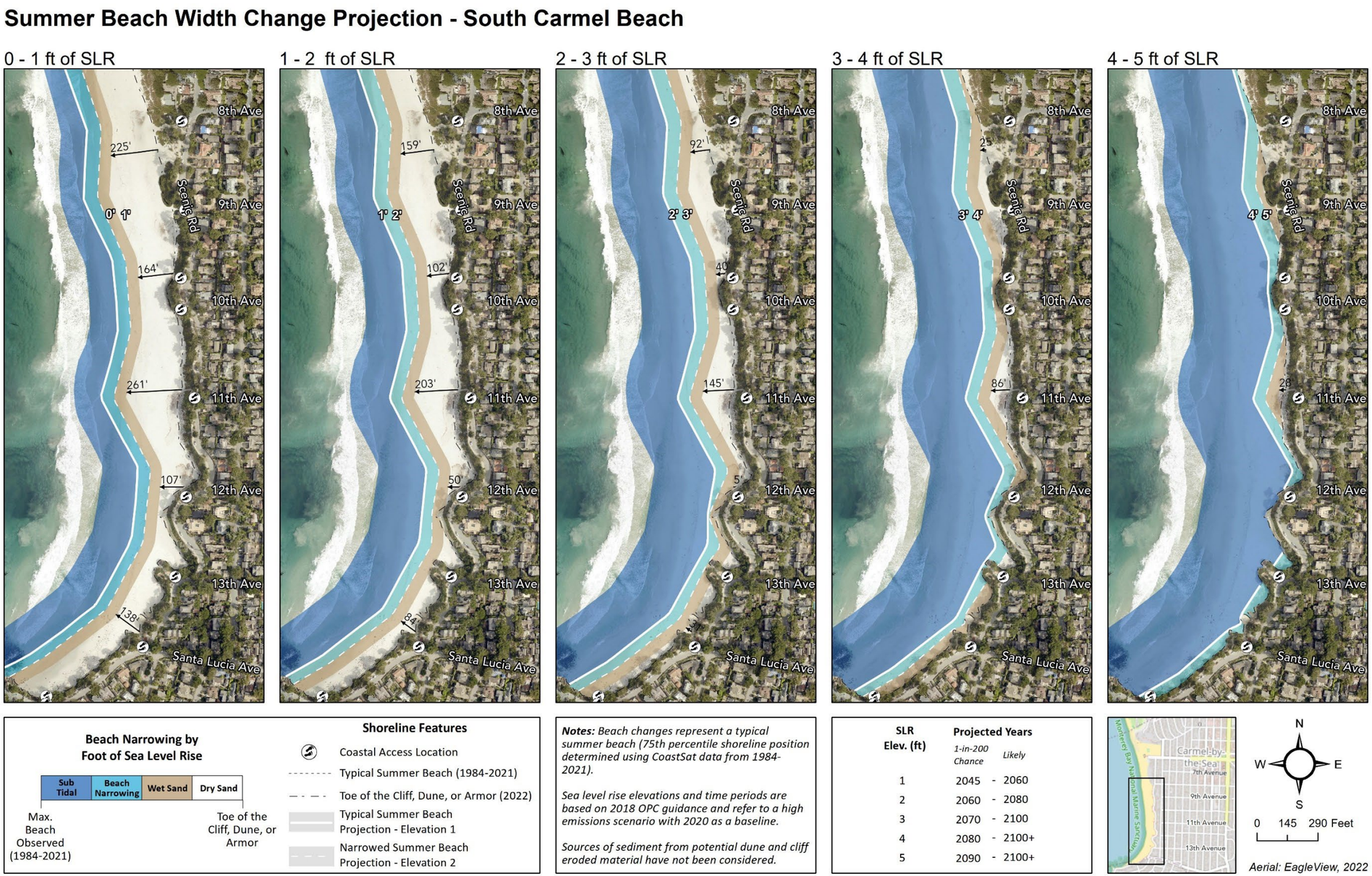

Figure 18. Summer dry sand beach loss in the southern beach between 0 to 5 ft of sea level rise.

TASK 4 VULNERABILITY ASSESSMENT

This section provides a narrative of vulnerabilities to sea level rise by each section of the City's shoreline. The focus of this assessment is on the direct exposure of City infrastructure, property, and structures to coastal erosion and sea level rise. This assessment does not consider the wide range of cascading impacts associated with climate change.

Section 1 South Beach—Scenic Road from 8th Avenue to Martin Way

This section of shoreline is composed of mostly armored cliffs along Scenic Road south of 8th Avenue and extends for ~0.6 mile. The contact elevation between the sandstone cliff and the softer terrace is lower in the north and rises toward the south, before dropping once more around 13th Avenue. This section experiences the most significant variability in seasonal beach width change.

The area between 9th Avenue and 11th Avenue has a FEMA base flood elevation of 31 ft, which is higher than other locations along Carmel Beach (24 ft in the south and 16 ft in the north). The Johnson (1983) study notes that the area around 10th to 12th Avenue is a possible fault zone and reports erosion of 25–40 ft here following the 1982-83 El Niño winter. These factors led to the assumption of a higher historical erosion rate for this section and yielded a higher erosion projection in the future.

The South Beach area is primarily residential, and a pedestrian pathway runs along this ocean-facing side of Scenic Road at the top of the bluff, which is a popular destination for locals and tourists.

Section 1 Vulnerabilities

Current Vulnerabilities

There is a restroom near Santa Lucia Avenue located along the bluffs (Figure 19). The base of the restroom is located at ~24 ft NAVD 88, which is at the same elevation of the FEMA base flood elevation for this area. This restroom will face an increased exposure to coastal wave flooding with sea level rise. The Johnson (1983) study notes that the rock stairway adjacent to this bathroom was almost destroyed in the 1982-83 El Niño storms.



Figure 19. Restroom at Santa Lucia Avenue.

Between 9th and 11th avenues, the FEMA 100-year coastal wave hazard zone extends to the residential properties on Scenic Road; however, none of the homes are exposed. Analysis shows total water level aligns with the FEMA base flood elevations, and additionally shows the potential for wave splash to exceed the bluff crest of the armored coastline between 13th Avenue and Martin Way.

The Scenic Road walkway, which abuts the bluff top edge, is vulnerable to erosion. Erosion could threaten the pathway and related amenities such as benches and signage, and safety features such as crib walls, guardrails, and handrails. The bluffs between 9th and 10th are especially prone to immediate erosion hazards as the contact elevation of the less erosion resistant bluff terrace and dune sands is much lower. Note that significant erosion of this walkway has occurred in the past, as documented in the Johnson (1983) study following the 1982-32 El Niño winter. Erosion distances from that series of winter storm events are depicted in Table 3.

Table 3. Observations of historical erosion events from the 1982-83 El Niño winter.

Observed Erosion from the Johnson 1983 Survey	**Location**
Loss of 20 ft of bluff	North of 8th Avenue
Loss of 30 ft of bluff	Between 8th and 9th Avenues
Loss of 40 ft of bluff	Between 9th and 10th Avenues
Loss of 25 ft of bluff	Between 10th and 11th Avenues
Loss of 30 ft of bluff	Near Santa Lucia Avenue

The stormwater drainage network, which is often buried beneath the bluff terrace and the cliff to drain stormwater to the beach, is likely to be exposed to storm wave flooding and erosion (Figure 20). Failure of a storm drain can also exacerbate erosion from terrestrial scouring during rain events.



Figure 20. Stormwater drainage near 13th Avenue.

There are ten beach access stairways that lead to the beach, and all of these stairways are vulnerable to wave attack, scouring and undercutting of their foundations, and coastal erosion. In addition, the failure of a stairway can exacerbate erosion of surrounding bluffs. Breakaway stair designs such as those just north of 10th Avenue can greatly reduce the potential for stairway failures to contribute to erosion.



Figure 21. Stairway at Santa Lucia Avenue. Note damage to the railing from past storms.

1 ft of Sea Level Rise (2045–2060)

By 1 ft of sea level rise, and without any adaptation measures, the typical summer dry sand beach could be reduced by 20%. Beach narrowing will be experienced most acutely south of 12th Avenue where typical beach widths are much narrower.

The areas with the greatest exposure to erosion include the armored cliffs between 8th Avenue and 11th Avenue and the unarmored cliffs around 12th Avenue. As erosion accelerates, this exposes the Scenic Road roadway to erosion in six probable locations between 8th Avenue and 12th Avenue.

A wastewater force main located under the Scenic Road walkway near Martin Way is likely exposed to erosion, as well as a wastewater main under Scenic Road between 9th Avenue and 10th Avenue, and a sewer main under the dunes near 8th Avenue.

Wave uprush and overtopping of the bluff crest is expected to occur more frequently along the southern seawall between Santa Lucia Avenue and Martin Way, and between 8th Avenue and 11th Avenue.

2 ft of Sea Level Rise (2060–2080)

By 2 ft of sea level rise, and without any adaptation measures, the typical summer dry sand beach could be reduced by 40%, and a loss of lateral beach access to areas south of the 12th Avenue headland may occur in the summer. The coastal erosion hazard modeling indicates that erosion rates will begin to accelerate as coastal armoring is more likely to be

overtopped by higher levels of wave splash and wave run up due to elevated water levels. Many areas behind the coastal armor have erosion hazard distances projected to be between 20 to 40 ft. Nearly the entire length of Scenic Road would then be exposed to erosion, including most of the underground water and wastewater infrastructure. By 2 ft of sea level rise, a water main under Scenic Road between 8th Avenue and 10th Avenue may become exposed. In the without armoring scenario, four homes between 9th and 12th Avenues are potentially exposed to erosion.

Wave splash and overtopping of the bluff crest are expected to be more severe between 9th and 10th avenues and may now be experienced between 12th to 13th avenues. In a without armoring scenario, four oceanfront homes would be exposed to erosion.

4 ft of Sea Level Rise (2080–2100+)

By 4 ft of sea level rise, and without implementation of any adaptation measures, the typical summer dry sand beach could be reduced by 80%, and only two small pockets of beach are projected to remain, one 1.5-acre pocket beach around 8th Avenue stairs, and one 1.5-acre pocket beach around 11th Avenue stairs.

Some of the highest erosion distances are projected between 10th and 12th Avenue, where a combination of factors related to wave exposure and local geology[4] yield projections of retreat up to 150 ft.

Between 2 and 4 ft of sea level rise, 42 oceanfront homes along Scenic Road may be exposed to erosion hazards. In the without armoring scenario, 53 homes, for a total of 57, are potentially exposed to erosion. Coastal erosion may threaten the wastewater and water laterals, as well as other utilities that connect with these homes. One additional water main location under Scenic Road south of 13th Avenue could become exposed to erosion, and one additional sewer force main location could become exposed to erosion near 8th Avenue.

Wave uprush and overtopping the bluff crest is expected to be more severe between 9th Avenue and 10th Avenue and may now be experienced at the higher cliffs by 12th Avenue. Along the lower cliffs between Santa Lucia Avenue and Martin Way, and north of 10th Avenue, wave splash above the bluff crest could exceed 5 ft turning that overtopping into a green water wave with more erosion potential.

[4] The Johnson (1983) study noted that this area may be part of an old fault zone which has more shattered and weakened the rock

Section 2 Central Beach—Private Property Area from Del Mar Parking Lot to 8th Avenue

The central beach extends alongshore for approximately 0.2 mile and is characterized by densely vegetated dunes known as the Del Mar Dunes, which are home to dune scrub habitat and the black legless lizard, a species of concern (City of Carmel 2010). Atop the rear dune are private homes. Although no riprap armoring is visible, armoring is mapped in the City's Shoreline Management Plan (2004) under the dunes at 8th Avenue. The sandstone bedrock is overlayed by dunes throughout this section, and it is assumed that the contact elevation between the sandstone bedrock and the sand and terrace soils is lower in the south and rises in the north around the Del Mar parking lot. Two coastal access sand ramps are located in this section. The intention of sand ramps is to provide coastal access and allow for access for those with limited mobility.

Section 2 Vulnerabilities

Current Vulnerabilities

Dune erosion was observed in this area during the winter storms of 2022-23 (Figure 22). The Johnson (1983) study notes that the dunes near 8th Avenue eroded 30 ft and formed a 14 ft-high scarp during the 1982-83 El Niño winter. Dune erosion hazards between 0 and 1 ft of sea level rise are projected to cause erosion of 30 to 40 ft in this area, corresponding with the severe winter storm erosion observed in the Johnson study.



Figure 22. A view looking south over the Del Mar Dunes. A dune scarp is evident along the sand ramp and the dunes. January 2023.

This shoreline section has less immediate bluff-top development than other areas of the City and faces fewer immediate vulnerabilities for the oceanfront homes due to wider setback distances. However, dune erosion and wave flooding could threaten the private coastal accessways, as well as the two coastal access sand ramps south of the Del Mar parking lot and the stairway at 8th Avenue. In addition, the City's stormwater drainage system is vulnerable to dune erosion, and this section also contains private stormwater drain pipes that are exposed to erosion (Figure 23).



Figure 23. Stormwater drain near 8th Avenue fronted by an eroded scarp following winter storms in 2023. Note the riprap boulder on the bottom right.

A gravity sewer line runs from the Del Mar Parking lot to 8th Avenue in front of the oceanfront homes along Scenic Road. This sewer line is located just inland of the dune crest and may be vulnerable to erosion. The depth and condition of the sewer line is unknown; however, exposure and potential failure could cause untreated wastewater to enter nearby homes, and or cause environmental harm to the nearby dune, beach, and ocean habitats.

1 ft of Sea Level Rise (2045–2060)

The foredune area is vulnerable to erosion, and this study projects up to 40 ft of recession with 1 ft of sea level rise. The sand ramps found in this section and Section 3 (North

Dunes) are constructed of bulldozed sand and buried drift logs (Shonman and D'Ambrosio 2003). With accelerating sea level rise, erosion scarping may become more frequent occurrences and the integrity of the sand ramps may be at risk as erosion threatens to expose the buried drift log core.

2 ft of Sea Level Rise (2060–2080)

By 2 ft of sea level rise, and without any adaptation measures, the dune erosion process may shift toward cliff erosion processes as the foredune retreats inland and contact with the underlying cemented beach deposits and sandstone occurs. The threat of coastal storm waves overtopping the dunes and threatening the homes along the backdune remains unlikely. By 8th Avenue, a wastewater lift station located at ~24.5 ft may be exposed to storm wave flooding (Figure 24). A sewer main under the dunes between 7th Avenue and 8th Avenue could be exposed to dune erosion although the condition of the underlying revetment is not well understood presently.



Figure 24. Wastewater lift station near 8th Avenue.

4 ft of Sea Level Rise (2080–2100+)

By 4 ft of sea level rise, and without any adaptation measures, a collection of three homes around Scenic Road and 8th Avenue are exposed to erosion. Under a more severe erosion scenario (worst case), an additional five homes, for a total of eight, could be threatened by erosion between 8th Avenue and Ocean Avenue.

Section 3 North Dunes Area from 4th Avenue to Del Mar Parking Lot

The North Dunes section is a mostly natural, unarmored area that provides numerous recreational opportunities for the public. The section is 0.1 mile long and begins at the public access stairway at 4th Avenue in the north end and extends to the Del Mar parking lot to the south. The northern half of this shoreline section is characterized by a heavily vegetated cliff and bluff. A concrete stormwater discharge outfall is located just south of the 4th Avenue coastal access stairway. The remainder of this section is more open, with clusters of vegetated dunes and trees that extend back to San Antonio Avenue, nearly 1,000 ft from the swash zone. This section is home to a range of dune habitats, including Tidestrom's lupine, a federally and state-listed endangered plant species, and the California black legless lizard, a species of special concern in the state (City of Carmel 2010). The southern portion of this section has a heavily used public bathroom, four popular sand volleyball courts, and a bluff-top viewing platform.

Section 3 Vulnerabilities

Current Vulnerabilities

The bluff-top viewing platform at Ocean Avenue is vulnerable to dune erosion, as is the coastal access stairway at 4th Avenue. A stormwater outfall and seawall just south of 4th Ave is likely exposed to erosion. The Task 1 Coastal Protection Assessment identified this seawall as being a high priority for repair.



Figure 25. Seawall and outfall just south of the 4th Avenue Stairway.

1 ft of Sea Level Rise (2045–2060)

This dune backed shoreline is susceptible to significant dune erosion, and this study projects between 15 and 30 ft of recession with 1 ft of sea level rise, and 0.18 acre of North Dunes Habitat area exposed to erosion. Large storm events could cause additional dune erosion and scarping. Coastal access at the northern sand ramp could be impacted unless a consistent supply of sand is maintained.

2 ft of Sea Level Rise (2060–2080)

By 2 ft of sea level rise, and without any adaptation measures, this dune-backed area may transform into a cliff-backed shoreline restricting access to the beach. An additional 0.33 acre of dune habitat would be exposed to erosion, for a total of 0.52 acre.

4 ft of Sea Level Rise (2080–2100+)

By 4 ft of sea level rise, and without any adaptation measures, an additional 0.64 acre of dune habitat is exposed to erosion, for a total of 1.16 acres.

The Del Mar parking lot could be exposed to coastal erosion. In the unarmored and worst-case erosion scenario, the public restroom and the beach volleyball courts are also likely exposed to erosion.

Two water storage tanks located near the Del Mar parking lot and may also be exposed to erosion. While the exact spatial locations were not available, maps referenced in the Shoreline Management Plan (2003) show that both likely fall within the erosion hazard zone.

With no additional adaptation implementation, this is one of the last areas of Carmel Beach that can expect to maintain a dry sand beach with up to 5 ft of sea level rise.

Section 4 North Beach—Private Properties from Pescadero Canyon to 4th Avenue

The North Beach is a 400-ft stretch of coast that makes up the very northern portion of the City Beach study area and consists of private properties on top of the bluffs. The bluff increases in elevation from about 20 ft near to Pescadero Canyon to approximately 50 ft just north of the 4th Avenue stairway. The upland area of this section is composed of just two oceanfront private parcels. The northern parcel maintains its own seawall and the southern parcel is unarmored.

Section 4 Vulnerabilities

Current Vulnerabilities

A private seawall (Figure 26) is vulnerable to wave attack and overtopping.



Figure 26. Privately owned seawall near Pescadero Canyon.

1 ft of Sea Level Rise (2045–2060)

In the armored erosion scenario, wave uprush and splash along this seawall are above the top of the armor height, yielding an erosion distance of 30 ft by 1 ft of sea level rise. Erosion distances are only projected to be just over 20 ft along the higher unarmored property due to the higher cliff and bluff terrace contact elevation.

2 ft of Sea Level Rise (2060–2080)

By 2 ft of sea level rise, and in a without armoring scenario, one home is potentially vulnerable to erosion.

4 ft of Sea Level Rise (2080–2100+)

By 4 ft of sea level rise, and in a with armoring scenario, both homes are potentially vulnerable to coastal erosion.

With no adaptation implementation, this is one of the last areas of Carmel Beach that can expect to maintain a dry sand beach with up to 5 ft of sea level rise.

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

backshore	Extreme inland limit of the beach
basal unit	Lower geologic formation of the cliff (sandstone in Carmel)
bluff	Soft unconsolidated materials found in the marine terrace deposits
bluff contact	Location where the bluff meets the cliff
bluff top	Location where there is an identifiable break from the steeper cliff and bluff to the gently sloping inland areas
cliff	Hard consolidated rock under the bluff
CoSMoS	Coastal Storm Modeling System (USGS)
DEM	Topographic Digital Elevation Model
dry sand beach	The portion of the beach that is landward of the mean high water mark
dunes	Areas where wave action and onshore winds have led to sand deposition, located landward of the beach
erosion (coastal)	Can refer to either beach narrowing or cliff retreat. For cliffs, this refers to the long-term loss or removal of land due to coastal or terrestrial processes. For beaches, this may refer to either the long-term, short-term, or localized (see scouring) removal of sediments from the beach.
FEMA	Federal Emergency Management Agency
green water	Occurs when waves break onto or over the coastal armoring and the overtopping volume is relatively continuous
NAVD 88	North American Vertical Datum of 1988 (NAVD 88). The vertical control datum used for surveying.
NOAA	National Oceanic and Atmospheric Administration
scour (beach)	Process by which waves and currents remove sediment from the beach (usually localized)
shoreline	Typically where water meets the land. In this report, it refers to the wet/dry line
splash	Occurs when waves break seaward of the coastal armoring, or where the armoring is high in relation to the wave height, and overtopping is a concentrated stream of water droplets

toe of the cliff	Location where the dry sand beach meets the base of the cliff
total water level	The combined effect of wave run-up height, storm surge, tides, and sea level elevations
USGS	U.S. Geological Survey

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APPENDIX A. SECTOR VULNERABILITY FINDINGS

This section provides a series of tables indicating the extent of hazard impacts to land Use and structures, roads and parking, and utilities and infrastructure. Findings are organized by the two erosion hazard zone scenarios, one for a **with** coastal armoring where erosion rates are reduced, and one for a **without** coastal armoring scenario, where erosion is modeled without consideration of armoring. A best estimate on future erosion rates are reported for both. Both scenarios are reported using the best estimate for

Land Use and Structures

Parcels

Reported as noncumulative area across horizons

Parcels	**With Coastal Armoring Scenario**				
	Existing (Bluff and Beach)	SLR (ft)			
Parcel Type		**1**	**2**	**4**	**Total**
Public (sq ft)	290,913	42,358	45,179	43,338	421,787
Residential (sq ft)	20,764	4,713	15,397	152,622	193,496

Parcels	**Without Coastal Armoring Scenario**				
	Existing (Bluff and Beach)	SLR (ft)			
Parcel Type		**1**	**2**	**4**	**Total**
Public (sq ft)	290,913	49,645	39,009	42,243	421,809
Residential (sq ft)	20,764	4,713	26,206	201,011	252,694

Reported as the number of parcels at the first instance of contact with the hazard zone

Parcels	**With Coastal Armoring Scenario**				
	Existing (Bluff and Beach)	SLR (ft)			
Parcel Type		**1**	**2**	**4**	**Total**
Public	9				9
Residential	3		29	40	72

Parcels	Without Coastal Armoring Scenario				
	Existing (Bluff and Beach)	SLR (ft)			
Parcel Type		1	2	4	Total
Public	9				9
Residential	3		38	33	74

Buildings

Reported as the number of structures at the first instance of contact with the erosion hazard zone

Buildings	With Coastal Armoring Scenario			
	SLR (ft)			
Building Type	1	2	4	Total
Public Restroom	1			1
Residences*		0	43	44

Buildings	Without Coastal Armoring Scenario			
	SLR (ft)			
Building Type	1	2	4	Total
Public Restroom	1			1
Residences*		5	54	59

**Excludes garages and the wastewater lift station structure (included in the wastewater section building)*

Roads

Roads and Parking	With Coastal Armoring Scenario		
	SLR (ft)		
	1	2	4
Scenic Road (ft)*	702	3,113	3,463
Ocean Ave Parking Lot (sq ft)*			2,149
Scenic Road (sq ft)*	2,864	56,877	96,067

Roads and Parking	Without Coastal Armoring Scenario		
	SLR (ft)		
	1	2	4
Scenic Road (ft)*	1,497	3,226	3,475
Ocean Ave Parking Lot (sq ft)			2,149
Scenic Road (sq ft)*	6,432	70,762	98,517

** Lengths and areas are cumulative across sea level rise horizons. Length of Scenic Road is measured from the oceanfront curb*

Utilities and Infrastructure

Stormwater

Stormwater	With Coastal Armoring Scenario				
	Existing (Bluff)	SLR (ft)			Total
		1	2	4	
CDS Separator	2			1	3
Inlets	1	3	10	11	25
Junctions	1		1		2
Manholes	3		2	2	7
Outfalls	17	2		2	21
Culverts		1	1	1	3
Drains (ft)*	1,391	1,888	2,891	3,581	

Stormwater	Without Coastal Armoring Scenario				
	Existing (Bluff)	SLR (ft)			Total
		1	2	4	
CDS Separator	2			1	3
Inlets	1	7	11	7	26
Junctions	1		1		2
Manholes	3		2	2	7
Outfalls	17	2		2	21
Culverts		1	1	1	3
Drains (ft)*	1,391	2,034	2,940	3,590	

**Lengths are cumulative across sea level rise horizons. Does not include private stormwater infrastructure.*

Wastewater

Wastewater Infrastructure	With Coastal Armoring Scenario			
	SLR			
	1	2	4	Total
DCO (cleanout)	1			1
Manhole		5	4	9
Pump Station			1	1
Sewer Main (ft)*	381	2,155	4,164	
Forced Main (ft)*	51	479	805	

Wastewater Infrastructure	Without Coastal Armoring Scenario			
	SLR			
	1	2	4	Total
DCO (cleanout)	1			1
Manhole	1	4	5	10
Pump Station			1	1
Sewer Main (ft)*	406	2,564	4,390	
Forced Main (ft)*	338	553	805	

**Lengths are cumulative across sea level rise horizons*

Water

Water	With Coastal Armoring Scenario		
	SLR (ft)		
	1	2	4
Hydrants	1	0	0
Water Main (ft)*	0	439	1,870

Water	Without Coastal Armoring Scenario		
	SLR (ft)		
	1	2	4
Hydrants	2	0	2
Water Main (ft)*	0	737	2,072

**Lengths are cumulative across sea level rise horizons. Does not include two water storage tanks located near the Del Mar Parking Lot. Water irrigation pipes are not included*

Carmel Adaptation Pathways

B

APPENDIX

Carmel Adaptation Pathways

Adaptation Alternatives, Priorities, and Triggers

Prepared for
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ACRONYMS AND ABBREVIATIONS

CAWD	Carmel Area Wastewater District
CCC	California Coastal Commission
CDP	coastal development permit
CEQA	California Environmental Quality Act
City	City of Carmel-by-the-Sea
LCP	local coastal program
MHTL	mean high tide line
NEPA	National Environmental Policy Act
SLR	sea level rise
USACE	U.S. Army Corps of Engineers

GLOSSARY

Armoring (coastal)	Hard protection structures, such as seawalls and revetments, that are built to prevent erosion
Backshore	The extreme inland limit of the beach
Basal unit	The lower geologic formation of a cliff (sandstone in Carmel)
Bluff	Soft, unconsolidated materials found in marine terrace deposits
Bluff top	The location where there is an identifiable break from the steeper cliff and bluff to the gently sloping inland areas
Cliff	Hard, consolidated rock beneath the bluff
Dry-sand beach	The portion of the beach that is landward of the mean high-water mark
Dunes	Areas that are landward of the beach where wave action and onshore winds have led to sand deposition
Erosion (coastal)	1) For cliffs, the long-term loss or removal of land due to coastal or terrestrial processes; 2) for beaches, either the long-term, short-term, or localized removal of sediments from the beach
Littoral cell	A relatively self-contained coastal compartment within which sand is transported between sources, transport zones, and depositional sinks, such as beaches, dunes, or submarine canyons
Living shorelines	A nature-based approach to reducing coastal erosion. Living shorelines use natural materials, like native plants, to stabilize shorelines. In many cases, these techniques can be combined with structural components such as rock, driftwood, or fiber rolls to stabilize the shoreline.
Nature-based solutions	A broad category of strategies that work with nature to build coastal resilience
Nourishment	The placement of sand to offset erosion or increase beach width
Revetment	A sloped structure of rock or concrete to absorb wave energy and protect landward areas
Scour (beach)	The process by which waves and currents remove sediment from the beach (usually localized)
Shoreline	The region where water typically meets the land; the wet–dry line (in this report)

Splash	The instance when waves break seaward of the coastal armoring, or where the armoring is high in relation to the wave height, and overtopping is a concentrated stream of water droplets
Toe of the cliff	The location where the dry-sand beach meets the base of the cliff

EXECUTIVE SUMMARY

This Adaptation Pathways Report provides a flexible roadmap to address sea level rise and coastal hazards at Carmel Beach. The development of this report was guided by extensive community outreach, public hearings, and a survey of residents and visitors. Outreach findings demonstrate a strong desire to maintain safe and reliable beach access and to protect recreational, scenic, and ecological qualities of Carmel Beach. Community members expressed a clear preference for nature-based solutions where feasible, favored early proactive planning rather than emergency response, and emphasized the importance of maintaining the quality of the beach's distinctive white sand.

This report evaluates a broad suite of adaptation strategies, including beach and dune management, engineered shoreline protection, and the phased relocation of vulnerable assets. Adaptation pathways are tailored to three planning areas of the shoreline: North Beach and North Dunes, Del Mar Dunes and Central Beach, and South Beach and Scenic Road. For each area, the report describes appropriate actions for immediate, near-term (1 ft of sea level rise), mid-term (2 ft), and long-term (4 ft) conditions. Cost considerations, regulatory feasibility, and integration with public safety and access goals inform how and when each strategy might advance.

Across the entire beach, immediate needs include maintaining and restoring the sand ramps and beach access stairways through access-focused repairs. The City can improve its storm readiness by reestablishing a sediment management program, implementing nature-based solutions, and enhancing shoreline monitoring to better track changes in beach width, erosion hotspots, and storm impacts. Stronger monitoring will also support public communication, funding pursuits, and the timely and transparent application of adaptation triggers.

In planning for future sea level rise, the City will face two major strategic decisions. The first concerns whether and how to implement beach nourishment. This strategy has strong potential to preserve beach width, but it depends heavily on identifying compatible sand sources within the regulatory context of Carmel Bay. The second involves the alignment of Scenic Road and the infrastructure beneath it. As erosion progresses, the City must weigh the secondary consequences between expanded coastal protection or pursuing selective retreat and realignment of upland development. A summary of some of the key adaptation strategies and the triggers for implementation is outlined below:

Table ES1. Summary of Adaptation Triggers and Strategies by Horizon

SLR Scenario	Adaptation Trigger(s)	Adaptation Strategies
Immediate	• Depth of sand at the sand ramps • Bedrock exposure duration • Condition of armoring and stairways	• Beach and dune management • Maintenance of coastal armoring • Targeted repair and improvement of stairways and sand ramps
Near-Term (1-ft SLR)	• Above + • Repair costs • Summer beach widths and beach recovery • Overtopping frequency at seawalls	• Nature-based solutions, including woody material for toe protection and vegetation to trap sand • Pilot program for shore platform enhancement, sand retention, and current deflectors
Mid-Term (2-ft SLR)	• Above+ • Frequency of waves reaching the dune toe • Availability of suitable sand sources	• Beach nourishment • Extension and raising of coastal armoring • Nearshore reefs and wave tripping structures
Long-Term (4-ft SLR)	• Above+ • Distance between upland development and the dune or bluff crest	• Managed retreat and realignment of upland development and infrastructure

Notes:

SLR = sea level rise

1 INTRODUCTION

This report is part of the City of Carmel Coastal Engineering and Adaptation Planning Project. Specifically, it fulfills the deliverable requirements for Phase 2, Task 4, "Adaptation Pathway Development." The scope of Task 4 focuses on the development of adaptation pathways for Carmel Beach—the region extending from Pescadero Canyon in the north to Carmel Point in the south—within the city of Carmel-by-the-Sea (City).

Adaptation pathways are frameworks that help navigate the uncertainties associated with climate change by laying out feasible adaptation approaches in a series of steps to be implemented over time. With this approach, instead of requiring a strategy to be implemented by a certain year, the community monitors a set of easily observable changes; when a specific trigger is met, planning then begins for the next phase of adaptation with enough lead time to avoid projected damages. Throughout all phases of the project, Integral Consulting Inc. and EMC Planning Group have had ongoing discussions with City staff, stakeholders, and regulators on site-specific vulnerabilities, immediate needs, and desires for longer-term adaptation to inform adaptation pathway development.

The adaptation pathways outlined in this report serve as high-level planning directions for Carmel Beach. Pathways are laid out for the entire beach and each of its planning areas (see Figure 3 in Section 1.3 for a map). They include strategy descriptions, rolled-up cost estimates, relevant triggers for considering new adaptation approaches, and recommendations for a monitoring program. This framework allows the City to consider both systemwide and site-specific adaptation strategies that address local shoreline characteristics. Adaptation strategies are organized by time horizon from the immediate term (0 ft of sea level rise [SLR] or 2025) to the near term (1 ft of SLR or ~2050), midterm (2 ft of SLR or ~2070), and long term (4 ft of SLR or ~2100) (OPC 2024).

This adaptation pathway report serves as a bridge between 1) the project's coastal hazards and vulnerability assessment completed in Phase 1 (Integral 2024), and 2) upcoming policy updates to the City's local coastal program (LCP) (Phase 2, Tasks 5–7). It also expands on a range of feasible SLR adaptation approaches that were developed under Phase 2, Task 1. These approaches were evaluated and ranked using a set of screening criteria and vetted through regulatory consultation, City input, and community outreach. Descriptions of these adaptation strategies—including their potential, secondary benefits, and consequences—are detailed in Sections 1.5–1.7.

In addition, this report builds on the project's Phase 2, Task 3, "Socio-Economic Analyses," which included 1) adaptation preferences that were informed by an outreach survey, 2) an analysis of visitation patterns using cellphone data, and 3) a travel cost model for a broader understanding of the non-market value of a beach visit. This report found that among survey participants, the areas of greatest concern are 1) coastal, storm-related cliff and dune erosion, 2) damage to coastal access stairs and sand ramps, and 3) the loss of the sandy beach area.

The respondents also expressed a preference for nature-based adaptation approaches over armoring strategies, despite their better familiarity with armoring approaches. They were generally satisfied with the City's maintenance of Carmel Beach (e.g., sand management and maintenance at the Del Mar Parking Lot, debris cleanup), but they were less satisfied with the City's emergency storm response. Survey respondents called for an improved storm response as well as the development of a more proactive and structured maintenance program to avoid and more quickly mitigate future damage.

This work is also intended to meet the requirements laid out in SB 272, which requires local jurisdictions to integrate SLR planning into planning processes and LCP updates. Among the requirements of this legislation is to develop a suite of recommended adaptation strategies that reduce risks from coastal hazards, identify the entities responsible for planning and implementation, and establish a timeline for adaptive measures based on evolving sea level projections. In subsequent phases, the project team will refine the adaptation pathways in this document into actionable policies, funding mechanisms, and permitting strategies that will support the City's goal of implementing proactive adaptation solutions to meet coastal resilience goals.

1.1 ADAPTATION PATHWAYS FOR SEA LEVEL RISE

An adaptation pathway allows the City to visualize a sequence of adaptation actions while accounting for lead times associated with planning and other efforts, such as outreach, permitting, design, funding, and construction. Because of the uncertainty over future physical conditions, natural variability, and changing societal values, an adaptation pathway should remain flexible. Appendix A includes a more detailed discussion of adaptation planning principles.

The core premise of an adaptation pathway is planning for future needs; this planning should be activated by predetermined triggers. Adaptation triggers are measurable signals that indicate when management actions must begin to avoid or limit coastal risks. The incorporation of these triggers into the LCP will help ensure that policy updates and permitting decisions remain adaptive, transparent, and consistent with evolving shoreline conditions. Triggers are typically developed by working backward from tipping points or thresholds where damages go from mild to significant. These indicators may include physical metrics (e.g., beach width, bluff retreat, overtopping frequency); social metrics (e.g., access disruption, safety hazards); or economic metrics (e.g., unsustainable maintenance costs, higher insurance claim costs).

The identification of adaptation triggers requires sustained monitoring, which provides the data needed to verify when thresholds are reached and guides the timing of future adaptation actions. A consistent monitoring program will allow the City to track shoreline changes, assess the effectiveness of implemented strategies, and adjust the management of measurements as conditions evolve. Overall, monitoring should be affordable and repeatable, and it should be

integrated into existing City operations. A monitoring program should rely on field observations, data from maintenance activities, and information from community partners. Modern tools, like shoreline cameras, are helpful in that they allow for the low-cost, continuous tracking of shoreline conditions and public use. Collecting higher-quality and more frequent data will improve the ability of the City and its contractors to evaluate conditions to determine if triggers are reached, and their conclusions will form the basis for adaptation decisions and budgeting. A more detailed explanation of specific triggers and monitoring approaches for Carmel Beach can be found in Appendix B.

1.2 ADAPTATION APPROACHES

Adaptation approaches to coastal hazards can be divided into separate components, beginning with project-level strategies and policies that can facilitate the implementation of specific initiatives. The goal of this project is to identify the types of approaches that 1) the community prefers, and 2) are deemed feasible for further investigation so that subsequent policy updates can be integrated into the City's LCP.

Following the establishment of project-level goals, adaptation strategies can be implemented horizontally and vertically in various zones (Figure 1). Within each zone, adaptation strategies can be divided into categories based on how they affect the physical processes and hydrodynamics that cause erosion (i.e., whether they stop or reduce erosion).



Figure 1. Horizontal and Vertical Zones for Coastline Adaptation Strategies

Some adaptation strategies have been previously implemented by the City; one such strategy is armoring the coast. Other strategies include measures that dissipate wave energy and reduce localized longshore currents or mimic natural defensive habitat functions. Erosion-reduction strategies can also include more nature-based approaches that utilize natural materials—such as driftwood and vegetation—to guide human uses and reduce the magnitude of physical processes that cause erosion. These different adaptation strategies are on a spectrum of "gray to green" (Figure 2). Gray approaches use engineered protection structures, such as seawalls and revetments, to stop erosion. Green approaches—including sand

management, beach nourishment, dune restoration, and living shorelines—use natural processes to build elevation and widen beaches, thereby reducing erosion and providing a buffer against storm waves. Carmel has historically relied on a combination of engineered protection strategies, including seawalls and revetments, to stop erosion. It has also relied on nature-based approaches, such as sand management, to reduce erosion.

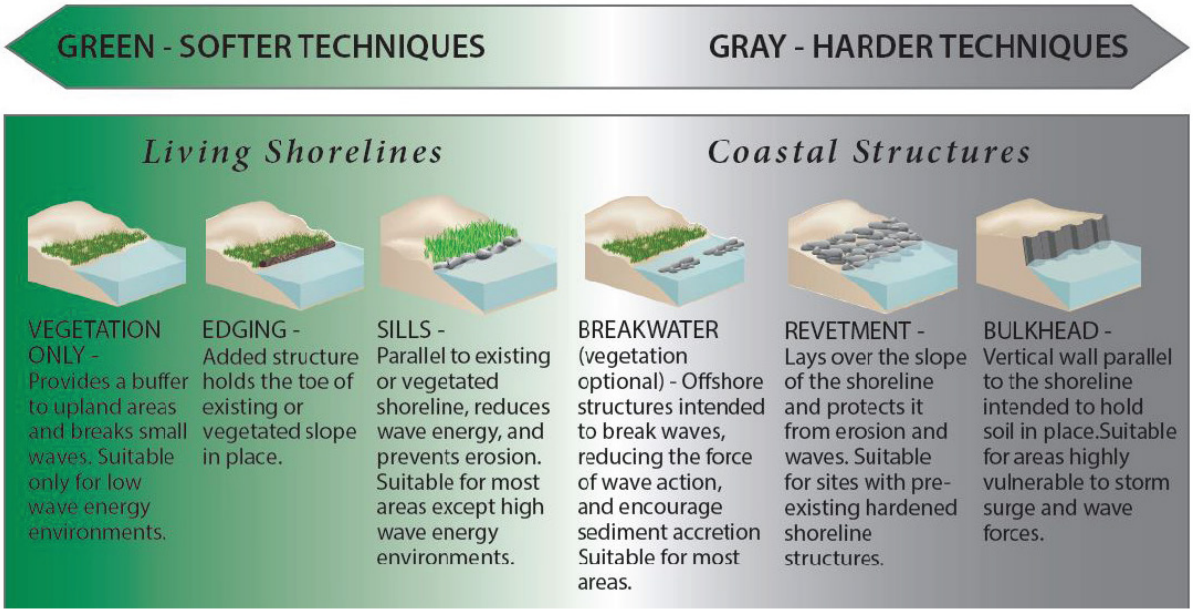


Figure 2. "Gray to Green" Adaptation Strategies for Erosion or Flood Mitigation (NOAA and USACE 2015; NOAA 2025)

These adaptation strategies differ in their approach to erosion mitigation. For example, engineered protections at the back of the beach, such as seawalls and revetments, are intended to stop erosive wave energy at the backshore to stop erosion and protect upland development. Conversely, nearshore protections, such as reefs, disrupt wave energy before reaching the beach and backshore, thereby reducing the forces that drive erosion. In addition, sand, dune, and vegetation strategies are intended to primarily reduce erosion by increasing dry-sand beach areas, providing root stabilization, and trapping sediment in place (Figure 2).

Another strategy avoids coastal hazards by retreating or relocating upland infrastructure and development away from high-risk areas while limiting new construction. This managed-retreat approach is not an evacuation; rather, it is a gradual moving away from high-hazard areas. It is guided by policies, land-use designations, and zoning ordinances that support the gradual removal of upland development and infrastructure. Early steps include 1) requiring real estate disclosures for property transactions that list coastal hazards and SLR impacts, and 2) limiting City liability for land-use decisions. The development of an equitable acquisition program is also important for the relocation of private development based on the community's vision of maintaining access to Carmel's beaches and coast. Over time, this approach becomes the most

cost-effective option compared to the maintenance of erosion control structures, and it ensures that retreats occur through a planned, controlled process that maximizes public and private benefits.

Some strategies are not practical for the project. For example, some strategies accommodate coastal hazards by modifying upland development (e.g., elevating structures or increasing setbacks, accommodating flood depths or accelerated erosion while reducing damages). Given the City's existing development patterns, however, which are relatively built out, most of the accommodation strategies are not applicable to the project. Section 1.6 details the range of feasible coastal adaptation strategies for the project, and Section 2 describes where and when these approaches may make the most sense.

The implementation of adaptation strategies requires lead times to plan, permit, design, finance, and implement the effort; adaptation efforts often blend these approaches across different locations and time frames. In addition, these potentially feasible adaptation strategies will require more technical work and community dialog. Immediate and short-term strategies (and potentially mid-term measures) that align with community preferences should be identified in policy updates to streamline financing and implementation in an updated LCP, as well as to meet California's Senate Bill 272 requirements, so that the City will be positioned for funding. Mid-term strategies that are currently identified will require additional technical work, consultations with regulatory agencies, ongoing dialogs with the community, and consistent monitoring to help identify transparently when it is time to decide which adaptation strategy should be pursued. These efforts should be based on evolving community vision, scientific information, and observable changes that reduce the existing uncertainty about future conditions.

1.3 STUDY AREA

This report focuses on the City-managed portion of Carmel Beach, from Pescadero Canyon in the north to Carmel Point in the south. The study area comprises three planning areas: North Beach and North Dunes, Central Beach and Del Mar Dunes, and South Beach and Scenic Road (Figure 3, left). These planning areas are based on prior work from a climate change vulnerability assessment report (Carmel-by-the-Sea 2021) and from Phase 1 (Integral 2024). For this study, some boundaries between sections have been modified slightly from prior work, and both North Beach and North Dunes have been combined into one section. Their details are provided below:

- **North Dunes and North Beach** include the armored private properties on the cliffs at the north end of the City as well as the mostly natural and unarmored North Dunes area. This section includes three sand ramps (used for beach access) and the Del Mar Avenue parking lot.

- **Central Beach and Del Mar Dunes** include the mostly unarmored dunes and private properties between 8th Avenue and the Del Mar Parking Lot. At 8th Avenue and Scenic Road, there is a coastal access stairway and an emergency access sand ramp that is currently closed because of erosion damage.
- **South Beach and Scenic Road** include the mostly armored cliffs and vegetated bluffs along Scenic Road that are south of 8th Avenue. This section includes eight coastal access stairways from 9th Avenue to Martin Way.

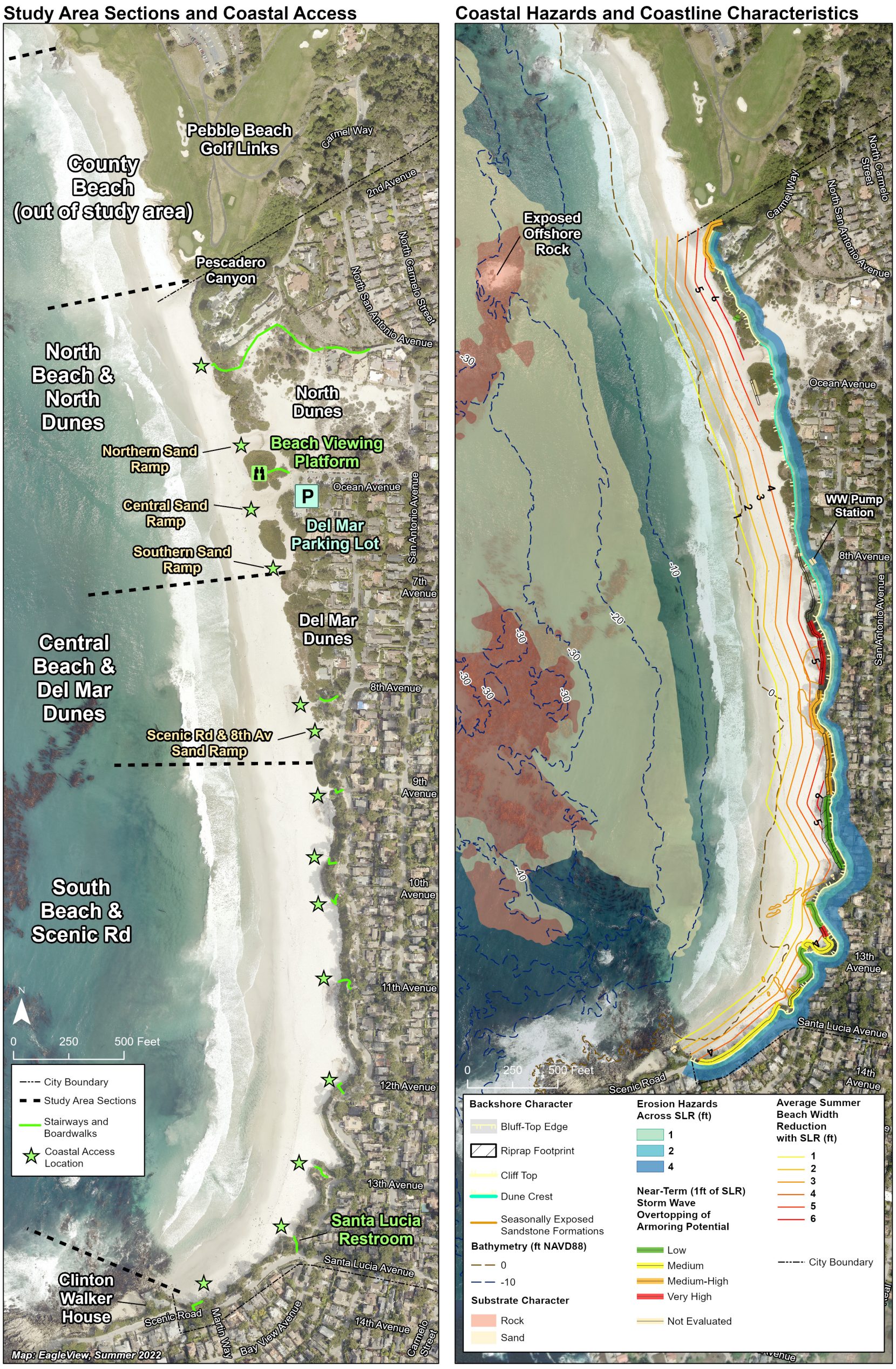


Figure 3. Carmel Beach Study Area and Adaptation Pathway Subareas (left); Coastal Erosion Hazard Zones and Areas of Concern for Wave Overtopping and Important Geomorphic Characteristics of the Upland Backshore, Nearshore, and Offshore Regions (right)

1.3.1 Existing Conditions

The City's existing approach to coastal erosion is the use of seawalls and riprap rock (revetments) to stop the erosion of the cliff and bluff. While this strategy has protected the backshore, it will have limited effectiveness as a long-term strategy with increasing sea levels, as it will eventually lead to the loss of the beach and a corresponding loss in natural resources, coastal recreation, and economic benefits. Naturally, Carmel Beach has the potential to maintain a wide and accessible beach despite the presence of extensive coastal armoring due to its relatively unique littoral cell setting. It forms a pocket beach that maintains a stable sand volume that is supported by retaining headlands, like smaller littoral systems found along the Oregon coast. As the sea level rises, this stability could be sustained through periodic beach nourishment.

Carmel Beach has distinctive sand that is derived from the abrasion of the granitic material found on the Monterey Peninsula (Appendix C). The sand has a fine texture and light color that is notably different from the coarser sand just to the south at Carmel River State Beach (Figure 4). A key challenge in planning for nourishment is identifying a compatible sand source. The most likely potential sources lie within Carmel Bay; however, extraction and placement may be limited by regulations of the Marine Protected Area and Monterey Bay National Marine Sanctuary.



Figure 4. Carmel Beach and Carmel River State Beach Locations (left); Carmel Beach (top) and Carmel River State Beach (bottom) Images (center); Carmel Beach (top) and Carmel River State Beach (bottom) Sand Colors (right)

1.3.2 Coastal Uses and Access

Carmel Beach supports a wide range of coastal uses that contribute to the community's identity and quality of life. User surveys have indicated that passive recreation, such as dog walking and nature watching, are top priorities for visitors and residents. Although active recreation—such as running, beach volleyball, fishing, and surfing—was less frequently mentioned in the outreach surveys, a dedicated group of users regularly engage in it. All these uses highlight the need to maintain safe and accessible areas for various recreational activities.

The most frequently used access points for the beach include the Del Mar Parking Lot, sand ramps, and the 8th Avenue sand ramp and stairs. The Del Mar Parking area and the Scenic Road Beach Bluff Pathway are among the most heavily used sections of the beach, which highlights their importance for beach access, recreation, community gathering, and socializing.

The Del Mar Parking area is the most accessible beach access location for those traveling via public transit. The area is served by Monterey Salinas Transit Lines 5 and 91, both connecting from the Monterey Transit Plaza into Carmel. Line 5 runs through downtown Carmel and stops at 6th Avenue and Mission Street, which is the closest transit access point to the beach. From this stop, the walk to the beach is approximately 0.3 mile, or about 5 to 7 minutes.

Line 91 provides neighborhood service farther south along San Carlos Street, with stops between roughly 9th and 13th avenues. These stops are approximately 0.4 to 0.6 mile from southern beach access points, corresponding to about an 8 to 12 minute walk. This provides broader spatial coverage but slightly longer walk distances. Overall, the Del Mar Parking Lot is the easiest to reach by transit, while the southern beach requires a longer walk of roughly 20 to 25 minutes from downtown.

1.3.3 Vulnerabilities to Sea Level Rise

SLR vulnerabilities along Carmel Beach vary by location. They are also shaped by seasonal beach widths, coastal wave exposure, and the location of upland development. Under current and near-term SLR conditions, beach access infrastructure—such as the sand ramps and beach access stairways, which are adjacent to the active beach—are exposed to coastal hazards. In the mid-term (1–2 ft of SLR), vulnerabilities are driven by progressive beach narrowing, increased coastal wave exposure, and accelerated coastal erosion. In this horizon, upland development—including the Scenic Road Beach Bluff Pathway, Scenic Road, and utilities like wastewater and water lines—is vulnerable. In the long term (4 ft of SLR), upland development becomes increasingly vulnerable, and private property and public infrastructure, such as the Del Mar Parking Lot, are at risk of coastal erosion. Table 1 summarizes the timing and areas of highest risk under progressive SLR scenarios; it identifies where early management attention is most critical. The right-hand image in Figure 3 provides spatial context for the hazards described in Table 1.

Table 1. Projected SLR Vulnerabilities with No Adaptation Measures and Current Armoring

SLR (ft)	Areas with High Overtopping Risk	Development at Risk from Erosion	Winter Beach Widths at Risk	Summer Beach Widths at Risk
0	Not applicable	All beach access stairways and sand ramps; all stormwater infrastructure along coastal bluffs and dunes	Not applicable	Not applicable
1	9th to 10th Avenue	Scenic Road Beach Bluff Pathway and a water line near Martin Way from 12th to 13th Avenue and 9th to 10th Avenue	12th Avenue south to the end of the beach	Not applicable
2	Above+ 8th to 13th Avenue; Martin Way; 4th Avenue to Pescadero Canyon	The entire length of the Scenic Road, including the pathway, street parking spaces, utilities, and the road; wastewater pipe under the Del Mar Dunes and the lift station near 8th Avenue	The area described above; the 10th Avenue headland impedes lateral access	Not applicable
4	Most of the cliff-backed shoreline	The areas described above; 44 homes along Scenic Road in the South Beach and at North Beach; the Del Mar Parking Lot and associated utilities	All but small pockets of the beach	Narrow width for the whole beach; little dry-sand beach recovers at the extreme southern and northern (county) portions

1.4 ADAPTATION GOALS

Adaptation goals describe the long-term vision for the shoreline and guide how management decisions are made to balance public access, habitat, recreation, and the protection of coastal infrastructure. For this project, the goals were informed through engagement efforts with community members, public works employes, and survey respondents, and they reflect the community vision for Carmel Beach.

Overall, the project team received 307 complete surveys. The survey included questions about beach visitation preferences and opinions on coastal adaptation. In addition, the project team also presented the project at eight city council and Forest and Beach Commission hearings to answer questions and solicit feedback on tasks. Feedback and comments from the City and the community at large emphasized several key priorities for adaptation:

- Pursue nature-based strategies that enhance natural resilience and ecological function.
- Take early and proactive action (rather than waiting for damage to occur).
- Promote environmental education and public awareness about coastal change.
- Support a managed retreat, where feasible, to allow for inland beach migration.
- Preserve the City's coastal identity by maintaining the existing quality of beach sand and recreational uses.
- Maintain public safety, create safe and accessible transitions to the beach (safe landings), and ensure lateral access along the beach.

1.5 EVALUATION OF ADAPTATION STRATEGIES

The evaluation and vetting process for the Carmel Beach adaptation strategies considered technical and political feasibility as well as broader tradeoffs for the community and the environment. Each strategy was screened based on criteria that included regulatory, financial, ecological, and social factors, and feasibility was judged based on cost, regulatory/legal factors, and secondary consequences. Each strategy was then assigned a priority index score balancing all these factors.

The scoring system ranked each criterion based on three levels: low, medium, and high. Regulatory viability was assessed as either viable, likely, less likely, or unlikely. The various secondary impacts were evaluated on a three-point scale, with "+1" for a favorable consequence, "0" for no effect, and "–1" for a negative impact. These scores allow strategies to be compared consistently across criteria and identify which adaptation strategies are most feasible; they are presented in Section 1.7 (Table 3).

The following sections detail the categories used to rank each strategy, and they summarize the range of strategies considered most feasible.

1.5.1 Timing for Implementation

The timing of implementation of coastal adaptation strategies varies based on public acceptance, feasibility, lead times, and constraints like costs. The highest priorities for early implementation include many of the more nature-based approaches—including beach, dune, and vegetation management strategies—while monitoring and maintaining the existing engineered strategies. More complex strategies that require additional technical studies and regulatory consultations—such as beach nourishment or nearshore reefs—fall into the mid-term category, as they require significant study, planning, permitting, and design. Longer-term strategies include realignment, relocation, and retreat strategies, as they require significant effort and collaboration among numerous stakeholders.

1.5.2 Cost

The cost category is divided into initial construction costs and ongoing maintenance costs. Construction costs are consolidated, providing an order of magnitude estimate for the implementation of an adaptation strategy, while maintenance costs reflect routine ongoing costs, such as periodic nourishment, monitoring, and repairs.

To ensure consistency across strategies, cost estimates were assigned using the following scale:

$	=	<$100,000
$$	=	$100,000–$500,000
$$$	=	$500,000–$1,000,000
$$$$	=	$1,000,000–$5,000,000

These symbols appear in the evaluation table and the adaptation pathways in Section 2 to allow comparisons across strategies based on initial construction and ongoing maintenance costs (the actual cost of a strategy is typically based on bids, which are influenced by many economic factors and can vary widely). Nature-based approaches—such as dune restoration, vegetation planting, and the beneficial reuse of sand—typically have low to moderate construction costs (beach nourishment being the exception) as well as moderate, consistent ongoing maintenance costs and monitoring needs. Engineered protection measures—like seawalls, revetments, and offshore breakwaters—tend to have high upfront construction costs and potentially moderate to high long-term maintenance costs and secondary impacts.

In addition to initial and ongoing costs, project planning must also account for the potential costs of inaction as well as indirect economic considerations, including potential economic impacts on tourism, beach access, and City revenue. Strategies that maintain wide, accessible beaches tend to offer long-term cost savings by reducing the need for frequent maintenance and protecting economic interests. However, these indirect economic factors were not

comprehensively assessed in prior phases of the work and need to be examined in greater detail in future stages of adaptation planning.

1.5.3 Regulatory Viability

Coastal adaptation projects in Carmel must comply with a range of state and federal regulations and coordinate approvals across multiple agencies (see Appendix A for more details). Larger projects may require coastal development permits (CDPs) and environmental reviews under the California Environmental Quality Act (CEQA) or National Environmental Policy Act (NEPA), but they are less likely to trigger federal review unless a disturbance occurs below the mean high-tide line. Carmel Bay has multiple marine protections and a variety of regulatory agencies. Depending upon the specific location of the adaptation, primarily above or below mean high water, the following special designations and their regulatory agency would require additional consultations: the National Oceanic and Atmospheric Administration, which oversees the Monterey Bay National Marine Sanctuary; the California Department of Fish and Wildlife, which oversees the Carmel Bay State Marine Conservation Area; and the State Water Resources Control Board, which oversees the Carmel Bay Area of Special Biological Significance State Water Quality Protection Area (note that the Carmel Pinnacles State Marine Reserve lies just offshore of this critical coastal area).

For projects like beach nourishment, permitting will also include U.S. Army Corps of Engineers (USACE) Section 404 permitting, while offshore structures, such as reefs, must be reviewed under the National Marine Sanctuaries Act.

Projects within the coastal zone either fall within the City's LCP jurisdiction or within the California Coastal Commission's (CCC) retained jurisdiction. A project may also require approval from the State Lands Commission and require federal permits under the Clean Water Act, Rivers and Harbors Act, Endangered Species Act, and National Marine Sanctuary Act. One major benefit of updating the City's LCP is to align with the CCC's adaptation priorities so that strategies above mean high tide line (MHTL) can be permitted by the City, leading to expedited implementation.

Regulatory details for specific approaches are described below:

- **Dune and sand management** approaches, such as dune restoration, generally have fewer regulatory barriers, lower construction costs, and stronger alignment with state guidance encouraging nature-based adaptation.
- **Engineered infrastructure** can be permitted by City if above MHTL. Note that certain engineered options may be deemed inconsistent with the Coastal Act's policies, especially when they contribute to coastal squeeze or a loss of public beach, and may be appealed to CCC. Strategies below MHTL must be permitted by CCC.
- **Retreat or relocation** strategies are socially and politically challenging, but they often encounter fewer regulatory obstacles with the CCC because they reduce long-term

hazard exposure and are generally aligned with the California Coastal Act. The major obstacles to these strategies are public acceptance, political will, and coordination with multiple agencies overseeing various lands and utilities. These strategies often have high upfront costs associated with planning and implementation.

1.5.4 Beach Widths

Adaptation strategies vary in their influence on beach width. Nature-based approaches, for one, vary in their scoring. Beach nourishment receives a positive score, as it maintains or widens the beach while enhancing storm buffering. In contrast, approaches like dune creation might take up space that otherwise could be used for beach recreation. Hard structures like seawalls and revetments receive a negative score, as they typically result in beach narrowing over time from passive erosion and coastal squeeze. Short-term strategies, such as opportunistic sand reuse, can provide temporary beach width increases but require ongoing maintenance. The strategy of managed retreat has a positive score, as it allows for the erosion of the backshore, giving space for the beach to migrate inland.

1.5.5 Environmental and Habitat Impacts

Nature-based strategies typically provide the highest levels of recreational and ecological benefits. Dune and vegetation restoration strategies enhance native habitat and biodiversity; thus, they have a positive score when weighing priorities. Beach nourishment is harder to judge, as this practice can help sustain coastal habitat and maintain sediment supply but may temporarily disturb ecological communities during construction, especially in intertidal zones, and thus receive a neutral score. The long-term ecological effect depends on sediment compatibility, placement timing, and frequency of nourishment cycles. Finally, hard protection structures tend to degrade habitats through passive erosion and increase nearshore currents and wave reflection; thus, their strategies have a negative score.

1.5.6 Public Access and Safety

Most strategies aim to balance hazard reduction with maintenance of beach access. Dune restoration and beach nourishment enhance access and safety by preserving beach widths and reducing wave energy at beach access points; thus, receiving a positive score. Strategies such as winter storm berms can temporarily improve storm safety, but lateral and vertical beach access may be affected, and it may require frequent rebuilding. Hard protection measures protect upland development, but they will eventually limit lateral movement along the beach, reducing accessibility during wintertime and high tides; thus, they received a negative score.

California's Coastal Act mandates that efforts should be made on reducing barriers to the coast, and to ensure equitable access for underserved communities and visitors with disabilities. In evaluating adaptation strategies, protection of transit-accessible beach entry points, such as the Del Mar Parking Lot, are relevant to equity considerations, as they represent

the shoreline location most readily accessible to visitors who rely on public transportation. Strategies that maintain or improve access to the coast and accessibility for these communities are given a positive score.

1.5.7 Secondary Consequences of Coastal Armoring on Beach Widths

Wherever a hard structure is built along a shoreline undergoing long-term net erosion due to SLR, there will be a gradual loss of beach in front of a seawall or revetment. Over time, as the water deepens and the shore face of the beach moves landward, the beach will eventually disappear (Figure 5). While upland development may be protected, the coastal recreation and habitats are lost. This process is known as *coastal squeeze*, and it occurs when the shoreline is fixed along an otherwise eroding stretch of coast. It will eventually lead to a loss in the recreational amenities associated with the beach unless the shoreline is continually replenished. At Carmel Beach, existing seawalls and revetments already limit the natural landward erosion of the shoreline, creating conditions of coastal squeeze.

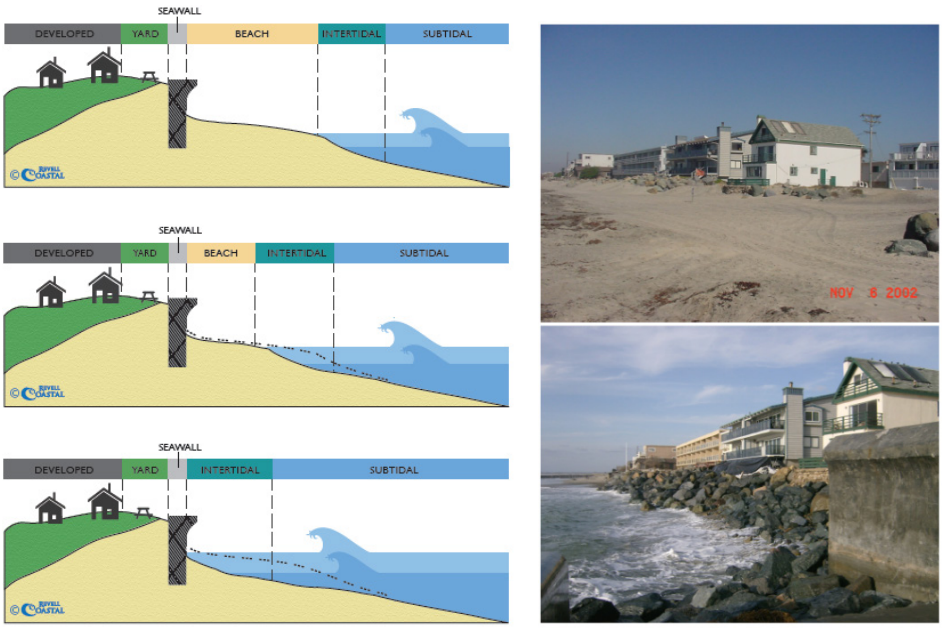


Figure 5. In-Place Backshore Fixing and Coastal Squeeze (left); Photographs from 2002 and 2012 at Imperial Beach Demonstrating Coastal Squeeze (right)

While Carmel has a unique littoral cell with a relatively stable volume of sand, as the sea level rises, Carmel Beach is projected to narrow significantly. In Phase 1, Task 2, the project team evaluated this coastal squeeze and projected the future summer beach narrowing with SLR. Results indicate a significant narrowing of beach widths after 3 ft of SLR (see Figure 3 for a map of beach widths), and in longer-term horizons, the recovery of the summer beach in its northern and southern ends may be limited, thereby limiting vertical and lateral access (Table 2).

Table 2. Typical Summer Dry-Sand Beach Remaining with SLR

SLR Elevation (ft)	Summer Beach (acres)	Percentage of Historical Summer Beach (1984–2021)
0	34.2	100%
1	27.4	80%
2	20.7	61%
3	14.1	41%
4	7.6	22%
5	2.6	8%

Note: The baseline year for SLR 2020. Summer dry-sand beach acreage is representative of the 75th percentile beach width from 1984 to 2021.

1.6 RANGE OF COASTAL ADAPTATION STRATEGIES CONSIDERED

The coastal adaptation strategies deemed most feasible—based on an alignment with community priorities and regulatory viability—are grouped into three categories: dune and sand management (green strategies), engineered protection (gray strategies), and managed retreat or relocation (Table 3 in Section 1.7). Together, these strategies provide various options that can be combined or phased over time into an adaptation pathway to enhance resilience and maintain the beach and access over time. Note that the range of strategies to consider in this process was informed by professional opinion and was based on expertise and knowledge of the unique characteristics of Carmel Beach. The ultimate list of strategies to consider, as described below, emerged from conversations with City of Carmel public works employees.

1.6.1 Dune and Sand Management

Nature-based strategies strengthen the natural defenses of the beach and dune system while maintaining habitat and recreational value. These approaches to reduce erosion use vegetation, sand placement, and natural materials like driftwood to absorb wave energy, support dune formation, and sustain beach width over time. By maintaining beach widths, the amount of erosive wave energy reaching the base of the cliffs and dunes can be reduced. These strategies result in a more resilient backshore and better buffer, even when the beach is scoured during severe winter storms.

The following sections describe the range of feasible dune and sand management strategies. Given the unique sand on Carmel Beach and the high priority placed on the beach by the community, additional studies will be necessary to further evaluate the feasibility and longevity of these strategies.

1.6.1.1 Sacrificial Winter Storm Berm (reduce erosion)

For winter storms, a low storm berm along the beach can reduce wave impacts on the backshore. The berm will erode naturally during winter storm events and can be rebuilt as needed with locally sourced sand. This strategy is not applicable where there are narrower beaches, and it is unnecessary where coastal armoring is already in place. Primary locations for implementation are likely to be along the dune-backed shoreline between 4th and 8th avenues.



Figure 6. Winter Storm Berm at Carpinteria City Beach Protecting a Low-Lying Neighborhood

1.6.1.2 Driftwood for Dune Stability (reduce erosion)

Driftwood that is strategically placed along the upper beach or back beach can trap sand and encourage dune formation. When combined with native vegetation, this method creates a self-sustaining natural barrier that enhances resilience and habitat value while maintaining a natural beach appearance. The City decided several years ago to leave driftwood in place on the beach, except where large logs pose a risk of damaging staircases or other infrastructure (Figure 7). In those cases, public works staff relocated these logs to the top of the 8th Avenue maintenance ramp or to the back of the beach (Culver and D'Ambrosio 2025, pers. comm.). Driftwood placed on the dune ramps can direct access routes and reduce the dune ramp deflation caused by excessive trampling.



Figure 7. Driftwood near 8th Avenue Sand Ramp (left); Natural Driftwood on the Beach near 8th Avenue (right)

Dunes constructed with driftwood core and vegetation could be designed and implemented along the existing dune-backed shoreline. For dune restoration and expansion, this work can be accomplished using earthmoving equipment, such as front-end loaders and bulldozers, to move sand into the dune areas. The equipment would sculpt the dunes in place to mimic the natural dune contour, and revegetation of the site would then follow (Figure 8; Figure 9). Suitable areas would be dune-backed areas, such as the 8th Avenue sand ramp and the northern sand ramp areas.



Figure 8. Rio del Mar State Beach in Aptos, California: Driftwood Logs Pinned Vertically and Cross-Braced to Form the Core of a New Dune Site (left); Sand Placed over the Logs (center); Post-construction with Dune Vegetation Establishment (right)

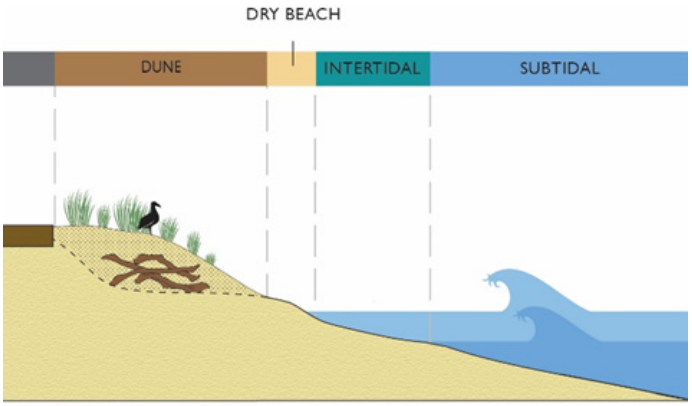


Figure 9. Driftwood-Cored Dune and Living Shoreline

1.6.1.3 Dune Restoration (reduce erosion)

The restoration of native dune areas focuses on building low, hummocky dunes along the existing dune-backed shoreline. Areas with extensive ice plants can be reshaped and stabilized using native plants to restore their natural form, and these actions will improve coastal habitat quality. This measure also improves visual quality while reducing erosion along the upper beach. Some restoration efforts to reduce impacts from access trampling may include terracing and the use of rice straw bales or jute netting on the dunes for contouring and protection to support long-term slope stability. The recommended location for this strategy is the Del Mar Dunes.

1.6.1.4 Vegetation and Landscaping to Reinforce and Protect Terrace Soils (reduce erosion)

Native vegetation and soil-stabilizing landscaping use the plant root networks to enhance the stability of the terrace and bluff soils and manage surface runoff (Figure 10). This method may also include terracing and the use of erosion fabric on the bluff to retain soil. Feasible locations for such a strategy would be along the backshore and terrace to the south of 8th Avenue.



Figure 10. Restoration Work along Bluff Area near West Cliff Drive, Santa Cruz in 2018 (left) (Groundswell Ecology 2018); Restored Bluff Section with Native Vegetation in 2025 (orange circle) (right)

1.6.1.5 Beneficial Reuse of Sand or Opportunistic Beach Nourishment (reduce erosion)

The beneficial reuse of sand includes the placement of small volumes of beach-compatible sand on Carmel Beach or at the top of the sand ramps once such material becomes available from nearby construction projects, utility work, flood control activities, or maintenance activities. Historically, these sands have been offloaded to the dump or sold off for landscaping purposes.

Placement typically occurs by truck and is generally modest in volumes that supplement the natural sand supply. These sediments must pass a specific set of tests to ensure sand compatibility, cleanliness, and quality. The City of Monterey and several jurisdictions in southern California have implemented these programs, which are also called sand compatibility and opportunistic use programs (Figure 11).

While it does not substitute for large-scale nourishment, this type of program provides a cost-effective and low-impact tool to support routine beach maintenance and maintain sand supply. As described in Section 3, a program for the opportunistic placement of sediment will strengthen resilience by identifying compatible sand, screening it for suitability, and ensuring that suitable material is beneficially reused on Carmel Beach whenever feasible. This practice helps ensure that sufficient sand is available to maintain the sand ramps.



Figure 11. Opportunistic Beach Nourishment at Goleta Beach in Santa Barbara, California (BEACON 2019)

1.6.1.6 Sand Management and Harvesting (reduce erosion)

Another adaptation strategy that falls under dune and beach management is active sand harvesting (i.e., the movement of sand from the foreshore to the back beach and backshore). This strategy widens the beach, potentially up onto the dune ramps, and has been implemented in the past. From the 1960s until 2015, the City conducted routine sand redistribution in late spring and early summer from Pescadero Canyon south to Marin Way. This work involved bulldozing sand from the lower beach (above the high-tide line) to the upper beach, and it was intended to improve public safety and compensate for sand that was naturally pushed downslope by visitors. Starting in 1984, the sand redistribution plan expanded, and the City contracted out the work (typically with Monterey Peninsula Engineers) to push sand up from just below MHTL (not into the surf zone) to the sand ramps and fully cover the revetments. The total sand redistribution volume varied between 50 and 100,000 cy, depending on conditions (mild winters required less sand movement than severe winters) (Shonman and D'Ambrosio 2003; Culver 2025, pers. comm.) (Figure 12; Figure 13).

From the 1980s until the early 2000s, the sand redistribution plan involved moving sand from lower on the beach landward. This action created a lowered area or depression behind the beach berm (Figure 13). Subsequent wave overtopping deposited sand into this depression, with the water then seeping out through the beach during lower tides. This process could still be considered sand harvesting, given the time of year when the winter nearshore sandbars were returning back to the beach. It is uncertain, however, what changes this practice may have caused, but recreating the practice—and conducting monitoring—could be a pilot project approach.

Ultimately, the City's larger-scale sand management program was discontinued, largely due to funding constraints (Culver and D'Ambrosio 2025, pers. comm.). Today, the City performs smaller-scale sand management in house to maintain the sand ramps. Typically, this practice

only lasts one season, before wind and foot traffic moves the sand away. The City also moves sand into the volleyball courts when it gets low (Culver and D'Ambrosio 2025, pers. comm.). Sand redistribution could be restarted and would assist the natural recovery of the beach following large winter storms. More sand volumes on the beach could buffer some of the impacts from winter storms and help maintain the investments in coastal access stairways and sand ramps. The entire beach would be a suitable location for this strategy.



Figure 12. Active Sand Management near Del Mar Parking Lot (Kenneth & Gabrielle Adelman, Coastal Records Project 2003)



Figure 13. Sand Management with Sand Bulldozed over Riprap Revetments near 13th Avenue (Kenneth & Gabrielle Adelman, Coastal Records Project 2003)

1.6.1.7 Beach Nourishment (reduce erosion)

Traditional beach and dune nourishment involved placing sand directly on the beach, while shoreface nourishment, which became common after the 1990s, relies on using natural marine processes to gradually move submerged sand landward to create a wider beach over time. Larger-scale nourishments distribute sand across the nearshore and dune system, allowing both marine and wind-driven processes to reshape the beach in cross-shore and alongshore directions. This approach provides a temporary (multiyear) direct protection of upland resources and widens the beach for improved recreational use.

The implementation of beach nourishment requires large volumes of compatible sand (usually from an offshore source) to be placed along the beach to restore or maintain beach widths. There are numerous challenges associated with beach nourishment at Carmel Beach including regulatory viability and sand compatibility. More information on this can be found in Section 3 and in Appendix C.

In Carmel, an additional placement at the top of the existing sand ramps could improve regulatory viability. This placement avoids many of the ecological impacts to the beach and may reduce permitting and regulatory hurdles. Potential locations are at the top of the sand ramps at North Dunes, Del Mar Avenue, or 8th Avenue.

Beach nourishment is a cyclical ongoing maintenance approach and needs to be repeated. A nourishment cycle is based on the timing needed between nourishments. As the rate of SLR accelerates, the time between nourishment cycles will decrease. The optimal time to conduct this work would be during the spring. Benefits of doing the work at this time are that the sand can be placed before summer visitation increases and can be available throughout the high-use beach season (summer).

Benefits

The benefits of this strategy are as follows:

- It maintains wider beaches, thereby benefitting coastal recreation.
- It mitigates adverse effects of coastal squeeze from engineered protection strategies on environmental and coastal access resources.
- It provides an additional buffer against wave attacks at the base of the dunes and bluffs.
- It results in limited sediment losses in the downcoast direction, which could prolong nourishment benefits.

Challenges

The challenges of this strategy are as follows:

- It requires the identification of a suitable source and volume of compatible sand.
- It is subject to regulatory approvals.
- CEQA and NEPA environmental permitting processes are required with regard to sediment placement and impacts on nearshore and marine species.
- It requires marine sanctuary approval (recent changes to Sanctuary regulations regarding opportunistic nourishment need to be further evaluated).
- There is a high potential cost of sand and unknown potential funding sources.
- It will require multiple nourishment cycles over time with high recurring costs.

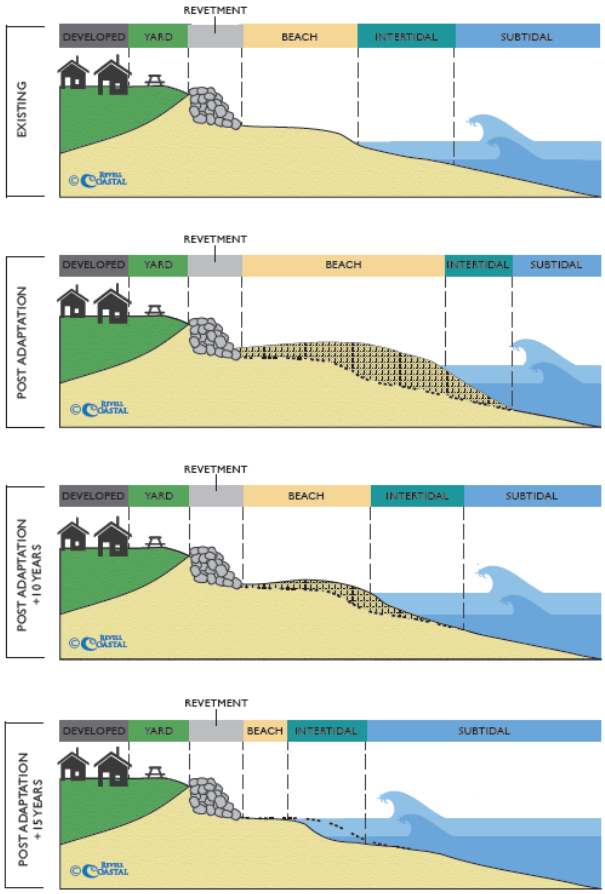


Figure 14. The Nourishment Cycle

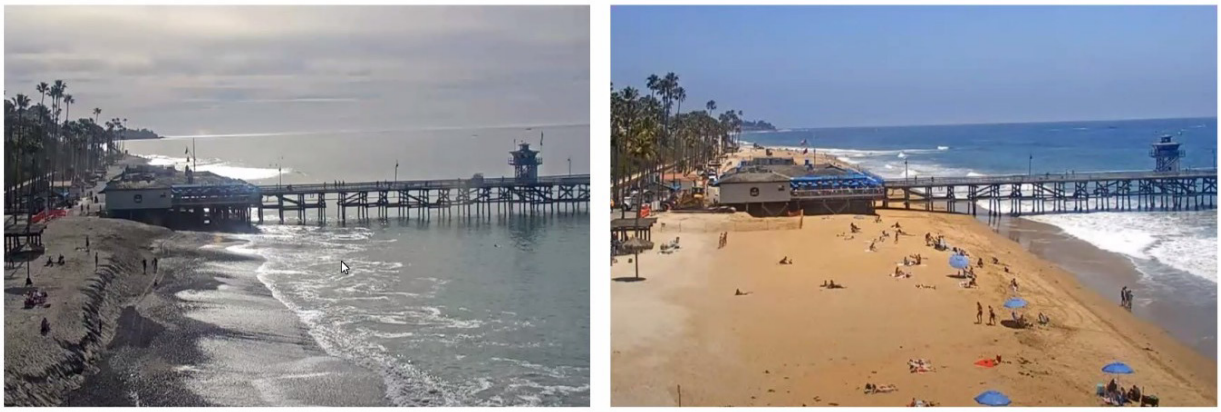


Figure 15. San Clemente, California, Before (left) and After (right) Beach Nourishment (City of San Clemente, 2025)

Note: The volume of sand added to the beach was approximately 251,000 cy, and the project footprint was 3,214 ft long.

1.6.1.8 Restoration of Kelp Ecosystems

Another approach is to investigate opportunities for programs and partnerships centered on kelp restoration and its potential to enhance both ecosystem health and coastal resilience. Kelp forests are naturally found in nearshore waters, and healthy kelp forests provide multiple benefits, including improved biodiversity and enhanced fisheries habitat. Kelp also contribute to improved sequestration and the cycling of carbon and oxygen, and they increase ecosystem productivity. Kelp restoration provides significant ecological and water-quality benefits.

Kelp restoration effects on erosion reduction, however, are poorly substantiated. There is scientific evidence that kelp reduces small, low-wave-height energy, but there is not much evidence for kelp's ability to reduce large, erosion, storm-wave energy—for this reason, it is not included in the list of feasible adaptation strategies (Table 3). However, combination of kelp restoration and other adaptation strategies, such as nearshore reefs, may provide appropriate and suitable mitigation.

Further studies should evaluate the feasibility of artificial reefs for the project. The City can conduct the necessary research by partnering with research institutions, nonprofits, and regulators to identify potential pilot restoration sites and develop best practices for kelp forest recovery in Carmel. Currently, the Giant Giant Kelp Restoration Project (2025) is underway at Tanker's Reef in Monterey, and it has identified areas within Carmel Bay that are suitable for restoration. Permitting from state agencies can be a significant challenge in Carmel Bay, and permitting requires significant investments in studies as well as alignment with the broader marine management goals of regulatory agencies.



Figure 16. Restoration Efforts at Tanker's Reef in Monterey in 2021 (Schmalz 2024)

1.6.2 Engineered Coastal Protection

Engineered infrastructure strategies use structural measures to protect the shoreline and reduce the erosion of bluffs and beaches. These approaches can preserve existing development and public access but generally require higher maintenance and more complex permitting than nature-based solutions such as living shorelines.

1.6.2.1 Integration of Wave Deflectors in Access Improvements

Currently, during winter storm events, localized currents accelerate erosion and wave run-up. As a mitigation tactic, the City has already seen some benefit by integrating wave and current deflectors into some of the beach access staircases (Figure 17). These deflectors are protrusions at the base of beach stair foundations that deflect wave energy and reduce current velocities. Access repairs and any future access enhancements or replacements should integrate these deflectors into their design to reduce erosion.



Figure 17. Wave Deflectors at the Base of a Beach Access Stairway

1.6.2.2 Elevation of Riprap and Seawall (stop erosion)

Phase 1, Task 3, identified locations of increased wave overtopping over four SLR horizons and found that, with increasing sea levels, many areas of coastal armoring will see significant threats from wave overtopping. A strategy to combat this threat includes restacking and raising revetments, raising the crest of seawalls, and building infill walls at unarmored backshore locations (Figure 18). This approach provides added protection to the underlying cliff and bluff terrace against increased wave overtopping with SLR. Potential project areas for this approach include all coastal protection areas south of 8th Avenue.



Figure 18. Conceptual Image of Raising Crest Elevations of Seawalls or Elevating and Restacking Riprap

1.6.2.3 Soil Nail Wall or Tie Back Wall to Protect the Bluff Terrace (stop erosion)

A soil nail or tie back wall can stabilize the bluff terrace and prevent an upper-slope bluff retreat in areas where erosion threatens upland development. These walls are typically finished with textured shotcrete to blend with the surrounding landscape, similar to the system used at Pebble Beach Golf Links (Figure 19). Candidate locations include the headlands, especially where the terrace is more exposed to wave energy and where there are fewer conflicts with existing trees and vegetation.

1.6.2.4 Replace Riprap with Vertical Seawalls (stop erosion)

Existing revetments in Carmel, based on Phase 1, Task 1, are typically about 10–20 ft high and built at a 1.5 to 2:1 slope, occupying roughly 15–40 ft of beach. The replacement of these structures with vertical seawalls or soil nail walls reduces the footprint of shoreline armoring and can widen the usable beach area. This approach improves lateral (along the beach) access while maintaining coastal protection.

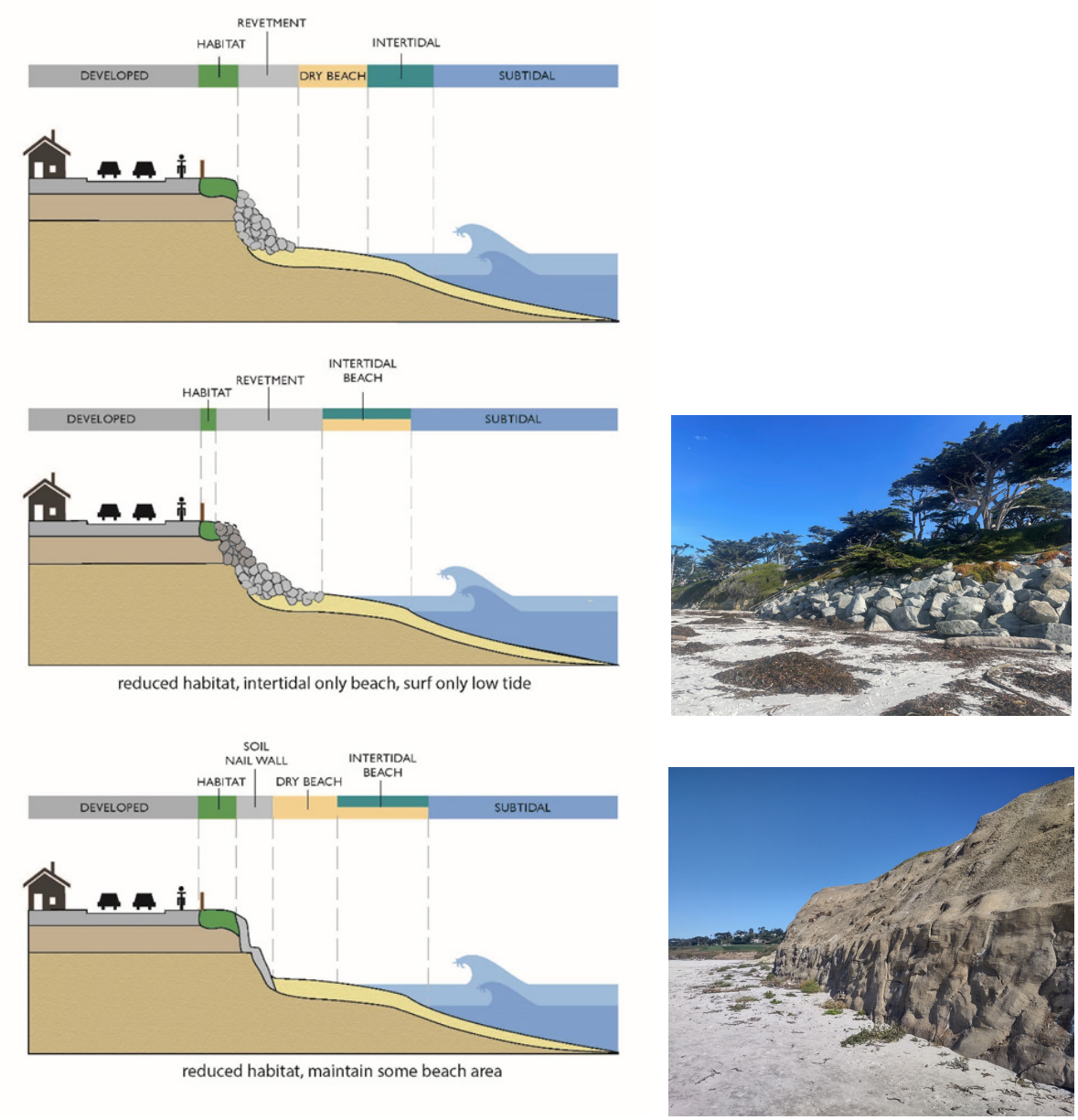


Figure 19. Passive Beach Erosion with Riprap Removal for Soil Nail Tie Back Wall over the Cliff and Bluff Terrace (left); Existing Riprap Revetments and Existing Soil Nail Tie Back Wall near 10th Hole of Pebble Beach Golf Links (right)

1.6.2.5 Low-Crested Structures to Reduce Erosion and Scour (reduce erosion)

As identified in Phase 1, Task 2, the existing engineered protection structures accelerate some of the localized currents, particularly in the south of Carmel Beach in gaps amidst the mudstone and sandstone outcrops. Low-crested structures, similar to sills, can be integrated into exposed shore platforms to break up waves and reduce nearshore currents (Figure 20). By dissipating wave energy before it reaches the bluff or beach, these structures reduce wave

energy, erosion, and scour and can be colored and texturized to preserve the natural appearance of the sandstone exposed in the winter and along the backshore.

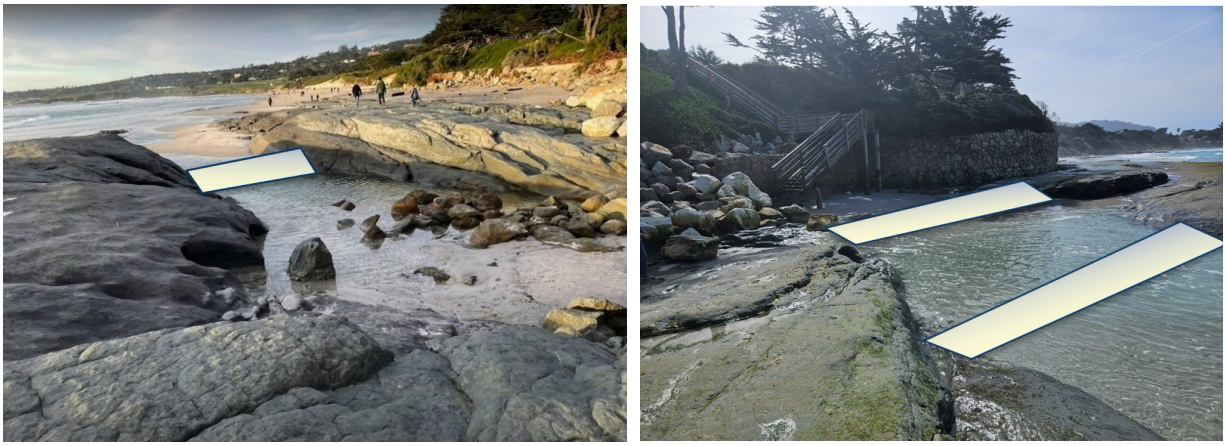


Figure 20. Illustrated Locations Where a Low-Crested Structure Could Provide Resiliency
Note: These structures could be in back-beach areas with gaps in the shore platform, where wave exposure is high.

1.6.2.6 Shore Platform Enhancement (reduce erosion)

Over time, the sandstone outcrops and existing shore platforms are eroding and decreasing in elevation, thereby reducing natural wave dissipation. With erodible textured concrete, these platforms can be augmented or extended using the existing shore platforms (also known as wave-cut terraces) to increase wave energy dissipation and reduce erosion. The features can be constructed using cemented sediments designed to match the color and composition of the existing sandstone and mudstone outcrops, thereby maintaining a natural appearance while improving coastal stability. These enhancements can also include lateral and vertical access considerations to maintain safe landings from access stairways and allow for some winter passage around traditionally challenging locations, such as 12th Avenue and Santa Lucia Avenue.

Benefits

Benefits of this strategy include the following:

- It reduces the wave energy impacting the backshore and likely depositing sand.
- It minimizes potential aesthetic impacts along cliffs and bluffs.
- It enhances habitat complexity and supports marine biodiversity.
- It promotes sediment retention and reduces local scour.
- It can be integrated with other nature-based measures, such as nearshore reefs.
- It provides an adaptive alternative to enhance lateral and vertical beach access.

- Appropriate cementation and texture could result in compatible sand material to be eroded over time while augmenting a small percentage of sand volume.

Challenges

Challenges of this strategy include the following:

- An evaluation of benefits is more complex than traditional approaches and would likely require pilot projects with detailed monitoring to quantify performance and ecological effects.
- Regulatory pathways and permitting requirements are still evolving and may vary depending on the project scale and materials used.
- Long-term maintenance needs and ecological interactions remain uncertain without extended study.
- Construction requires specialized materials and techniques to match local geological and hydrodynamic conditions.



Figure 21. Illustration of Shore Platform Enhancement

1.6.2.7 Nearshore Artificial Reefs (reduce erosion)

Around the Monterey Peninsula, natural nearshore reefs and offshore rocks provide important marine habitats and dissipate wave energy before it hits the shoreline. Offshore rock platforms and reefs also provide stable substrate to support kelp forests. Carmel Beach already has a

prominent and often photographed offshore rock that affects breaking wave patterns (Figure 22). A nearshore reef adaptation strategy could consider the construction of a series of submerged artificial reefs that are designed as rubble mounds or concrete structures with a crest at or below the waterline. These reefs, which would have multiple benefits, could dissipate wave energy and change erosion and accretion patterns. They could also focus wave patterns on armored sections of coast and promote sand retention, enhance marine habitats, and (depending on the design) improve surf recreation.

Benefits

Benefits of this strategy include the following:

- It reduces wave energy and coastal erosion.
- It enhances marine habitat and biodiversity.
- It promotes sediment deposition and stabilization near the shore.
- It may support recreational activities, such as snorkeling, diving, fishing, and surfing.
- It can complement kelp habitat restoration and other nature-based adaptation measures.

Challenges

Challenges of this strategy include the following:

- It requires detailed bathymetric and coastal modeling studies, as well as engineering, to identify suitable locations.
- Regulatory viability would be complex, challenging, and time consuming.
- Construction in the nearshore environment is challenging and costly relative to other nature-based approaches.
- Alterations to existing hydrodynamics would affect sediment transport and need to be carefully designed.

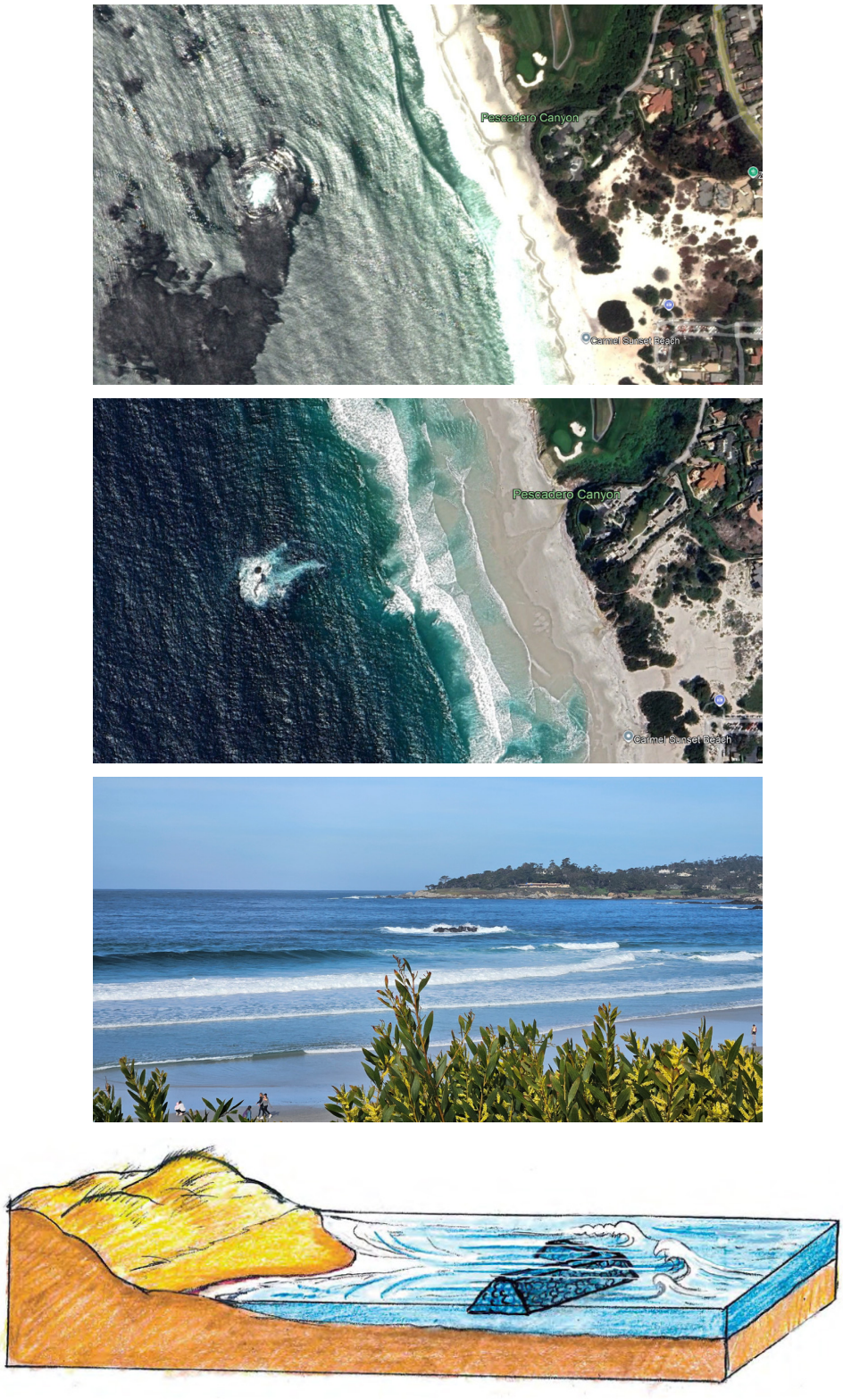


Figure 22. Offshore Rock near Pescadero Canyon on the Beach's North End (top three images); Illustration of a Submerged Nearshore Reef Structure (bottom)

1.6.3 Retreat or Relocation

There are two retreat or relocation strategies that are considered feasible for the project.

1.6.3.1 Transportation Realignment (avoid erosion)

Transportation realignment refers to realigning pedestrian and vehicular corridors away from hazardous areas. This strategy focuses on Scenic Road, which currently operates as a narrow one-way southbound road. The narrow nature of this path and roadway limits opportunities to shift alignments within the existing right-of-way as erosion continues, and it may necessitate creative solutions, such as dead ends with turnarounds.

Figure 23 illustrates how transportation realignment could unfold. In the early phases, the roadway and multiuse path can continue functioning in their current configurations; however, pathway-adjacent vegetation area may be lost. As erosion continues, the City will reach a decision point regarding how to balance competing priorities, which include the maintenance of parking and vehicular traffic, multimodal circulation, and safe pedestrian access. Potential adjustments at this stage include narrowing or removing travel lanes, modifying parking, or rerouting vehicular and pedestrian access to a new inland corridor, where feasible. In Figure 23, along the bottom row, the leftmost column represents a scenario that removes parking and multimodal circulation and maintains vehicular access, the central column represents a scenario that maintains multimodal circulation, and the rightmost column represents managed retreat of upland development and the preservation of open space. Each stage would need to evolve with community dialog based on observed changes in shoreline and erosion conditions, and it must balance local resident access to homes with public access to the coast.

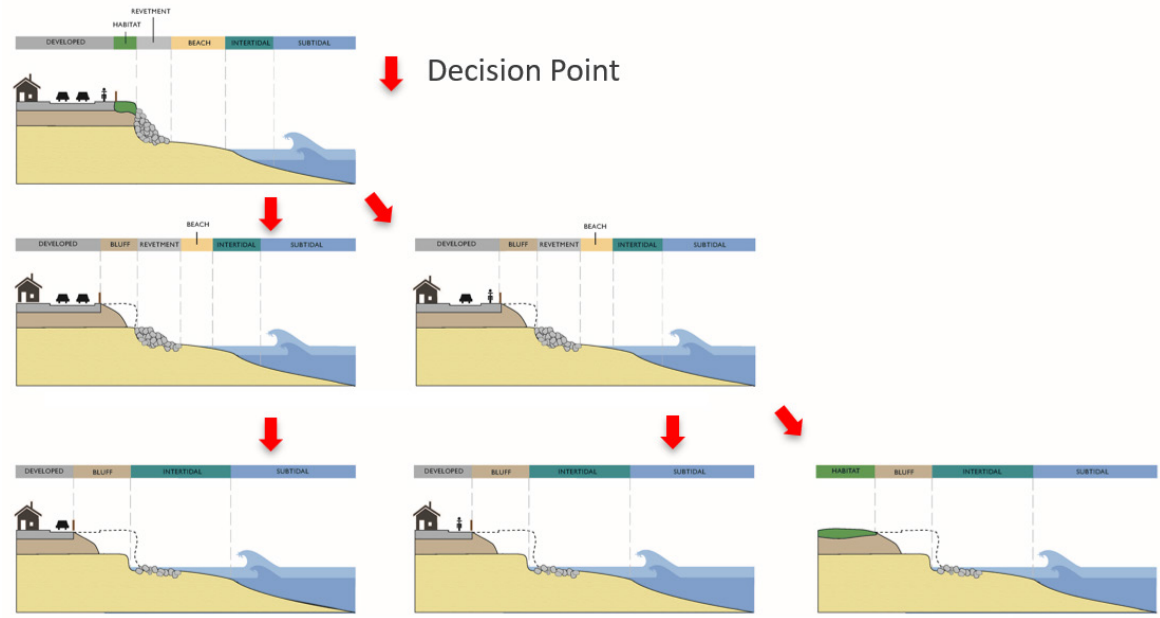


Figure 23. Transportation Realignment Pathways Considering Priorities of Vehicle and Pedestrian Access along the Narrowing Upland Corridor

The examples below (Figures 24 through 26) are from Santa Cruz County.



Figure 24. Grand Avenue at Depot Hill in Capitola, California in 1993 (left) and 2025 (right); Example of Former Continuous Road Transitioned to Continuous Lateral Access for Pedestrians Via Coastal Trail (vehicle access to ocean-fronting homes is afforded through alleyways from side streets)

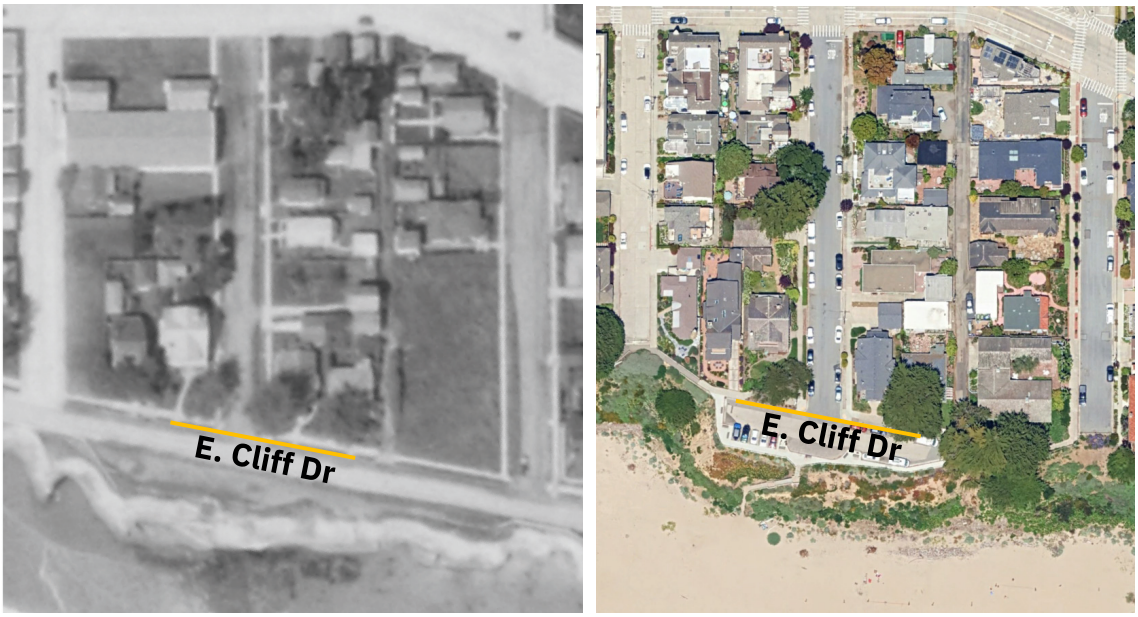


Figure 25. Third Avenue and East Cliff Drive at Seabright Beach in Santa Cruz, California, in 1931 (left) and 2025 (right); Example of Former Continuous Road Transitioned to T-Shaped Turnaround with Parking for Bikes and Vehicles and Continuous Lateral Access for Pedestrians along a Coastal Trail



Figure 26. Armored Pathway Along West Cliff Drive in Santa Cruz, California.

Note: Continued bluff erosion had led to the closure of these portions of the cliffside walkway and bike trail. Given that there was limited room to retreat the pedestrian path inland, the pathway was built up vertically from the bluff.

1.6.3.2 Relocation of Critical Infrastructure (avoid erosion)

The relocation of critical infrastructure refers to strategically moving vulnerable public and private assets away from high hazard areas to avoid damages, thus avoiding cleanup and emergency repair costs. Relocation may start with smaller assets—such as signage, garbage bins, and benches—that are easy to relocate. As erosion progresses, more substantial relocation will be required for bluff-adjacent infrastructure, such as coastal access staircases, storm drains, and lighting. In the long term, critical utilities managed by other entities, including the Carmel Area Wastewater District (CAWD), California American Water, and Pacific Gas & Electric Company, may need to be relocated. Many of these utilities represent high-cost assets, with limited flexibility for relocation. As part of Phase 1, Tasks 3 and 4, the numbers and lengths of critical assets exposed to erosion hazards were reported. A summary of these findings by 4 ft of SLR includes the following:

- 2,149 ft^2 of the Del Mar parking lot, threatening at least 15 parking spaces as well as the vehicular turnaround area that supports circulation and emergency access
- 3,463 linear ft of Scenic Road, equivalent to roughly 96,067 ft^2 of roadway, with multiple buried utilities at risk
- 4,390 ft of wastewater main beneath Scenic Road and the Del Mar Dunes
- 805 ft of forced main near 8th Avenue
- 2,072 ft of water main located beneath Scenic Road
- 59 private residences along Scenic Road and Carmel Way.

(Note: These findings assume no adaptation measures are in place by 4 ft of SLR.)

1.7 FEASIBLE ADAPTATION STRATEGIES TABLE

Table 3 lists the range of strategies described in Section 1.6 and outlines the results of the vetting process described in Section 1.5. This screening informs the range of actions that have advanced into the adaptation pathways described in Section 2.

Table 3. Carmel Beach Range of Potential Adaptation Strategies

Carmel Beach - Range of Potential Adaptation Strategies										
			Priorities		Cost		Regulatory Viability	Secondary Impacts		
Strategy Category	***Strategy***	***Strategy Description***	**Timing for Implementation**	**Priority Index Score (Balancing Effectiveness, Cost, and Other Criteria)**	**Construction**	**Maintenance (Including Cost Savings)**		**Beach Width Impacts**	**Environmental and Habitat Impacts: Water/Surf Quality and Ecological**	**Public Access and Safety**
			Immediate, Short-term (5-20yr), Mid-term (10-30yr), Long-term (30yr +)	*Index Score (0 - 20)*	*Low - $, Medium - $$, High - $$$*	*None to Low - $, Medium - $$, High - $$$*	*Viable, Likely, Less Likely*	*Negative, No Effect, Positive*	*Negative, No Effect, Positive*	*Negative, No Effect, Positive*
Dune & Sand Management	Vegetation and landscaping to reinforce/protect terrace soil	Planting and landscaping of bluff areas to reduce bluff erosion (typically due to stormwater). May include terracing or erosion fabric on the bluff with landscaping to retain soil and vegetation	**Immediate**	**18**	**$**	**$$**	**Viable**	**=**	**+**	**=**
Dune & Sand Management	Dune restoration	Creation of native low hummocky dunes along existing dune-backed shoreline	**Immediate**	**18**	**$**	**$$**	**Viable**	**+**	**+**	**=**
Dune & Sand Management	Beneficial reuse of sand	Locally sourced sand available from nearby construction or dredging projects, or capture of sediment	**Immediate**	**20**	**$**	**$$**	**Viable**	**+**	**+**	**=**
Dune & Sand Management	Living shorelines - utilize driftwood expanded dunes	Dunes with driftwood core and vegetation along existing dune-backed shoreline	**Immediate**	**19**	**$**	**$$**	**Viable**	**+**	**+**	**+**
Dune & Sand Management	Beach nourishment of upland dune ramps	Upland sand nourishment at high priority access locations that would erode onto the beach	**Short-term**	**20**	**$$**	**$$**	**Viable**	**+**	**+**	**+**
Dune & Sand Management	Beach nourishment	Sourcing and placement of sand directly along the beach usually from offshore or navigation sources	**Short-term**	**18**	**$$$**	**$$$**	***Depends***	**+**	**+**	**+**
Dune & Sand Management	Sacrificial berm	Creation of low berm(s) at the backshore along the dune-backed beach. Can work with sand management/harvesting	**Short-term**	**16**	**$**	**$$$**	**Likely**	**+**	**+**	**+**
Dune & Sand Management	Sand management/harvesting	Active harvesting and movement of sand from the foreshore to the back beach and backshore to widen the beach	**Short-term**	**15**	**$**	**$$$**	**Likely to Less Likely**	**+**	**-**	**+**
Engineered Protection	Monitoring and maintenance of existing structures	Program to monitor and maintain existing seawalls	**Immediate**	**17**	**$**	**$$$**	**Viable**	**-**	**-**	**+**
Engineered Protection	Integrate wave deflectors into access improvements	Concrete protrusions at the base of beach stair foundations to deflect wave energy	**Short-term**	**17**	**$$**	**$$**	**Likely**	**=**	**-**	**+**
Engineered Protection	Replace revetments with seawalls	Replacing existing revetments with vertical seawalls	**Mid-term**	**16**	**$$$**	**$$**	**Likely**	**+**	**=**	**=**
Engineered Protection	Wave tripping low structures on bedrock	Similar to a sill, built into exposed beach bedrock to reduce currents and wave energy	**Mid-term**	**13**	**$$**	**$$$**	**Less Likely**	**=**	**-**	**+**
Engineered Protection	Raise crest and redesign of seawalls	Raising the crest of seawalls to reduce wave overtopping, or seawall redesigns including recurved walls to redirect overtopping wave/spray	**Mid-term**	**12**	**$$$**	**$$$**	**Likely**	**-**	**-**	**+**
Engineered Protection	Shore platform enhancement	Augmentation and extension of exposed shore platforms (wave cut terraces)	**Mid-term**	**12**	**$$**	**$$**	**Less Likely**	**-**	**-**	***Depends***
Engineered Protection	Raise riprap	Adding more armoring stone to existing revetments to reduce wave overtopping	**Mid-term**	**11.5**	**$$$**	**$$$**	**Likely**	**-**	**-**	**+**
Engineered Protection	Infill seawalls	Adding seawalls to currently unarmored sections of backshore	**Mid-term**	**12**	**$$$**	**$$**	**Less Likely**	**-**	**-**	**+**
Engineered Protection	Soil nail wall or tie back wall to protect bluff terrace	Shotcrete textured wall similar to the one at Pebble Beach Golf Links	**Mid-term**	**12**	**$$$**	**$$**	**Less Likely**	**-**	**-**	**+**
Engineered Protection	Nearshore reefs	A rubble-mound or concrete structure(s) with the crest below the water line to reduce wave energy	**Mid-term**	**13**	**$$$**	**$$$**	**Less Likely**	**+**	**=**	**+**
Retreat/Relocation	Transportation Realignment (pedestrian path)	Plan and implement a strategy for accommodating erosion in relation to pedestrian and vehicular access along Scenic Rd.	**Long-term**	**17.5**	**Varies ($$)**	**$**	**Likely**	**+**	**+**	**+**
Retreat/Relocation	Retreat/Relocation	Plan and implement a phased relocation of infrastructure, parking lots, access ways, roadways, and homes from vulnerable locations. Includes policy on triggers related to repetitive losses, repairs, or other criteria	**Long-term**	**17**	**Varies ($$$+)**	**$**	**Likely**	**+**	**+**	**+**

1.8 PLANNING LEVEL ENGINEERING COST ESTIMATES

Planning-level cost estimates were developed to support the comparison of adaptation strategies and provide an order-of-magnitude understanding of potential investment needs for coastal adaptation at Carmel Beach (Table 4). These estimates are intended for planning purposes only. The project team has attempted to provide rolled-up costs accounting for design, permitting, and construction, but actual project costs may vary based on site conditions, regulatory requirements, available contractors, and market conditions at the time of implementation.

Costs were developed using a combination of industry-standard references, using comparable California coastal projects and professional judgment. For each strategy, a reference is provided for the cost estimate along with cost comparisons, when available. Estimated costs were developed for the primary adaptation strategy types identified in this study.

Table 4. Planning-Level Engineering Cost Estimates

Adaptation Strategy	Lower Unit Cost (-50%)	Higher Unit Cost (+100%)	Source and Note
Dune and Sand Management			
Upland Vegetation and Landscaping	$2,000/acre	$6,000/acre	LA County Beaches and Harbors (Moffatt & Nichol 2023)
Dune Restoration	$28,000/acre	$110,000/acre	LA County Beaches and Harbors (Moffatt & Nichol 2023)
	$150,000/acre	$600,000/acre	ESA (2018) (includes cobble)
Living Shorelines Utilizing Driftwood	$6,000/acre	$23,000/acre	Carpinteria project experience
Beach Nourishment, Upland Source[a,b]	$20/cy	$60/cy	Aerts et al. (2018)
	$20/cy	$60/cy	ESA (2018)
Beach Nourishment, Offshore Source[a,b]	$20/cy	$80/cy	ESA (2018)
	$4/cy	$20/cy	Aerts et al. (2018)
	$10/cy	$20/cy	Aerts et al. (2018)
	$30/cy	$130/cy	Coastal Frontiers Corporation (2025)
	$10/cy	$50/cy	GHD (2026)
Sand Management/Harvesting	$38,000/season	$152,000/season	Carmel-by-the-Sea Public Works Department, personal communication (2025)
	$50,000/year	$200,000/year	John Illasin and Delayni Miller, City of Carpinteria Public Works Department, personal communication (2025)

Table 4. Planning-Level Engineering Cost Estimates

Adaptation Strategy	Lower Unit Cost (-50%)	Higher Unit Cost (+100%)	Source and Note
Engineered Infrastructure			
Seawall Maintenance	$300/linear ft/year	$1,300/linear ft/year	ESA (2018); annual costs are assumed to be 2.5% of capital cost
Riprap Revetments	$2,000/linear ft	$6,000/linear ft	Hanak and Moreno (2008) and Stanford Center for Ocean Solutions (2018)
	$5,000/linear ft	$21,000/linear ft	ESA (2018)
New Concrete Seawall	$13,000/linear ft	$50,000/linear ft	ESA (2018)
Seawall Upgrades	$14,000/linear ft	$55,000/linear ft	ESA (2018)
Soil Nail Tie Back Wall	$10,000/linear ft	$40,000/linear ft	Metropolitan Transportation Commission (2023)
Nearshore Reef	$10,000/linear ft	$39,000/linear ft	ESA (2018)
Utilities			
Wastewater Gravity Line Removal and Restoration of Dunes	$100/linear ft	$500/linear ft	ESA (2018) (new wastewater line)
Wastewater Force Main Removal and Restoration of Dunes	$300/linear ft	$1,000/linear ft	ESA (2018) (asset replacement cost; new wastewater force main)
Ejectors Pumps	$25,000/home or unit	$100,000/home or unit	Carmel Area Wastewater District, personal communication (2025)
Pump Station Upgrades and Replacement and Associated Upstream Wastewater Piping at Del Mar Dunes	$750,000/home or unit	$3,000,000/home or unit	Carmel Area Wastewater District, personal communication (2025)

Table 4. Planning-Level Engineering Cost Estimates

Adaptation Strategy	Lower Unit Cost (-50%)	Higher Unit Cost (+100%)	Source and Note
Retreat Measures			
Demolition of Parking Lot	$1/ft^2	$3/ft^2	ESA (2018)
Demolition of Seawall	$200/linear ft	$1,000/linear ft	ESA (2018)
Demolition of Revetment	$400/linear ft	$1,800/linear ft	ESA (2018)
Demolition of Bathroom	$10/ft^2	$40/ft^2	ESA (2018)
Demolition of Roadway	$300/linear ft	$1,100/linear ft	ESA (2018)

Notes:

The unit costs presented in this table are suitable for comparative purposes and in planning. The accuracy of these estimates is considered to be -50%/+100%, consistent with the objectives of the report, and the level of conceptual design and engineering upon which the costs are based. Final project costs will vary from the estimates presented here, particularly with regard to changes in scope, timing and feasibility considerations addressed during later design phases.

Capital costs presented have been adjusted based on inflation indices to 2025 dollars. Capital costs and operation, maintenance, and management costs are presented undiscounted.

Indirect and ancillary capital costs, such as mobilization, demobilization, environmental controls, and construction management, are generally included in the costs presented. Design and permitting costs are not included.

Contingency costs, which would address cost uncertainties, are not included. Contingency costs are typically around 25% at the feasibility evaluation stage for similar projects. Contingency costs would cover scope contingency (approach changes during design, additional regulatory requirements, etc.) and bid contingency (delays due to external factors, market condition variations, etc.).

[a] Nourishment costs are rolled-up costs and include the survey, management, mobilization and demobilization, dredging/excavation, transportation, and placement. They do not include the full range of preliminary studies, monitoring, and maintenance, which can range from $200K to $300K per year both preceding and following the project. In addition, planning, permitting, and design can cost $1 million to $2 million based on the Los Angeles Harbor District estimate from Moffat & Nichol (2023). For the Cardiff nourishment effort in southern California, the dredge could produce 10,000–20,000 cy/day (Moffatt & Nichol 2023).

[b] For comparison, San Clemente of Orange County had a cost quote of approximately $15 million every 5–6 years (2025 dollars), with the federal government accounting for the remaining half for a total of $30 million. The project involves moving 200,000 cy of sediment every 5–6 years from offshore sources (Andy Hall, San Clemente City Manager, 2025, pers. comm.). In addition, for Surfers Beach in San Mateo County, a smaller, pilot project was quoted as having a construction cost of $2.4 million; it involves 100,000 cy of sediment removed from nearby material that accumulated inside Pillar Point Harbor's East Breakwater (Bob Batallio, ESA, 2025, pers. comm.).

2 ADAPTATION PATHWAYS

This section describes the high-level adaptation considerations for the entire beach. It also provides adaptation pathway graphics and descriptions for each of the three planning area sections of the City's coastline. For the entire beach, there is a description of key decisions that will influence longer-term adaptation pathway decisions related to beach nourishment and sand management. Thereafter, this section outlines immediate, near-term, mid-term, and long-term strategies—along with requisite studies, plans, and potential triggers—for the three sections of the beach described in Section 1.3:

- **The North Beach and North Dunes** area includes the Del Mar Parking Lot and adjacent dune habitat, where adaptation focuses on access maintenance, stabilization of the sand ramps, habitat restoration, and recreation.
- **The Del Mar Dunes and Central Beach** area contains the Del Mar Dune complex and the 8th Avenue sand ramp, where adaptation emphasizes maintaining emergency access, dune restoration, and infrastructure protection or realignment.
- **The South Beach and Scenic Road Pathway** area marks the southern end of the shoreline, which is characterized by narrower winter beach widths and an armored backshore. Here, adaptation efforts prioritize safe beach access, coastal erosion protection, and long-term planning for the retreat of vulnerable infrastructure and upland development.

The discussion of each area lists goals and considerations that were informed by 1) discussions with the City during site visits, and 2) community outreach events and surveys (see Task 3, Carmel Beach Socioeconomic Analysis for more information). These goals and considerations inform the City of how and where to apply the adaptation strategies. The approaches recommended in this section should remain flexible and responsive as strategies are tested, SLR science evolves, community priorities shift, and real-world conditions are monitored. Additional technical studies—including engineering feasibility and management studies—will be required before deciding which pathway approach, particularly in the mid-term, makes the most sense among the many adaptation strategies described herein.

2.1 ENTIRE BEACH

Historically, the City's adaptation strategy has been seawalls and revetments to stop erosion, and a yearly sand redistribution program to maintain beach widths and facilitate beach access. While the larger-scale sand management program was in place (up until the mid-2010s), it demonstrated effectiveness in accelerating beach width recovery and retaining more sand on the beach and sand ramps into the fall and winter. The protection approach of seawalls and revetments currently protects the backshore from existing erosion threats; however, it will have limited effectiveness as a long-term strategy, and it will eventually lead to a loss of the

beach and a corresponding loss in natural resources, coastal recreation, and economic benefits. A new set of strategies will be necessary to address these concerns, and ongoing community outreach and involvement will be essential to ensure that the process aligns with the City's goals and evolving community vision. Key adaptation goals currently include the following:

- Maintaining safe and reliable vertical and lateral beach access
- Maintaining sandy environments for recreation (e.g., volleyball) and erosion buffering
- Maintaining existing coastal protection
- Promoting community participation in adaptation planning and monitoring
- Promoting proactive planning for gradual adaptation toward nourishment, protection, or managed retreat when triggers are reached
- Improving response times to repairing damaged accessways.

In the immediate and near term, the City can continue to maintain its current infrastructure, build winter-storm readiness, and strengthen monitoring capacity. Building winter-storm readiness involves actions, such as beach and dune management, and living shoreline techniques, such as driftwood placement and dune enhancement. The strengthening of monitoring capacity actions typically includes enhancing data collection programs and integrating regular public works maintenance activities into active monitoring programs. Other priorities should also include improving public communication and outreach about coastal projects, updating key policies (like the LCP), and pursuing funding opportunities for pilot projects. This work will serve as a solid foundation for adaptive management as the City works toward mid- and long-term adaptation strategies. Many of those strategies are outlined in the beach-specific section below.

The following sections expand on questions concerning two adaptation planning mechanisms: beach and dune management and beach nourishment.

2.1.1 Beach and Dune Management

The dominant adaptation priority identified by the community was maintaining beach access and recreation. As described in Section 1.6.1, up until the 2010s, the City had an active sand management program (formerly called a sediment redistribution program) that moved sand from the foreshore to the back beach and backshore. As this program was scaled back, some noticeable changes have occurred along the beach. For instance, historical elevation data indicate a deflation in the sand ramp elevation of 1–3 ft since the sand management program was terminated. This trend suggests that access trampling and erosion have resulted in a loss of sediment from this system; it also indicates that City sand management activities have not kept up with sand loss from the ramps (Figure 27).

It is important for the City to reinvest in beach and dune management activities as an immediate and near-term adaptation strategy. There are many varieties of dune and beach management approaches (Section 1.6). In addition, a beach and dune management plan can provide clear direction on when, where, and how sand management actions can occur across the entire beach. Along the entire beach, there are unique sand management actions identified in the individual section adaptation pathways; however, there is an important component of all adaptation strategies that will require actions that allow the mechanized movement of sand on the beaches and dunes to maintain access and enhance coastal resilience.

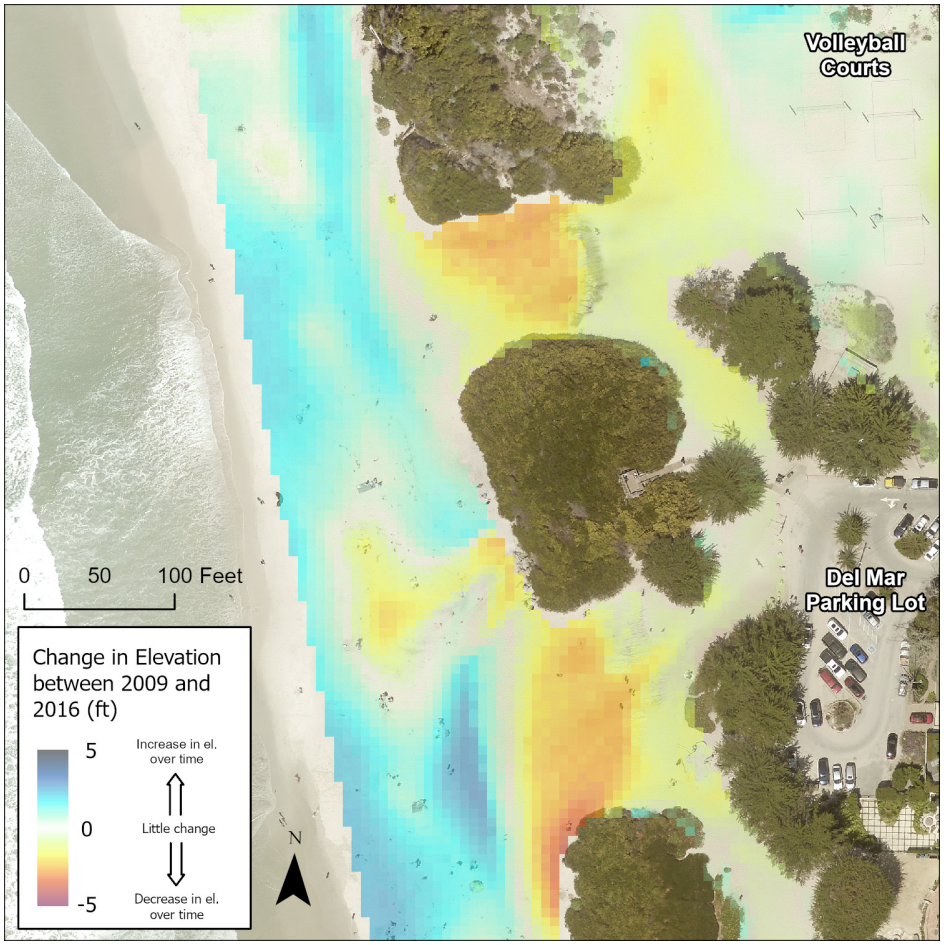


Figure 27. Elevation Change at Sand Ramps near Del Mar Parking Lot

Note: The sand ramps have experienced a deflation in elevation of 1–3 ft since 2009.

Some of the specific beach and dune management actions include the following:

- Movement of sand back onto the sand ramps
- Dune vegetation planting with guided access for dune stability and erosion reduction
- Covering of revetments

- Repair and maintenance of the 8th Avenue emergency access area
- Enhancement in the safety of the vertical access landings
- The integration of driftwood and vegetation with sand into nature-based approaches.

Beach and dune management actions will likely play a role at all stages of the adaptation pathway future to maximize access and recreation, regardless of what other mid- and long-term strategies are adopted.

2.1.2 Beach Nourishment Feasibility Study

Previous work from Phase 1, Task 2, showed that Carmel Beach functions as a closed pocket-beach system with a generally stable total sand volume. A stable sand volume does not mean the beach width stays the same all year; instead, the width changes seasonally as sand shifts. The beach widens in the summer and narrows in the winter when sand moves offshore into nearshore bars. The beach typically begins rebuilding in the spring, with the rate of recovery depending on winter wave energy. Overall, the stability of the total sand volume suggests that the long-term average beach width is also likely to remain relatively stable. This stable volume means that—even with extensive coastal armoring and a backshore facing coastal squeeze as the sea level rises—Carmel Beach could conceivably be maintained by augmenting sand into the littoral beach system.

As noted in the public engagement and described in Section 1.3, the sand quality in Carmel is unique, and the distinctive bright-white native sands (fine and quartz- and feldspar-rich) are highly valued by the community. Any potential additional sand resources must therefore match this unique grain size, color, mineralogy, and shell content. The most likely source would be nearby offshore sand deposits that have been created from the same abrasion and erosion of the Monterey Peninsula granodiorite, and these deposits will require sand source investigations. Furthermore, even if a source of sand is identified, many of the most promising offshore areas lie within overlapping regulatory jurisdictions that protect marine resources, including California Marine Protected Areas and Areas of Special Biological Significance. They also lie within the Monterey Bay National Marine Sanctuary, further complicating feasibility.

If an offshore source of sand to nourish Carmel Beach is identified, and if nourishment is deemed regulatorily feasible, then the City may be able to sustain beach width and storm-buffering capacity for a longer period, thereby preserving adaptation options like beach management, dune enhancement, and hybrid nature-based strategies. However, if nourishment from an offshore source is infeasible, the City may need to investigate other sediment sources and discuss whether having a change in beach sand quality would be preferred over potentially not having a beach at all. If all sediment-dependent strategies are removed from consideration, it would mark a significant fork in the adaptation pathway, and the City would need to consider a range of erosion-reduction, backshore-protection, and earlier managed-retreat or relocation strategies.

To better understand potential sand sources, an initial analysis using available scientific data and published reports was conducted. Initial findings show that some offshore areas in Carmel Bay may contain sediment with a compatible texture and mineralogy (see the areas in green between a depth of 10m and 30m in Figure 28). Details of this initial screening are further described in Appendix C.

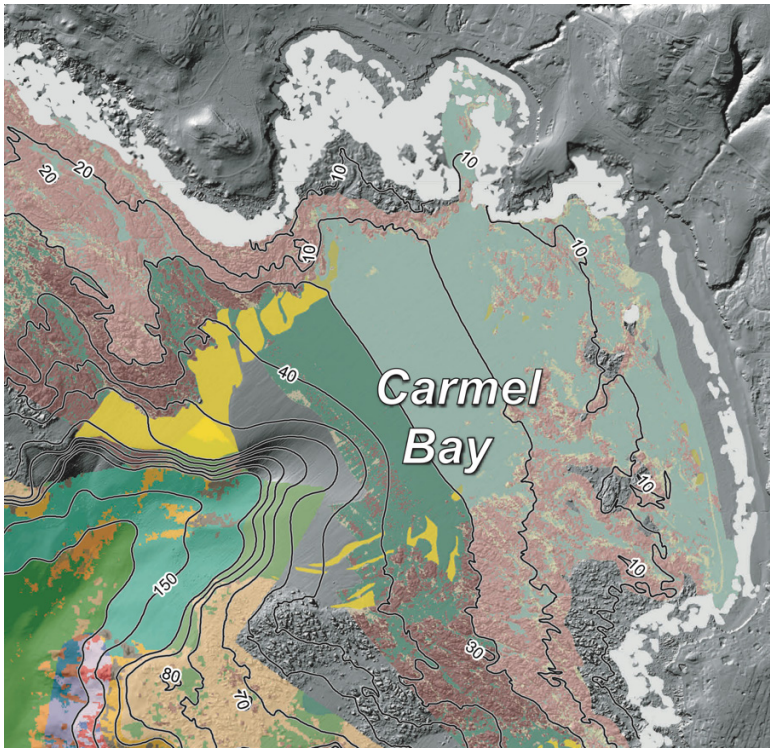


Figure 28. Seafloor Character Offshore of Monterey Map Area, California (Johnson et al. 2016)

Identifying a suitable sand source and determining whether it can be legally obtained and placed is a critical step in the process. To confirm whether a compatible and permissible source exists, more detailed sampling and sub-bottom profiling will be required. Close coordination with regulatory agencies will also be essential to understand the feasibility of both acquiring the sand and placing it on the beach. It is also possible that sand from other locations could meet the necessary criteria and support alternative placement methods, but these options would need further evaluation as well.

Note that with accelerating SLR, beach nourishment will eventually reach physical and financial limits, and the consideration of different sand sources or managed retreat will be necessary.

2.2 NORTH BEACH AND NORTH DUNES

North Beach and the adjacent North Dunes support the highest levels of public use of the beach. This area supports the largest public parking area along Carmel Beach, and it also contains the City's largest dune complex. The Del Mar Parking Lot functions as the primary

access point, linking beach goers via sand ramps (Figure 29). The shoreline reach is popular for family visits and ocean-viewing, and it also supports organized and informal beach sports, such as volleyball. The Del Mar Parking Lot is at the end of Ocean Avenue, near downtown, and is the location most used by out-of-town recreators for beach access and the most accessible location to public transit.



Figure 29. Del Mar Parking Area and Sand Ramps (Kenneth & Gabrielle Adelman, Coastal Records Project 2024)

Two private properties are located at the north end of this area, and existing armoring structures in front of those parcels are maintained by the owners (Figure 30). Future actions will require coordination with those owners on maintenance responsibilities, design standards, and consistency with public access goals.



Figure 30. North End of Subarea with Two Private Properties off Carmel Way (Kenneth & Gabrielle Adelman, Coastal Records Project 2024)

Within North Dunes is a stormwater outfall and seawall (Figure 31). This structure has been deteriorating and needs improvement.



Figure 31. 4th Avenue Seawall and Outfall

Stormwater runoff from the Del Mar Parking Lot and adjacent uplands contributes to erosional scour; small improvements to grading, landscaping, and stormwater could reduce these impacts. Wind exposure mobilizes sand from the North Dunes and sand ramp, then sends sand into the parking lot, which is a concern for visitors and for city maintenance. The City has noted that the Acacia plant acts as a wind barrier, and any future work should consider impacts on wind exposure (Culver 2025, pers. comm.).

An offshore rock formation emerges near the mouth of Pescadero Canyon and offshore of the 4th Avenue stairway. This feature can affect local wave focusing and currents during storms (Section 1.6.2).

Primary amenities for this section are as follows:

- Four beach volleyball courts
- An ocean-viewing platform with signage near the Del Mar Parking Lot
- Sunbathing areas and spaces for family-oriented beach use
- The Del Mar Parking Lot, with 122 parking spaces (Shonman and D'Ambrosio 2003)
- Coastal access at multiple sand ramps and one beach access stairway at 4th Avenue
- A restroom at the Del Mar Parking Lot
- Ecologically beneficial areas of the North Dunes, including sand storage areas, habitat for native vegetation and birds, and natural buffering areas for storm waves.

2.2.1 Adaptation Goals and Considerations

Adaptation goals for North Beach and North Dunes are focused on sustaining both recreational and ecological values while protecting beach access and the parking lot from erosion. Maintaining a balance between the needs of visitors and the preservation of ecological function and wildlife habitat in North Dunes should remain a priority. Residents have expressed support for maintaining wide beach areas, and future planning should weigh these preferences against practical limits in sand availability, staffing and equipment availability, and long-term maintenance costs.

A long-term goal should be to preserve and maintain the viewing platform and beach access under future SLR conditions. The dunes could be managed as a dynamic and living system, one that is capable of migrating inland with erosion. To maintain a scenic overlook at this location, the viewing platform can be designed to be movable, so it can easily retreat as the dune crest moves inland. The tops of the sand ramp should be managed as a repository of sand that can make its way down the ramps and onto the beach. Under long-term threats from erosion, parking and infrastructure should be relocated inland. If parking spaces are reduced beyond an acceptable threshold, the City may want to investigate alternatives, such as remote parking with shuttles.

The key adaptation goals are two-fold:

- Enhancing dune habitat in the North Dunes through restoration efforts, native vegetation planting, and fencing while promoting community participation in dune restoration and monitoring
- Protecting the Del Mar Parking Lot and associated infrastructure from erosion.

The strategies are described below and presented graphically at the end of this section in Figure 33.

2.2.2 Immediate Strategy

The immediate time frame should focus on maintaining current beach recreational amenities and dune conditions while addressing sand ramp deflation and the condition of the 4th Avenue outfall and seawall. Deflation of the sand ramps occurs seasonally as visitors trample sand downslope, and every year, the City pushes sand back onto the ramps. The recommended management actions in the immediate term are intended to extend the life of existing infrastructure and ensure continued recreational uses. The strategy outlined below represents the first step in the adaptation pathway for North Beach and the North Dunes and provides the foundation for either future nourishment, hybrid protection, or retreat strategies as SLR accelerates:

- Guide access and maintain sand on existing sand ramps to sustain safe beach access and reduce deflation of the sand ramp.
- Restore and expand native dune vegetation to improve sand trapping and dune stability, and implement small-scale public access improvements in the North Dunes to guide visitors away from sensitive vegetation areas.
- Repair and improve the 4th Avenue outfall and seawall to improve drainage performance and reduce the chances of failure in the future. Consider the current redesign to allow for future alterations, such as adding a vertical access point, if the adjacent sand ramp is eroded or is no longer a viable access point.
- Develop a coastal armoring monitoring and maintenance plan that includes conducting regular inspections of the 4th Avenue seawall and revetments near the stormwater outfalls to assess conditions and implement restorative actions promptly.

This strategy's triggers are as follows:

- Depth of sand at the sand ramps and exposure of the underlying consolidated material
- Bedrock exposure
- Percentage of time the revetments are exposed
- Erosion scarp at the toe of the sand ramp
- Conditions relative to an established baseline for summer beach widths.

Aside from the repair of the 4th Avenue outfall and seawall, these actions are low cost, and all are achievable in the immediate term. They are intended to maintain public access and dune stability while building readiness for future adaptation measures that may involve nourishment, protection, or relocation of infrastructure.

2.2.3 Near-Term Strategy (1-ft SLR)

The near-term phase builds on current maintenance activities by introducing small-scale opportunistic nourishments at the top of the sand ramps. It also involves monitoring—via the installation of staff plates to gauge sand depths—and pilot efforts for driftwood and vegetation as part of nature-based solutions. These actions aim to protect the habitat of the North Dunes, maintain safe beach access, and collect the data necessary to guide future adaptation. The focus is on 1) proactive, low-cost interventions that enhance the natural system's ability to recover from seasonal erosion while preparing for a potential larger nourishment program, or 2) alternative hybrid protections for higher sea levels.

The near-term strategy is as follows:

- Opportunistically nourish the top of sand ramps using locally available sand to maintain safe and functional beach access (Figure 32).

- Start a sediment management program to offset seasonal sand loss and sustain beach widths.
- Implement living shoreline features that integrate woody material to enhance sand trapping and dune toe protection.
- Design and construct a movable viewing platform that can be relocated or elevated as dune morphology changes.
- Develop a monitoring program to better understand beach visitation and seasonal beach width dynamics.

This strategy's triggers are as follows:

- Availability of suitable local sediment sources for opportunistic nourishment
- Depth of sand at the sand ramps
- Bedrock exposure duration
- Dune vegetation coverage levels below a target density
- Average summer beach widths narrowing beyond 75 percent of baseline conditions
- Erosion scarp height of the sand ramp beyond safety or design thresholds
- A distance between the viewing platform and the dune crest that indicates progressive dune retreat.

These near-term measures provide a foundation for data-driven management and adaptive decision-making. Aside from the design and construction of a new viewing platform, they are relatively low-cost to implement and will maintain the recreational importance of this area, and they will improve the City's understanding of beach width dynamics, supporting timely transitions to larger-scale interventions for SLR adaptation.



Figure 32. Sand Ramps at Del Mar Parking Lot (left); Underlying Consolidated Sand and Sandstone to Emerge with Sand Ramp Deflation (right)

Note: The placement of sand at the top of the existing sand ramps avoids many of the permitting and regulatory hurdles with sand delivered to the beach during erosion events.

2.2.4 Mid-Term Strategy and Alternatives (2-ft SLR)

The mid-term phase represents a transition point where a reduction in beach widths may mean that the existing sand ramps may no longer provide sufficient functionality. This period focuses on evaluating long-term sustainability, identifying when to phase away from sand ramp maintenance, and implementing either nourishment to widen the beach and maintain the sand ramps or some other beach access strategy.

The mid-term strategy is as follows:

- Determine when to abandon the sand ramps as a coastal access strategy based on cost, maintenance effort, and safety thresholds.
- Establish clear triggers for ongoing maintenance cost and the level of effort to ensure cost-effective adaptation.

As a partial alternative, there is a retreat strategy that can be employed in the mid-term known as Alternative 2A. Early retreat is an option for the North Dunes part of this section, as there is limited vulnerable upland development in the mid-term horizon. This alternative shifts away from the continued sediment placement and management of the sand ramps, and it shifts towards an engineered approach, such as beach access stairways or a ramp. The strategy for Alternative 2A is to investigate and prepare for alternative coastal access methods (e.g., engineered stairways or ramps). Triggers for initiation are as follows:

- Depth of sand on the sand ramps
- Bedrock exposure duration

- Average summer beach widths narrowing beyond 50 percent of baseline levels
- Erosion scarp heights of the sand ramp beyond safety or design thresholds
- Frequency of waves reaching the dune toe
- Cost of repairs and maintenance of the beach access, including the sand ramps and the 4th Avenue Beach access stairs.

The retreat strategy moves away from sand ramps and toward an engineered beach access. This pathway emphasizes reduced sand management, which may come with high upfront costs, but lower ongoing costs associated with maintaining sand on the sand ramps.

Similarly, there is another alternative, Alternative 2B, that uses beach nourishment. This strategy focuses on maintaining a wide, accessible beach and sustaining the sand ramps through sediment and vegetation management. The strategy is as follows:

- Nourish the beach using suitable sand sources to sustain sand volumes and beach widths to maintain recreational and protective functions of the beach.
- Manage and restore dune vegetation to stabilize nourished sand.
- Integrate woody material for living shoreline dune toe protection.

Beach nourishment has high upfront and ongoing costs that reflect dredge, transport, mobilization, demobilization, and permitting expenses. This option sustains current beach widths and recreational benefits but requires ongoing financial commitment and consistent monitoring to ensure effectiveness.

Alternative 2B's triggers for initiation are as follows:

- An indication from state or federal regulations for a regulatory pathway for nourishment
- Suitable sediment sources that make nourishment feasible
- Average summer and winter beach widths narrowing beyond performance thresholds
- Difficult or expensive maintenance of sand ramps, indicating accelerated erosion and a need for imported sand.

Finally, Alternative 2C is a protection alternative strategy to delay and reduce seasonal beach scouring. This option focuses on the dissipation of wave energy and protection of the upland development. The strategy is as follows:

- Prioritize the sand ramp maintenance for as long as feasible and continue opportunistic nourishment at the top of the ramps if sediment is naturally available.
- Implement living shoreline features while incorporating woody material for sand ramp protection. When this action is no longer feasible, implement an engineered strategy for beach access.

- Evaluate and consider wave energy dissipation measures, including nearshore reefs or substrate enhancement.
- Consider vertical access stairs or a similar solution if the underlying cliffs become exposed.

The protection and wave dissipation strategy would also incur high upfront costs, but these costs could be highly variable and dependent on wave energy dissipation strategies, if any. The implementation of nearshore reefs is expensive, reflecting high permitting, design, and construction expenses. Smaller-scale wave dissipation strategies, such as shore platform enhancement, would be less expensive.

Triggers for Alternative 2C are as follows:

- Depth of sand on the sand ramps
- Bedrock exposure duration
- Feasibility and performance of wave dissipation approaches
- Average summer and winter beach widths declining below critical thresholds
- Increasing frequency of wave exposure at the dune toe
- Erosion scarp height beyond designed safety levels.

2.2.5 Long-Term Strategy (4-ft SLR)

The long-term SLR horizon anticipates significant shoreline change and an eventual tipping point where ongoing maintenance of existing infrastructure and sand management practices may no longer be sustainable. At this point, planning for retreat should become the priority. The City will also want to work collaboratively with private property owners at the north end of this section to identify potential retreat options for at-risk areas of their parcels (these larger lots may allow for inland retreat within the same parcel). At this horizon, the City may consider implementing open-space improvements in the North Dunes to accommodate reduced beach widths and provide safe areas for recreation in the winter (when beach widths are narrow).

The long-term strategy is as follows:

- Plan for the retreat of at-risk areas within the Del Mar Parking Lot area, including associated upland infrastructure, such as lighting, electrical systems, irrigation networks, and the two underground cisterns.
- Develop plans for alternative or emergency beach access at Del Mar Avenue if the 8th Avenue access location is no longer a viable option.
- Consider offsite parking with shuttles to compensate for lost parking in the Del Mar Parking Lot.

This strategy has the following triggers:

- Distance between the parking lot and an established dune crest decreasing below a defined safety or slope stability threshold
- Rising costs of sand management and maintenance to levels above feasible budget constraints
- Summer beach widths narrowing to 25 percent of the baseline
- Bedrock exposure duration
- Winter beach width narrowing to a threshold
- Increasing frequency of overtopping at the north end of the beach, which threatens private homes.

The long-term strategy has high upfront costs. These expenses reflect coordinated capital investment for infrastructure relocation and site transformation. As a benefit, however, this strategy results in reduced ongoing maintenance costs, as less infrastructure is at risk. These actions mark a transition toward managed retreat, prioritizing safety in response to long-term SLR.

NORTH BEACH & NORTH DUNES

PHASE		STRATEGY	TRIGGER(S) TO INITIATE STRATEGY	UPFRONT COST / MAINTAIN
CURRENT	0	• Reduce sand ramp deflation and guide access • Repair and improve the 4th Ave outfall and seawall • Monitor and maintain existing riprap near the Del Mar Parking outfall	• Depth of sand at the sand ramps • Bedrock exposure • Percentage of time revetment is exposed • Condition of the 4th Ave outfall and seawall • Erosion scarp at toe of sand ramp • Summer beach widths - baseline monitoring	$$ - $$$ / Low
NEAR-TERM	1	• Opportunistically nourish the top of sand ramps • Seasonal beach and sand management • Implement NbS including the integration of woody material as dune toe protection • Trap sand and guide access with vegetation • Design and implement a movable viewing platform	• Availability of suitable sand sources • Depth of sand on the sand ramps • Bedrock exposure duration • Coverage of dune vegetation • Summer beach widths - 75% of typical • Erosion scarp at toe of sand ramp • Distance between viewing platform and dune crest	$ - $$ / Med
MID-TERM	2A	**Retreat** • Transition from sand ramps to engineered beach access stairways / ramp at Del Mar Ave	• Availability of suitable sand sources • Depth of sand on the sand ramps • Bedrock exposure duration • Summer beach widths - 50% of typical • Erosion scarp at toe of sand ramp • Frequency of waves reaching dune toe • Cost of repairs related to beach access	$$$ - $$$$ / Med
	2B	**Beach Nourishment** • Nourish the beach and sand ramps		$$$$+ / High
	2C	**Protect** • Consider wave energy dissipation including near-shore reefs or shore platform enhancement		$$$$+ / High
LONG TERM	3	**Retreat** • Manage the retreat of vulnerable portions of the Del Mar Parking Lot and associated infrastructure and relocate upland development to maintain beach widths • Plan for future emergency beach access at Del Mar Ave	• Distance between parking lot and the dune crest • Costs of repairs • Bedrock exposure duration • Winter beach width narrows to a threshold • Summer beach widths - 25% of typical	$$$$ / Low

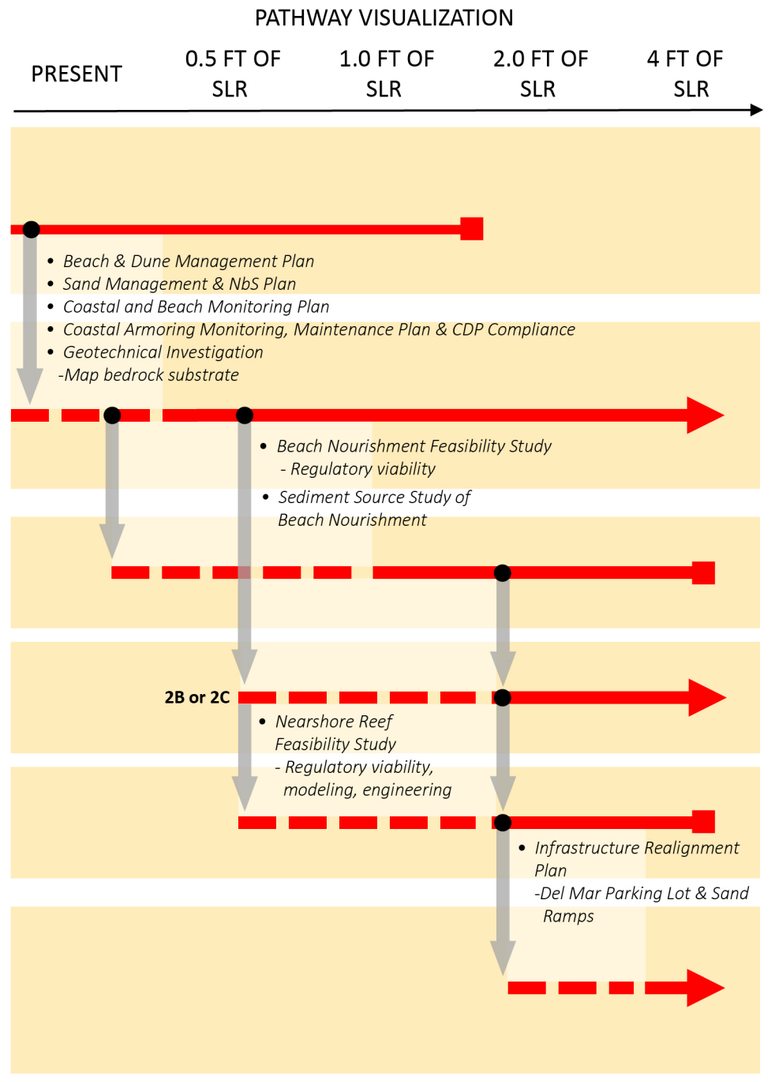


Figure 33. Adaptation Pathway for North Beach and North Dunes

2.3 DEL MAR DUNES AND CENTRAL BEACH

Located in the middle of the Carmel Beach system, the Del Mar Dunes and Central Beach area connects the wide, recreational beaches of the north with the narrower, armored shoreline to the south. This area provides both significant ecological and recreational value, and the dunes provide natural protection for upland infrastructure, including wastewater utilities. The 8th Avenue access location serves as a key emergency vehicle access location, and it provides pedestrian access to the beach. It is also one of the most popular beach access locations for local residents.



Figure 34. Del Mar Dunes and 8th Avenue Sand Ramp and Stairs (Kenneth & Gabrielle Adelman, Coastal Records Project 2024)

2.3.1 Adaptation Goals and Considerations

Future adaptation in the Del Mar Dunes and Central Beach area should balance dune restoration and habitat protection with the need to maintain safe beach access and protection of critical infrastructure. The goals are threefold:

- Maintain, restore, and enhance the Del Mar Dunes to improve sand retention, improve habitat quality, and create a natural erosion buffer.
- Prioritize nature-based solutions that use vegetation, driftwood placement, and sand management to reduce wave energy at the backshore and stabilize the back beach.
- While working with CAWD, consider the projected exposure to wastewater infrastructure, including exposure to the pump station and conveyance pipe.

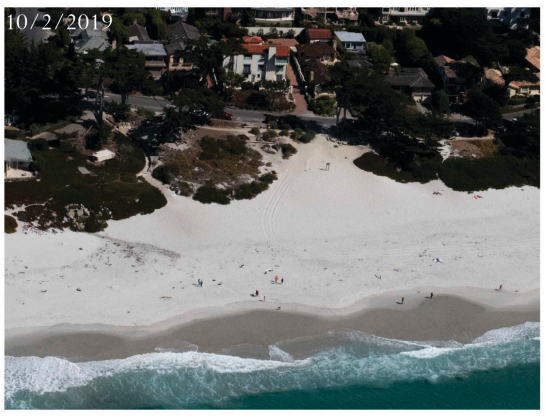
The strategies for these goals are illustrated in Figure 37 and described in the following sections.

Private property owners front the Del Mar dunes in this area, which introduces some challenges for adaptation planning, particularly for water and wastewater services. Coordination with these landowners will be essential to ensure that adaptation strategies are compatible with private property rights. Future adaptation actions—such as dune enhancement, armoring, or utility relocation—should be designed in consultation with private property owners while progressing broader shoreline resilience goals and community visions for the beach.

The 8th Avenue sand ramp has historically been the primary access for emergency services. This access has experienced significant erosion following major El Niño events in 1983–1984, 1997–1998, and in more recent years. Current damages, sustained in January 2023, have created eroded conditions such that the ramp no longer serves as a location for emergency vehicle access. A visual storyline of the loss of this access point is documented in Figure 35.

8th Ave Sand Ramp Storyline

Pre-Winter Storm Conditions



8th Ave sand ramp in 2019



Run out at the bottom of the 8th Ave sand ramp looking south



Run out at the bottom of the 8th Ave stairs looking southwest



Large Winter Storms Arrive Winter of 2022/23



Post-Winter Storm Conditions



Significant erosion post-storm events in the spring of 2024



Scarping still present in the fall of 2024



8th Ave Sand Ramp post-storm event in the fall of 2024

Figure 35. 8th Avenue Sand Ramp Storyline, 2019–2024

2.3.2 Immediate Strategy

Immediate actions should focus on restoring emergency access and functionality at the 8th Avenue sand ramp for continued, safe use under current conditions. Repair of this accessway would likely qualify under emergency permit conditions for the CCC and may also be a CDP decision at the City's discretion under its existing LCP.

The strategy is as follows:

- Regrade and repair the 8th Avenue access location to restore safe emergency and maintenance access on historical alignment. Perform sand management and sediment redistribution to ensure continued, safe use and reduce potential future beach scour and erosion.
- Monitor the emergency access ramp to document damages and the level of maintenance effort to maintain emergency access.
- Monitor and maintain the existing revetment near the 8th Avenue outfall to ensure structural integrity.

Triggers to initiate this strategy are as follows:

- Depth of sand at the sand ramps
- Bedrock or revetment exposure duration
- Percentage of time the revetment is exposed
- Erosion scarp at the toe of the sand ramp
- Establish baseline for summer beach widths.

2.3.3 Near-Term Strategy (1-ft SLR)

The Del Mar Dunes area will face increasing exposure to erosion and wave impacts that threaten both the 8th Avenue emergency access location and the wastewater infrastructure. Near-term actions should focus on restoring the 8th Avenue access location until damages recur and the City spends what is deemed an excessive amount on maintenance.

Pending the City's evaluation of the potential for beach nourishment, this area may warrant further technical evaluation of erosion causes and an alternative plan to protect or realign the emergency beach access location. This could involve inland realignment of the sand ramps (Figure 36). Any improvements in this area should also implement public access improvements and restoration of vegetation to improve sand trapping and stabilize the dunes.

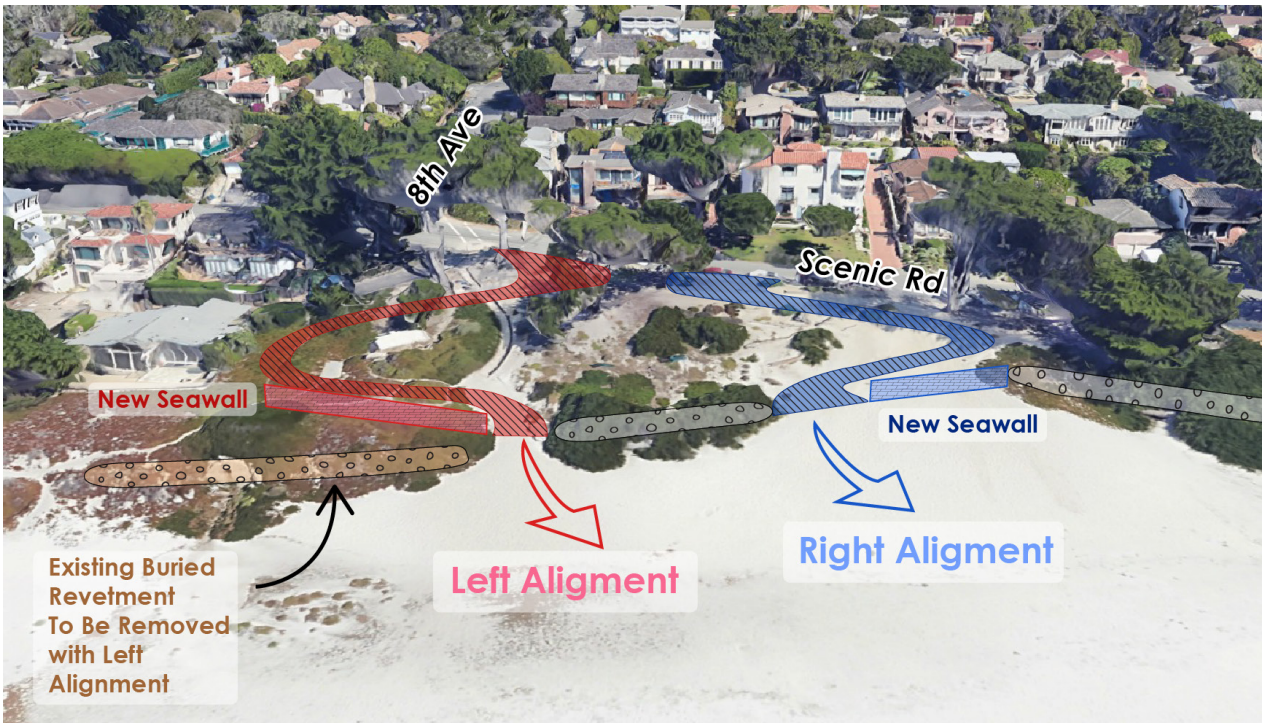


Figure 36. Possible Alternative Alignments for 8th Avenue Emergency Access Location

Notes: Red represents moving the alignment 200 ft to the north, which would serve a dual purpose of providing beach access and protecting the wastewater pump station in place, but this option would require movement of the existing coastal access stairway. Blue represents the alignment that would use the existing sand ramp location but would be stepped back to limit exposure to coastal erosion.

A wastewater pipe and pump station are also at risk in this area in the mid-term horizon. Planning for the protection or relocation of this critical infrastructure will involve significant effort and require substantial lead time, and it will need to involve CAWD and targeted outreach to nearby Scenic Road property owners. Early in this process, the City should determine community preferences on whether to 1) pursue armoring to protect the wastewater line and pump station, or 2) retreat the infrastructure and transition to ejector pumps that connect homes to the wastewater line upslope on Scenic Road. Throughout this process, potential funding sources should be investigated, and responsibilities should be clarified for how costs would be shared among property owners, the City, and CAWD.

The near-term strategy is as follows:

- Maintain an improved 8th Avenue emergency and vehicular access location that provides safe and reliable coastal entry. If triggers are met, plan, design, and implement an improved, more resilient configuration for the 8th Avenue access location.
- Use seasonal sediment management to maintain beach widths and support dune recovery.

- Implement nature-based solutions, such as integrating dune toe protection to reduce erosion and vegetation restoration to enhance bluff or dune stabilization.
- Work with CAWD to begin the investigation for the protection or potential retreat of wastewater infrastructure behind the Del Mar Dunes.

Triggers to initiate the near-term strategy are as follows:

- Bedrock exposure duration
- Distance between the wastewater pipe and the dune crest reducing beyond acceptable thresholds
- Depth of sand at the sand ramp
- Percentage of time the revetment is exposed
- Average summer beach widths narrowing beyond 75 percent from baseline monitoring
- Erosion scarp height of the sand ramp exceeding safety or design thresholds
- Damages and costs of repairs at the 8th Avenue access location.

2.3.4 Mid-Term Strategy (2-ft SLR)

In the mid-term, increasing dune erosion and wave exposure are expected to threaten the wastewater infrastructure under the Del Mar Dunes. At this stage, proactive coordination with affected homeowners and agencies becomes essential to identify feasible adaptation choices and establish clear trigger points for transitioning from business as usual to beach and dune nourishment or protection.

There are two viable mid-term strategies for this area; they are described below:

- **Beach Nourishment Alternative:**
  - Maintain existing 8th Avenue sand ramp access location or examine alternative alignments (as illustrated in Figure 36).
  - Implement nature-based solutions, such as dune toe stabilization and bluff reinforcement, to support habitat and natural sediment exchange during the transition period.
- **Protection Alternative:** Implement armoring to protect the wastewater line to extend the useful life of the wastewater line.
  - Extend and raise the crest of the existing revetment to protect the wastewater line and pump station.
  - Plan for and implement additional armoring where the wastewater line is vulnerable.

  - Design and implement an integrated vehicular access ramp with coastal protection for infrastructure and public access (as illustrated in Figure 36).

The protection alternative will delay the need for retreat; however, it involves high upfront costs and ongoing maintenance to remain effective under increasing SLR. It is intended as an interim measure, and the implementation of new armoring will require substantive regulatory efforts that likely need to be combined with a future removal and retreat strategy (or sunset clause). If protection is deemed infeasible or too costly, the City may consider retreat of the wastewater infrastructure and transition to ejector pumps, as described in long-term strategy section below.

Triggers to initiate either a nourishment or protection strategy are as follows:

- Findings from a preliminary study, as well as from public and stakeholder outreach, that indicate a direction towards protection, nourishment, or alternatively, retreat
- Feasibility and availability of funding these strategies
- Depth of sand on the sand ramp
- Bedrock exposure duration
- Average summer beach widths narrowing beyond 50 percent from baseline widths
- Erosion scarp height of the sand ramp beyond safety or design thresholds
- Frequency of waves reaching the dune toe
- Frequency of overtopping of seawalls
- Costs of repairs related to beach access
- Damages to 8th Avenue access.

In summary, mid-term adaptation strategies represent a decision point between two fundamentally different pathways that are partially dependent on the feasibility of beach nourishment: the beach nourishment alternative represents maintaining wide beaches and using nature-based solution to protect existing infrastructure, and the protection alternative represents extending protection measures to maintain the current infrastructure so long as it is feasible. If neither of these strategies is deemed feasible, then the retreat strategy outlined in the next section should be evaluated. The preferred approach should be determined through stakeholder engagement and a cost–benefit evaluation.

2.3.5 Long-Term Strategy (4-ft SLR)

In the long term, continued SLR and dune retreat are expected to significantly reduce beach widths, and the Del Mar Dunes may experience significant erosion. At this stage, adaptation measures should transition toward managed retreat for long-term resilience as well as the reconfiguration or relocation of the 8th Avenue coastal access location and Scenic Road.

The retreat strategy provides long-term resilience and reduces future maintenance liabilities but requires significant early planning and community support. In addition, it will have a high upfront cost associated with higher logistical efforts. The effort will require a reliance on coordinated funding, property-level agreements, and technical feasibility studies for the ejector pumps.

The long-term strategy is as follows:

- If dune erosion threatens the wastewater infrastructure, and protection strategies are not viable, work with CAWD and property owners to plan and implement ejector pumps to relocate wastewater service upslope to Scenic Road. Either retire the wastewater equipment in place or remove the existing pipes and pump station infrastructure from the dunes.
- Implement a managed retreat plan for the private properties backing the Del Mar Dunes. Identify at-risk parcels, establish appropriate trigger points for action, and coordinate with property owners on relocation or structural modification options that preserve parcel homes while reducing the exposure to erosion to an acceptable risk threshold.
- Prioritize and maintain emergency access to the beach. If the 8th Avenue emergency vehicle access location becomes increasingly threatened by coastal erosion, move the emergency vehicle access location to the Del Mar Parking Area.

Triggers to initiate this strategy are as follows:

- Distance between the upland development and infrastructure and the dune/scarp crest reaching a defined distance, allowing for the implementation of the select strategy
- Maintenance or repair costs of the 8th Avenue coastal access location becoming unsustainable
- Bedrock exposure duration
- Frequency of waves overtopping the armoring
- Summer beach widths narrow to 25 percent of the baseline width.

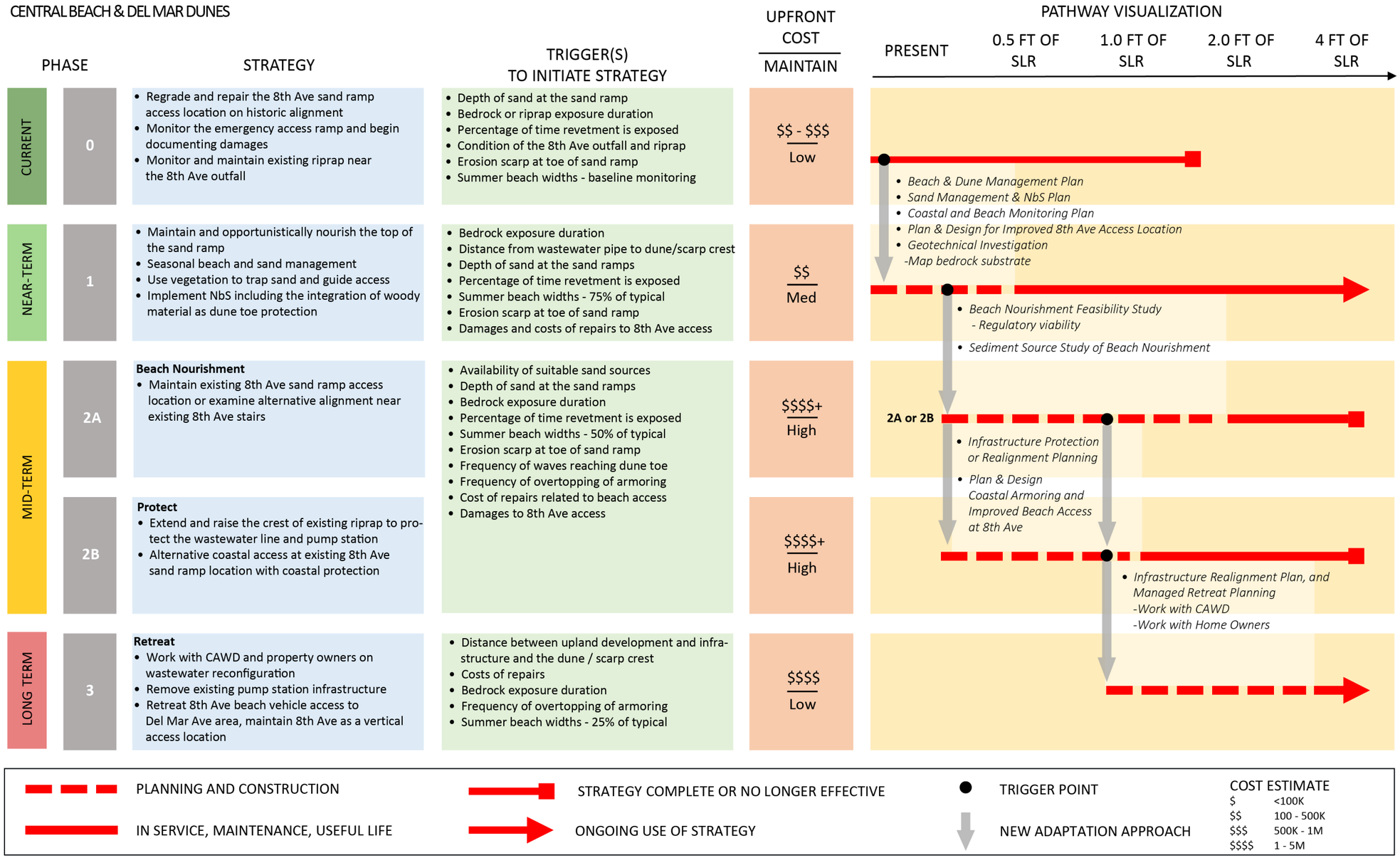


Figure 37. Adaptation Pathway for Del Mar Dunes and Central Beach

2.4 SOUTH BEACH AND SCENIC ROAD

The South Beach area transitions to a narrow beach that is backed by armored coastal cliffs (Figure 38). This area has historically seen the widest fluctuations in beach widths following major storm events, and seasonal sand loss in the winter regularly exposes the underlying sandstone and mudstone geology (also called *shore platforms*). When the beach is removed, wave energy can splash above the current seawall crest elevation, thereby wetting the erodible softer terrace deposits and driving longshore currents that accelerate erosion and scour the base of seawalls and revetments. These eroded winter conditions limit lateral access along the beach, particularly around the 12th Avenue and 13th Avenue rocky point outcrops. However, the eroded winter beach condition also exposes a series of tidepools that draws locals and residents alike. Collectively, these seasonal changes and recreational, scenic, and ecological qualities make South Beach an important community and environmental asset.



Figure 38. South Beach Area between 10th Avenue and 13th Avenue (left); South Beach Area between 13th Avenue and Martin Way (right) (Kenneth & Gabrielle Adelman, Coastal Records Project 2024)

The Scenic Road corridor atop the cliffs above South Beach is one of the most heavily visited and distinctive parts of Carmel Beach (Figure 39). It provides an important public amenity with opportunities for recreation, relaxation, and coastal viewing, and it has numerous beach access locations. The restroom at Santa Lucia Avenue supports year-round public use, and the free streetside parking along Scenic Road makes this segment easily accessible for both residents and visitors. There are parking spaces for 127 vehicles on Scenic Road between 8th Avenue and Martin Way (Shonman and D'Ambrosio 2003).



Figure 39. Narrow Road Width of Scenic Road Causing Use Challenges between Vehicle Traffic, Parking, and Pedestrians

The history of Scenic Road traces the history of coastal bluff erosion at Carmel Beach. When the road was first constructed, it allowed vehicles to travel in both directions. Starting in the 1960s, vehicles driving between 8th Avenue and Santa Lucia Avenue were restricted to just one-way southbound travel. In 1988, following a large project to improve stormwater drainage and coastal access following the El Niño storms of 1982/83, the road was further narrowed to provide more space for the Beach Bluff Pathway and landscaping (Shonman and D'Ambrosio 2003). In the future, the pressures from coastal erosion, public use, and desires for lateral and vertical access for both pedestrians and vehicles will necessitate creative thinking.

2.4.1 Adaptation Goals and Considerations

The goals for the South Beach segment focus on maintaining safe and reliable public access, protecting vulnerable coastal infrastructure, and preserving the recreational and scenic value of the shoreline and Scenic Road.

As seasonal sand levels fluctuate, the beach often narrows or even disappears entirely during the winter months (Figure 40). Adaptation efforts should focus on reducing the wave energy and longshore currents while retaining the area's aesthetic and recreational qualities. Maintaining and improving stormwater drainage infrastructure, as well as reducing wave overtopping at the seawall, should be prioritized because saturated soils can accelerate bluff erosion. The goals are threefold:

- Protect and maintain the coastal armoring and plan and implement improvements (i.e., strategies) to reduce both scouring currents and wave overtopping.
- Maintain the Scenic Road Beach Bluff Pathway.
- Maintain both vertical and lateral beach access for as long as feasible.



Figure 40. Examples of Sandstone Impeding Lateral Access When the Beach Is Scoured in the Winter

The South Beach segment presents several key considerations that will shape future adaptation and management strategies. Historically, the revetments along this portion of the shoreline were seasonally covered with sand through the City's sand redistribution program. Community feedback has indicated a preference to continue this program because sand-covered rock improves the recreational experience and maintains the natural visual character of the beach. Some of the riprap is over-steepened and needs maintenance to avoid injuries or structural failure.

The strategies for this area are illustrated in Figure 43 and detailed below.

2.4.2 Immediate Strategy

Coastal access stairways have experienced significant damages in the past two winter storm seasons, leading to stairway closures. As stairways are repaired, the City should design and implement strategies to remedy the drop-offs or gaps at the bottom of stairways. These gaps are a source of concern, as scouring can make beach access difficult, even when stairs are still safe for use (Figure 41).



Figure 41. Gap at Bottom of 12th Avenue Stairs (Easton Geology 2016)

The immediate strategy is as follows:

- Fix stairways that are currently closed and implement stairway improvements, including wave energy deflectors and safe landings at the base of stairways.
- Monitor and maintain coastal armoring, stormwater infrastructure, and stairways.
- Survey the extent and elevations of the shore platforms and geology underlying the beach at the end of the winter, during beach scoured conditions.
- Restore bluff vegetation and control access.

2.4.3 Near-Term Strategy (1-ft SLR)

In the near term, the Scenic Road Beach Bluff Pathway and utilities (e.g., the water line running under Scenic Road) will become increasingly threatened by erosion. Some of the areas most vulnerable to erosion and overtopping are at the southern end of the beach by Martin Way, and at the lower-lying areas from 8th Avenue to 11th Avenue. In addition, beach width reductions will lead to longer periods of lateral access constraints around the headland at 12th Avenue, where the underlying sandstone can create a barrier along the beach.

As existing coastal access stairways are increasingly threatened by beach scour and storm wave exposure, the City should develop a coastal public access improvement plan that studies both horizontal and vertical beach access. This plan should help prioritize strategies for each

coastal access location and a set of triggers for each, such as ongoing repair costs of stairways and sand ramps, the depth of sand at the sand ramps, and summer beach widths. To improve horizontal beach access, strategies may include building steps along the backshore (which traverses headlands) and obstructions for continuous horizontal beach access. For vertical beach access, possible strategies may include the improvement, removal, and relocation of stairways as well as the transition to temporary or retractable stairways that are installed in the summer and removed in the winter. This may include consolidating beach accessways or integrating improvements such as wave/current deflectors. These efforts will be part of ongoing community discussion and consultation with CCC. In addition, depending on the feasibility of nourishment (sand source and regulatory) in the mid-term horizon, there are forks in the adaptation pathway that would inform the timing of these efforts.

To mitigate the impacts of nearshore wave energy and lateral scouring currents, the City should also study the potential of shore platform enhancement, low-crested structures, sand retention structures, or current deflectors where existing headlands and the substrate would make them effective (Figure 42). This study can build off geotechnical investigations and requires a pilot program to test the effectiveness of these methods.

In summary, the near-term strategy is as follows:

- Add public access improvements into the Coastal Access and Recreation Element that is informed by public outreach.
- Conduct seasonal beach and dune management to manage summer beach width recovery and winter preparedness.
- Implement a pilot program for shore platform enhancement, low-crested sand retention structures, or current deflectors. These solutions would be unique to Carmel Beach, and further study would be required.
- Through public outreach efforts and discussions with City officials, discuss the acceptance of seawall design aesthetics, including the continued use of golden granite rock or other alternatives.
- If flooding triggers are reached, implement floodproofing to the public restroom on the bluffs at Santa Lucia Avenue.
- Extend and raise the crest of existing armoring as needed.



Figure 42. Former Stone Stairway near 12th Avenue, Remnants of Which Run Perpendicular to Backshore

Note: If built out further into the shore platform, this type of structure could function to disrupt lateral scouring currents.

The triggers to initiate this strategy are as follows:

- Repair and maintenance costs for beach access and armoring
- Distance from the Scenic Road Beach Bluff Pathway to the bluff edge, accounting for bluff face erosion and soil loss in areas where the bluff edge is adjacent to the pathway
- Summer beach recovery reduction and winter bedrock exposure duration
- Frequency of beach access closures
- Frequency of overtopping of revetments and seawalls
- Summer beach widths narrowing beyond 75 percent from baseline monitoring.

2.4.4 Mid-Term Strategy (2-ft SLR)

In the mid-term, without beach nourishment, there will be a significant reduction in summer beach width recovery and increased wave exposure during winter storms. This reduction is expected to create significant erosion risks to Scenic Road, upland development, and infrastructure. The mitigation of these impacts will necessitate either regular beach nourishment, wave energy dissipation, or significant improvements to coastal armoring; otherwise, wave overtopping may become unmanageable.

There are two mid-term strategies the City can employ. The first is a protection alternative:

- Extend and raise the crest of existing armoring. Where the raising of armoring is not viable, develop a plan to either 1) redesign coastal armoring to increase overtopping protection, or 2) implement additional coastal armoring to protect the softer terrace deposits.

- Investigate infill armoring at the 12th Avenue promontory.
- Implement lateral access improvements in the shore platforms/underlying geology.
- Install nearshore reefs and wave tripping structures.
- Enhance shore platform.

The other alternative is beach nourishment. This strategy can involve an investigation to extend the headland at the southern end of the beach to better retain sand that may be moving around Carmel Point and escaping the littoral cell.

Triggers to initiate either strategy are as follows:

- Repair costs for beach access and armoring
- Distance from Scenic Road Pathway to the bluff edge
- Winter bedrock exposure duration and summer beach recovery reduction
- Frequency of beach access closures
- Frequency of overtopping of revetments and seawalls
- Summer beach widths reduced by 50 percent from baseline.

2.4.5 Long-Term Strategy (4-ft SLR)

SLR of 4 ft will narrow the beach because of coastal squeeze. It will also accelerate the wave overtopping of existing coastal armoring, thereby causing bluff erosion and increasing maintenance costs. At this stage, the Scenic Road Corridor—including the pathway, landscaping areas, parking spots, and roadway—will be increasingly exposed to erosion, and the maintenance of existing infrastructure through protection alone may no longer be sustainable. Adaptation should shift toward managed retreat and the relocation of vulnerable infrastructure and utilities to avoid emergencies and catastrophic damage.

Long-term adaptation measures should aim to protect and maintain Scenic Road and the critical infrastructure beneath the road for as long as feasible. However, once triggers have been observed, the City should work with private homeowners and other stakeholders on a managed retreat plan for the road and highly vulnerable properties. It may be possible to retreat portions of the road while realigning utility connections to San Antonio Avenue. If this method is feasible, highly vulnerable portions of Scenic Road may transition to a no-through road. Santa Cruz has some examples of the managed retreat of roadways with public access pathways and private homes remaining in place (Section 1.6.3; Figure 24–Figure 26).

The long-term strategy is as follows:

- Develop a plan for the realignment of Scenic Road and the Beach Bluff Pathway.

  - Integrate managed retreat planning into future updates to the LCP and capital improvement program, including limitations of City liability and real estate disclosures.
  - Work with utility providers and property owners to plan for a phased relocation or realignment of Scenic Road and underground utilities farther inland.
  - Identify alternative routes for transportation connectivity and emergency access.
- Identify areas where vertical beach access can be maintained.

The triggers for this strategy are as follows:

- Distance between the bluff edge and Scenic Road or critical utilities reaching a minimum safety threshold
- Repair costs—especially recurrent maintenance or stabilization costs for the roadway or bluff protection—exceeding sustainable levels
- Summer beach widths reduced by 25 percent from the baseline
- Winter bedrock exposure duration
- Erosion events resulting in repeated losses of public access or failures of shoreline armoring at multiple locations.

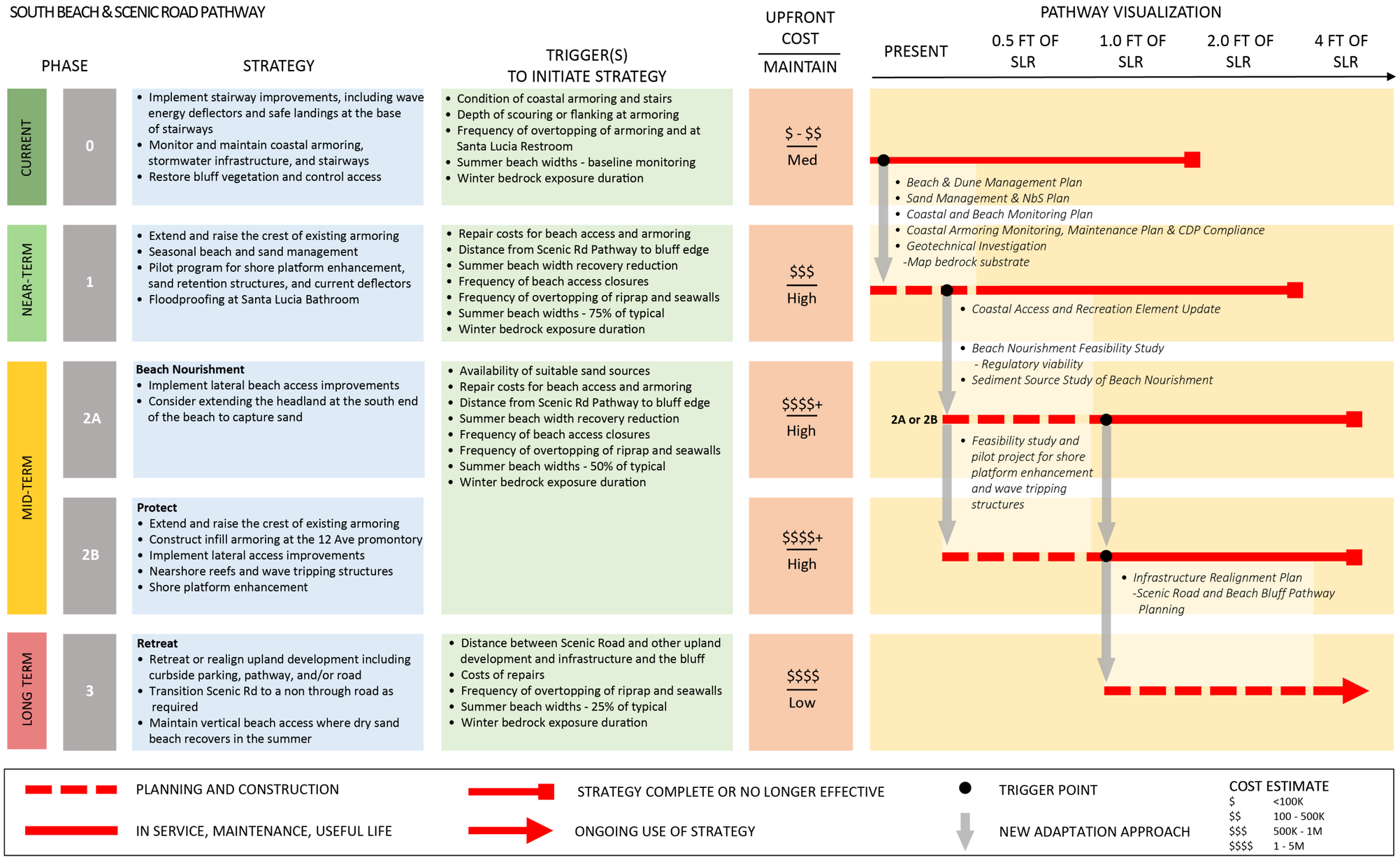


Figure 43. Adaptation Pathway for South Beach

2.5 COSTS ASSOCIATED WITH ADAPTATION

Adaptation costs are tied to the various parts of the beach and the implemented strategies. This section discusses the costs for the entire beach and compares the alternative mid-term strategies for each area.

2.5.1 Beach Nourishment

Beach nourishment represents a potential strategy for extending the beach width and buffering against erosion. Nourishment volumes would depend on sediment source proximity, placement method, and mobilization constraints. As a point of reference, San Clemente in Orange County had a cost quote of approximately $15 million (2025 dollars) for the city, with the federal government accounting for the remaining half for a total of $30 million (San Clemente 2025). The project involves moving ~200,000 cy of sediment every 5–6 years from offshore sources. Preliminary estimates to nourish the area from Arrowhead Point to Carmel Point could be on a similar order of magnitude; however, smaller scale nourishments could cost between $2 million to $4 million per nourishment.

2.5.2 Nearshore Reefs

Regarding the implementation of nearshore reefs, San Clemente serves as a suitable example. There, rolled-up costs amounted to $89 million for one structure, including $45.5 million for nourishment behind the structure for a sand salient. Removing the nourishment component, the structure alone cost $43.5 million (Moffatt & Nichol 2025).

2.5.3 Protection or Retreat of the Wastewater Infrastructure at the Del Mar Dunes

CAWD (2024) estimates that the implementation of ejector pumps costs approximately $50,000 per home. There are 20 homes along this stretch, making the cost for the City approximately $1 million based on the CAWD estimation. Furthermore, CAWD (2024) estimates that the cost to remove the existing wastewater infrastructure and restore the dunes would be approximately $1.5 million, making the total cost for the City approximately $2.5 million.

Assuming the cost to implement hybrid revetments with dunes to be $5,000 per linear foot, armoring approximately 600 ft of vulnerable wastewater infrastructure via the protection strategy would cost approximately $3 million.

3 RECOMMENDATIONS AND NEXT STEPS

This section outlines recommended actions the City can take now and in the near term to support long-term coastal resilience. The recommendations provide guidance for monitoring, maintenance, and updates to the LCP. They are intended to bridge the technical findings with the practical steps needed to implement adaptation measures, secure additional funding, streamline permitting for key near-term strategies, and facilitate repairs following future storm impacts.

Early action should focus on improving monitoring; maintaining existing coastal armoring; repairing access; enhancing winter storm preparedness; restoring bluffs, dunes, and vegetation; and performing maintenance. If thresholds are exceeded, or if maintenance becomes unsustainable, other measures—such as beach nourishment, wave dissipation, or expanded coastal protection—should be considered.

Each strategy should be tied to measurable triggers—such as erosion distance, beach width, or overtopping frequency—to ensure timely decision-making and an efficient use of resources. Triggers help to reduce the uncertainty associated with future climate changes and the projected impacts; they are easily observable. Triggers require community agreement and monitoring for transparency, the process of which also opens an opportunity for engaged community members to get involved in citizen science. There are many active community groups that can assist with studies, monitoring, and work on the ground. The community and these groups should be brought along as engaged stakeholders. Some of these groups include the following:

- Carmel Cares
- Senior centers
- Local dog groomers
- Women's voting groups
- Annual surfing events
- Nonprofits, such as the Giant Giant Kelp Restoration Project.

The overarching goal is to sustain a resilient and accessible shoreline that continues to serve the community, visitors, and the natural environment under future SLR conditions.

3.1 RECOMMENDED TRIGGERS AND THRESHOLDS BY BEACH AREA

The triggers and thresholds in Table 5 identify when adaptation strategies should transition from the current management phase to a near-term or subsequent phase. These measurable conditions define the points at which existing approaches may no longer be sufficient and new

strategies should be initiated. Note that specific triggers for later horizons will have to be established after establishing baseline conditions and a monitoring program. See Appendix B for a description of specific and observable trigger examples. The establishment of these future triggers will require continued collaboration with City staff and partners who conduct regular monitoring activities.

Table 5. Near-Term Adaptation Triggers and Thresholds by Beach Section

Area	Beach Width	Erosion Distance	Maintenance Cost Threshold	Other Indicators
North Beach and North Dunes	<75% of dry-sand beach width by the summer	Dune crest to Del Mar Parking Lot	$1 million in cumulative stairway, seawall, and outfall maintenance within 5 years	Depth of sand along the sand ramps
Del Mar Dunes and Central Beach	<75% of dry-sand beach width by the summer	Dune crest to wastewater line	$1.5 million in dune restoration or sand movement costs within 5 years	Condition and damages to the 8th Avenue access
South Beach and Scenic Road	<75% of dry-sand beach width by the summer	Bluff face or cliff failure; Pathway to blufftop edge	$10 million in stairway, wall, or drainage repair costs within 5 years	Seawall overtopping more than three times or 10 hours/year; duration of bedrock exposure

Notes:

These triggers align with the transitions shown in the pathway figures.

In the pathways, triggers change from near-term and beyond as conditions change.

3.2 OVERVIEW

In the near-term the City must 1) commit to long-term monitoring, 2) maintain existing coastal armoring and accesses, 3) investigate the feasibility of beach nourishment and additional sources of compatible sand, and 4) develop a beach and dune management plan that supports winter-storm readiness and access improvements.

Actions that build monitoring capacity include the enhancement of data collection programs as well as the integration of regular public works maintenance activities into active monitoring programs. Building winter-storm readiness involves actions such as sediment redistribution and living shoreline techniques, such as driftwood placement and dune enhancement. Other priorities should also include maintaining ongoing public communication and outreach about adaptation and coastal projects, updating key policies in the LCP, and positioning and diversifying funding opportunities for adaptation. All this work serves as a foundation for

adaptive management in the immediate and near term as the City works toward identifying the feasibility of mid- and long-term adaptation strategies.

Recommendations for next steps are organized into three categories—namely, studies, plans, and policies—to align with the City's coastal resilience planning.

3.3 STUDIES

For all of the studies listed in this section, the City should conduct an evaluation of socio-economic and environmental trade-offs between a do-nothing approach, and the various adaptation alternatives. The City should perform the following studies:

3.3.1 Sediment Source Study of Beach Nourishment

Beach nourishment is a strategy to offset coastal squeeze impacts by widening the beach as sea levels rise, thereby providing a buffer to wave energy while preserving recreational and environmental value. It also complements other forms of adaptation to provide multiple layers of protection along the coastline. Even relatively small volumes of sand could result in a lasting benefit, as Carmel Beach is a semi-contained littoral cell in between headlands with lower rates of sediment loss. Developing a more robust sediment budget would be a fundamental goal of this study to help determine how much sand would be needed to nourish.

The City should begin a beach nourishment feasibility study as soon as possible due to the long lead times associated with identifying and permitting suitable sand sources. Early efforts should focus on conversations with regulators on permit conditions and feasibility. If these conversations signal that beach nourishment is feasible, future investigations should assess potential compatible sand sources and evaluate how sand placement would influence coastal processes and beach conditions along the entire shoreline. Appendix C provides a premilitary investigation of nearby offshore sediment sources; however, further investigations are required to assess the feasibility, sediment compatibility, and environmental implications of any specific beach nourishment activity.

Nourishment projects should not be considered one-time events but should instead include planned maintenance and subsequent nourishment efforts. Any planning efforts for nourishment activities should also be conducted in collaboration with the County of Monterey, which is responsible for the beach north of Pescadero Canyon, as well as the Pebble Beach Golf Links.

3.3.2 Nearshore Reefs Feasibility Study

The City should also investigate the feasibility of establishing or enhancing nearshore reefs to support coastal resilience, habitat diversity, and surf recreation. An evaluation of the technical,

ecological, and regulatory feasibility of such projects can determine their potential role in Carmel's adaptation strategies. While limited examples exist on the Central Coast, nearshore reefs are being considered in Oceanside under the REBEACH study,[1] and San Clemente is studying a hybrid breakwater/reef in Orange County (Moffatt & Nichol 2025). Both of these projects have had initial support from key regulatory agencies.

The unique marine environment and protections in Carmel Bay require further study and consultation to assess regulatory feasibility. If the reef strategy is feasible, future modeling and engineering studies should investigate potential reef configurations, ecological compatibility, impacts on sediment, and long-term maintenance needs of any constructed features to ensure that the reefs provide both habitat and protective benefits without unintended impacts on adjacent shorelines.

For reference, the California Department of Fish and Wildlife is currently leading the California Artificial Reef Program. This program—anticipated for 2026—will include guidance on artificial reef materials, design, siting, function, and general performance standards, and it will build on lessons learned and feedback received from stakeholder outreach. This guidance is expected to be released in 2026; however, the program is primarily focused on the biological enhancements of reefs, not the secondary effects for coastal adaptation. The City may consider engaging elected officials to expand this focus.

3.3.3 Shore Platform Enhancement Study and Pilot Project

Shore platform enhancement can restore and bolster the underlying sandstone and mudstone rock to provide erosion protection. This strategy would be a novel approach to living shorelines that, while currently lacking established standards and guidelines, could prove to be an important element of long-term climate resilience. The design of enhancement features would need to be fine-tuned to mimic the different nearshore rocky substrate types and account for sediment retention, public safety, and coastal access considerations. A detailed geotechnical study and modeling will be necessary to characterize material properties and evaluate stability under wave and current conditions.

3.4 PLANS

Implementations of larger-scale actions should be planned to ensure a good return on the investment in time and resources. These plans should ensure that strategies are aligned with City and community goals—such as maintaining the recreational, ecological, and scenic value of the shoreline—while reducing exposure to coastal hazards over time.

[1]More information can be found at: https://www.rebeach.org/

3.4.1 Coastal Armoring Monitoring, Maintenance Plan and CDP Compliance

The CCC typically requires the submittal of a coastal armoring monitoring and maintenance plan for any new structure. However, even with existing armoring structures, a certified CDP is beneficial. Once such a plan is approved, repairs and maintenance for coastal armoring and stairways are allowable without further permitting requirements. It is recommended that the City develop such a plan and gain appropriate regulatory approvals.

Any necessary maintenance of an existing coastal protection structure or stairway access provides an opportunity to incorporate additional protective capacity to account for projected SLR, provided that the improved structure remains in compliance with the Coastal Act and other local hazard mitigation policies. Structures that cannot be retrofitted for the higher total water levels will likely require replacement to protect against increased coastal hazard exposure. In addition, a thorough assessment of any bluff stabilization infrastructure improvement project will be required to ensure compliance with relevant state and local policies, and these assessments will be required to consider the potential trade-offs associated with armoring projects.

The City should integrate plan activities into existing public works efforts, which should be updated routinely in the coastal infrastructure and data management systems, to ensure consistent tracking and coordination across departments. Activities—such as the maintenance of grout on seawalls, rock restacking, and repairs in response to wave damage—will be more streamlined and cost effective over time and reduce the risk of any coastal armoring failure. A coastal armoring monitoring and maintenance program will support timely identification of coastal change and help inform adaptive management decisions.

3.4.2 Maintenance and Targeted Improvement of Coastal Infrastructure

Continued maintenance or targeted improvement of coastal infrastructure will be an important component of mitigating coastal storm damage and bluff erosion. Many of the existing engineered bluff protection structures will continue to be effective under near-term conditions, provided that they are regularly inspected and maintained to ensure ongoing protective functions.

The monitoring of storm drains and outfalls will help identify when maintenance is required, ensure effective drainage during high-water events, and reduce localized erosion that can accelerate dune or bluff instability. Monitoring actions include checking for blockages following heavy rainfall, assessing whether outfalls become buried or exposed by seasonal sand movement, and documenting any damage caused by wave impacts or overtopping during winter storms.

Financially tracking the frequency and cost of these repairs will also support long-term planning and budgeting. It will also help determine when relocation or redesign of infrastructure should be considered under future conditions.

3.4.3 Coastal and Beach Monitoring Plan

The City should develop a coastal and beach monitoring plan to establish baseline monitoring conditions for adaptation triggers using a combination of remote sensing technologies, observations, daily maintenance logs, annual reporting, and citizen science. In the 1980s and 1990s, beach width surveys were conducted twice yearly between 9th Avenue and Santa Lucia Avenue, and surveyed benchmarks were established as part of the process. These surveys were conducted in both the spring and fall; however, budget constraints eventually ended the effort, and they were discontinued (D'Ambrosio 2025, pers. comm.). The City should locate this data and consider these locations for future beach width monitoring to ensure consistency with prior efforts. In addition, as a near-term goal, the City should reimplement the beach monitoring program as identified in the shoreline management plan (Shonman, D., and G. D'Ambrosio. 2003).

Additionally, advances in technology since the 1990s could make restarting and maintaining this effort more achievable. As part of the coastal monitoring plan, the identification of specific locations, frequencies, and measurements is crucial. It will also be important to incorporate routine maintenance actions, such as sand movement onto volleyball courts, inspections of storm drainage infrastructure and beach access stairways, budgeting, and assessments of cleanup costs and or damages along the dunes, bluffs, and upper beach. This work should correspond with the development of a centralized database and public-facing dissemination tool so that this information can be more easily communicated to City staff and the public, which would further assist with public works, marine safety, and engaging the public in citizen science, the last of which helps continue the dialog on adaptation approaches.

In addition to measurements, it is recommended that the City track staff time and total expenses related to beach maintenance and coastal adaptation projects. This tracking includes larger expenses, such as the purchase of a skid steer for repair work or fixing and maintaining coastal access stairways. These data will demonstrate the City's history of work and help inform future decisions, such as the potential relocation of assets that are damaged repeatedly.

In summary, coastal and beach monitoring efforts could look like the following:

- Identify data collection and storage framework applications to integrate routine City activities into long-term monitoring.
- Incorporate drone or unmanned aerial vehicle measurements routinely with LiDAR (light detection and ranging) or structure from motion (SfM) photogrammetry surveys to measure shoreline position, beach width, and dune volume while monitoring erosion by

tracking changes in beach and bluff elevations over time. This information could support field surveys to help document detailed responses to storm events.

- Deploy beach cameras along the coastline to capture continuous visual records of beach conditions, wave activity, and visitor use according to best practices (Surfline 2025). The footage can be used to track shoreline change, document storm impacts, estimate visitation trends to support future socioeconomic evaluations, document habitat and species, and support the early detection of erosion or flooding events.
- Utilize satellite-derived imagery (e.g., USGS and UNSW 2025) to assess regional shoreline trends and supplement local data collection.
- Encourage citizen science participation for beach and vegetation observations as well as post-storm documentation, as done by UNSW and NSW (2025).
- Develop a public-facing monitoring website and visualization products to communicate long-term monitoring results to support adaptation triggers and pathway implementation.
- Install base plates or survey benchmarks along the sand ramps to measure changes in sand depth over time.
- Coordinate with ongoing research institutions to align local monitoring with regional coastal change studies.
- Share lessons learned and monitoring program development with the regional partners through venues such as Central Coast Climate Collaborative.

These coordinated monitoring efforts will provide a robust foundation for evaluating adaptation triggers, supporting planning updates, and tracking the effectiveness of implemented strategies (see Appendix B for additional details on triggers and monitoring systems)

3.4.4 Beach and Dune Management Plan

The City's shoreline management plan is part of its overall LCP (Carmel-by-the-Sea 2003), and the Del Mar Master Plan (Carmel-by-the-Sea 2010) provides a plan for the North Dunes and Del Mar Dunes. Together, these plans aim to manage coastal resources through specific policies and recommendations. The City should build on these documents with a unified beach and dune management plan.

First, the City should integrate field measurements into standard beach maintenance activities and document remediation variables (e.g., volumes and frequencies of sand moved, sand accumulation in the parking lot or other maintained areas following wind events). Using the City's preferred work management software, new data entry columns should be added to help track this information. Data collected through monitoring should be used to guide nourishment and sand placement practices, helping the City maintain the minimum beach width required for safe access and erosion buffering (Section 3.4.1).

As part of this plan, the City should also continue targeted sand management actions that support public access. These works include periodic dune grading to maintain a stable and healthy dune system while reducing erosion. They also include the placement of sand over exposed revetments (when conditions allow) and prioritization of sand ramp maintenance by adding sand to offset seasonal deflation. Documentation of the timing, sand depths, and sand volumes of these activities will help with evaluating long-term sustainability as sea levels rise and will provide a clearer basis for determining when alternative access or shoreline strategies may be needed.

3.4.5 Sand Management and Nature-Based Solution Plan

Nature-based solutions provide an adaptive, self-sustaining approach to coastal protection that enhances ecological function. A nature-based solution plan can help the City identify, prioritize, and coordinate projects that use natural processes to reduce coastal hazards, improve resilience, and maintain and improve the scenic character of Carmel Beach. Nature-based measures can also complement engineered protection and nourishment efforts, providing a hybrid approach to sustaining beach access and width, while enhancing ecological function.

A nature-based solution plan could also outline opportunities for integrating efforts for vegetation planting, dune enhancement, the replanting of native vegetation on cliffs, and driftwood placement into ongoing beach maintenance and management activities. It should define suitable sites, design parameters, and monitoring metrics for each action in congruence with the Beach and Dune Management Plan.

The implementation of a nature-based solution plan would also establish clear guidelines for design, permitting, and adaptive management. These guidelines should ensure consistency with the Coastal Act, Monterey Bay National Marine Sanctuary regulations, and local environmental objectives. Some of these elements may include the following actions:

- Identify priority areas for dune and vegetation establishment.
- Evaluate potential co-benefits, such as improved public access, scenic value, and biodiversity.
- Establish monitoring protocols to track dune stability, vegetation cover, and dune reliance during storms.
- Coordinate with community groups and academic partners for implementation and stewardship.
- Integrate projects into existing capital improvement and coastal management programs.

3.4.6 Infrastructure Realignment Plan

In the near- to mid-term horizon, the City should develop an infrastructure realignment plan to identify appropriate triggers for the retreat or relocation of critical infrastructure and upland development, such as the Scenic Road Beach Bluff Pathway, Scenic Road, and associated infrastructure. This plan should identify what triggers would indicate moving toward abandonment and retreat and identify appropriate funding strategies. This study should also assess economic feasibility and funding mechanisms for realignment.

3.5 POLICY

Effective adaptation requires policy tools that guide future development, ensure consistency with SLR science, and provide a clear framework for integrating climate change into long-term decision-making. Policies help align private and public actions, reduce exposure to coastal hazards, and create predictable pathways for redevelopment, maintenance, and adaptation over time. Policy approaches also help manage expectations of residents and developers, and they limit the City's liability. The following policy approaches can support the City in managing risk, increasing resilience, and ensuring that adaptation strategies remain coordinated across departments and regulatory agencies.

3.5.1 Encourage Adaptation Action through Policy

The City can encourage proactive adaptation through targeted policy measures that make resilient, low-impact strategies easier and more attractive to implement. Nature-based and low-impact adaptation measures can be supported through incentives or streamlined permitting pathways. For example, it would be beneficial to develop an opportunistic sediment reuse policy that allows sand recovered from construction or landscaping activities to be beneficially reused on Carmel Beach, when it is compatible. A preference for nature-based solutions or the maintenance of existing coastal armoring helps reduce conflict in permitting. For example, if beach nourishment is deemed feasible with a suitable sand source, then a policy prioritizing that adaptation strategy would help direct City funds or justify mitigation fees to be applied to the strategy implementation.

3.5.2 Establish In-Lieu Fees or Direct a Percentage of Existing Funding Streams to Support Coastal Access Maintenance and Dune and Beach Management

The City may also benefit from an in-lieu fee program that is tied directly to CDPs or conditions of approval whereby activities that may affect the beach could result in a fee. The CCC currently assesses in-lieu fees typically tied to coastal armoring structures, such as a lost recreational value fee and a sand mitigation fee for the loss of sand supply. Alternatively, if the

City establishes a parking fee structure, funding from that fee could support access and sand management activities.

3.5.3 Adopt a Coastal Hazard Overlay Zone

A coastal hazard overlay zone can serve as a policy tool for guiding long-term adaptation by identifying areas with elevated exposure to future SLR. Establishing an overlay zone ensures that City development decisions, permit reviews, and public disclosures reflect the best available science and clearly communicate coastal risks.

The overlay zone should be based on the completed hazard mapping from Phase 1 of this project. Furthermore, it should be reviewed every 5–10 years to incorporate the emerging scientific understanding of SLR and coastal hazards as well as regional approaches to adaptation planning.

A coastal hazard overlay zone could trigger the following:

- Real estate disclosures associated with each land transaction for coastal hazards (described below)
- Requirements for a site-specific coastal hazard and SLR report as part of a coastal development permit application, which evaluates the specific risks to a proposed development for the life expectancy of the project
- Implementation of development constraints for new projects and expansions, including construction standards or development setbacks from hazardous coastal areas.
- Assumed liability by property owners for future coastal hazards and costs before permit approval is granted.

3.5.4 Develop Real Estate Disclosures

The development of real estate disclosures requires that, for any real estate transaction, buyers of properties in coastal hazards zones (Section 3.5.3) are made aware of potential hazards to their property. This disclosure informs buyers that they may face hazards, such as erosion or coastal wave flooding because of climate-induced impacts like SLR. This type of real estate disclosure would be like the flood insurance disclosure, which is already a part of hazard disclosures if a property is within a creek flood hazard zone. The education of landowners and potential buyers is important for a general understanding of the risk of owning property in a hazardous area.

In addition, real estate disclosure could acknowledge that the City may not always be able to provide access and some public services to the property. In that manner, it provides some liability protections for the City.

3.5.5 Continue Existing Armoring Policies Under the Coastal Act and LCP

The City should continue the existing armoring policies outlined in the Coastal Act and the certified LCP. Developing a certified Coastal Armoring Monitoring and Maintenance Plan for all the City's coastal armoring will expedite repairs and reduce the regulatory permitting burden for maintenance activities.

Any request for new or modified armoring should include a detailed, site-specific coastal hazard analysis that evaluates anticipated SLR, erosion rates, wave runup, and potential impacts on beach width, habitat, and public access. This analysis should demonstrate that armoring is necessary to protect existing development and that alternatives—such as relocation, dune restoration, or hybrid solutions—have been fully considered while also identifying the design life of the armoring structure to ensure consistency with the City's long-term adaptation pathway.

3.5.6 Link Permit Renewal or Redevelopment Approvals to Updated Coastal Hazard Assessments and Adaptation Triggers

Permit renewal and redevelopment should be tied to updated coastal hazard assessments and the City's adaptation triggers to ensure that project decisions reflect the best available SLR and erosion science. Updated analyses for each major permit action provide a consistent checkpoint such that development remains safe and appropriate under future conditions. To support this method, the City should standardize the planned design life of all new development and redevelopment, so it aligns with projected SLR timelines and long-term adaptation planning.

3.5.7 Update the LCP to Integrate SLR Triggers

The City should update its LCP to formally integrate SLR triggers so that adaptation actions are tied to observable measurements rather than fixed arbitrary dates. This approach helps manage the uncertainty with the timing of impacts. By embedding these triggers in the LCP, residents, staff, decision-makers, and regulatory agencies will be aligned on timelines for specific adaptation steps, and there will be a transparent and predictable framework for long-term planning. As part of this update, the City should also incorporate managed retreat policies that outline when and how relocation or removal of at-risk development would be considered once trigger thresholds are met. The inclusion of both SLR triggers and managed retreat policies in the LCP will help the City transition from reactive responses to proactive, planned adaptation consistent with future coastal conditions.

3.5.8 Update Building Codes

The City's should update its building codes to incorporate coastal hazard resilience standards that reflect projected SLR and erosion conditions. Updates could include 1) definitions for appropriate foundation types in hazard zones that may allow for the relocation of structures, 2) requirements for the use of flood- and corrosion-resistant materials, and 3) the integration of design life expectancies that are consistent with the City's adaptation timeline. These updates ensure that new and redeveloped structures are built to withstand future coastal conditions and reduce long-term maintenance and safety risks. These building codes may also apply to access ways so that repairs can increase resiliency or add additional design features over time. Building codes may also apply to access ways so that repairs can increase resiliency or incorporate additional design features over time.

3.6 PRIORITIZED ADAPTATION POLICIES, PLANS, STUDIES, AND ACTIONS

Table 6 summarizes the prioritized adaptation policies, plan, studies, and actions for the project.

Table 6. Studies, Plans, and Policies to Be Prioritized in the Near Term by Adaptation Pathway

No.	Description
	Studies
1	Sediment Source Study of Beach Nourishment
2	Nearshore Reefs Feasibility Study
3	Shore Platform Enhancement Study and Pilot Program
	Plans
4	Coastal Armoring Monitoring, Maintenance Plan and CDP Compliance
5	Maintenance and Targeted Improvement of Coastal Infrastructure
6	Coastal and Beach Monitoring Plan
7	Beach and Dune Management Plan
8	Sand Management and Nature Based Solutions Plan
9	Infrastructure Realignment Plan
	Policy
11	Encourage Adaptation Action Through Policy
12	Establish In Lieu Fees or Direct a Percentage of Existing Funding Streams to Support Beach and Dune Management
13	Adopt a Coastal Hazard Overlay Zone
14	Develop Real Estate Disclosures
15	Maintain Existing Armoring Under the Coastal Act and LCP
16	Link Permit Renewals or Redevelopment Approvals to Updated Coastal Hazards Assessments and Triggers
17	Update LCP to Integrate SLR Triggers
18	Update the Building Codes

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Appendix A

Adaptation Planning Principles

Appendix A.
Adaptation Planning Principles

As sea level rise adaptation advances, focused analysis on the feasibility and effectiveness of specific strategies should be conducted. The State of California has developed guidance documents to direct local municipalities through the adaptation planning process. These documents provide valuable information and useful recommendations regarding the applicability, challenges, and legal and financial constraints that should be considered when selecting adaptation options. For the City of Carmel-by-the-Sea, one of the most applicable is the California Coastal Commission Residential Adaptation Policy Guidance (2018/2020),[1] which provides policy guidelines for addressing sea level rise in local coastal programs and coastal development permits.

The following draft planning principles are suggested for incorporation into policy development for the City. These guiding principles are derived from the requirements of the Coastal Act and complement the priorities outlined in the State of California's climate adaptation strategy, the 2014 Safeguarding California plan. The following are some high-level planning principles to consider:

- Remain flexible to change and changing conditions
- Find a balanced approach with co-benefits
- Maintain ecosystem services whenever possible
- Prioritize nature-based solutions that do not need extensive maintenance over time
- Require new coastal development to plan for coastal storm and sea level rise hazards
- Maintain consistency with the General Plan and other Management Plans
- Conserve, maintain, and, when necessary, restore beaches and access to beaches for the enjoyment of future generations, flora, and fauna.

High Level Questions for Decision-Makers

There are many challenges to adaptation planning that decision-makers must consider. Answering these questions will require a combination of community dialogue, stakeholder engagement, detailed technical evaluation, numerical modeling, economic analyses,

[1] Document can be found here: https://documents.coastal.ca.gov/assets/climate/slr/vulnerability/residential/RevisedDraftResidentialAdaptationGuidance.pdf

engineering design and costing, and political will. This section is intended to provide a list of questions that need to be considered at a high level as well as more detailed considerations for cost–benefit analyses and inclusion of social equity:

1. Does the strategy buy decision-making time to incorporate the evolving science of sea level rise?
2. Does the strategy increase flexibility and not lock the community into a single long-term solution?
3. Does the strategy incentivize good practices and adaptation (e.g., reward early actors and avoid maladaptation)?
4. How do we take a holistic adaptation approach that considers safety, coastal resources and habitats, and community identity?
5. Does the strategy support the protective role of ecosystems and sustain their physical processes?
6. Does the strategy allow for the evolution from one adaptation approach to the next?
7. How much sea level rise will the strategy accommodate?
8. How much does the strategy cost to implement initially?
9. Does the strategy require increased maintenance costs over time, and who bears the costs and responsibilities for maintenance and success?
10. Does the strategy avoid high costs and demonstrate a strong net benefit over time?

Ensure That the Plan Is Actionable

The Capital Improvement Plan (CIP) is an important planning process that outlines budget expenditures to address current needs and long-term capital needs. Many of these expenditures relate to public facilities, infrastructure, and amenities. Incorporating the probability of sea level rise and coastal hazards into the CIP process would be an effective way to ensure public projects are accounting for future hazard risks. These projects also present opportunities to include strategies to build adaptive capacity into coastal resources where feasible.

Public Education and Outreach

Public education and outreach programs can be utilized as a form of planning-level sea level rise adaptation within the City. These programs aim to enhance community understanding of potential sea level rise hazards and their potential impacts on coastal resources within the City. Community workshops serve as an effective platform for outreach and education related to sea level rise. Multiple workshops have already been conducted as part of this project, and future workshops may be necessary in response to

significant adaptation projects, such as beach nourishment, or following coastal hazard events that raise community concern.

Understanding Physical and Ecological Implications of Coastal Armoring

Selecting among adaptation options requires understanding the secondary consequences associated with each strategy. Some strategies entail high construction or maintenance costs, while others may have temporary environmental or social impacts. Structural measures may protect upland infrastructure but reduce habitat or recreational opportunities over time. Conversely, nature-based approaches often provide ecological and aesthetic benefits but may offer less immediate protection to developed areas. Others may inhibit access to the beach, or affect the aesthetics or views of the coast. Selecting the appropriate strategy therefore requires weighing trade-offs between coastal habitat preservation, public access, recreation, and protection of upland development. In many cases, hybrid or combined strategies, such as pairing dune restoration with targeted structural protection, can balance these competing objectives. The decision-making process should remain adaptive, allowing the City to adjust priorities as monitoring data, funding opportunities, and regulatory guidance evolve.

Active Erosion

Active erosion from coastal armoring refers to interactions between coastal armoring and the physical processes that increase erosive forces. Some of these processes include wave reflection; positive wave interference, which causes waves to get bigger before breaking; increased beach scouring; and “end effects.” In some cases, armoring may increase longshore currents, which increases the rate of beach loss in front of the structure, and in turn escalates the erosion effects at the “ends” of adjacent, unarmored sections of the coast (Figure A1). Active erosion is typically site-specific and dependent on the length of the structure, sand supply, wave direction, specific design characteristics, and other local factors.



Figure A1. Lateral currents near the headland at 13th Avenue

Placement Loss

Wherever a hard structure is built, there is a footprint of the structure. The footprint of this structure results in a loss of coastal area known as placement loss. This inevitable impact

can bury the beach beneath the structure and reduce the usable beach for recreation or habitat purposes. For example, a 20-ft high revetment may cover up to 40 horizontal feet of dry sand beach. A vertical seawall typically has a smaller placement loss than a riprap revetment.

Limits to Access

Typically, vertical beach access (the ability to get to the beach) on a cliff-backed coast can be limited unless there are beach access stairs. Additionally, if passive erosion occurs, lateral (along) beach access can also be impacted.

Ecological Impacts

A study by Dugan et al. (2008)[2] has shown that armoring reduces habitat, causes biodiversity loss, and is associated with a reduction in kelp deposition on the beach and a resultant loss of sand crabs, shorebirds, and certain species of fish. Given the negative ecological impacts of coastal armoring, more attention is now being focused on the implementation and effectiveness of natural, green, or soft solutions for shoreline protection. Soft solutions involve the creation or restoration of shoreline ecosystems using nature-based solutions. These solutions rely on natural physical, biological, or geologic processes to enhance the natural ability of coastal landforms to buffer erosion and flooding. Nature-based features can be designed, engineered, and constructed to mimic nature and may include sediment management and redistribution. When implemented correctly, soft solutions can be more self-sustaining after an initial establishment phase, possibly resulting in lower ongoing maintenance costs. Soft options may be required as mitigation for the construction of hard structures, are more favorably looked upon by permitting agencies, and offer added benefits, such as water filtration, wildlife habitat, and recreational opportunities. However, certain beach management practices, such as mechanical grooming or frequent sand redistribution, can also disrupt ecological processes by compacting sediments, removing wrack that supports invertebrates and shorebirds, and altering the natural exchange of sand between the beach and dune system. These benefits will be considered in the future cost–benefit analysis of prioritized adaptation strategies.

Safety Considerations

In the long term, design elements should consider public safety related to coastal access and recreation. Coastal structures, such as revetments or stairs, must include appropriate signage, barriers, or design features that reduce the risk of injury from falling or accidental entry into hazardous areas. It is also essential that emergency access to the beach remains viable, and communication systems remain functional and clearly marked. In Carmel, recent erosion near key beach entry points, such as the Del Mar parking lot ramp

[2] Dugan, Jenifer & Hubbard, David & Franco Rodil, Iván & Revell, David & Schroeter, Stephen. (2008). Ecological effects of coastal armoring on sandy beaches. Marine Ecology. 29. 160 - 170. 10.1111/j.1439-0485.2008.00231.x.

and the 8th Avenue ramp, has already reduced the reliability of emergency vehicle access, highlighting the need for proactive design and maintenance measures to ensure continued safety and response capability during future storm and high-water events.

Maladaptation

According to the Intergovernmental Panel on Climate Change, maladaptation inadvertently increases vulnerability to sea level rise and related hazards and can result from poorly planned adaptation actions or decisions that prioritize short-term benefits over long-term resilience. An example of maladaptation in Carmel would be the installation of hard protection structures, such as a seawall or revetment, in front of the Del Mar Dunes. While such a measure may temporarily protect existing development behind the dunes, it would accelerate beach narrowing and loss of recreational and ecological value over time, ultimately increasing community exposure to coastal hazards as wave reflection and scour intensify.

Avoiding maladaptation requires applying a long-term, systems-based approach that accounts for cumulative effects, future sea level rise, sediment dynamics, and social equity. Continuous monitoring, adaptive management, and alignment of project-scale measures with regional adaptation plans are essential to ensure that near-term interventions contribute to sustained resilience rather than increased vulnerability.

Regulatory Viability/Consideration/Feasibility

The primary federal laws that coastal projects must comply with are the Clean Water Act, National Environmental Policy Act, Coastal Zone Management Act, and Rivers and Harbors Act. The primary state laws and regulations include the California Environmental Quality Act, California Coastal Act, California Endangered Species Act, California Ocean Plan, California Department of Fish and Wildlife Code, California Public Resources Code, and the Porter-Cologne Water Quality Control Act.

State and federal agencies involved in conducting, reviewing or approving, and permitting potential projects identified in this plan include the U.S. Army Corps of Engineers (USACE) and the Carmel Bay State Marine Conservation Area (under the authority of the California Department of Fish and Wildlife). The U.S. Environmental Protection Agency and USACE are the two main agencies involved in regulating discharges of fill and dredged material.

State agencies involved in conducting, reviewing, or approving potential projects include the California Coastal Commission (CCC), California State Lands Commission (CSLC), and the California State Coastal Conservancy (SCC). The agencies with primary regulatory responsibility over shoreline protective structures are CCC and CSLC. SCC is involved with funding coastal adaptation projects, so its involvement may vary depending on funding.

Carmel Bay has multiple marine protections and a variety of involved regulatory agencies. Depending upon the specific location of adaptation, primarily above or below mean high

water, the following special designations and their regulatory agency would require additional consultations: the National Oceanic and Atmospheric Administration (NOAA), which oversees the Monterey Bay National Marine Sanctuary; the California Department of Fish and Wildlife, which oversees the Carmel Bay State Marine Conservation Area; and the State Water Resources Control Board, which oversees the Carmel Bay ASBS State Water Quality Protection Area (note that the Carmel Pinnacles State Marine Reserve lies just offshore of this critical coastal area).

Section 404 of the Clean Water Act

USACE is the chief decision-making agency for beach nourishment projects. For USACE to approve a project, the proponent must demonstrate that the proposed project is the "least environmentally damaging practicable alternative." Additionally, under Section 404 permitting, either an environmental assessment or an environmental impact statement is required for beach nourishment projects. Under Section 404, there are two types of applicable permits that are required: for larger-scale projects with the potential to cause significant impacts, an individual permit is typically required; for activities with minimal potential environmental impacts, a general permit is usually required.

Marine Sanctuary Permits

All hard structures, such as offshore breakwaters or submerged features like artificial reefs that dissipate wave energy before reaching the shoreline, would trigger review by the marine sanctuary. This review is conducted by the Office of National Marine Sanctuaries within NOAA. The permitting process ensures that any activity proposed within a designated National Marine Sanctuary is consistent with the site's management plan, resource protection objectives, and the National Marine Sanctuaries Act. The review considers potential impacts on seabed habitats, sensitive species, sediment transport, water quality, and the overall ecological integrity of the sanctuary.

Sections 7 and 10 of the Endangered Species Act

Pursuant to the Endangered Species Act, the lead agency responsible for environmental review of a proposed project must determine whether any species listed as threatened or endangered are present within the project or plan area and whether the project could result in significant impacts to those species or their habitats. If potential impacts are identified, the project proponent is required to prepare a Habitat Conservation Plan and submit it to the U.S. Fish and Wildlife Service for review and approval.

Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) was the first legislation to mandate an ecosystem-based approach to marine resource management. Under the MMPA, Congress directed that the primary objective of marine mammal management should be to maintain the health and stability of the marine ecosystem and, when consistent with that primary objective, to obtain and maintain optimum sustainable populations of marine mammals.

Projects that have a direct or indirect impact on marine mammals would be subject to this act.

California Coastal Commission Development Permits

California Coastal Commission Development Permits (CDPs) are permits required for development projects within California's Coastal Zone. They ensure that development activities, such as construction, grading, or changes in land use, are consistent with the California Coastal Act and the relevant Local Coastal Program (LCP). While local governments often issue CDPs under their certified LCPs, the Coastal Commission retains permitting authority and appeal jurisdiction along Carmel Beach.

Occupational Safety and Health Administration

During implementation, all adaptation measures must adhere to construction safety standards and minimize conflicts with public access and sensitive habitats. This includes compliance with Occupational Safety and Health Administration (OSHA) requirements, local safety codes, and site-specific health and safety plans to manage heavy equipment operation, unstable slopes, and weather-related risks. Construction routes and staging areas should be carefully located to reduce disturbance to beach users and adjacent dune ecosystems.

Appendix B

Triggers and Monitoring

Appendix B.
Triggers and Monitoring

ADAPTATION PATHWAY TRIGGERS

Adaptation planning relies on the use of triggers, which indicate when a change in management or strategy is required to limit risk. Triggers are established to ensure that adaptation actions are implemented proactively rather than reactively, providing decision-makers with a clear signal for when intervention is needed.

Trigger points are often developed by working backward from a potential tipping point, or threshold, and identifying early warning indicators that provide sufficient lead time for design, permitting, funding, and implementation of the next adaptation step. This proactive approach reduces uncertainty and supports smoother transitions between adaptation phases.

Triggers represent measurable or observable conditions that, once reached, signal the need to reevaluate existing management actions or initiate the next stage of adaptation. Trigger points should be selected to reflect both physical and social indicators, ensuring that changes in shoreline conditions, infrastructure performance, or community tolerance are all captured within a monitoring framework. Triggers should be regularly reevaluated and updated in the future to capture advances in sea level rise science and changing conditions. Strategies can then be implemented before a threshold is met. The following section outlines several examples of potential trigger points and describes how each could be monitored.

Measurements

Observable and measurable entities, which may include physical distances, elevations, or rates of change, form the basis of monitoring and trigger evaluation. These measurements provide the quantitative evidence needed to assess progress toward adaptation thresholds and determine when a management response is required.

Common examples include measurements of beach width, bluff retreat, shoreline position, depth of sand, dune elevations, or flood depths recorded during tide events and storm events. Additional parameters, such as wave runup extent, bluff area lost, and associated infrastructure damage, can supplement physical measurements to provide a more comprehensive understanding.

To ensure accuracy and consistency, all measurements should be collected relative to established benchmarks or reference point locations, and using standardized survey or remote sensing methods. Data should be stored in an organized system to support future trend analysis, visualization, and integration into decision-support tools.

Beach Widths

Measuring beach width involves surveying the beach or documenting beach widths using other methods, such as ground-based cameras or remote sensing. A trigger may be when the beach width in the spring is 50 percent narrower than normal for that beach section, then an adaptation strategy such as sediment redistribution or placement should be pursued.

Note that the City of Carmel-by-the-Sea has a history of beach width surveying; however, it no longer actively monitors beach profiles. The City should develop a beach-width monitoring strategy, which may include ground-based cameras, traditional surveying, or remote sensing. Understanding beach width is essential because it influences both recreational use and ecological habitat value. Thresholds for acceptable beach width can be defined according to the size, location, and function of each individual beach.

Recommended Monitoring Method: Conduct biannual beach profile surveys and use automated camera systems (such as Surfline or CoastSnap) to capture daily shoreline position and sand recovery trends.

Erosion Distance

If erosion distance exceeds a defined threshold, it will trigger a corresponding management action. Erosion can be measured horizontally, vertically, or by the volume of material lost. For example, scarping of the sand ramps or dunes at the Del Mar Dunes can be quantified by measuring the height of the exposed scarp, supported by pre- and post-event photographs to document changes over time.

For bluff areas, erosion distance is commonly measured at the top of the bluff edge, while for harder sandstone or consolidated basal material, measurements can be taken relative to the depth of gaps or undercutting adjacent to armoring. Erosion may also be expressed as the remaining horizontal distance between upland development and the bluff edge, which provides a clear indication of remaining buffer space.

Consistent monitoring of these parameters allows for early detection of accelerating erosion trends and supports the timely implementation of adaptive management actions before critical thresholds are reached.

Recommended Monitoring Method: Use high-resolution drone or LiDAR surveys every 5–10 years to measure cliff position change, supplemented with field GPS mapping and photo documentation after major storm events and during maintenance activities.

Depth of Sand

The depth of sand to the underlying mudstone or sandstone is an important parameter for evaluating beach and dune system stability. This measurement is particularly relevant at locations such as sand ramps, where maintaining adequate sand depth is necessary to preserve access, provide for pedestrian safety, and mitigate erosion of the underlying consolidated material.

A threshold can be established to indicate when sand management techniques, including replenishment and redistribution, are required. For instance, if the sand depth falls below a specified value (such as 2 ft at the top of the sand ramp), it may trigger an action to move sand from lower areas back to the top of the ramp to restore its form and continuity. This approach is especially useful following winter storm events, when high-energy waves can scour and redistribute large volumes of sand.

Recommended Monitoring Method: Set up a staff plate at locations such as the volleyball courts, along the sand ramps, at revetments and seawalls, or at coastal access stairs would be critical for supporting timely maintenance and adaptive management. In addition, regular monitoring of sand depth using probes or even ground-penetrating radar can help identify the depth of sand in locations without staff plates.

Vegetation Cover

Vegetation cover on dunes or bluffs serves as an indicator of surface stability and resilience. A reduction in vegetative cover below a defined percentage threshold may signal increased vulnerability to erosion. Trampling and dune scarping can all contribute to reduced vegetation density and a corresponding decrease in sand volume.

Recommended Monitoring Method: Vegetation cover can be monitored through field surveys or remote methods such as drone-based imagery. Comparing field survey transect data or remotely sensed imagery over time allows for the detection of spatial patterns of vegetation loss and recovery, supporting targeted restoration or access management actions when thresholds are exceeded. Monitoring should be targeted toward key indicator dune species or species of concern.

Dune or Sand Ramp Erosion

If erosion of the dune exceeds a defined threshold, such as retreat of the dune toe or dune crest by more than 10 ft, then it may trigger a transition to a different management strategy. Potential actions could include adding protection at the toe of the dune using less erodible materials to retain sand, such as armor stone, geotextile bags, drift logs, or another type of coastal structure. Alternatively, soft approaches such as dune restoration and planting may be appropriate depending on site conditions and long-term goals.

A sunset strategy can also be established whereby, if dune erosion exceeds a larger threshold (for example, more than 20–40 ft of retreat), management actions should be initiated to reduce risk to upland development and infrastructure. Clearly defining these thresholds provides a structured basis for decision-making and helps ensure that adaptation actions are implemented before critical losses occur.

Recommended Monitoring Method: Elevations may be captured with an auto-level or total station and tied to a benchmark. Changes in topography can be measured from prior surveys.

Bluff Erosion

Bluff erosion can be monitored using several measurable indicators, including horizontal retreat distance, slope angle, and proximity of critical assets to the bluff edge. If the rate or extent of erosion exceeds a defined threshold—such as when the bluff terrace reaches a certain angle of repose or when the distance between the bluff edge and infrastructure (for example, Scenic Road) becomes critically narrow—management actions should be initiated to reduce risk.

Thresholds should be tailored to site-specific conditions, including local bluff composition, erosion rates, and the design life of nearby structures. In areas where retreat threatens public infrastructure or private property, adaptation measures such as bluff stabilization, drainage improvements, or relocation planning may be warranted. Establishing clear trigger distances or slope criteria helps ensure that intervention occurs before safety risks or significant structural impacts arise.

Recommended Monitoring Method: Site inspections following storm events, and periodic monitoring of bluff conditions.

Public Access and Recreation Reduction

A decline in shoreline accessibility or sustained disruption of recreational use can be monitored, and triggers can be established based on problems reported to the City by the public.

Frequency

Frequency refers to how often a particular event or condition occurs within a given time period. In the context of coastal monitoring, this can include metrics such as the number of wave overtopping hours per season or year, or the duration and recurrence of beach or roadway closures caused by storm-related flooding and erosion. Tracking the frequency of these events helps identify emerging trends in coastal hazard exposure and supports timely adjustments to management and adaptation strategies.

Wave Exposure Frequency

Monitoring the frequency of backshore exposure to wave action is essential for understanding when and how often key features, such as dunes, cliffs, or coastal armoring, are directly impacted. This includes tracking how frequently waves reach the toe of a dune, cliff, or structure, and how often wave runup overtops and saturates the bluff terrace behind the armoring.

Trigger thresholds can then be defined based on the number of occurrences or the duration of exposure that exceeds a set limit within a given year. For example, if wave overtopping or flooding at a specific site occurs more than a defined number of hours or events annually, it may indicate that adaptation measures or design modifications are needed.

Recommended Monitoring Method: To monitor the frequency of flooding and wave exposure, the City should document each coastal flooding event by recording the date, location, type, depth, and severity of the event. Beach cameras and other automated monitoring systems can be programmed to track these occurrences and supplement field observations.

Toe of a Structure or Dune

Monitoring should focus on how frequently waves reach or expose the toe of dunes, seawalls, or revetments, as repeated exposure can cause scour, destabilization, or increased erosion rates.

Top of the Seawall

For coastal armoring, frequency is often measured by the number of hours or events in which waves overtop the seawall. Consistent overtopping may signal that the structure is undersized for future sea level rise conditions and may require modification or supplemental protection.

SEA LEVEL RISE OR FUTURE DATE

Sea Level Rise Elevation or Rate

Carmel Beach is already susceptible to significant coastal wave and erosion hazards that occur during El Niño years, major storm events, and seasonal high tides. Future sea level rise will increase both the frequency and severity of these impacts, and monitoring of sea level rise provides a practical way to track changes and establish quantitative triggers for adaptive management. Triggers can be defined based on specific elevation increases in

sea level relative to present conditions—such as 0.5, 1, or 2 ft of rise—or based on the rate of change over time.

Recommended Monitoring Method: The City should monitor data from the Monterey tide gauge, and this should be compared with modeled projections to assess progress toward identified thresholds. Because sea level varies naturally due to both astronomical tides and atmospheric conditions, use a 6-month averaging period to help filter out short-term variability associated with seasonal and El Niño fluctuations, ensuring that trigger points reflect long-term trends rather than temporary anomalies.

Future Date

This trigger type specifies that by a defined future date (for example, 2030), a particular set of strategies, policies, or programs must be implemented or completed. Future date triggers are most effective as follows: when used to schedule regular reviews or updates of adaptation policies, when they align with permit expiration and renewal timelines, or for more predictable events, such as the end of life of a structure. Establishing clear review dates provides predictability for both the City and regulatory agencies, which often require periodic evaluations to ensure that adaptation approaches remain current with evolving science and local coastal conditions. Note that the limitation of time-based triggers is that unpredictable extreme hazard events or other factors may reduce their reliability.

Cost, Condition, and Feasibility

Damages and Ongoing Maintenance and Repair Costs

The City can track and keep records of storm damage events and information related to storm damage and repair costs. This can also be a collaborative effort between City Public Works staff and residents, involving the collection of photos and videos documenting flood events and damage. Information such as the date, type, location, and severity of flooding, including associated information regarding wave runup and overtopping elevations, as well as any resulting damage, can be compiled into a central database.

The goal is to monitor changes in the frequency, extent, and severity of flooding over time. In the event of significant or extreme flood events, additional storm data (e.g., water levels and wave conditions) can be gathered to help establish risk-based thresholds.

Recommended Monitoring Method: Assets to track for public works staff include beach access stairways and sand ramps, with documentation of the extent of damages and associated costs to maintain. If they are required to be repaired a certain number of times over a 2- to 5-year window, then a transition to another strategy should be considered. Another measure could be to use cost; for instance, once the City spends a certain amount on ongoing maintenance and repair costs, then additional steps need to be taken.

A more nuanced approach to determining cost thresholds is considering costs from a cost–benefit analysis, whereby the benefits for the existing infrastructure or other adaptation approaches are weighed against their ongoing maintenance and repair costs, as well as the costs to the community.

Condition Ratings

By the time a coastal armoring structure has failed, it is too late. Early signs of potential failure include souring, flanking, spalling, dislodged armor stone, and visible cracks. Regular condition assessments are required to identify these early signs of failure, and plans should be set in place for when to sunset structures and transition to the next strategy, which may include eventual replacement of the structure or retreat at that location. The City can identify what actions should take place given structural conditions, which may include repair if the condition is average, replace if the condition is poor, and plan to relocate if the structure experiences repeated issues.

MONITORING

Identifying and monitoring triggers will allow the City to anticipate when management adjustments are needed, prioritize funding and permitting efforts, and remain flexible as conditions evolve. The City and its partners should regularly monitor and evaluate progress toward these thresholds to determine when they are reached. Monitoring indicators may include physical parameters, such as beach width, bluff retreat distance, and storm damage recurrence, as well as social and economic factors, such as public access disruptions or maintenance costs. A monitoring and maintenance plan will be needed to ensure that data collection methods remain standardized and results are comparable over time.

The ideal monitoring system should be low-cost and integrated into the day-to-day activities of the City and the community. Effective monitoring systems are essential for tracking coastal change, verifying adaptation triggers, and guiding future management decisions. They should also be readily observable and agreed upon in advance, and preferably codified into the local coastal program or shoreline management plan. This will ensure transparency, and once a trigger is reached through monitoring, all stakeholders will understand the process and next steps. Monitoring can also encourage citizen science participation, and foster community engagement and shared ownership of coastal management. For example, the CoastSnap app (Harley and Kinsela 2022) enables beach users to take repeat photos at the same location via a smartphone cradle and upload them to build a long-term record of shoreline change (Figure B1).



Figure B1. CoastSnap is a phone app that relies on repeated photos at the same location to track how the coast is changing over time. CoastSnap encourages citizen participation, and stations can be set up at coastal overlook locations (Harley and Kinsela 2022).

Although monitoring of the beach has been recommended in the City's Shoreline Management Plan, implementation has historically been time intensive and costly, and thus has never been fully established. Regular, structured monitoring is therefore essential to support informed decision-making and efficient budgeting.

Recent advances in technology now make it possible to collect continuous, low-cost data that can greatly enhance coastal monitoring efforts. New tools such as camera systems equipped with machine-learning software can automatically analyze beach use, track visitor numbers, and identify patterns of recreational activity along the cliffs and shoreline. Similar systems are already in use through Surfline's coastal camera networks, which provide real-time imagery and wave data that can be archived and analyzed for beach width, runup, and public use.

Other tools such as GPS-based tracking, can record patterns of movement by beachgoers, cyclists, and drivers, providing valuable insights into how different parts of the coast are used over time (Patsch et al. 2024; Figure B2). These data sources, when integrated with traditional survey and visual inspection methods, can help verify adaptation triggers and guide future management decisions. Together, they offer a flexible and scalable framework for tracking shoreline change, wave conditions, and community use in near real time.



Figure B2. Heat map of hourly visitation, Carpinteria State Beach (Patsch et al. 2024).

The City is advised to make routine inspections of the coastline as well as utilize these new technologies to inform annual maintenance and budget planning.

Recommended monitoring parameters include:

- Vehicular use (parking, types of vehicles, direction, and volume) on Scenic Road and surrounding roadways
- Pedestrian counts on Scenic Road Pathway
- Monthly beach widths
- Visual inspections following any wave event with a recurrence greater than 10 years
- Documentation of Scenic Road and the Bluff Pathway impacts from cliff erosion (location, scale, and repair costs).

The City of Santa Cruz, California, provides a useful example through its Coastal Change Monitoring Network. Through this network, 14 scientific, civic, and community organizations are co-developing a coastal monitoring program that integrates both geophysical and social indicators of coastal change into an analytical dashboard. The program uses affordable and replicable tools to track shoreline dynamics, storm impacts, and community observations. Outputs from the dashboard include visualization products, early-warning notifications, and a communications plan to support public awareness and proactive decision-making.

Another useful example comes from the City of San Clemente in Orange County, which has implemented Surfline camera systems along its shoreline to record and archive visual data for both scientific and public purposes (Figure B3). These systems allow for the automated

monitoring of beach width, wave runup frequency, and nearshore conditions, while also supporting recreational and safety uses. The archived imagery has proven valuable for quantifying coastal change, documenting storm impacts, and informing maintenance decisions.

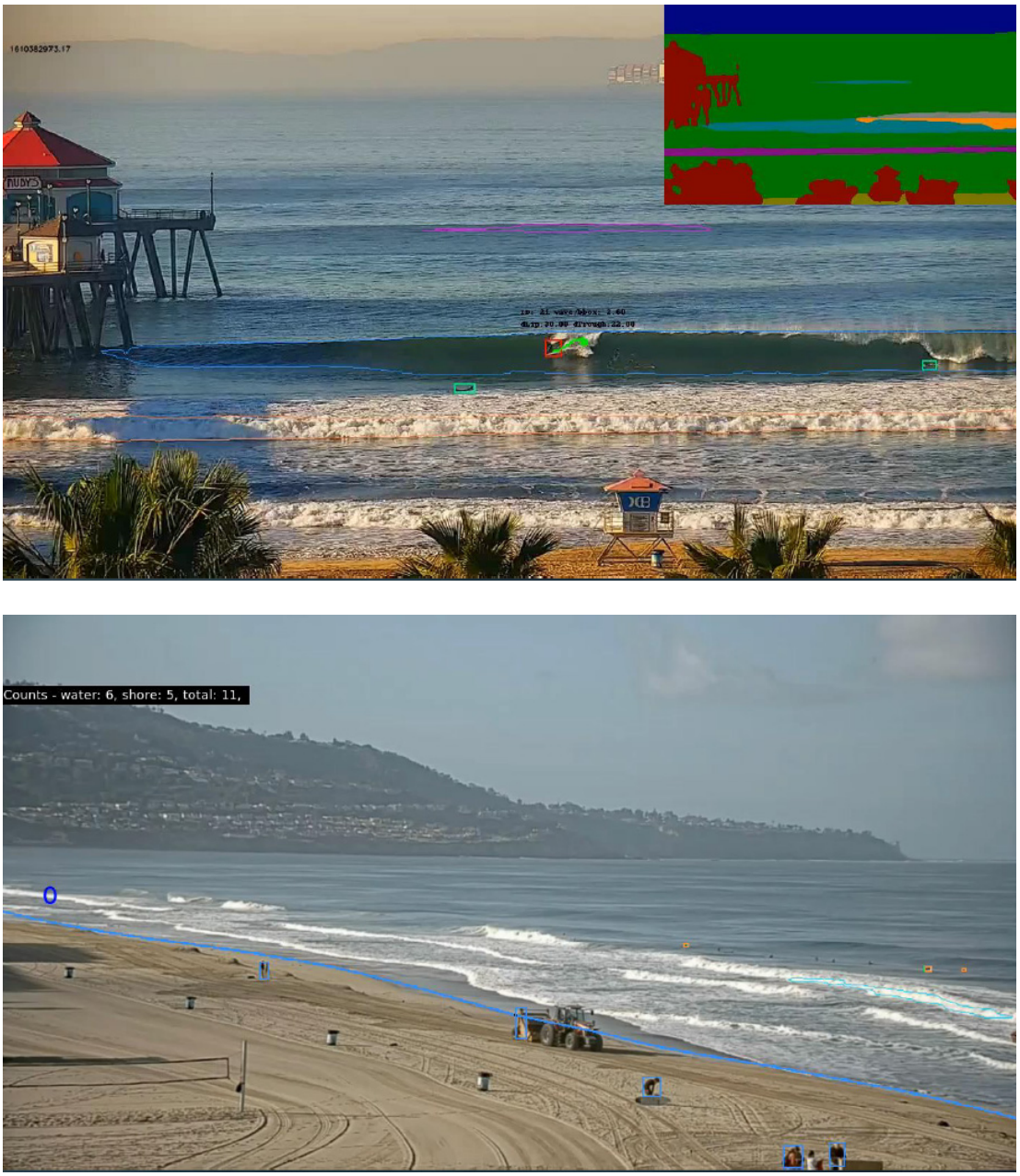

Figure B3. Stills from a Surfline monitoring camera. Top, Newport Beach in Orange County, Bottom, Redondo Beach in LA County. The camera can provide data on wave heights, surface currents, visitors, beach widths, weather conditions and more. All of this is processed in real-time with cloud archiving and access to an API.

A similar approach could be considered for Carmel Beach, where strategically placed cameras such as near the Del Mar Parking Lot or the Santa Lucia Restroom, could provide consistent visual records to supplement survey-based monitoring. These data could help track the frequency of dune or bluff toe exposure, wave overtopping, and seasonal sand recovery. Some private cameras, such as those operated near Pebble Beach Golf Links, already provide limited views of the coastline and could potentially inform future collaborations or data-sharing opportunities if appropriate privacy and access considerations are addressed.

In addition to physical monitoring, these systems can support collaboration with local environmental groups and academic institutions. Collected imagery and metadata can be shared for ecological monitoring, such as tracking vegetation recovery, wildlife presence, or the effectiveness of dune restoration efforts. Establishing clear data sharing agreements and privacy considerations will be essential to ensure transparency and responsible use of the information collected. Collaborative monitoring partnerships may also help reduce overall costs by allowing expenses for installation, maintenance, and data management to be shared among multiple organizations with overlapping research or management interests. Further research will be required to evaluate system feasibility and confirm suitable locations before implementation.

Implementing a monitoring system to identify when actions should be triggered can involve numerous stakeholders. Monitoring data can be collected by the City during routine maintenance activities, extracted from remote sensing data, or collected in partnership with local research institutions such as the U.S. Geological Survey, National Oceanic and Atmospheric Administration, or nearby research institutions. Ideally, a program that monitors triggers would be integrated into routine City public works activities so that regular data collection forms the basis for adaptation decisions.

Some recommendations for this are further discussed in Section 3.4.

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Appendix C

Initial Offshore Sediment Investigation for Augmenting Sand Supply on Carmel Beach

Appendix C.
Initial Offshore Sediment Investigation for Augmenting Sand Supply on Carmel Beach

This appendix section provides an initial screening investigation of possible offshore sand supply for the sediment cell encompassing Carmel Bay and Carmel Beach. Carmel Beach is constrained by two rocky headlands—Arrowhead Point to the north and Carmel Point to the south. As a large pocket beach, the sand volume is mostly contained between the headlands, with minimal sediment exchange beyond the system. Carmel Beach is a picturesque 1.25-mile-long pocket beach that is recognized for its distinctive bright white sand, which gives the shoreline its unique character and is highly valued by the community and visitors alike (Figure C1). This white sand is characterized by its fine, soft texture and color, often likened to powdered sugar. Composed primarily of quartz and feldspar, the grains are small, smooth, and uniform, creating a bright, reflective surface that feels comfortable underfoot and gives beaches a pristine, inviting appearance.



Figure C1. Sand ramp near the Del Mar Parking Lot, which showcases the unique white sand.

As the City contemplates adaptation strategies, augmenting the existing sand volume is a promising approach. This initial investigation examines existing literature and data on the quality and quantity of offshore sand in Carmel Bay that may be compatible with the unique characteristics of Carmel Beach, with particular attention to color compatibility, which is the community's primary concern.

Sand supplied to Carmel Bay comes from several sources. The primary contribution is erosion and abrasion of granodiorite bedrock on the Monterey Peninsula, with transport southeast toward Carmel Bay, as shown in Figure C2 (Storlazzi and Field 2000). Additional inputs include erosion and weathering of shoreline and offshore rocks, and terrigenous debris delivered by the Carmel River and smaller drainages such as San Jose Creek, which Carter (1971) identified as a major source of sedimentary deposits to Carmel Bay. However, both the Carmel River and San Jose Creek channels have been stabilized through armoring of the banks and planting of non-native vegetation. Increased soil runoff in the agricultural areas upstream has effectively reduced these waterways' ability to erode bedrock and create sediment for the littoral environment by choking the channels with fine sediment (Storlazzi and Field 2000).

What many people perceive as the "beach" is only the visible portion of a larger sandshed system, where sediment is constantly moving between the dry beach, nearshore bars, and offshore zones (Figure C3). Sediment movement within the system can occur either north or south (alongshore) or off- and onshore (cross shore) based on seasonal changes in wave energy and direction and in response to large storm wave events. The dry sand beach at Carmel is part of a highly dynamic coastal system that experiences seasonal and event-driven fluctuations. During the winter months, large storm waves, especially those approaching from the west, erode the dry beach, transporting sand offshore and often exposing the underlying bedrock. In contrast, calmer summer wave conditions allow that same sand to return onshore, gradually rebuilding the beach. These seasonal patterns of erosion and recovery are typical for pocket beaches like Carmel, where sediment tends to remain trapped between headlands, resulting in long-term volume stability despite dramatic short-term shoreline and beach changes.

During large storm wave events, sand is removed from the beaches and transported into offshore sandbars. However, recovery after major storm events (such as El Niño winters) can take multiple years, depending on wave direction, wave period, and the depths at which the large storm wave events deposit sand as well as the availability of mobile upcoast sediment. Sediment transport at Carmel Beach will be influenced by sea-level rise and increased storminess, which are long-term factors influenced by climate change.

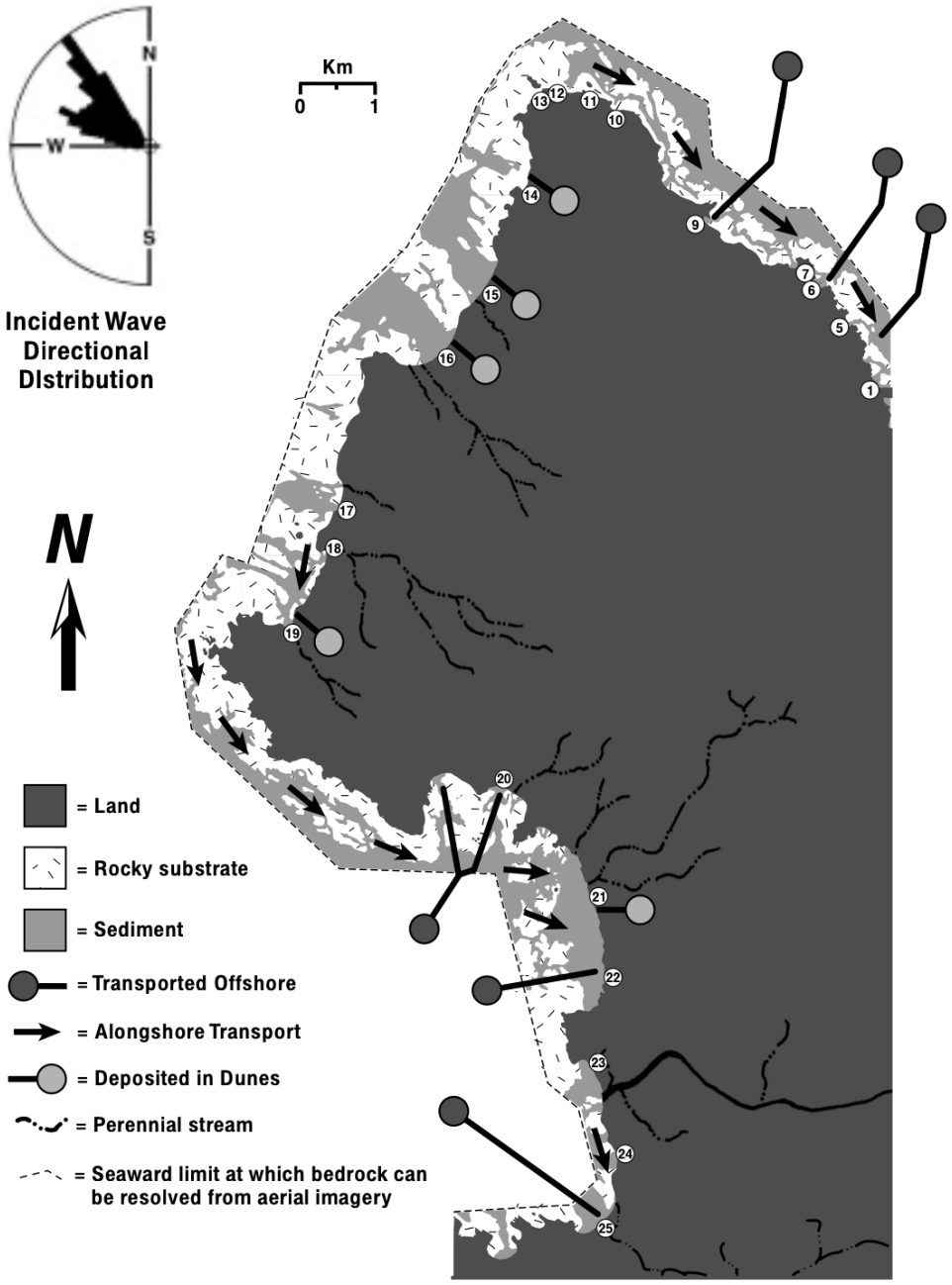

Figure C2. Interpreted sediment distribution overlain by the dominant littoral sediment transport pathways and sinks along the study area. The wave rose for the central coast was compiled from over 12,000 deep-water buoy observations between 1995 and 1998 (Coastal Data Information Program 1998). Note the correlation between transport pathways and sediment patterns (Storlazzi and Field 2000).

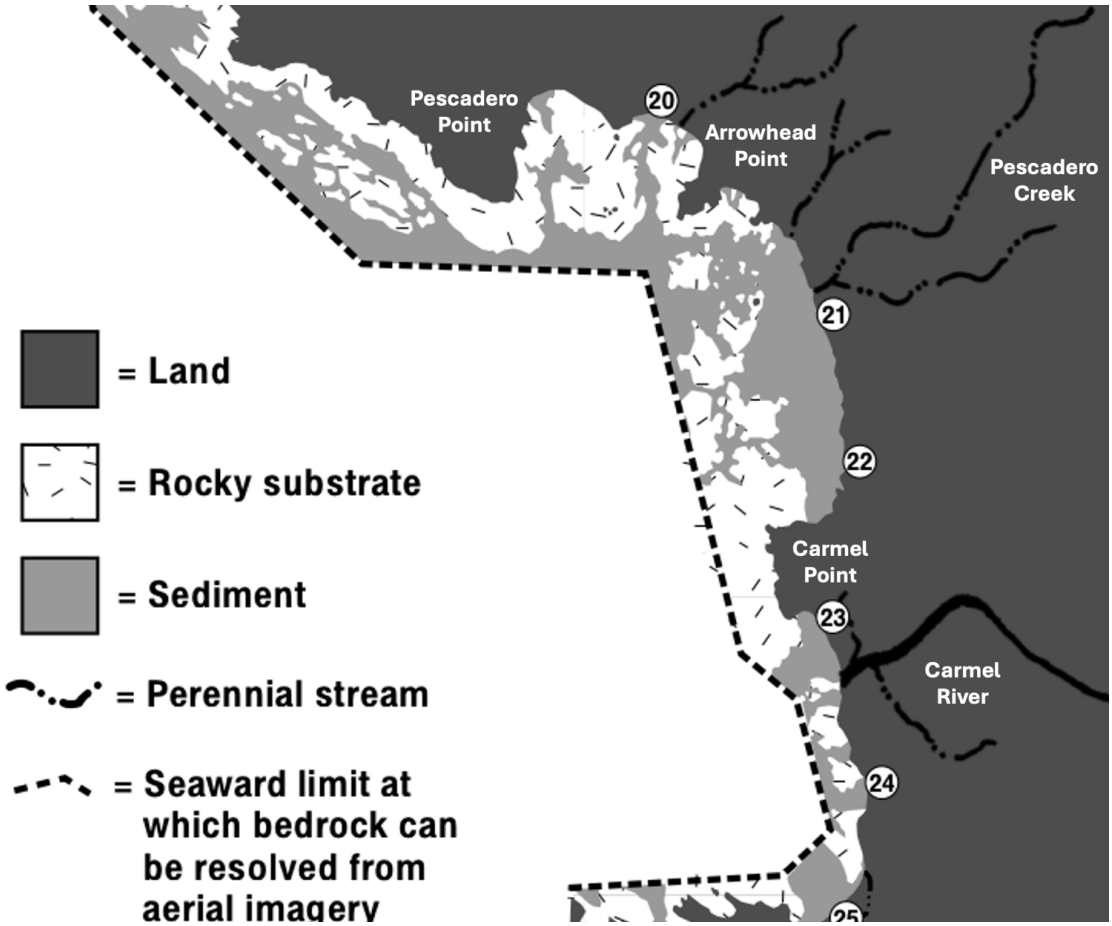

Figure C3. Location of beaches and distribution of sediment and bedrock in the nearshore and inner shelf along the Monterey Peninsula and Carmel Bay (Storlazzi and Field 2000).

Table C1 shows that Stillwater Cove (see #20 above) has a relatively coarse mean grain size, comparable to the southern part of Carmel Beach (#22), whereas the northern part of Carmel Beach (#21) is more similar to Carmel River State Beach (#22). The quartz percentage at Stillwater Cove and Carmel Beach is lower, and the feldspar percentage higher than at Carmel River State Beach and Monastery Beach (Storlazzi and Field 2000).

Table C1. Textural and mineralogic properties of the littoral sediments (all mineralogic distributions are % by mass of a 50–100 g sample rounded to the nearest 5%) (Storlazzi and Field 2000).

Site #	Beach Name	Mean (ϕ)	Sorting (ϕ)	Skewness (ϕ)	Quartz (%)	Feldspars (%)	Heavy Mineral (%)	Shell Material (%)
20	Stillwater Cove/ Pebble	1.74	0.42	0.94	40	30	30	<5
21	Carmel Beach (north)	0.57	1.92	−0.44	35	50	15	<5
22	Carmel Beach (south)	1.87	0.52	0.89	40	45	15	<5
23	Carmel River State Beach (north)	0.68	0.83	0.04	60	25	15	<5
24C	Carmel River State Beach (central)	0.96	0.82	0.40	60	30	10	<5
24S	Monastery Beach	−0.87	0.44	−0.56	65	30	5	<5

Carmel Beach is split among northern and southern sections in the study by Storlazzi and Field (Figure C3 and Table C1). We consider the compatible sediment range to reflect the combined properties of both areas. Therefore, suitable sediment for nourishment should have a mean grain size (ϕ) between 0.57 and 1.87, sorting values (ϕ) ranging from 0.52 to 1.92, and skewness (ϕ) between −0.44 and 0.89 (Table C1). This represents a relatively wide range of compatible grain sizes. It is important to note, however, that coarser-grained material generally remains on the beach longer than finer-grained material, which is more easily mobilized and transported offshore. Mineralogically, compatible sediments should contain 35 to 40 percent quartz, 45 to 50 percent feldspar, approximately 15 percent heavy minerals, and less than 5 percent shell material.

DEPTH OF SEDIMENT SOURCES

Based on regional practices and logistical feasibility, sediment for beach nourishment in California is most commonly sourced from depths of less than 30 m. This range balances dredging accessibility, operational efficiency, and environmental permitting. For example, the Sunset Beach nourishment project in San Francisco sourced sediment from depths between 10 and 20 m (USACE 2009), while the SANDAG Regional Beach Sand Project off San Diego sourced material from borrow sites at depths of 15 to 18 m (SANDAG 2005). These cases reflect a broader trend where offshore sand deposits between 15 and 30 m are targeted for their compatibility with native beach grain sizes and manageable extraction costs. Given these constraints, any offshore sediment considered for nourishing Carmel Beach is most likely to come from within this depth range, particularly in bathymetric lows (Figure C4) or paleo-channel features where sand accumulates.

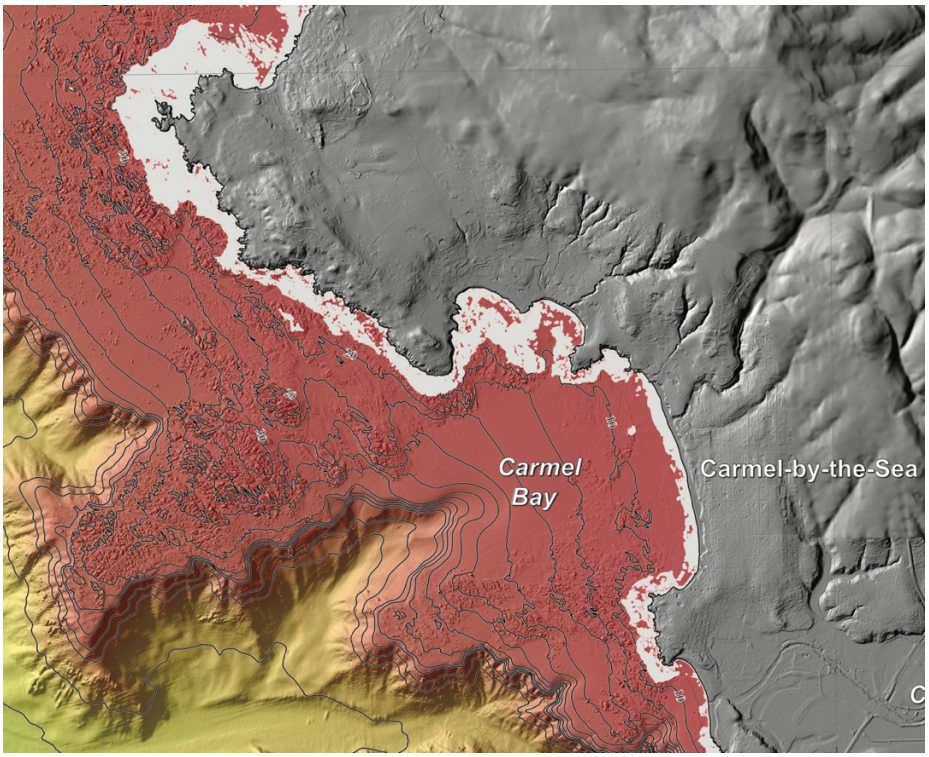

Figure C4. Bathymetric contour intervals: 10 m (Johnson et al. 2016).

Compatible Sediment

Based on the characteristics of Carmel Beach, suitable sediment for nourishment is expected to consist of fine to medium sand with a moderate to high quartz content. This is supported by seafloor character data from the U.S. Geological Survey map series, as shown in Figure C5. In this figure, light green areas represent sandy substrate in depths shallower than 30 m, whereas dark green areas indicate sandy zones between 30 and 100 m. These regions correspond to areas where the seafloor texture and composition appear most similar to native beach material. While these zones suggest potential compatibility, the interpretation is based on acoustic classification. Ground-truth sampling and laboratory grain size analysis would be required to confirm whether the sediment meets the physical and mineralogical criteria defined in Table C1. Figure C6 shows similar grain size distributions in offshore areas adjacent to Carmel Beach, supporting the possibility that sediment in these regions falls within the acceptable sediment sorting range (expressed on the ϕ scale). However, without direct sampling, the presence of coarse material, fine silts, or excessive shell content cannot be ruled out.

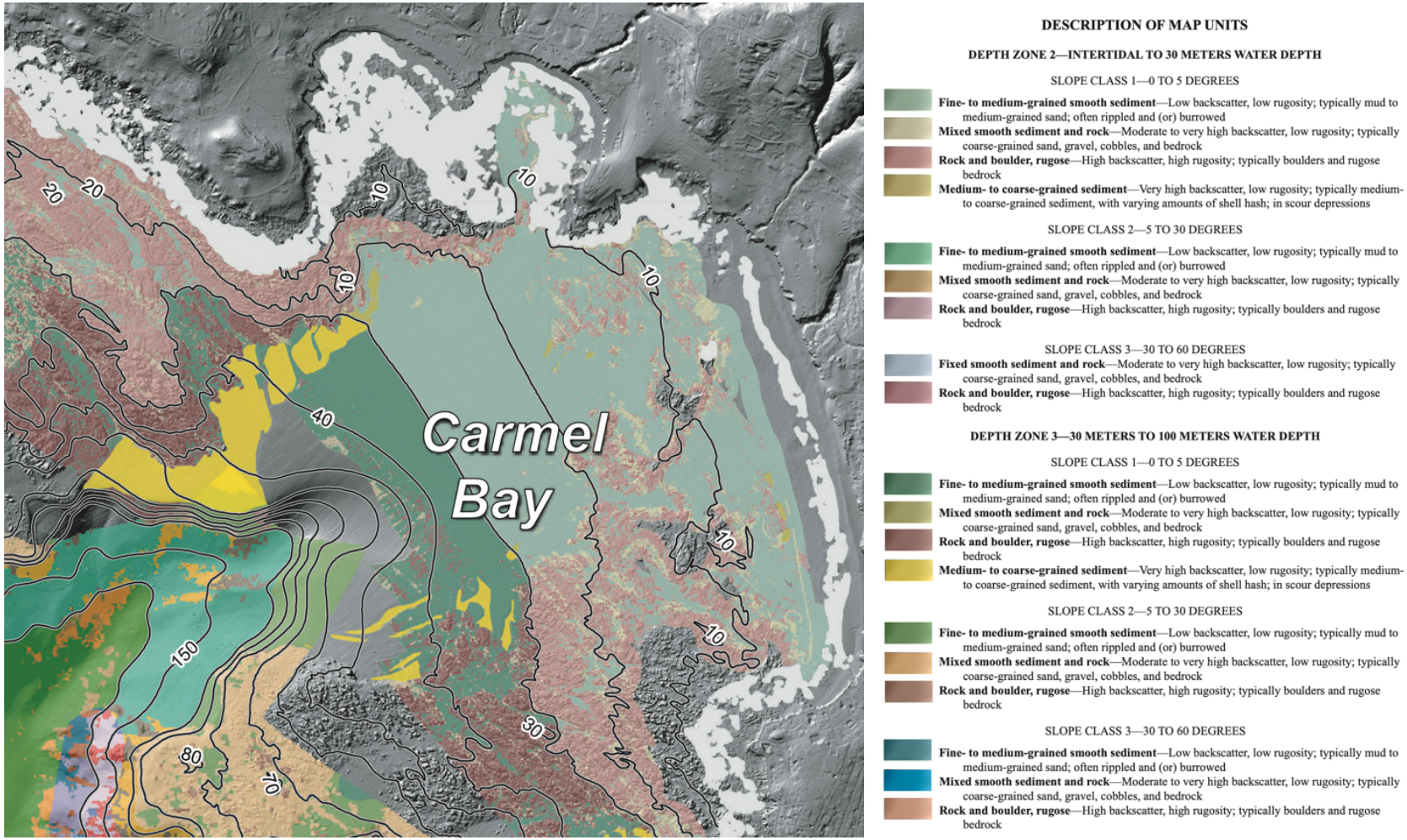

Figure C5. Seafloor Character, Offshore of Monterey Map Area, California (Johnson et al. 2016).

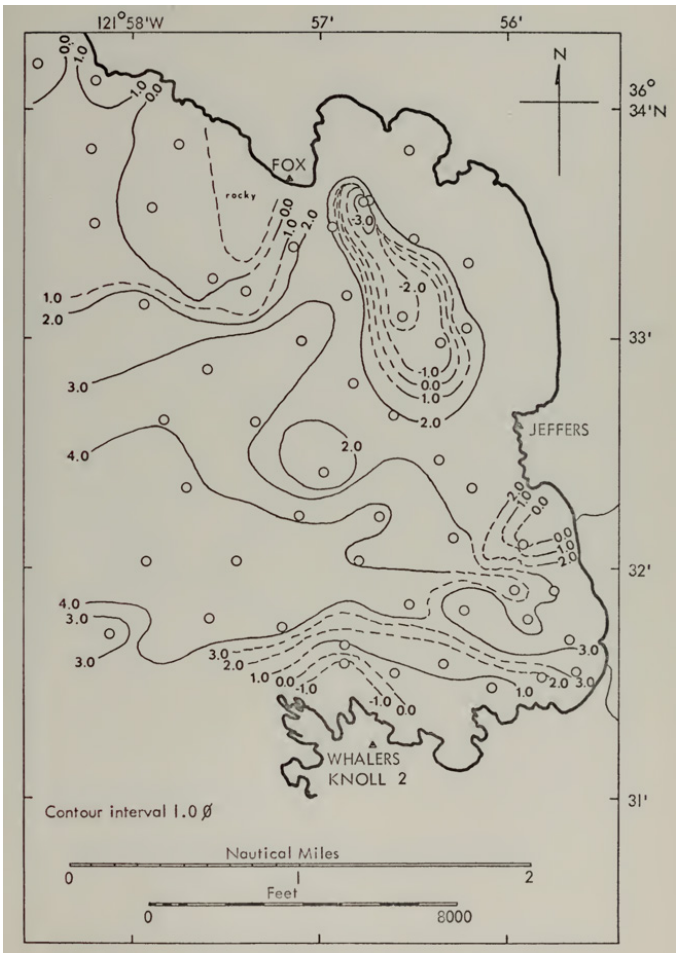

Figure C6. Sediment mean grain-size distribution (Carter 1971).

Shell Content

Shell content is another important factor to consider when evaluating the suitability of offshore sediment for beach nourishment. Excessive shell fragments can alter the visual appearance of a beach, affect compaction and drainage, and potentially reduce recreational or ecological value. For Carmel Beach, the native sediment has been shown to contain less than 5 percent shell material, indicating a preference for mineral-dominated sand with limited shell content. Figure C7, based on Carter's 1971 survey of offshore sediments, presents the spatial distribution of shell content across Carmel Bay. The map shows that much of the offshore area below 30 m depth, particularly zones that contain fine to medium sand, has a shell content ranging from 0 to 49 percent by mass. While this upper range appears high, the data are grouped broadly, and a significant portion of these areas likely fall within the lower end of that range, closer to the target of less than 5 percent. The co-occurrence of suitable grain size and low to moderate shell content in these offshore zones suggests potential compatibility with native beach sediment. However, because the Carter survey is based on surface grabs with limited resolution, further sediment sampling and laboratory analysis will be necessary to confirm whether specific offshore deposits meet the shell content threshold for nourishment.

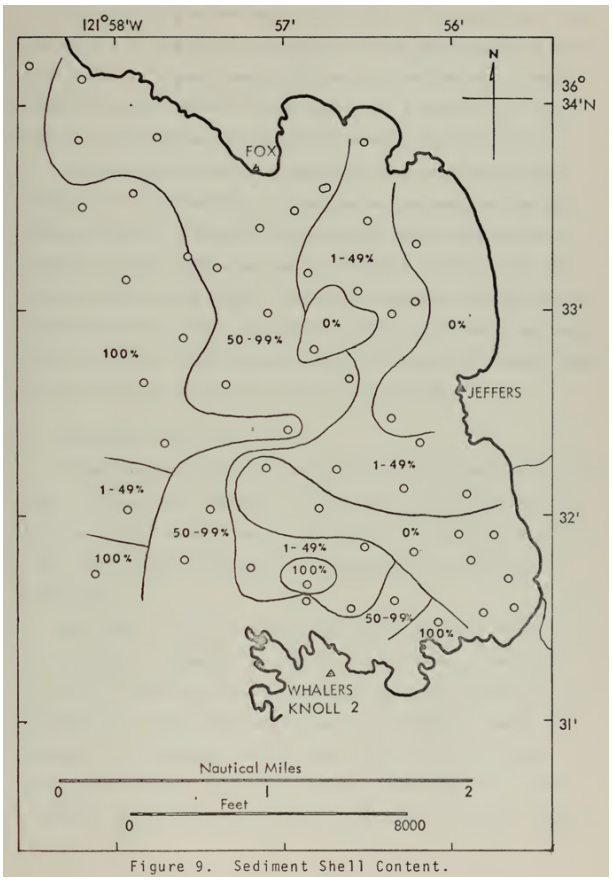

Figure C7. Sediment shell content (Carter 1971).

usSEABED Sample Locations

Table C2 and Figure C8 display the sample locations and grainsize and sorting characteristics of the most immediate usSEABED data.

Table C2. Grainsize and sorting data by location from usSEABED (Buczkowski et al. 2020).

Object ID #	Latitude	Longitude	Grainsize (phi)	Sorting (phi)
26	36.52113	-121.9672	-2	
64	36.52483	-121.9343	1	
76	36.52721	-121.9648	-2.5	
78	36.52783	-121.9477	1	
81	36.5285	-121.9687	1	
114	36.539	-121.9617	1	
119	36.54002	-121.9698	6	
120	36.54033	-121.9493	1	
123	36.54134	-121.9637	1.5	
137	36.544	-121.9637	1	
148	36.54783	-121.9597	1	
151	36.54911	-121.9501	1.5	
160	36.5515	-121.9423	-3.6	0.9
162	36.55233	-121.9653	1	
166	36.55333	-121.9563	-2.5	
171	36.55488	-121.9478	1.5	
177	36.5565	-121.9458	2.5	
178	36.5565	-121.9458	0.3	0.8
187	36.55833	-121.9697	1	
191	36.55917	-121.9647	1	



Figure C8. Grainsize and sorting data by location from usSEABED (Buczkowski et al. 2020)

Sediment Thickness

In addition to grain size and composition, the thickness of the offshore sediment layer is an important factor when evaluating potential source areas. Figure C9 shows the estimated sediment thickness (in meters) across the Carmel Bay shelf. According to this map by Johnson et al. (2016), the sediment layer begins to exceed 1 m in thickness at around 20 m depth. Between 30- and 40-m depth, the sediment layer increases to approximately 5 m thick in some areas.

While dredging beyond 30 m depth is generally considered less practical because of increased costs, the presence of thicker sediment deposits in these deeper areas may make them worth further investigation. These locations could offer larger volumes of sand with fewer constraints related to patchiness or exposure but would require additional feasibility studies to determine whether extraction is viable and environmentally acceptable.

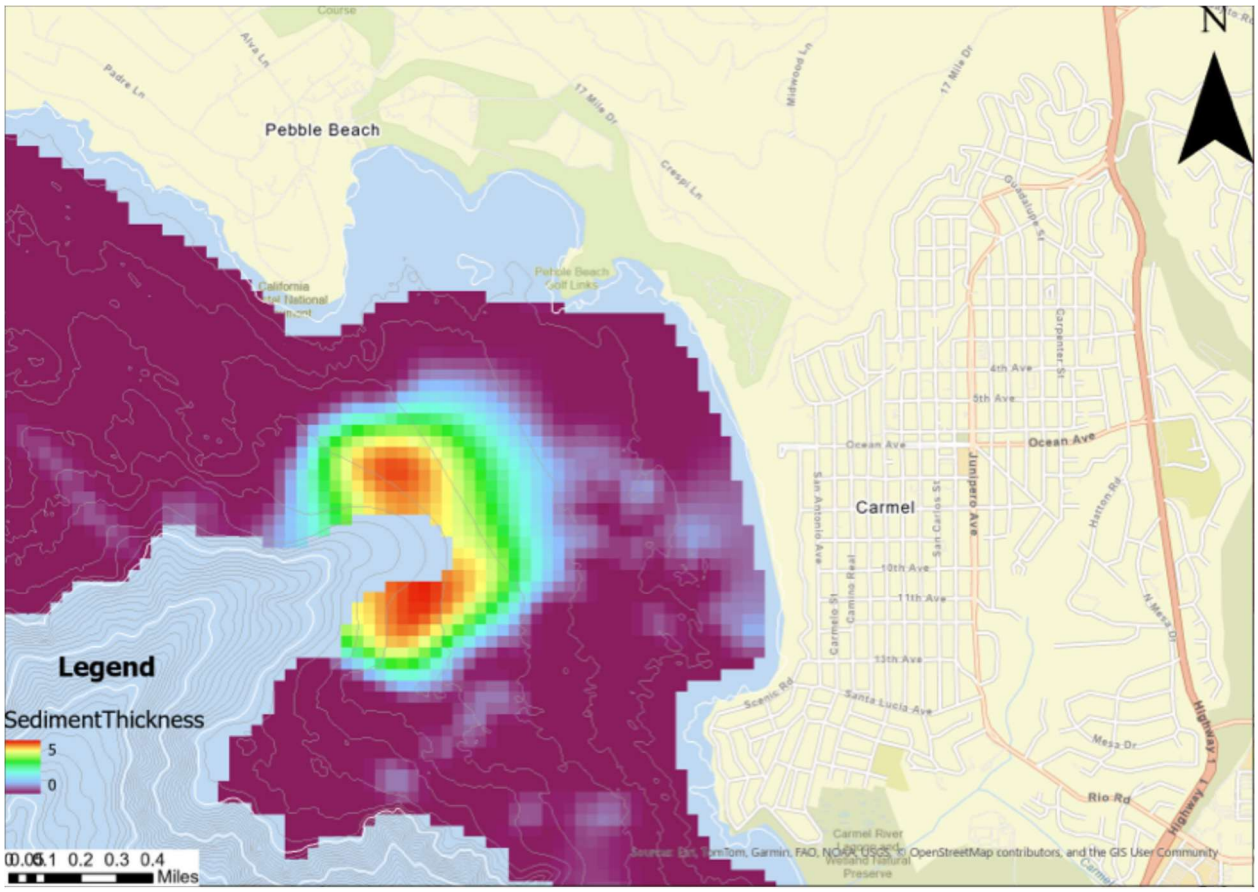

Figure C9. Sediment thickness (meters) with 10-m bathymetric contours shown in gray (Johnson et al. 2016).

PALEO STREAM CHANNELS AS SEDIMENT SOURCE

One of the most important features influencing offshore sediment accumulation in Carmel Bay is the presence of paleo stream channels. These are ancient riverbeds carved into the landscape during periods of lower sea level and now lie submerged on the seafloor. Such features have been documented in the nearshore and inner shelf of the Monterey Peninsula and Carmel Bay, particularly by Storlazzi and Field (2000), who describe them as structurally bounded depressions that function as effective traps for littoral sand.

In regions where the coastline is exposed to the dominant northwest wave direction, sediment tends to accumulate in shore-normal bathymetric depressions interpreted as paleo stream channels that trap littoral sand. These channels often align with former onshore drainage paths and are typically carved into bedrock. As sediment infills these depressions, it creates linear sediment bodies surrounded by rocky substrate, as illustrated in Figure C10 and Figure C11. In areas where stream channels enter the coast perpendicularly and the coastline runs parallel to prevailing wave energy, sediment is distributed both within these shore-normal features and along narrow, shore-parallel ribbons at depths of 2 to 6 m. In contrast, where no major fluvial inputs exist, sediment tends to occur as discontinuous, shore-parallel patches typically found at depths greater than 15 m (shown in Figure C10 as a purple line).

Their typical depth range of 10 to 30 m places them within reach of common dredging equipment, and their location in protected structural lows suggests they could retain high-quality sediment suitable for nourishment. However, their suitability cannot be confirmed without further investigation. Detailed sub-bottom profiling and coring will be required to determine the volume, grain size, shell content, and mineral composition of sediment within these channels, as well as to assess the environmental and geomorphic impacts of potential extraction.

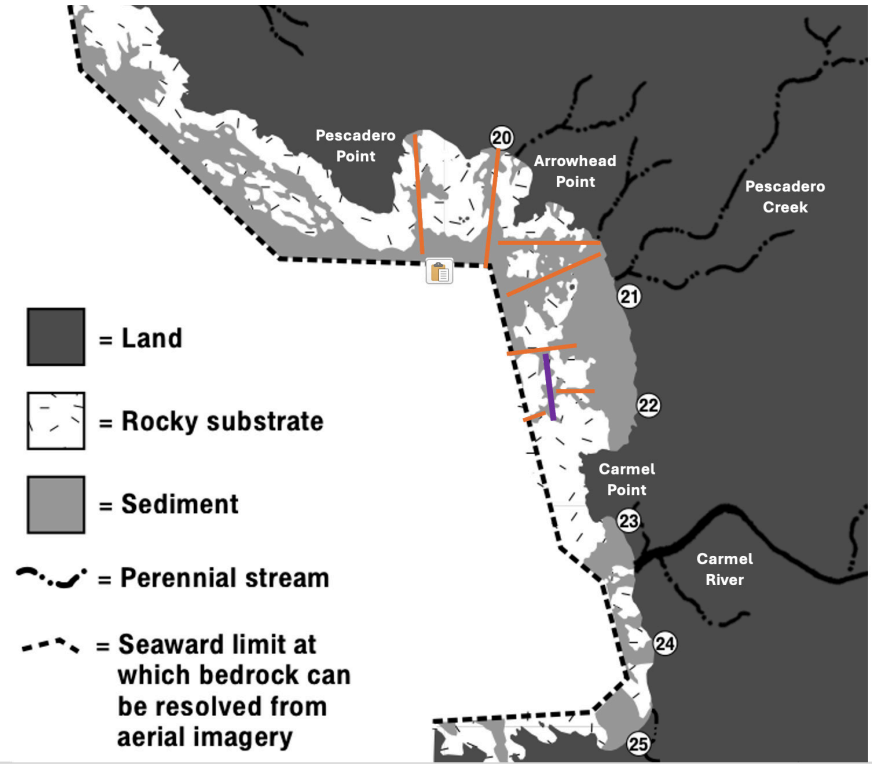

Figure C10. Potential paleo stream channels offshore of the Monterey Peninsula, inferred from sediment-filled depressions bordered by rocky substrate (Storlazzi and Field 2000).

In Carmel Bay, paleo channels are most likely to be found offshore of current and former river mouths. The most promising area is directly offshore of the Carmel River, where bathymetric maps and seismic profiles show a shore-normal depression aligned with the river's historical outflow. Additional candidate locations include the area near Pescadero Canyon, where Simpson (1972) documented sediment pockets up to 22 m thick.

These features are expected to contain fine to medium sand, partially or fully filling the paleo channels. However, sediment sourced from the Carmel River and the adjacent Monastery and Carmel River State Beach sediment cell is compositionally and visually distinct from the native sand at Carmel Beach and is likely a poor compatibility match for nourishment. Any consideration of these offshore deposits should therefore include grain size and mineralogical analyses as well as explicit color evaluation to confirm suitability. Learning from Figure C11, seasonal wave conditions and sediment exchange strongly influence retention of placed sand. Winter storms drive sand offshore and increase the risk that newly placed material is lost to bars, while late summer and fall are characterized by calmer conditions and more frequent onshore transport that favor beach accretion. If this area is selected as a sediment source, scheduling dredging and placement in the fall should maximize stability of the nourishment, reduce turbidity dispersion and rehandling, and avoid early winter storm losses. Under this scenario, dredging the upper region of the deposit in fall is likely the most feasible option, pending permit and biological work windows. Aligning work windows with seasonal habitat cycles and targeting

unconsolidated sand bodies away from rocky reef, kelp, and grass also reduces habitat disturbance, minimizes turbidity exposure, and limits the footprint of temporary impacts.

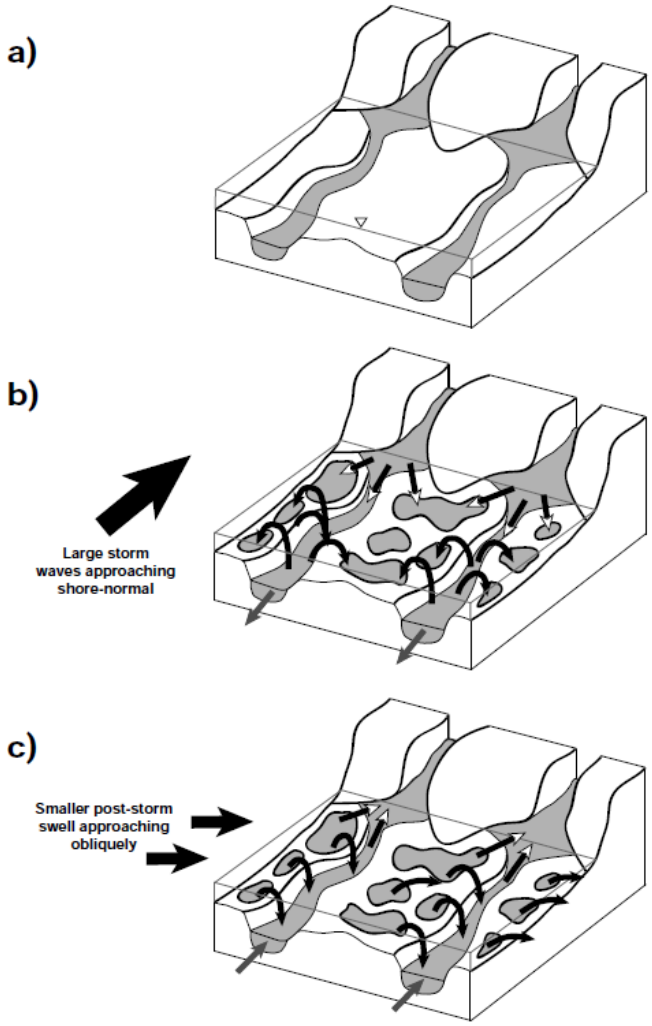

Figure C11. Schematic diagram showing hypothesized model for alongshore sediment transport along a rocky, embayed coastline. (a) Pre-storm: a subaerial beach between headlands and sediment offshore in a paleo-stream channel bounded by subaqueous bedrock ridges. (b) Storm: subaerial beach sediment is eroded and carried offshore (white-tipped arrows), sediment in the paleochannels is suspended and dispersed across shoreface (black-tipped arrows), and a percentage of sediment in the paleo-stream channels is transported farther offshore to the mid-shelf (gray arrows). (c) Recovery: smaller short-period waves (moving from left to right) would sweep the bedrock ridges clear of sediment, transporting the sediment either onshore to rebuild the pocket beach (white-tipped arrows) or into the adjacent downcoast paleo-stream channel (black-tipped arrows). The reconstruction of the pre-storm shoreface profile would then be aided by long period, low-energy swells carrying sediment onshore from greater depths (gray arrows) (Storlazzi and Field 2000).

EXAMPLE OF A MULTICRITERIA SUITABILITY MODEL FOR OFFSHORE SEDIMENT SOURCES

This analysis is provided here for reference. This process uses a multiplicative, multicriteria raster overlay to evaluate the suitability of offshore areas for sediment sourcing. Each criterion, such as grain size, shell content, sediment thickness, source depth, proximity to Carmel Beach, and depth of closure compliance, is first normalized on a scale from 0 to 1, with 1 indicating full compatibility. The final suitability score for each raster cell is calculated by multiplying all individual scores. This approach ensures that if a location fails to meet even one of the criteria, its overall suitability becomes zero. As a result, only areas that satisfy all minimum requirements will receive non-zero scores, with values approaching 1 indicating the most compatible zones. This method is particularly useful for strict screening processes, such as identifying offshore sediment sources for beach nourishment under regulatory constraints.

1. **Grain size (Johnson et al. 2016).**

   Score 1.0 if mean grain size on the phi scale is within 0.57 to 1.87. Values outside this range may be linearly scaled toward 0 if partially compatible.

2. **Color**

   Score 1.0 when the sand closely matches native Carmel Beach sand. A color scale will be set up.

3. **Sediment thickness (Johnson et al. 2016).**

   Score 0.3 if thickness is at least 1 m, 0.6 if at least 2 m, and 1.0 if at least 3 m.

4. **Depth of source (Johnson et al. 2016).**

   Score 1.0 if the area lies between the local depth of closure and 30 m. Assign 0.5 for depths between 30 and 45 m. Values outside this range are scaled down or set to 0.

5. **Proximity to Carmel Beach**

   Use an inverse distance function so areas closer to the placement reach receive higher scores. For example, 1.0 at the shoreline, decaying toward 0 with increasing distance.

6. **Depth of closure constraint**

   If the location lies seaward of the estimated depth of closure, assign a score of 1. Otherwise, assign a score of 0.

7. **Shell content (Carter 1971)**

Score 1.0 if shell content is less than 5 percent. Use 0.9 for 5 to 50 percent, 0.5 for 50 to 75 percent, 0.25 for 75 to 95 percent, and 0 for 95 percent or higher.

Final Suitability Score Calculation

The overall suitability score is calculated by multiplying all individual raster layers:

Suitability, normalized = G × C × S × T × D × P × Z

Where:

G = grain size
C = color
S = shell content
T = sediment thickness
D = depth of source
P = proximity to Carmel Beach
Z = depth of closure compliance

This multiplicative method ensures that all critical conditions must be met for a location to receive a non-zero score. It strongly favors areas that are fully compatible with nourishment requirements, making it well-suited for regulatory screening and high-confidence sediment sourcing.

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City of Carmel-by-the-Sea

SHORELINE MANAGEMENT PLAN

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Coastal Biologist

And

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Assistant City Administrator
City of Carmel-by-the-Sea

Accepted by the City Council: September 2003
Approved by the California Coastal Commission: February 2004

CARMEL-BY-THE-SEA

SHORELINE MANAGEMENT PLAN

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Barbara Livingston
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1 INTRODUCTION: A Shoreline To Be Managed

To some, the concept of managing Carmel's shoreline may seem, at first, an impossible task. So many of its characteristic features appear to be out of our control: sparkling white sands that disappear and re-appear each year, ancient dunes, bluffs, rocky promontories, and decades-old Monterey cypress that are exposed to erosion from wind and wave, a vast and powerful ocean whose sea level appears to be on the rise, and intense winter storms generated by weather patterns that seem to be less predictable than in the past.



Photo 1 – *The Carmel Shoreline*

Yet, in the face of these powerful forces, the City of Carmel-by-the-Sea has shown that it is possible to maintain, protect, and even enhance its shoreline. Over the past half century, the City has embarked on a series of projects and programs that have:

- helped protect Carmel's coastal dunes, bluffs, and Scenic Road (including its infrastructure and houses) from erosion;
- provided and maintained ample horizontal and vertical shoreline access;

- maintained a landscape of native drought-tolerant and "natural-looking" plants that protect the dunes and upper bluffs; and most important; and
- provided for the health, safety, and welfare of the residents and visitors who enjoy the City's shoreline.

1.1 MANAGEMENT OF THE CARMEL SHORELINE

1.1.1 *City Departments, Commissions, Task Forces*

For many years, management of Carmel's shoreline was the responsibility of its Department of Public Works. In 1988, the City created a separate Forestry and Beach Department that shared some of the beach maintenance responsibilities with Public Works. Then, in 1995, Forestry and Beach became the Department of Forest, Parks, and Beach, a name that more accurately reflected its mission.

Even now, responsibilities along Carmel's shoreline are still shared between the Public Works and Forest, Parks, and Beach Departments. The two departments work cooperatively on issues affecting the Carmel shoreline. They are both housed in the same building (on Junipero Avenue), and there is extensive formal and informal dialogue between the leadership of the two departments. Regular maintenance along the Beach Bluff Pathway, litter and trash pick-up from the Pathway and beach areas, maintenance of trees, landscape plants, Pathway irrigation system, beach access stairways, and restroom facilities are all performed by personnel from the Forest, Parks, and Beach Department or by City contractors. Maintenance and repairs of shoreline walls and revetments, beach access stairways and ramps, the Beach Bluff Pathway, storm drains, Scenic Road, and other structures, are the responsibility of the Department of Public Works.

The City's Forest and Beach Commission also deals with issues affecting the coastline. Members of this advisory group are appointed by the Carmel City Council. As with the department it advises, the Forest and Beach Commission grew out of the Forestry Commission in 1988.

On at least two occasions, the City Council has appointed task forces to deal with specific issues related to Carmel's shore. In response to the extraordinary damage to the City's beach bluffs and shoreline structures caused by the devastating 1982/83 El Niño storms, the Carmel Beach Rehabilitation Task Force was created in 1983. It worked with City staff and consultants to oversee structural repairs during Phase I of the Carmel Beach Rehabilitation Project. From 1984 through 1988, this Task Force assisted in Phase II: the planning and development of the Carmel Beach Bluff Pathway project.

Then, in 1996, the City Council created the Carmel Beach Master Plan Task Force. This group worked with City staff and produced the *Beach Master Plan*, which was approved by the City Council in 2000.

1.1.2 *Previous Carmel Shoreline Management Documents*

Over the years, three documents have provided information and direction for management of the Carmel shoreline:

Beach Bluff Pathway Landscape Plan

Between 1985 and 1988, the Carmel Beach Rehabilitation Task Force and landscape architects Royston, Hanamoto, Alley, and Abey (RHAA) of Mill Valley, California, developed the landscape design plan for the Carmel Beach Bluff Pathway.[1] Plants utilized in the design were chosen because they "fit" well with the Carmel shoreline environment; these native or "native-like" plants could thrive when exposed to salty air, coastal winds, and limited water.[2] This landscape plan and its accompanying plant list were approved by Carmel's Forestry Commission, Planning Commission, and City Council, as well as the California Coastal Commission. The plan provides the framework for the City's current shoreline landscape. Approval of Coastal Development Permits for some of Carmel's recent shoreline projects has been based, in part, on conditions specifying that the City continue to follow the RHAA landscape plan.

Shoreline Emergency Action Response Plan

In 1989, coastal biologist David Shonman and Assistant City Administrator Greg D'Ambrosio developed emergency response guidelines for dealing with damage to Carmel's beach and bluff. The *Shoreline Emergency Action Response Plan* was written primarily in the form of worksheets, describing procedures for shoreline monitoring and erosion repair. Carmel's *Beach Master Plan*, described below, recommends that the City:

> "Continue the implementation of the BEACH EMERGENCY ACTION RESPONSE PLAN[3] … to minimize the dangers to public

[1] The Carmel Beach Bluff Pathway is detailed in the project EIR (City of Carmel-by-the-Sea. 1986. Carmel Beach Restoration Phase II Final EIR). The project's landscape plans are on file with the City Forester.
[2] The Task Force and landscape architects also chose plants whose leaves and flowers were "subdued" in color, to better match existing native coastal plants.
[3] The *Beach Emergency Action Response Plan* is now called the *Shoreline Emergency Action Response Plan*

safety and facilities that may be caused by winter storms or other natural disasters."[4]

Beach Master Plan

The *Beach Master Plan* was the City's first planning document to establish goals, objectives, and policies for the Carmel shoreline. This Plan was developed by the Beach Master Plan Task Force and amended by the Carmel Planning Commission and City Council. The *Beach Master Plan* was approved by the City Council in September 2000.

Each of these documents deals with some aspect of managing Carmel's shoreline, but no one document constitutes a complete management manual. The RHAA design plan, written more than a decade ago, has not been assiduously followed by the City. Many of the plants recommended in this City-approved landscape design have since been replaced by other species, for reasons that have never been documented. The *Beach Master Plan* omits mention of the numerous seawalls and revetments that line and support the beach bluffs. The *Shoreline Emergency Action Response Plan* only deals with conditions that might be encountered along the shoreline south of Eighth Avenue. None of these plans provides guidance regarding the level of action along the shoreline that will require review by City planners in order to conform to the Carmel LCP and State coastal law. Finally, none of these plans serves as a practical document that City staff can use for managing the shoreline.

In 2001, the City received approval from the California Coastal Commission to repair its shoreline damaged during the 1997/98 El Niño storms.[5] One of the conditions of permit approval was that the City prepare a "comprehensive shoreline management plan."

1.1.3 *Carmel Shoreline Management Plan*

This *Carmel Shoreline Management Plan* (SMP) is a response to the Coastal Commission's 2001 directive. It also responds to concerns expressed by City staff and consultants regarding the need to consolidate prior documents into a single useable plan.

[4] City of Carmel-by-the-Sea. Beach Master Plan, section (VI)(E)(OM-4). Sept. 2000.
[5] The permit was for the "Carmel Bluff and Beach Access Improvement Project" (Coastal Development Permit # 3-00-140), approved on April 13, 2001.

The *Shoreline Management Plan* is an appendix to the Carmel Local Coastal Program's Implementation Plan. It replaces the Carmel *Beach Master Plan*, while incorporating its Goals, Objectives, and Policies. It utilizes principles that guided the original Beach Bluff Pathway landscape design. It also incorporates and updates the *Shoreline Emergency Action Response Plan*, bringing it into compliance with the City's Local Coastal Program and the California Coastal Act.

In the case of development review, it is important to note that the majority of the actual beach and base of bluff area at Carmel Beach (including the revetments and the seawalls) is located within the California Coastal Commission's retained coastal permitting jurisdiction. Because of this, the standard of review for development in this area is the Coastal Act. In those cases, the General Plan/Implementation Plan can and will provide non-binding guidance to the Commission in making permitting decisions, but the decisions will be based on the policies of the Coastal Act.

The *Shoreline Management Plan* is a comprehensive document that will guide future management of the City's shoreline area, including its beaches, dunes, bluffs, landscape, and associated infrastructure. Periodically, it will be updated to reflect new ordinances, policies, plans, and information necessary for optimal management of the City's shoreline. Pertinent information from the upcoming Del Mar and North Dunes Master Plan will be added to the *Shoreline Management Plan* upon adoption.

1.2 A Word About Words

This management plan deals with Carmel's beach, dunes, bluffs and bluff tops, Ocean Avenue, Del Mar, Scenic Road, adjacent streets, and pedestrian access/ drainageways. In the past, the City, its departments, commissions, task forces, documents, reports, and plans, all have used the word "beach" to refer to different parts of Carmel's coast. Sometimes "beach" has actually meant Carmel's sandy beach, but other times, it has referred to portions of the City's coastline, including its dunes, bluffs, and surrounding areas. In this management plan, "beach" specifically refers to the portions of Carmel's shoreline where sand is naturally deposited by wave action. "Dunes" refers to areas of wind-blown sand, especially landward of the beach. When referring to Carmel's coastal area in general, this management plan uses the words "coast" "shore" and "shoreline."

2 THE CARMEL SHORELINE

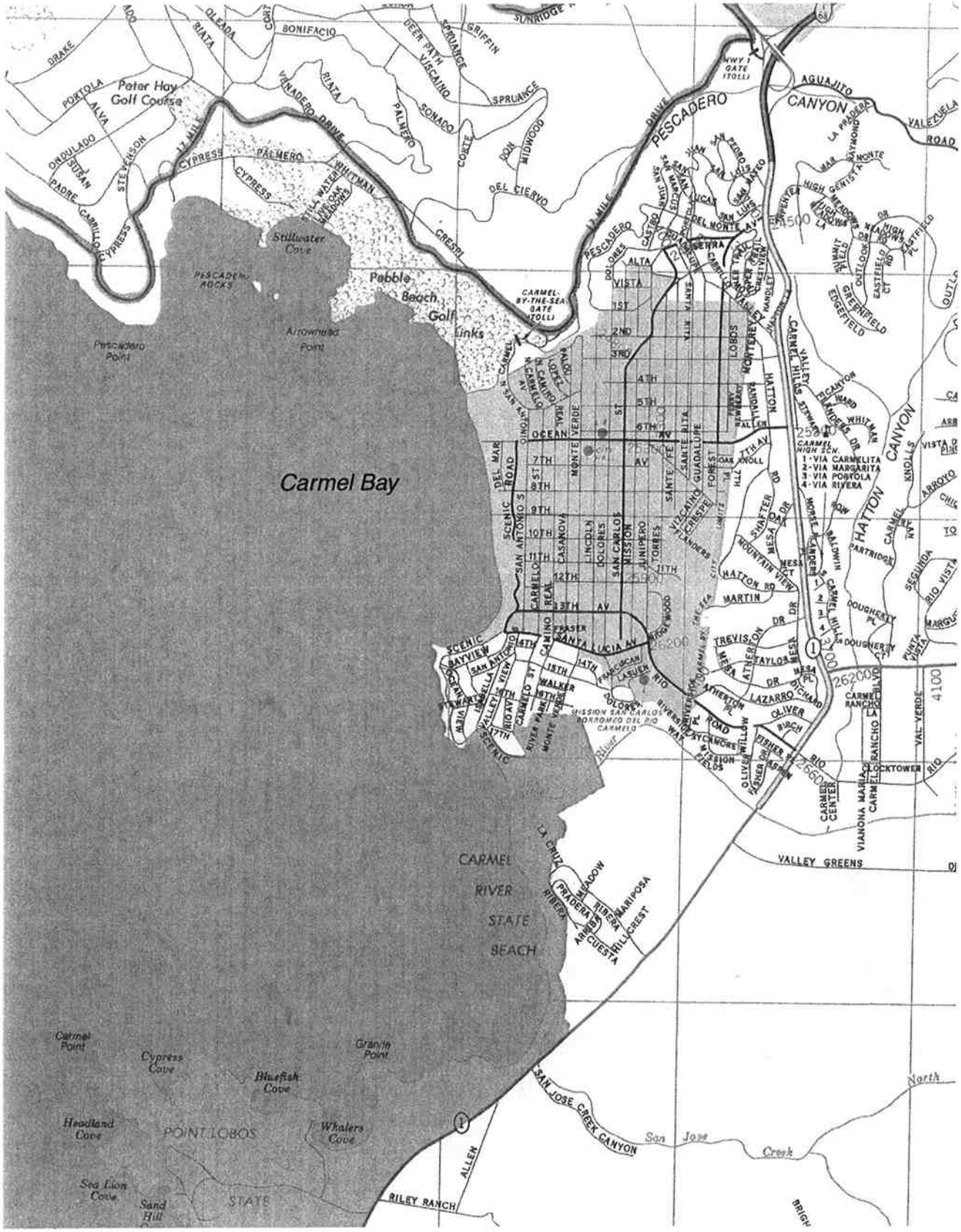
The Carmel shoreline is situated mid-point along the coast of Carmel Bay. It consists of a broad white beach that is backed by steep coastal bluffs in the far northern and southern reaches and by gently sloping dunes in the remaining portions.

Carmel's shoreline is the most dynamic of all the City's public lands. Portions of the coastline are in a state of almost constant change: the amount of sand on its beach, the shape of its dunes, the location of its coastal bluff edge and its waterline – each may fluctuate yearly, seasonally, daily, or even hourly. The natural forces that alter the Carmel shoreline also have a direct consequence on City facilities and visitor-serving amenities, on Scenic Road and its infrastructure, and on nearby private homes. The geologic, oceanographic, and meteorologic forces that have shaped, and continue to shape, Carmel's shoreline are described in detail by Simpson (1972)[6] and Johnson (1984).[7] This section of the *Carmel Shoreline Management Plan* provides an up-to-date summary of what is currently understood about the Carmel shoreline.[8]

2.1 CARMEL BAY

Carmel Bay is a 2.8 mile-wide open bay that is protected by the granitic headlands of Pescadero Point in the north and Point Lobos in the south (Fig. 1). The Bay is divided into two smaller cells, separated by Carmel Point in the middle. The City of Carmel's shoreline is located in the northern cell;[9] the southern cell[10] contains Carmel River Beach and San Jose Creek Beach ("Monastery Beach").[11] Though the two cells appear nearly contiguous, their physical features differ in important

[6] Simpson, John Page III.1972. The Geology of Carmel Bay, California. Unpublished M.S. Thesis. Naval Postgraduate School, Monterey, California. (Document on file in the "Carmel Beach Document Collection" at the Carmel-by-the-Sea City Hall.)
[7] Johnson, Rogers E. and Associates. 1984. Carmel Beach Coastal Erosion. Phase I. Final Report. Unpublished report. (Document on file in the "Carmel Beach Document Collection" at the Carmel-by-the-Sea City Hall.)
[8] An in-depth discussion of the oceanographic forces that impact the Carmel shoreline appears in Appendix 9.1.
[9] Called "Northern Carmel Bay" in Storlazzi and Field (2000)
[10] Called "Southern Carmel Bay" in Storlazzi and Field (2000)
[11] Both Carmel River Beach and San Jose Beach are part of the Carmel River State Beach.



Source: H. M. Gousha

Figure 1
Carmel Bay

ways. The northern cell is served by a single small seasonal watercourse, Pescadero Creek. The southern cell is also served by a small seasonal creek (San Jose Creek), but is dominated by the Carmel River, which delivers substantial amounts of sediment into Carmel Bay during late fall, winter, and early spring.

The southern cell is deeply etched by the Carmel Submarine Canyon,[12] which is an offshoot of the Monterey Submarine Canyon. The head of the Carmel Canyon begins just offshore of Monastery Beach, then quickly reaches a depth of 300 feet within a quarter-mile of shore. Both the Carmel River and the Carmel Canyon have significant impacts on the Bay's southern cell but do not appear to have a noticeable impact on the Carmel shoreline in the northern cell.

2.2 CARMEL BEACH

Carmel Beach is recognized as one of the world's most beautiful public beaches. It is a crescent-shaped pocket beach that extends from the upper portion of Carmel Point (sometimes referred to as Abalone Point) about one and one-quarter miles northward to Pescadero Canyon.

Like beaches everywhere, Carmel's beach is subject to periodic changes. Successful management of Carmel Beach requires an understanding of the dynamic processes that are responsible for these changes.

2.2.1 *Beach Processes*

Beaches are composed of any available material, of sufficient size and composition, which can be deposited on the shore by ocean waves. Throughout the world, beaches are made from a wide variety of materials: broken coral, mollusk shells, foraminifera tests (the shells of single-celled amoeba-like organisms), and rocks of various sizes, from boulders to cobbles to sand grains. As beach material varies in composition, it also varies in color, from the pink beaches of Bermuda (foraminifera) to the black beaches of Hawaii and Shelter Cove, California (eroded volcanic rock) to the tan sands of Monterey Bay and Big Sur to the sparkling white sands of Carmel.

Typical Beach Formation

Carmel's white sand beach is formed by processes that differ somewhat from those that generate most typical California beaches. Sands on those beaches are

[12] The Carmel Submarine Canyon is also referred to as the "Carmel Canyon" or the "Carmel Offshore Canyon."

produced by the erosion of inland mountains, hills, and fields. Erosion produces sediment that is carried by streams and rivers out to the ocean where it is sorted and distributed along the shore by wave action. The color and texture of these beaches results from the materials that have been discharged by local rivers, not just during present times, but throughout past millennia.

Once sediment has reached the coast, it is usually acted upon by two different transport mechanisms. The first, "littoral drift," is a natural process that moves sediment either upcoast or down coast, depending on the angle at which waves strike the shoreline. These waves produce a current ("longshore current") that transports sand along the shore, parallel to the beach. Sediment carried by this current can often be seen to pile up on one side of a coastal structure (e.g. a rock jetty). Along the Pacific Coast, littoral drift usually moves sediment southward, though during winter storms, the direction may be reversed.

The second mechanism is the onshore/offshore sand cycle, an annual process that typically deposits sand onto a beach during summer months and then moves that sand off the beach during winter. This occurs because waves that usually reach the shore during summer are "constructive" waves: low energy waves that pick up subtidal sand and deposit it onto the beach. Waves that reach the shore during winter, however, are usually "destructive" waves: high energy, steep waves that strike the shore with tremendous force, scouring sand from the beach. At many locations, this sand is deposited onto offshore sand bars, where it can then be re-deposited back on the beach by future summer waves.[13]

Within a coastal cell, sand will continue to be moved by the longshore current until:

- it is moved onto the land via the onshore/offshore sand cycle. There, it might either be blown farther landward by onshore winds, or returned to the ocean (and the longshore transport) by shoreline erosion; or
- it is moved by powerful storm waves into deeper water, where it will remain out of reach of the longshore transport. In some areas, sand may be transported down into a coastal submarine canyon, from which it will not likely return to the shoreline without global tectonic changes.

[13] There are exceptions to this pattern. Summer storms can generate destructive waves, and benign winter conditions can create constructive waves, but these are unusual seasonal variations.

Carmel Beach Formation

The model described above, so typical of most California beaches, does not apply to Carmel Beach. Most importantly, the City's beach is not significantly affected by river discharge. Sediment from the Salinas River, the largest river north of Carmel, does not appear to be transported around the Monterey Peninsula.[14] Pescadero Creek, at the north end of Carmel Beach, does discharge sediment into the bay at Carmel Beach, but its impact appears to be minimal. The Carmel River, whose mouth is located approximately one mile south of Carmel, releases plumes of sediment that are sometimes transported northward during winter storm periods. Griffin (1969)[15] concluded that only a very minor quantity of Carmel Beach sands (located closest to Carmel Point) might be derived from Carmel River's winter sediment discharges.

There is also no evidence that sand on Carmel Beach is affected by littoral drift. Johnson (1984) characterized Carmel Beach as a pocket beach that is "unusual because there is no significant littoral drift supplying sand from upcoast, or downcoast, in contrast to many other California beaches." Griffin (1969) describes Carmel Beach as being "effectively isolated ... by Arrowhead and Carmel Points."

Carmel Beach's white sand is composed primarily of medium-sized grains of quartz and feldspar (Johnson, 1984). These minerals are characteristic of the granodioritic headlands and offshore rocks found at the western end of the Monterey Peninsula (e.g. Cypress Point, Pescadero Point, and Arrowhead Point). Geologists and oceanographers have concluded that gradual erosion of these rocky features by direct wave action is the source of Carmel Beach sand.

Once created,[16] these grains are moved onto and off of Carmel Beach by the annual onshore/offshore sand cycle. Each year, winter storm waves remove large volumes of sand from Carmel's beach. By the following summer, sand levels appear to return to their "normal" condition. During severe winters, substantial volumes of sand are removed from the beach, exposing large underlying rock formations. However, within a year or two, the beach usually appears to regain its normal sand level.

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[14] Cooper, W.S. 1967. Coastal Dunes of California. Geological Society of America Memoir 104. 131p.

[15] Griffin, Paul Adolph.1969. Heavy Mineral Investigation of Carmel Bay Beach Sands. Unpublished M.S. Thesis. Naval Postgraduate School, Monterey, California.

[16] There have been no studies that describe precisely how these grains are moved laterally within Camel Bay's northern cell. Bascom (1946) states that "sand movement (off Carmel Beach) seems to be local and within the rocky reef which lies about 1200 feet offshore" (cited by Johnson, 1984)

2.2.2 *Carmel Sand*

For most people, it is this sparkling white sand that best characterizes Carmel Beach. The fine white sand has provided the backdrop for many memorable beach-going experiences and photographs. These special sand grains are also one of the most important factors in protecting the Carmel coast from erosion. They represent the first line of defense against the onslaught of wave attack.

Unfortunately, much about Carmel's vital beach sand still remains unknown. How much new sand is created every year? How much sand is stored in offshore sand bars? How much sand has been moved out-of-reach of "constructive" waves? Has the volume of sand on Carmel Beach changed over the years – has it increased? Decreased? How has it been affected by City activities like seawall construction and sand redistribution? The answers to these questions could play a critical role in the City's response to future shoreline erosion (see Sec. 6.2).



Photo 2 – *Sand Scour and Exposed Outcrops on Carmel Beach south of Twelfth Avenue*

2.2.3 *Beach Berm and Water Ponding*

During the spring and early summer, natural beach-building processes lead to the creation of a wide sand berm that runs along the beach. Behind the berm, beach sand is at a lower level. During any season when periods of high tide occur, wave

run-up may overtop the sand berm and create ponds of seawater landward of the berm. At some locations, the ponded water can cut off access to and from the City's stairways.

During fall and early winter, heavy rains and storm-water runoff can also create beach ponds behind the berm. This also can have a detrimental effect on access.

Ponded water can also despoil Carmel's beach environment by creating a debris field, by depositing silt/mud in the pond's still water, or by harboring animal wastes that could make the ponds a health hazard.



Photo 3 – *Sand Berm and Ponded Water*

2.2.4 *Human Impacts*

Carmel Beach is one of the most frequently visited beaches in central California, and is greatly affected by human activities. Trash and garbage, littered by beach-visitors, along with storm water debris, all degrade the natural beach environment. Other material, such as coals from beach fires[17] and mud discharged from storm water outfalls (or left over from ponded water) discolor Carmel's signature white sand. These affect only limited areas and are usually remedied by the beach's annual sand cycle that deposits clean, sorted white beach sand every spring.

[17] Carmel allows fires on its beach, but their location (south of Tenth Avenue and seaward of the high tide line) and size are regulated by City ordinance: Carmel Municipal Code Section 8.32.160 (1995).

The City's annual sand redistribution program has a substantial impact on Carmel Beach. This procedure, discussed in more detail in Section 5, involves bulldozing sand from the lower beach to the upper beach. This task enables the City to compensate for sand that will be pushed downslope by summer beach visitors and covers unsightly and potentially dangerous shoreline revetments. Carmel's sand redistribution program expands and improves the public's access to Carmel Beach. The operation usually takes place during late spring/early summer and has been conducted for more than 30 years.

Since 1958, the City has built seawalls and installed engineered rock revetments at several sites along its shore. Hard shoreline protection structures have long been associated with the loss of beach sand from adjacent areas along other shorelines. Such impacts have not yet been documented at Carmel Beach. Carmel's seawalls and shoreline revetments, as well as their possible impacts, are discussed more fully in Section 6.

2.3 CARMEL BEACH BLUFFS

Coastal bluffs, rocky promontories, and coves are found at the northern end and throughout the southern half of Carmel Beach. These beach bluffs consist of sandstone bedrock overlain by deposits of siltstone and claystone, and then covered by an upper layer of partially cemented ("semi-consolidated") terrace deposits. In the north, the terrace deposits are covered with dunes of uncemented ("unconsolidated") fine-grained, wind-blown sand.

The composition of these materials is a critical factor in determining how Carmel's bluffs will respond to erosive forces. Along the shore, sandstone provides the most resistance to erosion. Siltstone, claystone, and the terrace deposits are respectively less resistant. Finally, the unconsolidated dune sands are the most vulnerable; they are even susceptible to wind ("subaerial") erosion.

Another important factor is the structure of Carmel's shoreline bedrock. According to Johnson (1984), this bedrock "has been folded, fractured, and faulted due to tectonic forces that have influenced the geology of the area for millions of years. Faults and joints in the bedrock have affected the rates of erosion and, as a consequence, the shape of the coastline." The Cypress Point Fault, which may be inactive, cuts across Carmel Bay from the northwest (at Pescadero Point) to the southeast (at Abalone Point). On the shore, Johnson describes two "strong sets of

fractures" that have allowed surf erosion to "selectively attack" specific points along Carmel's southern shore.[18]

2.3.1 *Human Impacts*

Along Carmel's shoreline bluff tops, south of Eighth Avenue, the City created a pedestrian pathway. Completed in 1988, the Beach Bluff Pathway provides a safe place for people to walk, while enjoying unmatched coastal scenery. This meandering path, built alongside Scenic Road, leads beach visitors to all beach access stairways and sand ramps located between Eighth Avenue and Martin way. The Pathway is discussed in greater detail in Section 3.

Since the 1930s, the City has built a series of beach access stairways to enable people to traverse from the bluff top to Carmel Beach. As described in Section 3, these stairways allow people to travel safely up and down the steep bluffs without damaging their fragile vegetation. Foot traffic on Carmel's beach bluffs leads to severe erosion, is unsafe, unsightly, and violates City ordinances.[19] A number of techniques are used to discourage bluff-cutting, including guardrails, plantings, boulders, driftwood log barriers and informative signs.

Nearly all of Carmel's shoreline bluffs south of Eighth Avenue are protected by seawalls, retaining walls, and engineered revetments. Beginning in 1958, the City has used these armored structures in response to severe erosion caused by winter storm waves. Carmel's shoreline walls and revetments are discussed in more detail in Section 6.

Over the years, the City has added significant amounts of fill material to Carmel's coastal bluffs. For many years, this fill consisted of sand, dirt, dead vegetation, rocks, concrete, and other material. During the past two decades, the City has limited its use of fill material to "clean fill" from Carmel area soils. At some locations, vegetative fill material has decomposed, creating hollows just under the surface. These areas may present a potential safety hazard for anyone who walks on the beach bluffs, from City personnel who do so in performance of their duty, to citizens who do so in violation of posted City ordinances.

2.3.2 *Wildlife*

Some portions of the City's coastal bluff tops have been weakened by the actions of California ground squirrels[20] (*Spermophilus beecheyi*). These rodents are commonly found throughout most of California. Over the past 20 years, ground

[18] Examples of this are the Thirteenth Avenue Cove and sites north of the Santa Lucia stairway.
[19] Carmel Municipal Code Section 12.32.165B.
[20] Also called "Beechey Ground squirrels"

squirrels have become a nuisance in many parts of the Monterey Peninsula, including Carmel's shoreline bluffs. They eat a wide variety of plant parts, including leaves, stems, seeds, fruit and nuts. They have also been known to eat bird eggs and gnaw on plastic sprinkler heads, as well as a surprising variety of other objects.

Ground squirrels also cause damage to Carmel's coastal bluffs by digging extensive systems of burrows; some may extend as long 20 feet. In many areas (i.e. near Del Mar, Tenth, Twelfth to Thirteenth, and Santa Lucia Avenues), burrows are causing undermining, and could even result in collapse of the bluffs. Ground squirrels are also known carriers of several diseases, including bubonic plague.

The recent growth of Carmel's ground squirrel population has been mainly attributed to visitor feeding. These "cute" squirrels are not shy, and can often be seen "begging" for food.[21] This has led to a larger population than available natural resources can support, making these rodents susceptible to the spread of disease. Control of ground squirrel populations is discussed in more detail in Section 8.

2.4 CARMEL DUNES

The City of Carmel was originally founded on an extensive dune field (Cooper, 1967). Carmel's dunes are built from sand that was transported by wind action from the beach. These wind-blown sands have similar composition, but are finer-grained than the Carmel Beach sands.[22] Today, only two remnant sand dune areas still exist: the Del Mar Dunes and the North Dunes. These dunes were described by Jones and Stokes Associates, Inc. (1995).[23] Both dune areas, along with the Ocean Avenue/Del Mar parking lot, have been identified as a future Master Plan Area, and will soon be the subject of more extensive study ("Del Mar and North Dunes Master Plan").

[21] The areas along the Carmel shoreline where the ground squirrel problem is most prevalent are also the most popular areas for picnics and transient visitors.
[22] It is reasonable to assume that portions of these dunes were formed during a prior glacial period, when sea level was lower.
[23] Jones and Stokes Associates, Inc. 1995. Final Results of the Environmentally Sensitive Habitat Area Study Conducted for the City of Carmel-by-the-Sea. Unpublished report.

2.4.1 *North Dunes*

Carmel's largest stretch of dunes is the North Dunes. This is a 4 – 5 acre tract of substantially disturbed dunes bordered by Fourth, North San Antonio, and Ocean Avenues. This extensive area is the site of past development, including:

- a public restroom and four sand volleyball courts (near the west end of Ocean Avenue);
- two storm water outfalls and underground storm water drainage pipes; and
- a private housing development – "Sand and Sea" (near the intersection of Fourth and San Antonio Avenues).

The North Dunes are host to some exotic, invasive vegetation, but also include significant areas of native California dune plants, including one species protected by state and federal laws (described in Sec. 4).

2.4.2 *Del Mar Dunes*

The Del Mar dunes are a thin stretch of disturbed coastal sand dunes, extending from the end of Eighth Avenue north to the foot of the Ocean Avenue/Del Mar parking lot. The eastern boundary of these dunes is defined by the Ocean Avenue/Del Mar parking lot and by a line of private homes.

These dunes are physically and biologically disturbed. Erosion by high-energy waves occurred during the 1982/83 El Niño winter storms. In 1983, engineered revetments were installed beneath the Ocean Avenue storm water outfall, and seaward of the Eighth Avenue outfall and stairway. Following installation, the City restored the Del Mar dunes to their original size.[24] The seaward edge of the Del Mar Dunes is maintained during the City's sand redistribution operations.

The dunes' natural community is also significantly disturbed; it is vegetated primarily with exotic, invasive species (described in Sec. 4). This area is an opportunity for habitat restoration consistent with sections 30240(b) and 30251 of the Coastal Act. This issue will be studied in conjunction with public access opportunities in the Del Mar and North Dunes Master Plan process.

[24] Major portions of these revetments have remained buried since their installation in 1983.

2.5 MANAGEMENT POLICIES[25]

- Pursue scientific studies that document physical processes occurring at Carmel Beach (e.g. sediment transport, sand bar dynamics and influences from the Carmel Offshore Canyon). Seek funding for such studies from governmental agencies. (P5-1)

[25] All Management Policies in this *Carmel Shoreline Management Plan* are statements of the Goals, Objectives, and Policies established in the City's Coastal Land Use Plan (approved June 2003) (adopted by the Carmel City Council on 2 Jun 2003; certified by California Coastal Commission on 17 July 2003).

3 ACCESS TO THE CARMEL SHORELINE

The white sand beaches, rocky promontories, and breathtaking vistas make the Carmel coast one of the most popular destinations in central California. The City of Carmel's shoreline is a 22.5-acre public park that is used by both visitors and residents alike. It is served by an extensive public access system that includes roadways, parking areas, pedestrian pathways, beach access stairs, sand ramps, and bus service.[26]

3.1 VEHICLE ACCESS TO CARMEL'S SHORELINE

Many residents and visitors use vehicles for travel to Carmel's shore. Some drive along Scenic Road and enjoy the view. Others park to watch the ocean from their vehicle. Most seek a convenient parking space and walk along the Pathway or down to the beach.

Travel on the Ocean Avenue/Del Mar parking lot loop and Scenic Road is open to all vehicles other than buses and large trucks, but the City prohibits parking of over-sized vehicles on roads near the Carmel shoreline.[27]

3.1.1 *Ocean Avenue / Del Mar and North Dunes*

The primary access to Carmel Beach is located at the lower end of the City's main street, Ocean Avenue. This is one of the few places within the City limits where the upper beach rises to meet street level.[28] Here, Ocean Avenue intersects with Del Mar, a street easement that has been abandoned and modified into a beach access parking lot.

The Ocean Avenue/Del Mar parking lot is primarily used by day-visitors to the City (Fig. 2). Parking spaces here allow convenient access right up to the edge of the sand, and to the City's main beach restroom facilities.

[26] Monterey-Salinas Transit (MST) currently brings bus passengers within two short blocks of the shoreline.
[27] This prohibition applies to any vehicle that exceeds 12,000 pounds gross weight, or 20 feet in overall length (including bumpers), or seven and one-half feet in height at its highest point. These vehicles can stop when "engaged in the loading or unloading of passengers or goods as may otherwise be permitted by law." Carmel Municipal Code, section 10.32.080G.
[28] This condition is maintained through the City's annual sand redistribution program.

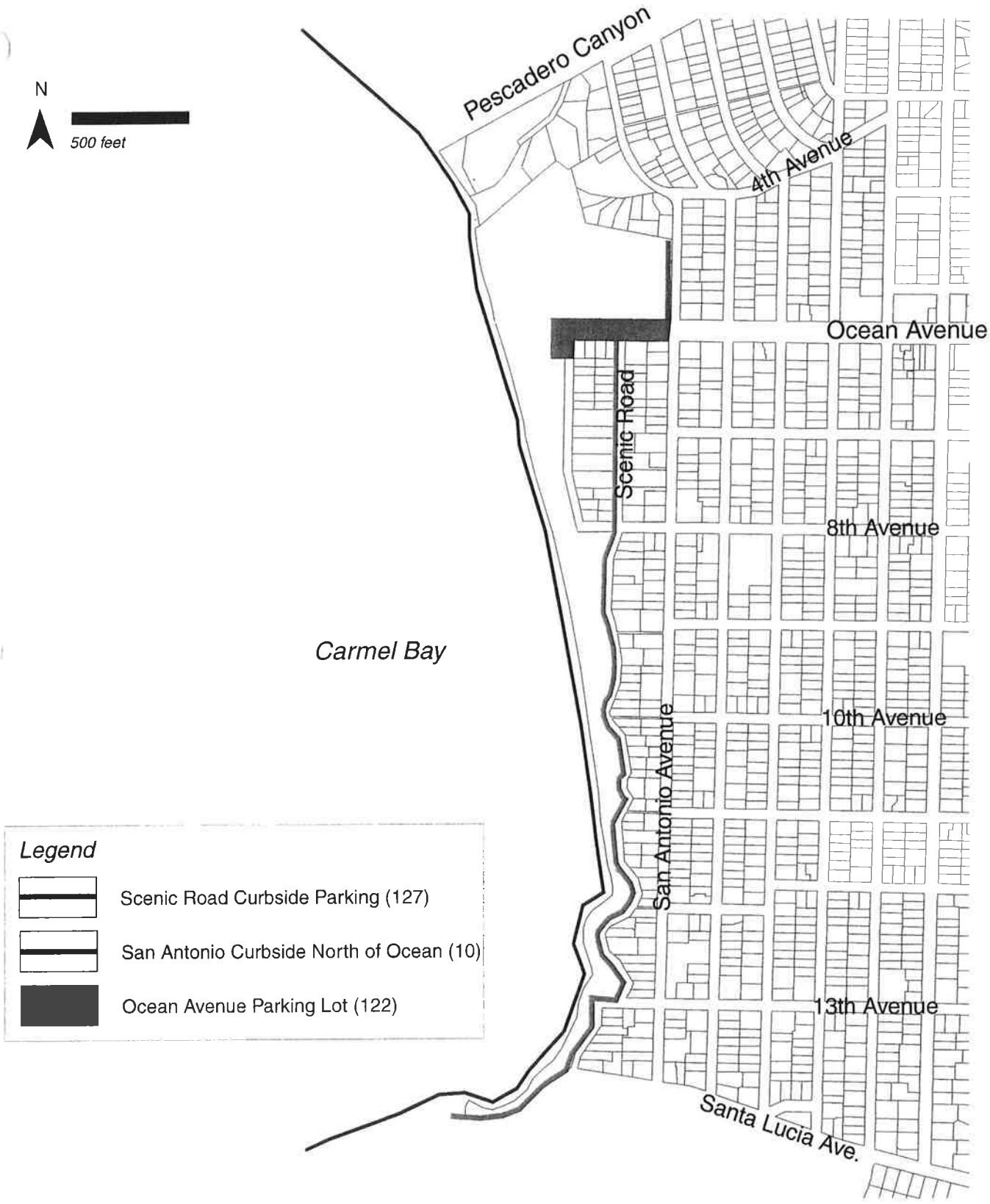

Figure 2
Shoreline Parking Resources

This lot contains spaces for 122 vehicles; four of the spaces near the City's main beach restroom are sized and marked for disabled parking. The roadway here is narrow, and movement of over-size vehicles can be difficult, especially when the parking lot at Del Mar is full.

People visiting the North Dunes can use available parking either in the Ocean Avenue/Del Mar parking lot, or along the west side of North San Antonio Avenue between Ocean Avenue and the "Sand and Sea" development (near Fourth Avenue), which has room for ten vehicles.

3.1.2 *Scenic Road*

Scenic Road is a street that truly lives up to its name. The portion that stretches between Ocean and Eighth Avenues is typical of many attractive streets in residential Carmel. But at Eighth Avenue, visitors and residents are greeted with stunning vistas of Carmel Bay, framed through tall Monterey cypress and accented by white beach sand. In many respects, the history of Scenic Road traces the history of Carmel's coastal bluff erosion, increasing public use, and the City's efforts to preserve lateral and vertical beach access.

Scenic Road winds along the bluffs above the beach and continues past the City's southern limit. The road continues to the south end of Carmel Point, in an unincorporated portion of Monterey County. When it was constructed, Scenic Road carried traffic in both directions. During the early 1960s, vehicles driving between Eighth and Santa Lucia Avenues were restricted to southbound travel. In 1988, this stretch of Scenic Road was narrowed to provide additional space for Carmel's Beach Bluff Pathway and landscape improvements while preserving ample space for curbside parking.

The portion of Scenic Road between Eighth Avenue and Martin Way provides curbside parking for many visitors to the City's shoreline. This stretch of Scenic Road has 127 parking spaces; all are adjacent to the Beach Bluff Pathway. There are two stalls located on either side of the pedestrian sand ramp, between Eighth and Ninth Avenues, which are sized and marked for disabled parking. The City has also established two passenger loading zones; one located at Eighth Avenue and the other at Eleventh Avenue.

3.1.3 *Scenic Road Neighborhood (Adjacent Streets)*

On many warm summer days, especially weekends and during special events (e.g. Great Sand Castle Contest), beach parking spills over onto neighboring streets. On

these occasions, vehicles often park along streets that intersect with Scenic Road and San Antonio Avenue: Eighth, Thirteenth, and Santa Lucia Avenues.

During the busiest periods, vehicles also park along San Antonio Avenue, Carmelo Street, and even Camino Real Street. Occupants of vehicles parked at these locations then walk a short distance to the Carmel shore along one of the Avenues between Eighth and Santa Lucia. At San Antonio Avenue, some pedestrians may use one of the four narrow pedestrian pathway/drainageways[29] between Ninth and Twelfth Avenues; these are discussed below. Vehicle access and available parking spaces are generally well dispersed. The public is afforded easy access to all parts of Carmel's shoreline and impacts are not concentrated in any one area. This is consistent with Section 30212.5 of the Coastal Act.

3.2 PEDESTRIAN ACCESS TO CARMEL'S SHORELINE

Walking is a popular way for residents and visitors to access the shore. Many enjoy walking on the Beach Bluff Pathway above the beach. Others walk from their parked vehicles, on nearby residential streets, and need a safe, convenient route to the nearest beach access (Fig. 3). In contrast to many areas along the California coast, pedestrian shoreline access in Carmel is abundant and convenient. Lateral access is continuous along the City's entire coast and, from Eighth Avenue southward; vertical access is available at intervals of one block or less.

3.2.1 *North Dunes and Del Mar Dunes*

The North Dunes and upper Carmel Beach are easily accessible to many pedestrians via North San Antonio and Ocean Avenues and the Ocean Avenue/Del Mar parking lot. This area of beach and dunes can also be reached by a pedestrian access easement, maintained by the City, which passes through the privately owned "Sand and Sea" development, near the intersection of Fourth and North San Antonio Avenues. The Fourth Avenue shoreline access easement is described in more detail in Section 3.2.5.

The Del Mar Dunes are reached from the north via the Ocean Avenue/Del Mar parking lot and from the south by the Eighth Avenue beach access stairway. Pedestrians may walk in the dunes between these two access points, but there is no improved lateral access through the dunes.

[29] These pathway/drainageways (at Ninth, Tenth, Eleventh, and Twelfth Avenues) have sometimes been referred to as "easements." They are, however, owned in fee by the City. They are recorded in *Cities and Towns* vol. 2, p. 23, as seven foot-wide "footpaths," and they connect San Antonio Avenue and Scenic Road.

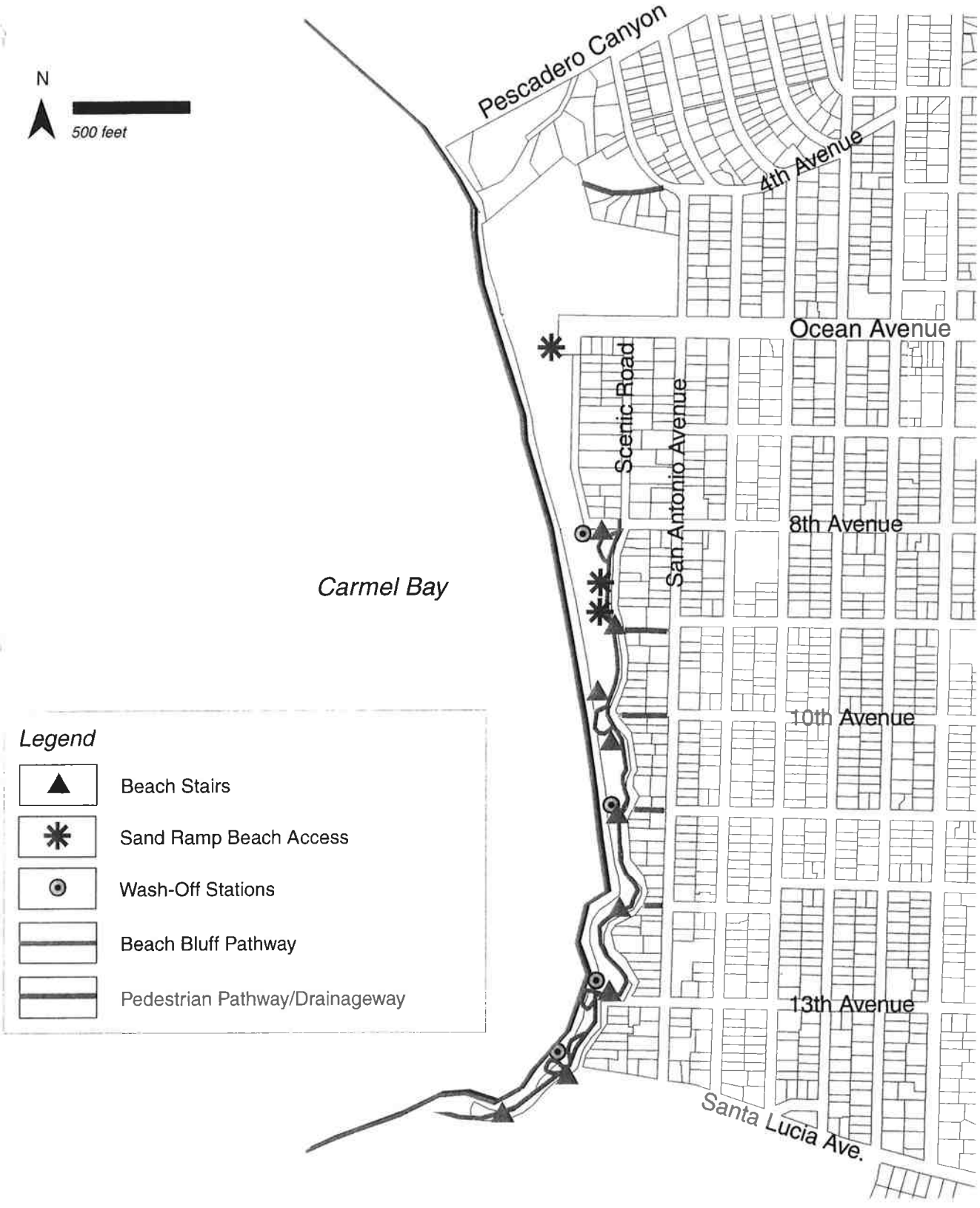

Figure 3
Public Access

The *Carmel Beach Master Plan* (2000) addressed the lack of lateral access by recommending the installation of a boardwalk in the dunes that links the "Del Mar area" with the Beach Bluff Pathway at Eighth Avenue.[30,31] Recently, the City designated the Del Mar Dunes as an Environmentally Sensitive Habitat Area (ESHA).[32] The establishment of formalized lateral access through the Del Mar Dunes could help protect them by controlling errant foot traffic, but such a development must be undertaken with great care. As noted in the *Beach Master Plan*, the City should support public activities that are "consistent with the sensitive dune environment."

Pedestrian access issues in both dune areas discussed above will be addressed through preparation of the Del Mar and North Dunes Master Plan.

3.2.2 *The Carmel Beach Bluff Pathway*

The Beach Bluff Pathway has been designed to serve pedestrians traveling along Scenic Road (Fig. 3). Before the Pathway was built, Scenic Road was a one-way, broad, busy thoroughfare that lacked a safe space for people to walk or jog. Pedestrians walking in the roadway were often forced to weave among parked cars and dodge moving vehicles.

After the 1982/83 El Niño storms, the bluffs were ravaged, storm water drainage facilities were destroyed and, in places, Scenic Road itself was threatened. At this time, there were only five narrow stairways remaining that connected Scenic Road with the beach. Impatient beach-goers often climbed on the City's coastal bluffs and trampled protective vegetation, instead of using the beach access stairways.

The City addressed these problems by installing bluff armoring and improving drainage facilities during Phase I of the Carmel Beach Rehabilitation Project. During Phase II, the City addressed access and landscape issues. Scenic Road was narrowed and a meandering Pathway was created that enabled people to enjoy the beautiful vistas of Carmel's shoreline in serenity and safety.

The 3,250 foot-long Pathway winds along the bluff top, near the seaward edge of Scenic Road. It extends from Eighth Avenue southward to the City limits, just south of Martin Way. The Pathway is built primarily of decomposed granite

[30] Carmel Beach Master Plan (2000) policy PDM-4.
[31] Consideration of lateral access through the Del Mar Dunes should include examination of various styles and materials, including boardwalks of wood or composites and pathways of decomposed granite.
[32] This was based, in part, on the biological survey of the Del Mar Dunes by Jones and Stokes (1995).

(DG),[33] and averages four to five feet in width. It was designed to provide access for people who have limited mobility or are physically disabled.

The Pathway design was jointly developed by the Carmel Beach Rehabilitation Task Force and consulting landscape designers from the firm of Royston, Hanamoto, Alley, and Abey (RHAA);[34] it was formally opened in 1988.

The Carmel Beach Bluff Pathway project has won several awards, including the American Society of Landscape Architects (ASLA) National Merit Award (1988), the ASLA Northern California Chapter Merit Award (1988), and the Garden Club of America Award for Significant Contribution to Horticulture (1991).



Photo 4 – *The Carmel Beach Bluff Pathway*

Pathway Design and Purpose

The Beach Bluff Pathway was designed to play a critical role in the City's overall plan to protect its shoreline while improving coastal access. Its design was based on five guiding principles adopted by the Task Force:

[33] Pathway material consists of 95% decomposed granite + 5% cement. The cement was tinted with Davis Concrete Color ("Mesa Buff" no. 5447), mixed dry at 2 lbs./94 lb. bag of I-II Portland Cement.

[34] The key RHAA personnel were Principal Planner Robert Royston and Associate Planner Lucille Biesbroeck.

- Restore and retain the natural, pristine beauty of Carmel Beach, which is unique in the world.
- Strive for natural, timeless design.
- Design elements so as not to intrude upon the scenic beauty; no apparent structural intrusions to mar vistas from residences, roadway, walkway, beach, etc.; maintain an uninvaded panorama of the Bay.
- Maintain the "meandering style" that is typical of Carmel (e.g., intimate, narrow, winding paths leading from the main walkway to isolated, unobtrusive resting places).
- Introduce new and innovative schemes to control behavior of people and dog traffic (e.g., guide people to accesses and encourage sitting and meeting on the beach instead of on the roadway).[35]

Guided by these principles, the designers created a Pathway that protected pedestrians and the City's vulnerable coastal bluffs by modifying where people walked, parked, and congregated along the Carmel Beach bluff top.

Pedestrian Protection

The Beach Bluff Pathway provides safe lateral access for pedestrians along the shoreline bluff top. This clearly responded to the needs of beach visitors who walk along Scenic Road (from their residences or cars) in order to reach one of the City's numerous beach access stairways or sand ramps.

The Pathway design also enhances the experience of shoreline visitors whose activities are limited to the bluff top area. These include: people whose physical condition makes walking on the beach difficult or impossible; people who prefer to sit or stand on bluffs overlooking the shore and enjoy the scenic vistas; and people who use the bluff top area for walking or running.

Finally, the Pathway provides a coastal experience during those times when conditions discourage use of the beach itself. These conditions, characteristic of the Carmel shoreline, cause many people to limit their shoreline visit to the City's coastal bluffs, instead of the beach:

- Climate – local weather conditions often include periods that range from cool and windy to wet and foggy. These conditions are most likely to occur during the period of highest public use (mid-spring through early fall). Many find these conditions are more conducive to strolls along the bluffs in warm clothes rather than the more stereotypical beach activities.

[35] City of Carmel-by-the-Sea. 1986. Carmel Beach Restoration Phase II Final EIR.

- Tides – Like most sections of the central California coast, tides at Carmel Beach range from –2.0 to +8.0 feet. Under some winter conditions, travel on the beach during high tide may be difficult or dangerous; this is especially true of the beach south of Twelfth Avenue.

- Sand Level – During severe winters, sand scour can expose massive bedrock platforms that can deter pedestrian movement along the beach.

Bluff Protection

Many facets of the Beach Bluff Pathway were designed to remedy problems caused by people who climb on Carmel's coastal bluffs. "Bluff-cutting" damages vegetation and can lead to severe erosion from storm water runoff. The Pathway landscaping includes plants, boulders, and protective wooden barriers that serve to keep people from straying onto the City's vulnerable coastal bluffs. Discreet signs along the Pathway remind people to stay off the slopes. Other signs direct pedestrians to the nearest beach accessway.

The success of the Carmel Beach Bluff Pathway can be attributed to the interplay of all its elements: pathway layout, beach accessways, landscape plants, boulders, guardrails, signs, and other amenities (discussed in detail in Sec. 4). Changes to the design of any one of these elements may impact the function of other elements and of the Pathway as a whole. Therefore proposed changes must be undertaken with great insight and care.

3.2.3 *Beach Access Stairways and Sand Ramps*

The Pathway was designed to seamlessly integrate with a series of beach access stairways and sand ramps (Fig. 3). Some of these accessways were built years earlier, and survived the 1982/83 El Niño storms. Others were built as part of the Phase II project. At present, the City has nine stairways and two sand ramps that provide access for beach visitors (see Fig. 3).

Stairways

Carmel's shoreline stairways provide the critical link in the City's beach access program. These structures enable people to travel safely from the bluff top down to the beach at nine locations, from Eighth Avenue south to Martin Way (see Table 1). The stairways are built in varying styles using a variety of materials: some are built of wood, some utilize reinforced concrete with "golden granite" facing, and some use a combination of these materials. Some

stairways carry people over irregular rock revetments, tall seawalls, or steep cliffs. At Twelfth Avenue, the stairway guides people down to a beach 50 feet below.

Yet, these stairways are the most vulnerable of the City's shoreline structures. To perform their function, they are built in "harm's way," extending out beyond the protective bluffs and walls. Over time, Carmel's beach access stairways often incur significant damage during winter storms. Some stairways have been damaged by direct wave attack while others were broken by the sheer weight of seaweed flung onto, or draped over, exposed sections.

Table 1 - CARMEL BEACH ACCESS STAIRWAYS

Location	Year Built	Composition and Features
Eighth Avenue	late 1930s[36]	Carmel stone and golden granite rock Includes Foot Wash-off Station
Ninth Avenue	1984	Wood beam and posts. Break-away design.
Tenth Avenue (North)	1974[37]	Wood beam and posts Break-away design
Tenth Avenue (South)	1986	Upper section: Wood beam and posts Lower section: Reinforced concrete faced with golden granite; wave deflectors at bottom
Eleventh Avenue	late 1930s	Golden granite rock with exposed aggregate treads Includes Foot Wash-off Station
Twelfth Avenue	1986	Wood beam and posts Temporary[38]
Thirteenth Avenue	late 1970s	Reinforced concrete and golden granite rock Includes Foot Wash-off Station
Santa Lucia Avenue	late 1930s	Golden granite rock and exposed aggregate treads Includes Foot Wash-off Station
Martin Way	1958/59	Upper section: Reinforced concrete faced with golden granite. Lower section: Wood beam and posts

[36] Modified in 1985/86
[37] Redesigned in 1986
[38] This temporary stairway built in the Twelfth Avenue cove is discussed in more detail in Section 3.4.1.



Photo 5 – *The Tenth Avenue (South) Stairway*

Some of the stairways constructed during the Phase II project employed the concept of "break-away" sections. On these stairways, the lowest section was built to be separate from the upper section. This design arose out of observations of stairway failures during the 1982/83 El Niño storms:

> First, waves attacked the lowest portion of a stairway, undercutting its foundation.[39] As the bottom section was destroyed, it pulled the (attached) upper portion of the stairway away from the bluff. In at least one case (Ninth Avenue stairway), loss of the upper stairway section caused massive erosion of bluff soils and toppling of two large Monterey cypress.

Understanding that Carmel's beach access stairways will always be exposed to potential wave damage, designers created new stairways whose lowest portions could separate from the upper sections. When attacked by high-energy storm waves, these sections would break cleanly away. In most cases, the upper stairway sections and the upper bluffs escape extensive damage. This greatly reduces potential repair costs as well as the threat of bluff erosion.

This concept has been tested in recent years. The lower section of the Tenth Avenue (North) stairway was severely damaged by high-energy waves during the 1997/98 El Niño winter storms; the upper section and surrounding bluffs were relatively undamaged. Within a year, the lower section was repaired and

[39] These observations apply to both wood and concrete/masonry stairways.

re-opened to public access. During the Winter of 2000/01, storm waves again damaged the lower sections of the stairways at Tenth Avenue (North) and Martin Way. The upper section and surrounding bluffs suffered only minor damage. Approved designs for these "break-away" lower sections are on-file with the City; replacement sections can be built when conditions allow.



Photo 6 – *Limited Damage to the Upper Portion of the Break-Away Stairs at Tenth Avenue (North)*

All stairways are complemented with trash/recycling container enclosures; four have foot wash-off stations (these are described in Sec. 4).

With one exception,[40] beach access stairways along the Pathway are located adjacent (or very near) to a Pathway access ramp that allows disabled access from Scenic Road. Each ramp is located within one of Scenic Road's marked crosswalks, providing Pathway access from the intersecting streets or pathway/drainageways. This creates a coordinated "access system" that leads pedestrians safely and conveniently to the beach.

[40] The exception is the Twelfth Avenue stairway, which was built approx. 100 feet west of where the Twelfth Avenue pedestrian access intersects with Scenic Road. The curb ramp is located at that intersection, within the marked crosswalk.

Sand Ramps

Along the shoreline, the City has built and/or maintained three sites where beach sand has been moved up to the street/parking level. These allow pedestrian access to and from the beach. Each also provides access to the sands of the upper beach for people who have limited mobility or who are physically disabled.[41]

The largest is located adjacent to the City's main beach parking lot at the foot of Ocean Avenue/Del Mar. This sandy area is primarily a natural formation, but its sand level is maintained by bulldozing activities during the City's sand redistribution program.

The other two sites are sand ramps that are maintained by the City's annual sand redistribution program. One ramp is located just south of Eighth Avenue and is constructed of bulldozed sand in a GEOWEB® cellular confinement system covered with a cap of compacted decomposed granite (DG). When necessary, it is used as an equipment-access ramp for maintenance and emergency vehicles.

About 40 feet south, the City has built another sand ramp. It is constructed of bulldozed sand and buried driftwood logs; it is for pedestrian use only. The buried driftwood logs help stabilize the ramp by controlling the downslope movement of sand. The logs also serve to prevent exposure of irrigation pipes and valve control wires. When these logs are not well covered by sand, they may become obstacles for pedestrians. The ramp should be regularly monitored and exposed logs should be re-covered with sand.

Each sand ramp is equipped with a concrete curb access ramp that provides accessibility for the disabled to/from Scenic Road.

3.2.4 *Pedestrian Pathway/Drainageways*

The Pathway provides pedestrians with safe access along Carmel's shoreline bluff top and directs them to the City's convenient beach access stairs and ramps. Bringing pedestrians and vehicles west to Scenic Road and the Pathway are five streets (Ocean, Eighth, Thirteenth, and Santa Lucia Avenues, and Martin Way). Four other City streets (Ninth, Tenth, Eleventh, and Twelfth Avenues) provide vehicle access only as far west as San Antonio Avenue. Here, each of these four streets becomes a narrow storm water drainageway that also doubles as a

[41] This is discussed in greater detail below.

pedestrian walkway. These pathway/drainageways can provide safe pedestrian travel only in the absence of heavy storm water runoff, which may create difficult-to-hazardous conditions for pedestrian passage.

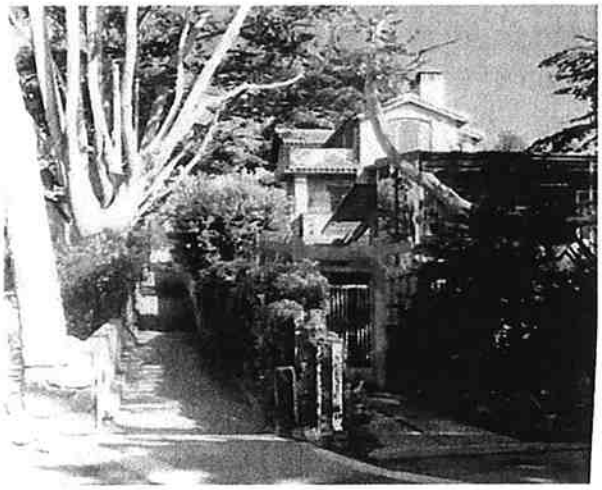

Photo 7 – Pathway/drainageway at Ninth Avenue

3.2.5 *Pedestrian Access Easement*

The City provides public access to the northern portion of Carmel Beach with a pedestrian walkway that begins near the intersection of North San Antonio and Fourth Avenues. The eastern portion of this walkway is a paved easement across the privately-owned "Sand and Sea" development.

Pedestrian travel to, and along, this walkway is sometimes difficult. To reach the access, pedestrians must walk in the street along a narrow stretch of North San Antonio Avenue. On this section of roadway, pedestrians encounter a blind curve where fast-moving vehicles travel to and from the nearby Carmel Gate to Pebble Beach. This portion of North San Antonio Avenue lacks both convenient parking and a dedicated pedestrian lateral pathway/walkway. The entrance to this coastal access, as yet, is not adequately signed.

Once pedestrians reach the easement, they must walk across the paved "Sand and Sea" driveway. The final portion of the walkway is a dirt trail that traverses dunes and coastal bluffs before leading to the North Dunes of the Carmel shoreline (near the Fourth Avenue storm water outfall).

3.3 DISABLED ACCESS TO CARMEL'S SHORELINE

Carmel Beach is located at the base of a series of high dunes and shoreline bluffs. Public access to the beach is primarily via the parking lot at the foot of Ocean Avenue, as well as from numerous sites along Scenic Road. But from these locations, access to the tideline requires a descent that ranges between 12 and 50 feet, depending on location and season. This trek can be challenging for many beach visitors and impossible for those with limited mobility.

The City of Carmel has an abiding commitment toward making its shoreline as accessible as possible, given the existing topographic conditions. The Beach Bluff Pathway and its shoreline restroom facilities were all designed to meet existing Americans with Disabilities Act (ADA) guidelines for disabled accessibility. The City's two sand ramps,[42] as well as the sand annually bulldozed up to the Ocean Avenue/Del Mar parking lot, allow access to the upper beach for disabled persons. These three sites have been certified by the State of California as offering reasonable disabled access to the shoreline.

Carmel maintains six spaces that are sized and marked for disabled parking: four are in the main beach parking lot, at the foot of Ocean Avenue/Del Mar and two are located on either side of the sand ramp north of Ninth Avenue.

It is important to note that those features that guarantee disabled access also promote use by the numerous shoreline visitors who, while not legally classified as "disabled," are nonetheless of limited mobility. Experience has shown that their shoreline visits are enhanced by the City actions described above.

3.4 FUTURE PROJECTS

3.4.1 *Twelfth Avenue (Point) Stairway*

Many of the beach access stairways damaged during the 1982/83 El Niño storms were re-designed and rebuilt as part of the Beach Bluff Pathway project[43] in 1987/88. In 1986, while the Pathway was still in the design phase, the City built a temporary stairway in the cove near Twelfth Avenue to provide short-term "emergency" access to the beach. This wooden structure is the tallest stairway along Carmel Beach and is less integrated with the adjacent bluffs, than other beach stairways.

[42] Located: 1) just south of Eighth Avenue, and 2) just north of Ninth Avenue.
[43] Carmel Beach Rehabilitation Project Phase II

During development of the Pathway project, the Beach Task Force had planned to re-design and rebuild the damaged stairway originally located at the Twelfth Avenue point. However, installation of the temporary stairs in the cove reduced public pressure for beach access in this area and the Task Force left this project for a future time.

In recent years, this stairway has received the brunt of several high-energy winter storms. Inspections by the Department of Public Works and the City Engineer have determined that the stairway's superstructure is out of alignment and is in need of repair.

A replacement permanent stairway for the Twelfth Avenue point has been designed and proposed. It would consist of an upper section built of wood beams and posts and a lower section, along with two wave deflectors, that would be built of reinforced concrete with golden granite facing. The proposal also includes a stone patio located at the top of the bluff that would merge with the Beach Bluff Pathway. The patio would contain a trash/recycling container enclosure, benches, and a bike rack.

3.5 MANAGEMENT POLICIES

- Provide for maximum public access to, and recreational use of, the shoreline consistent with private property rights and environmental protection. (G4-1) Development shall not interfere with the public's right of access to the sea. (Coastal Act)

  - Maintain frequent and safe points of access along the beach. (O4-1)

    - Continue to provide vertical access along the Carmel shoreline at approximately one or two block intervals. (P4-2)

    - Improve and sign the vertical access at Fourth Avenue. Consider development of a pedestrian path from the foot of Jane Powers walkway to the Fourth Avenue beach access through Sand and Sea. Investigate and implement opportunities to establish or reestablish additional vertical access from North San Antonio to the beach to the extent feasible. (P4-3)

    - Periodically reestablish the sand dune at the foot of Ocean Avenue, to provide convenient beach access from the Ocean Avenue/Del Mar parking lot. Reestablish and regularly maintain a vehicle and disabled-access ramp south of Eighth Avenue. (P4-4)

- Enhance pedestrian access to the shoreline from San Antonio Avenue using existing pedestrian access easements/drainageways that connect San Antonio Avenue with Scenic Road located at Eighth, Ninth, Tenth, Eleventh, and Twelfth Avenues. Redirect surface storm water flows in these easements/drainageways to underground culverts to improve pedestrian safety, access, and aesthetics. (P4-5)

- Establish a local segment of the California Coastal Trail through Carmel-by-the-Sea by connecting existing pedestrian paths and developing new pedestrian paths or routes as required to create a continuous trail through the City. (O4-2)

  - Designate the Beach Bluff Pathway as part of the California Coastal Trail (as long as this does not require any alteration to design or use). Coordinate with Monterey County to increase public awareness of the new segment of the Trail. (P4-9)

  - Coordinate with Monterey County to establish a continuous coastal trail through Carmel that links Rio Park, Carmel Point, the Beach Bluff Pathway, and the trail network in Del Monte Forest. Support efforts by Monterey County to establish a pedestrian pathway around Carmel Point to continue the California Coastal Trail. (P4-10)

  - Establish, in coordination with the State Department of Parks and Recreation, Monterey County Regional Park District and the Monterey County Parks Department, a trail network linking the state-owned Odello land and Carmel River State Beach to the Carmel Mission, Mission Trail Nature Preserve and Beach Bluff Pathway. (P4-46)

- Develop a Master Plan for the Del Mar and North Dunes area. Upon approval, the Coastal Land Use Plan shall be amended to incorporate all elements of the Master Plan. (G4-2)

  - Appoint an ad hoc citizens committee to develop the Del Mar and North Dunes Master Plan. Address issues related to parking and circulation, access, recreation facilities, aesthetics, special events, impacts on residents and visitors and protection of environmental resources. Guide Plan development using the goals, objectives and policies of th(e) (Coastal) Land Use Plan consistent with Coastal Act policies, for provision of public access and protection of sensitive resources. (O4-3)

- Improve pedestrian circulation between the north end of the Beach Bluff Pathway at Eighth Avenue and the beach facilities at Ocean Avenue and the Del Mar Avenue parking lot as part of the Del Mar and North Dunes Master Plan. (P4-11)

- Provide safe and adequate pedestrian access from the Carmel Gate at the North City boundary to Ocean Avenue while protecting environmental resources. (P4-12)

- Address circulation and parking problems, make the area more pedestrian/people friendly and protect the environment. (P4-15)

- Use City staff along with needed consultants (environmental restoration specialist, traffic engineer, landscape architect) to develop a plan of balanced improvement. (P4-16)

- Consider reallocating parking so it will flow in a more efficient manner. Consider a regular shuttle from downtown or from a designated parking area. (P4-17)

- Improve the pedestrian experience through the Del Mar parking area for those arriving on foot and from parked vehicles to the beach. Consider construction of boardwalks or other improvements to aid beach circulation, protect tree roots and protect the sensitive vegetation in the North Dunes area. (P4-18)

- Provide disabled access consistent with ADA requirements. Provide access that blends with the beach and allows disabled individuals the opportunity to enjoy a more natural beach experience. (P4-19)

- Provide adequate and aesthetically pleasing trash containers. (P4-20)

- Provide secure bicycle racks. (P4-21)

- Continue to support passive beach activities that are consistent with maintaining the natural beach setting. Active recreational opportunities need not be enhanced. (P4-22)

- Do not install formal picnic tables or benches. Rather, provide driftwood logs for seating. Picnicking on the beach should be conducted in a traditional manner with blankets, etc. (P4-23)

- Retain the informal atmosphere of the volleyball courts. (P4-24)

- Provide a parking program for Carmel Beach that supports convenient access without compromising aesthetics, environmental quality or residential character. (O4-8)

  - Develop a design plan for the Del Mar parking area that improves circulation, reduces congestion, enhances visual quality, and enhances community character. The redesign shall avoid or minimize any loss of parking spaces. (P4-42)

  - Continue to regulate beach parking using time limits. Retain beach parking as a free resource to the public facilitating access for all. Keep public spaces along the Beach Bluff Pathway small, intimate and dispersed to avoid large congregations of people that would disturb nearby residents. (P4-43)

  - Provide convenient and free public beach parking from 5:00 a.m. until 12:00 midnight daily. Parking outside of these hours along Scenic Road and at the Del Mar parking lot shall be limited to residents and guests with a resident's parking permit. (P4-44)

4 THE CARMEL SHORELINE LANDSCAPE

Carmel's shoreline landscape constitutes everything that people see along the shore, including the ocean, beach, dunes and bluffs, flowers, shrubs, trees, and boulders, as well as the Pathway, guardrails, beach accessways, signs, and stone walls. Even the momentary changes of weather, wildlife, people, automobiles, and other transient scenery make up the landscape mosaic of the shoreline experience.

4.1 NATURAL LANDSCAPE

During the past one hundred years, people have changed much of Carmel's natural shoreline landscape. Photographs taken in the early 20th century depict a shore covered with low native scrub plants and very few trees (Photo 8). As the City of Carmel grew, much of the shoreline was planted with flowers, shrubs, and trees from other parts of the world.



L.S. Slevin photo Pat Hathaway Photo Collection, Monterey

Photo 8 – Southern Carmel Shoreline (from 11th Ave. to Martin Way) 1908

4.1.1 *Native Species and Habitats*

At one time, much of what is now the City of Carmel was covered with a surprisingly diverse community of native flora and fauna. Near the shoreline, these species were able to tolerate, and even thrive in, the area's harsh coastal conditions: exposure to salt, burial by shifting sand, lack of nutrients, and blasting by sand-laden winds. Today, there remain only a few remnants of Carmel's original native shoreline community – mostly in the North Dunes.

Upper Beach

Beaches are subjected to heavy disturbance by both natural forces and human activities. As a result, they are seldom vegetated. Along Carmel's upper beach, near the Tenth Avenue (North) stairway and just south of the Eleventh Avenue stairway, are thriving stands of a native beach/dune grass (*Elymus* [= *Leymus*] *mollis*). These plants grow well in the face of the shoreline's natural challenges, but are not very tolerant of trampling. (During the late 1980s, the City planted *Elymus* along the upper beach between Eighth and Ninth Avenues, but the plants eventually succumbed to trampling.)

North Dunes

The North Dunes represent one of the City's most significant native coastal biotic community. Jones and Stokes (1995) found bush lupine (*Lupinus arboreus*), beach sagewort (*Artemesia pycnocephala*), pink sand verbena (*Abronia umbellata*), and mock heather (*Ericameria ericoides*) along with several other native plant species.

Of special note is the presence of Tidestrom's lupine (*Lupinus tidestromii* var. *tidestromii*), a state- and federal-listed endangered plant species. Jones and Stokes (1995) documented the first record of Tidestrom's lupine at Carmel, reporting 280 individual plants within the North Dunes ecosystem. An informal survey conducted in 2001, in conjunction with this *Carmel Shoreline Management Plan*, confirmed the presence of several hundred plants.

The North Dunes may also be inhabited by the California Black Legless Lizard (*Anniella pulchra nigra*). In 1985, 12 specimens were located in Carmel area dunes by federal wildlife biologists;[44] suitable habitat is thought to exist in portions of the North Dunes. The status of the California Black Legless Lizard

[44] Bury, B.R. 1985. Status report. *Anniella pulchra nigra* Fisher, black legless lizard (Anniellidae: Sauria) in Central California. Ecosystems Studies Section, Denver Wildlife Research Center. Fort Collins, CA. Prepared for U.S. Fish and Wildlife Service, Office of Endangered Species, Portland, OR. (cited in Jones and Stokes, 1995).

has changed since the Jones and Stokes (1995) report: This species is currently designated as a "Species of Special Concern" by the California Department of Fish and Game, but is no longer a candidate for Endangered Species listing by the federal government.

Based on the presence of Tidestrom's lupine and potential habitat for the California Black Legless Lizard, the City has designated the North Dunes as an Environmentally Sensitive Habitat Area (ESHA). This is shown on Fig. 4.

The North Dunes are also haven to several exotic invasive plant species, including acacia and Hottentot-fig ice plant (*Carpobrotus edulis*). As described below, these aggressive plants tend to overwhelm native plants, replace habitats for native coastal wildlife, and simplify coastal ecosystems. In some portions of the North Dunes, expansion of aggressive ice plant growth could eventually crowd out slower growing native species, including the endangered Tidestrom's lupine.

Protection of the North Dunes and their native habitat will be studied during the upcoming Del Mar and North Dunes Master Plan process.

Del Mar Dunes

Native plant- and wildlife habitats in the narrow Del Mar Dunes have been disturbed by occasional coastal erosion and by the growth of exotic, invasive ice plant and acacia. Jones and Stokes (1995) studied these dunes and determined that they represent potential habitat for native dune plants and animals. The Del Mar Dunes have been designated as an Environmentally Sensitive Habitat Area (ESHA); the restoration of the Del Mar Dunes native habitat would be consistent with the California Coastal Act. This area will also be part of Carmel's Del Mar and North Dunes Master Plan.

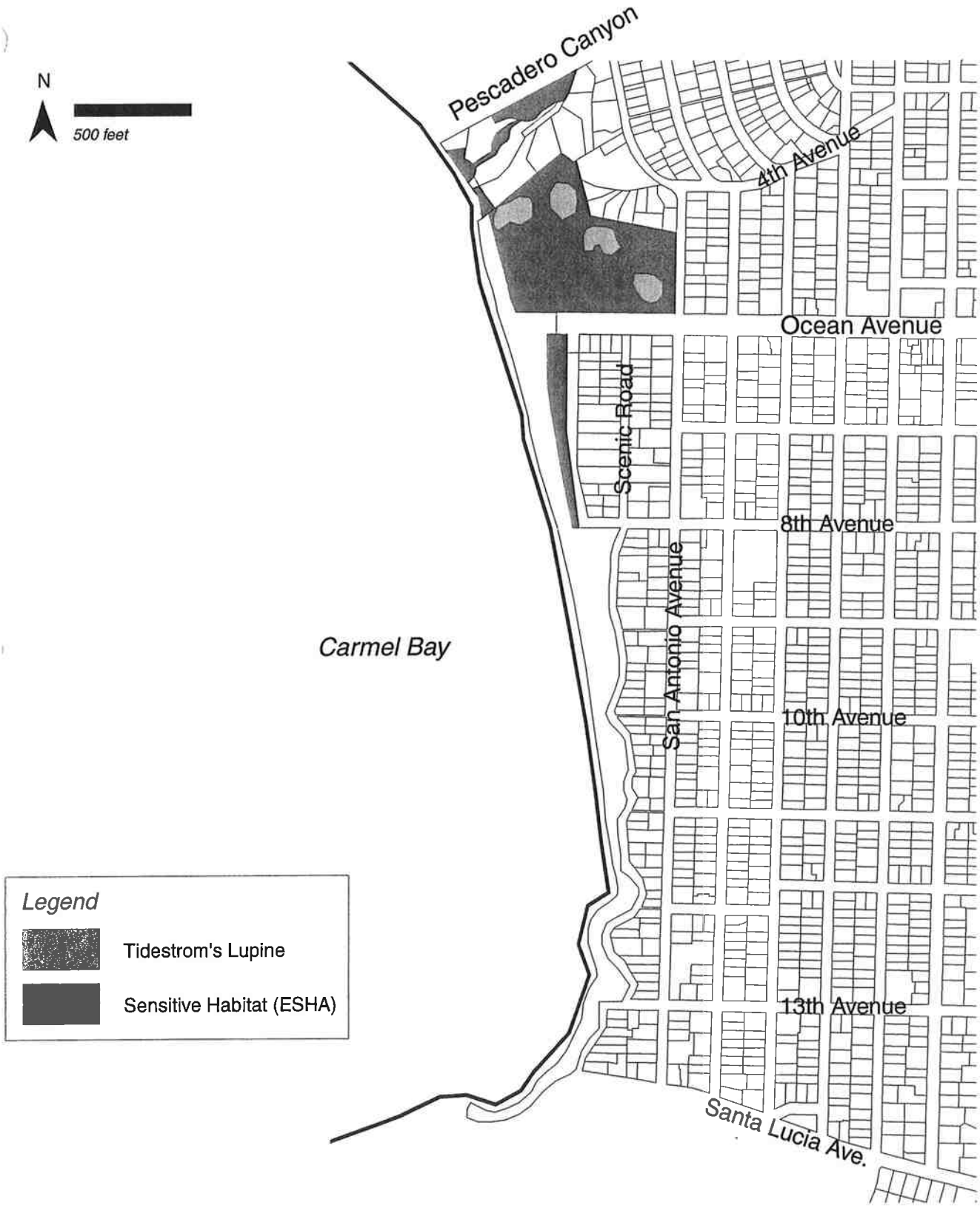

Figure 4
Environmentally Sensitive Habitat Areas

4.1.2 *Horticultural and Introduced Plants*

Most of the plants growing along Carmel's shoreline are native to other regions. Some were used to help stabilize the ever-changing coastal dunes. But most were introduced to serve as ornamental elements in a public or private landscape.

Upper Beach

Over the years, the stretch of upper beach extending between Pescadero Creek and Eighth Avenue has become vegetated mainly with Hottentot-fig ice plant (*C. edulis*), acacia (*Acacia* sp.), and sea rocket (*Cakile maritima*); both ice plant and acacia are exotic invasives. They grow aggressively, outcompeting, and eventually replacing, native California beach and dune plants. This produces a restrictive monoculture that can limit populations of native wildlife that are closely linked with the native plants. Sea rocket is also thought to be an introduced species, but its growth characteristics are not known to have a detrimental impact on California beach and dune communities.

North Dunes and Del Mar Dunes

The invasive exotics, Hottentot-fig ice plant and acacia, also grow in the North Dunes and Del Mar Dunes. In the past, City staff or residents purposely planted each of these species in an attempt to stabilize shifting dunes. Both species are now well established; without control, they out-compete neighboring plants and replace native wildlife habitats.

Beach Bluff Pathway

Plants growing along the remainder of Carmel's shoreline are primarily introduced horticultural species. With the exception of the ubiquitous Hottentot-fig ice plant and acacia, most other plants were introduced as part of the Beach Bluff Pathway landscape.

The original Pathway landscape plants were selected to serve two purposes: to enhance the aesthetic qualities of the Scenic Road/bluff top area, and to protect the City's fragile coastal bluffs from damage.

The palette of plants selected by the Pathway designers (landscape architects from Royston, Hanamoto, Alley, and Abey, in conjunction with the Carmel Beach Rehabilitation Task Force, City staff, and consultants) met several criteria. They were:

- tolerant of coastal conditions, especially exposure to salt spray;

- drought tolerant (or able to thrive on limited water);
- tolerant of human activity;
- suitable for erosion control;
- non-invasive;
- relatively easy to grow;
- commercially available; and
- "natural looking" (native or "native-like" - subtle in color).

The species originally selected for the Pathway landscape are listed in Table 2, below:

Table 2 – APPROVED CARMEL BEACH BLUFF PATHWAY PLANTS[45]

Large Shrubs

Arbutus unedo	Strawberry Tree
Atriplex lentiformis 'breweri'	Brewer's Saltbush
Leptospermum laevigatum 'compactum'	Australian Tea Tree
Pittosporum crassifolium	NCN
Rhus integrifolia	Lemonade Berry

Barrier Plants

Ceanothus impressus 'Joyce Coulter'	Joyce Coulter Ceanothus
Ceanothus impressus 'Julia Phelps'	Julia Phelps Ceanothus
Echium fastuosum	Pride of Madeira
Escallonia 'Newport Dwarf'	Newport Escallonia
Griselinia lucida	NCN
Pinus mugo	Mugo Pine

Color Planting

Chrysanthemum leucanthemum	Ox-Eye Daisy
Erigeron glaucus	Sea Daisy
Eschscholzia californica	California Poppy
Ferns	Ferns
Iris douglasiana	Pacific Coast Iris
Lupinus chamissonis	Lupine
Limonium perezii	Sea Lavender (Statice)

Low Shrubs

Ceanothus griseus 'horizontalis'	Carmel Creeper
Cistus skabergii	Hybrid Rockrose
Cistus ladanifer	Crimson Spot Rockrose
Lavandula angustifolia	English Lavender
Lavandula dentate	French Lavender
Ribes viburnifolium	Catalina
Santolina chamaecyparissus	Lavender Cotton
Teucreum fruticans 'compacta'	Dwarf Bush Germander

[45] These plants were part of the Beach Bluff Pathway landscape design that was approved by the Forest and Beach Commission, Planning Commission, City Council, and California Coastal Commission in 1987 (*From:* RHAA Landscape Plan for the "Carmel Beach Restoration Project.")

This plant list[46] is a critical feature of the City's overall plan for the shoreline. As part of the Carmel Beach Rehabilitation Project, the landscape plan was approved by two City commissions,[47] the City Council, and the California Coastal Commission[48] in 1987. Over the past decade, this landscape plan has been used as a guide for the re-vegetation of the coastal bluffs and bluff tops in several shoreline repair projects.[49]

The Carmel Beach Bluff Pathway floral landscape is in need of revitalization; steps required to achieve this renewal are described in Section. 4.3.1.

4.1.3 *Shoreline Trees*

Carmel has been described as "a small village in a forest." The City's shoreline is also blessed with a large number of trees. Monterey cypress, Monterey pine, coast live oak and acacia are the most dominant and dramatic landscape features along the City's shoreline (Fig. 5).

Cypress overwhelmingly populate the bluffs, dunes and the Ocean Avenue/Del Mar parking lot area. All the Monterey cypress along our shore were planted from seedlings gathered from those native stands at Cypress Point to the north and Point Lobos across Carmel Bay to the south. These trees, some 100 strong, were planted by one of Frank Devendorf's[50] maintenance workers and his young daughter, who nurtured each for several years until established. Now, many are over a century old. Over the years, many cypress that were past their prime, declined and died. During the 1982/83 El Niño storms, 16 large cypress were lost.

Monterey cypress are the sentinels of our shoreline. Whether standing tall or twisted and gnarled, they define the transition and progression of our community's landscape. From the water's edge, past the tidal zone up to the bluffs and dunes, Monterey cypress provide the foundation for all other landscape plantings.

Monterey cypress are the primary arboreal element of the Carmel coastal landscape. Views of the beach, bluffs, and ocean through cypress boughs are a unique visual component of the City's shoreline. Plants that conflict with, or

[46] RHAA landscape plans, entitled "Carmel Beach Restoration Phase II." Copies of these plans are kept on file at the Carmel-by-the-Sea City Hall, and at the Departments of Community Planning and Building and Forest, Parks, and Beach.
[47] Forestry Commission and Planning Commission
[48] Coastal Development Permit #3-83-217-A2, approved June 9, 1987.
[49] Coastal Commission approval of the recent Carmel Bluff and Beach Access Improvement Project was based, in part, on the City's promise to follow the RHAA landscape plans when re-vegetating areas affected by the project.
[50] J. Frank Devendorf was one of Carmel's founders.

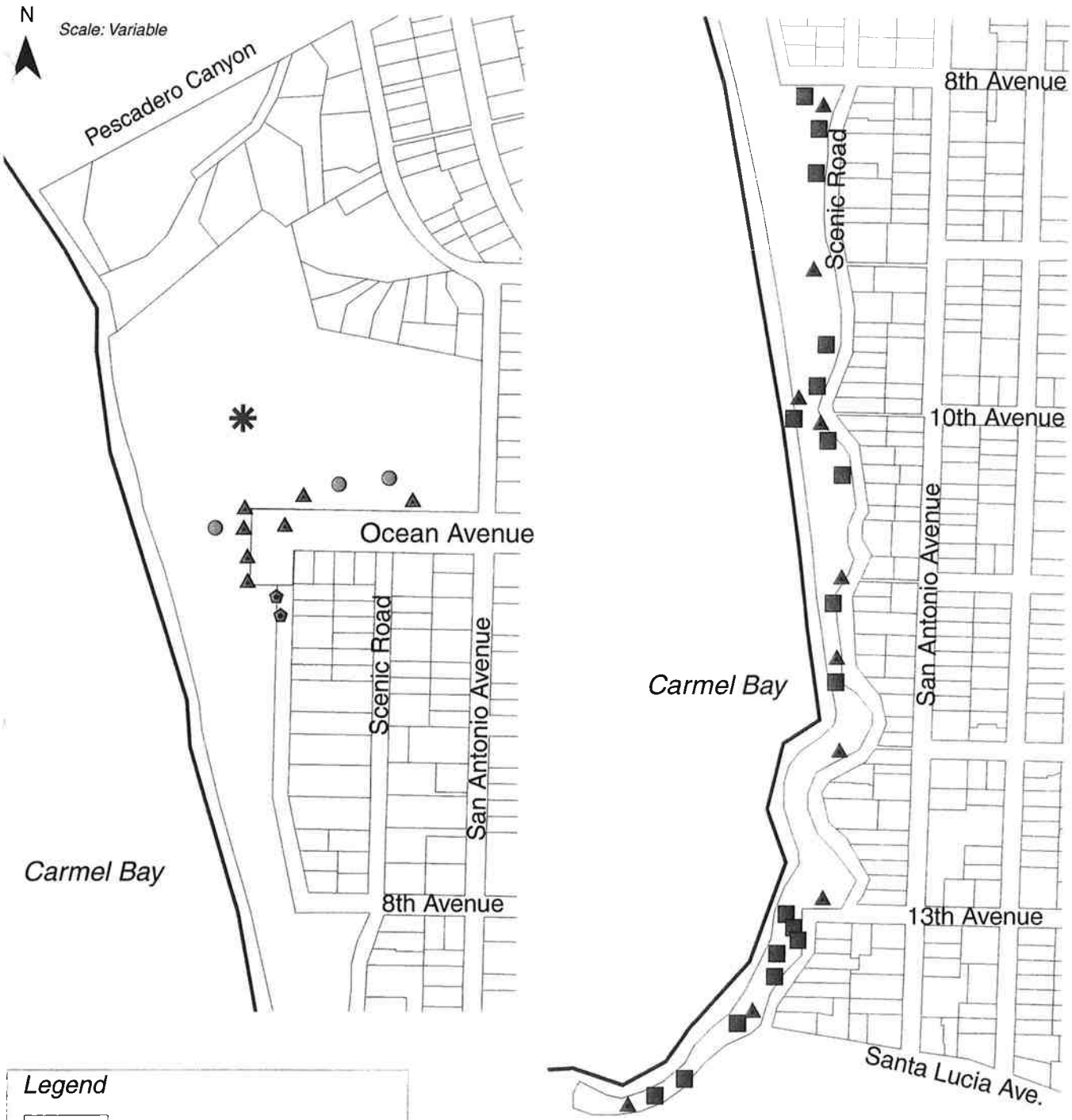

Figure 5
Shoreline Support Facilities

disrupt, the cypress viewshed should be carefully trimmed to avoid encroachment on this viewshed.[51]

Even in death, the Monterey cypress is a noble, majestic feature of our shoreline landscape. Its wood resists decay when other tree species have long since crumbled and returned to the soil. Over the years, those that have died have been allowed to remain as part of the scenic landscape for thousands to appreciate, photograph and paint. Only when they finally weaken and succumb to nature's constant attack are they removed from the shoreline.

The Forest, Parks and Beach Department inspects the structural integrity of all trees along the bluffs and the dunes. If a tree is determined to be a hazard and presents a clear and present danger to the public, then the Department will remove that tree and replace it. In many cases, mature trees are replaced with young seedlings germinated from local seed stock well in advance of their removal. By continuing these management practices, our forested beach lands will remain in balance.

In the North Dunes, when trees are removed, the trunk(s) should remain as part of the landscape and only those portions that would be considered a fire hazard (small limbs and branches) should be disposed. This practice would create a more interesting dune environment; one that provides shelter and protection, and aids in the dune building process.

Other tree species have established themselves in small groves in and around the North Dunes. A small stand of Monterey pines (and more seedlings) are thriving on the sands near the northern City border very close to the Fourth Avenue pedestrian access. Two groups of coast live oak are at home in the heart of the dunes just north of the Ocean Avenue parking lot; they hug the edge of the "Sand and Sea" residences near Fourth Avenue. All of these trees have germinated from seed transported there by some natural means. A lone eucalyptus, the largest in the City, dominates the North Dunes and beach parking lot entry at the corner of Ocean and N. San Antonio Avenues.

Finally, acacia thickets grow at several locations in the City's coastal area: throughout the North Dunes, along the northern bluffs, in many pockets on the Del Mar dunes, and on shoreline bluffs south to the Santa Lucia stairway. These thickets promote landform stability by trapping sand and binding bluff soils. Conversely, acacia's aggressive growth enables it to dominate some areas of the upper beach landscape, out-competing and replacing native species, leaving less room for shoreline visitors to enjoy. Acacia thickets have become convenient

[51] See Carmel Coastal Land Use Plan (approved June 2003) Policy P5-35.

places for illegal trash disposal, and are attractive sites for transients to set up residency.

Carmel's shoreline trees and shrubs are trimmed periodically. Trimming of the massive Monterey cypress trees reduces the length and weight of upper boughs, protecting the tree from structural damage during periods of high winds; this also protects the safety of people who walk, park, or live under these trees. Trimming of acacia and *Myoporum* helps maintain coastal viewsheds and protects neighboring plant habitats from encroachment. Thinning of acacia thickets discourages transient activity and illegal trash dumping.

4.1.4 *Beach Landscape Progression*

The landscape design of the Carmel Beach Bluff Pathway affects, and is affected by, private property landscapes along Scenic Road between Eighth Avenue and Martin Way. One goal of the original Pathway design was to create a landscape link between public lands and adjacent private property. This landscape progression concept would help unify the visual experience of the shoreline. This goal has been only partially achieved. Progress in this area could result in a revitalized holistic landscape theme for the City's entire shoreline.

4.1.5 *Coastal Viewshed*

Carmel's shoreline affords extraordinary views of the ocean and coastline. Protection of this unparalleled coastal viewshed is one of the cornerstones of the City's shoreline management program. Designers of the Beach Bluff Pathway sought to avoid structures or dense plantings that conflict with the coastal viewshed. Plants that have grown tall enough to partially obscure these special views are continuously noted during independent shoreline assessments and, when necessary, are attended to by City staff and/or contractors.

The City, however, allows a limited amount of short-term coastal viewshed interference by some of the adolescent Monterey cypress trees that line the public shoreline. As described above (Sec. 4.1.2), Carmel values views of the coast through the open boughs of its Monterey cypress. When young, these trees are characterized by dense foliage. Only as they mature do Monterey cypress grow into the tall, open "sentinels of the shoreline." To achieve this valued shape, some loss of coastal viewshed must be tolerated during a tree's early years.

4.2 STRUCTURAL LANDSCAPE

The Carmel shoreline landscape is also composed of many inanimate structural elements that were designed to serve the public in myriad ways. Some are required for public safety (guardrails), others support and/or protect the shoreline and its landscape (walls and revetments, boulders, irrigation system), while still others provide important public amenities (stairways, restrooms, benches, drinking faucets) or information (signage). Though artificial, their design and construction should reflect the important role they play in the Carmel shoreline's visual landscape.[52]

4.2.1 *Guardrails*

At many locations, the City uses wooden guardrails as a barrier between the Pathway and the beach bluffs. Guardrails, in conjunction with landscape plantings and boulders, help prevent beach visitors from trampling vegetation or walking on fragile and sometimes dangerous slopes. Guardrails are substantial structures, and are usually built no higher than 30 inches. City personnel must be prepared to install additional guardrails, plants, and/or boulders, if changes in pedestrian traffic patterns threaten other less-protected areas.

4.2.2 *Walls and Revetments*

For nearly fifty years, the City has responded to erosion of its coastal bluffs by building seawalls, retaining walls, and engineered rock revetments. These structures are discussed in detail in Section 6 of this *Shoreline Management Plan.*

4.2.3 *Rocks and Boulders*

One special component of the shoreline's natural landscape is the use of rocks and boulders. All public walls along Carmel's beach and bluffs are either built from stone or from reinforced concrete that has been faced with stone.

The Eighth Avenue stairway is built of "Carmel stone," flat pieces of "soft" limestone that were quarried locally. Two patios located near Eleventh Avenue and the entries to all stone trash/recycling container enclosures are built with "Arizona sandstone," an imported "hard" stone that creates an excellent walking surface.

At most other locations, the City used locally quarried golden granite rocks. Some of the earliest shoreline walls were built with golden granite rocks and mortar.

[52] See City of Carmel Coastal Land Use Plan (approved June 2003) Policy P5-12 and P5-5.

Walls constructed after 1978 are constructed of reinforced concrete faced with golden granite. This style is used for seawalls, retaining walls, and on many stairways and trash/recycling container enclosures.

Large granite boulders are an integral part of the shoreline landscape and undeniably contribute to its aesthetic character. Boulders punctuate planting areas. They also serve as natural benches. At strategic locations, they are used to help guide pedestrian flow along the Pathway.

4.2.4 *Water Storage Tanks*

Irrigation water for the Beach Bluff Pathway landscape is supplied by an innovative system that collects spring water in two underground storage tanks. These 10,000 gallon fiberglass tanks are buried in the dunes just south of the Del Mar portion of main beach parking lot.

At this site, spring water flows continuously throughout the year. During the drought of 1978, the City recorded flows of 12 gallons per minute, and during the peak of the 1982/83 El Niño winter storms, flows of 60 gpm were recorded.

In 1985, the City installed a single underground water storage tank; three years later, a second tank was connected in series. Water from these reservoirs is now pumped through a two-inch diameter underground PVC pipe to the Pathway irrigation system controller at Eighth Avenue. From there it is piped to numerous sites along the Beach Bluff Pathway.

Water from these storage tanks is also used to fill the City's street sweeper, sidewalk-cleaner, tree-planting/watering trucks, and fire apparatus. In addition, this water could serve as an emergency back-up for water commercially supplied to the City.[53] Use of this spring water has greatly reduced both the amount and cost of Carmel's potable water consumption.

4.2.5 *Benches*

Pathway designers wanted to ensure ample places for people to sit along the bluff top and enjoy the shoreline's scenic vistas. In keeping with the project's design philosophy, they chose to build benches of a simple style, made of wood and/or stone.

[53] This spring water has been tested and found to range from pure to containing low levels of coliform bacteria. This water could easily become potable if treated using standard water purification techniques.

Some benches were fashioned from large pieces of driftwood that washed up on Carmel Beach. City personnel began setting these aside, even before the final plan had been approved. During the Pathway's construction phase, the most suitable driftwood was sanded, attached to cement plinths, and installed at strategic locations. These informal benches have become a popular design element of the Beach Bluff Pathway.

In addition to benches, the City has also placed large boulders in selected locations to be used for sitting.

4.2.6 *Signage*

Signs provide information for shoreline visitors. They identify traffic and parking regulations, give directions to nearby beach accesses, warn of hazardous conditions, and inform about City ordinances regarding alcohol use, beach fires and fragile slope protection.

Of all the topics dealt with by the Carmel Beach Rehabilitation Task Force, signage was the subject of the most intense deliberations. The final design was a compromise between notifying beach visitors of pertinent information and not causing them to be overwhelmed or the unique coastal viewshed to be disrupted.

The number of signs along the Pathway was limited by consolidating information at selected locations (e.g. signs on trash/recycling container enclosures and on "access" sign posts). All informational signs were of muted earth tones to sustain the integrity of the landscape design. To avoid unsightly rust, non-metal signs and fasteners were used. When signs were legally required to be made of metal (e.g. traffic and parking signs); they were enclosed within a wooden frame.

One type of sign purposely stands out from the others. The signs that warn of hazardous surf conditions are standard dark brown with bright yellow lettering and made of metal. They were designed by a consortium of Monterey Bay municipalities, in conjunction with the California Department of Parks and Recreation and the U.S. Coast Guard. They are placed mid-level on each beach accessway and are double-sided to be seen from both the beach and the bluff.

Over the years, the number and types of signs have gradually increased. Sign colors and locations have expanded beyond the original design and intent. At some locations, signs are now competing with the natural viewshed.

Signage is a critical part of Carmel's shoreline management program. To ensure that signs enhance, rather than detract from, the City's coastal resources, adopted policies require that signs:[54]

- provide information in a clear, accurate and concise manner;
- are visible to the public without detracting from protected coastal viewsheds;
- are consistent in design style, use of color and materials;
- are efficiently used, limiting overall numbers and avoiding a cluttered appearance; and
- reflect the aesthetic sensitivities of the Carmel community.

4.2.7 *Shoreline Amenities/Recreational Support Facilities*

The shoreline landscape also contains many elements that serve those who walk, run, or play throughout the Carmel shoreline area (Fig. 6).

Beach Access Stairways

The stairways that provide public access to and from Carmel Beach are discussed in Section 3.

Restrooms

Carmel's shoreline visitors are served by restroom facilities located at nearly opposite ends of Scenic Road (Fig. 7). The main restroom is sited at the foot of Ocean Avenue, adjacent to the City's primary beach parking lot. This facility contains separate restrooms for men and women. Each is complete with running water, sinks, and appropriate toilet facilities. The women's side also includes a fenced privacy area for changing clothes.

The outside of this facility is faced with golden granite stone, and its appearance fits well with other structures along the City's coastline. The inside of the restroom was designed to facilitate cleaning, including gently sloping floors and drains for easy cleaning. This facility meets ADA requirements for disabled accessibility.

In 1995, the City established temporary restroom facilities at "Lloyd Point," near Santa Lucia Avenue. These facilities consist of two portable toilets screened by a few Monterey cypress trees and a wooden fence. Both facilities may be used by men and women; one provides accessibility to the physically

[54] The City of Carmel plans to implement a comprehensive shoreline area sign program once its Local Coastal Program has been certified.



Figure 6

Shoreline Public Trees and Landscaping

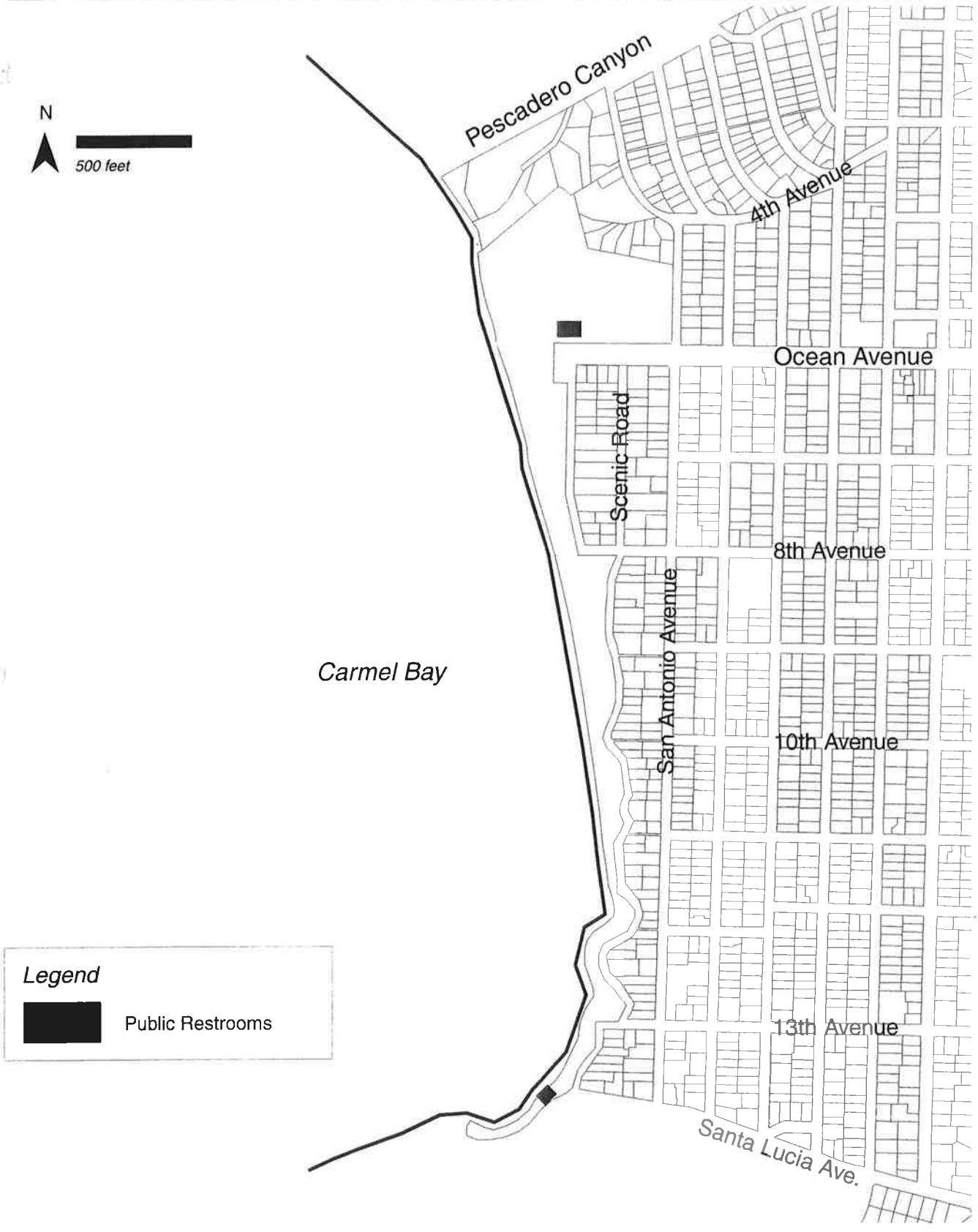

Figure 7
Public Restroom Facilities

disabled. Both facilities have water containers for hand-washing. These restroom facilities are serviced by a private company under contract to the City.

Foot Wash-Off Stations

The City has installed foot wash-off stations at four beach access stairways (Eighth,[55] Eleventh, Thirteenth, and Santa Lucia Avenues). Each supplies potable water for rinsing sand and watering pets. All wash-off stations consist of a concrete floor (with drain)[56] surrounded by low granite-faced walls; each is served by a self-closing faucet.

Drinking Fountains

Drinking fountains are located at the main beach restroom (Ocean Avenue) and at the top of the Thirteenth Avenue stairway. Each draws from the City's commercial water source.

Trash/Recycling Containers and Enclosures

Throughout the Carmel shoreline area, the City has built enclosures for its trash and recycling containers. These enclosures serve many purposes:

- They screen the containers from public view;
- They protect the containers from being knocked over;
- They are located at sites easily accessible to the City's trash disposal contractors;
- They are easily cleaned by City maintenance personnel; and
- They serve as appropriate sites for posting beach informational signs.

At present, there are 17 trash/recycling container enclosures along the shoreline. The seven enclosures located in the Ocean Avenue/Del Mar parking lot are made of wood, while the ten enclosures located along the Pathway are built of reinforced concrete and faced with golden granite. Enclosures in each area face different sets of conditions, and, so, were built in different styles and of different materials.

[55] The wash-off facility at Eighth Avenue has never been connected to the commercial (potable) water system.

[56] Unfortunately, the wash-off station drains have a tendency to become clogged with sand. At present, they require more frequent cleaning; in the long-term, they will need redesigning/rebuilding.

Fire Pits

City ordinance limits recreational beach fires to that portion of the beach located south of Tenth Avenue and seaward of the high tide line.[57] In addition, Carmel also allows fires to be built in three stone fire pits located near the Ocean Avenue/Del Mar parking lot – these pits are located a very short distance from convenient parking spaces and are popular with beach visitors.

Volleyball Courts

In the dunes near the foot of Ocean Avenue, the City has installed posts for four sand volleyball courts; players must supply their own net and ball. These are often used on weekends and during the summer.

4.3 FUTURE PROJECTS

4.3.1 *Revitalization of the Beach Bluff Pathway Landscape*

The Beach Bluff Pathway landscape is now in need of revitalization. Since its initial planting in 1988, the landscape has strayed from its original design theme. Species, locations, and densities of horticultural plants have changed, but unfortunately, these changes have not been documented. In some areas, plants have grown tall enough to obscure portions of Carmel's unique coastal viewshed. At other sites, landscape plants that had successfully grown to maturity, became senescent and died. These were rarely replaced by younger, more vigorous plants. There are now entire Pathway planter areas where plants have completely disappeared and replaced by a sterile medium of wood chips.

These conditions were described in recent shoreline assessments; some have been addressed by City staff and/or contractors. The Pathway landscape, however, continues to be affected by the lack of: 1) an operational program that guides staff in their daily efforts, and 2) adequate staff-time and funding to perform tasks necessary to maintain the landscape.

Renewal of the Pathway landscape, if based on a combination of the project's original design concepts and lessons learned during the past fifteen years, would help return the Pathway to its award-winning condition. As mentioned above, the Pathway's landscape plants are important for their aesthetic qualities as well as for the protection they give to Carmel's fragile shoreline bluff tops. Steps recommended for the revitalization of the Pathway landscape are listed below.

[57] Recreational beach fires are discussed in greater detail in Section 5.

Landscape Plans and Concepts

The original plans and design concepts should be reviewed. They were the result of a very active process involving a citizen task force, world-renown landscape architects, City staff and consultants, along with ideas that grew out of several public hearings. Each species, its color, size, and location, was selected to perform a specific function in the overall landscape design. The original Pathway was greeted by wide acclaim and was the recipient of several awards. The Task Force understood that not all plants would be successful and future adjustments would be necessary. These changes, however, should be made with an understanding and appreciation for the project's original design intent.

Plant Selections

With experience gained during the past fifteen years, the original Pathway plant selections can be assessed, perhaps at the rate of one block per year. Many plants have been successful; others have not. Some failed to thrive because they could not tolerate the harsh forces of nature or the intense human impacts that characterize Carmel's shoreline. Others may have failed because they lacked proper care. Some of the plants were unable to thrive in their planned locale. Others proved to grow too slowly or too tall for their intended purpose. All plantings that do not appear successful should be assessed according to a standard procedure:

If a given plant is not thriving:

- **Is it not suitable for its location?**
  Perhaps this species will grow well in a different section of the Carmel shoreline landscape.
- **Was its failure due to trampling or other human/dog activity?**
  Perhaps the addition of guardrails or boulders could help achieve success.
- **Was there a problem with watering or fertilizing?**
  These should be adjusted before removing a species from the plant list.

If, after these assessments, it is determined that a planting should be modified or a species replaced, then new plants/species must be selected that fit well with the Pathway landscape design criteria, stated above. Any changes to the plant selection must be recorded, and periodically considered by the Carmel Forest and Beach Commission.

Staffing

Changes to the Pathway landscape should take into account the availability of Forest, Parks, and Beach staffing. New plantings have little value if there is not enough staff (or funding for contract labor) to maintain them.

Training

One key to the success of the Pathway landscape project will be staff training. The City's shoreline differs from landscapes in other parts of Carmel. The important role that the Pathway plays in bluff top protection, the protection of coastal viewsheds and the ability of plants to withstand harsh coastal conditions are concepts in need of discussion.

The day-to-day work performed by City staff is as important as the deliberations, plans, and reports produced by commissions, task forces, and consultants. Most projects will not succeed if on-site workers do not "buy into" the plan. Conversely, staff must also be able to share their knowledge and insights, often gained through years of field experience.

4.3.2 *Restrooms at Santa Lucia Avenue at Scenic Road)*

The two portable restrooms located along the bluff top near Santa Lucia Avenue help meet an important need for all who visit the Carmel shoreline. The City intends to continue use of these temporary facilities until permanent restrooms can be built at an appropriate location, somewhere along the shoreline between Eighth Avenue and the south City limit.[58]

4.4 MANAGEMENT POLICIES

- Provide adequate facilities that will serve the needs of the public, mitigate damage to the environment, and respect the neighborhood. (G4-3)

    - Limit development along the Carmel shoreline to facilities that support passive and active recreational activities, beach access, bluff protection and protection of infrastructure. Bluff protection and protection of infrastructure shall be permitted only when required to protect existing structures that are in danger from erosion. (O4-6 excerpt)

[58] City of Carmel Coastal Land Use Plan (approved June 2003) Policy P4-41

- Discourage any further incursion of recreational activities into the North Dunes habitat. Sensitive resources in the North Dunes habitat area shall be protected. (P4-48)

- Provide restroom facilities consistent with the volume of people who use the beach and Beach Bluff Pathway. (O4-7)

  - Retain the existing restroom facility at the Ocean Avenue/Del Mar parking lot and consider improvements to increase its capacity. (P4-40)

  - Retain the current second restroom facility at Santa Lucia Avenue until it can be replaced by a permanent site. Remove this facility upon construction of one or more additional permanent restrooms south of Eighth Avenue. (P4-41)

  - Maintain as operational all wash-off stations located adjacent to the stairways at Eighth, Eleventh, Thirteenth, and Santa Lucia Avenues. (P4-55)

- Perpetuate the mix of native dune and horticultural plants in an informal natural beach landscape. (O5-3)

  - Sustain and maintain the Beach Bluff Pathway design concept and landscape plant selection. Authorize the Forest and Beach Commission to review and approve minor design changes and plant selections. Require a coastal development permit for significant changes or any change that would substantially alter the design concept. (P4-13)

  - Evaluate the Pathway landscape, including plant selection and associated design elements in consultation with a coastal landscape specialist; identify sites that require revitalization and implement restoration based on the Pathway Design Plan. Address the most severely impacted sites first. (P5-32)

  - Install more seating along the beach pathway. (P4-14)

  - Keep the vegetation on San Antonio Avenue near pedestrian access easements pruned for safe visibility of pedestrians by motorists. (P4-6)

  - Continue the use of Monterey cypress as the predominant tree species on the beach bluff and North Dunes. The exact number of

trees may vary over time, but whenever a tree dies or is lost during a storm, replacement trees should be planted in approximately the same location. Maintain a low-to-medium density of trees (40 to 60 trees) in the North Dunes. (P5-25)

- Protect Monterey cypress from structural damage caused by high winds. Develop a proactive trimming program to reduce length and weight of limbs and branches. (P5-33)

- Encourage neighborhood cooperation and volunteers to assist City staff with the care of the landscape along the pathway. (P5-26)

- Maintain an attractive mix of plant material that favors native species and other drought-tolerant, non-invasive species. (P5-27)

- Encourage the extension of the City's Pathway landscape style onto neighboring properties:
  - Bring all City-owned property along this portion of Scenic Road into compliance with the approved Pathway plan.
  - Encourage private property owners to draw from the broad palette of plants used in the Pathway design.
  - Make presentations to the Scenic Road Property Owners' Association about this concept and share with the Association the plant list and a list of local suppliers.
  - Encourage the use of plants from this palette when reviewing projects on Scenic Road through the Design Review processes.

  (P5-31)

- Maintain the vegetation and trees along the shoreline in a safe and healthy condition. (O5-4)

  - Encourage the use of existing stairs, trails, and pathways, and discourage off-trail "short-cuts" on or over the bluff face. Install landscaping barriers at each "short cut" on the face of the bluffs and immediately restore damaged landscaping. (P5-7)

  - Prune or repair trees immediately following limb failure to mitigate any safety hazards. At other times, trees may be pruned in accordance with City policy, keeping public safety, access and the tree's health as the primary goals. (P5-34)

  - Pruning of vegetation will be done as needed for the health of the plants. This is a natural landscape and formal garden pruning is to be avoided. The Pathway must be kept clear of overgrowth and periodic

pruning is desired. However, neat straight edging is discouraged. Prevent shrubs from growing too high and blocking views of the ocean through the Cypress trees along the Beach Bluff Pathway. (P5-35)

- Ensure that long-term management activities maintain the natural dune ecology of Carmel Beach in a manner consistent with public safety. Protect areas of the beach from loss of habitat where special status plant species are growing. (O5-40)

  - Restore dune areas to improve habitat for Tidestrom's lupine and other native dune plants. (P5-28)

  - Improve habitat values for the preservation of the California black legless lizard. (P5-30)

  - Avoid disturbance or degradation of resources when maintenance vehicles and equipment enter sensitive habitat areas. (P5-161)

  - Retain a qualified botanist to monitor the population of Tidestrom's lupine and other special status species on the North Dunes of Carmel Beach. The population should be assessed annually (or based upon a schedule agreed upon by the Department of Fish and Game, Coastal Commission and US Fish and Wildlife Service) to determine if the population is stable and if measures to protect the population should be instituted. If the population appears heavily affected by public use, the City should consider fencing or placing barriers around the lupine habitat on the beach. (P5-173)

- Protect the fragile dunes and sensitive plants in the Del Mar Dunes and North Dunes against any significant disruption of habitat values. (O5-7)

  - Prohibit planting and control the spread of invasive non-native plants. (P5-29)

  - Restore, maintain and enhance the degraded habitat in the Del Mar Dunes area to enhance environmental resources and aesthetics. Protect sensitive habitat and special-status species through development and implementation of the Del Mar and North Dunes Master Plan. (P5-42)

- Prevent further planting and spread of invasive horticultural species within the dunes at Carmel Beach. (P5-174)

- Remove any non-native invasive vegetation from special status habitat to eliminate competition and implement a dune restoration plan. (P5-175)

- Implement a Dune Restoration Plan. (P5-176)

- Minimize spread of non-native plants. (P5-177)

- Conduct black legless lizard surveys and manage appropriately. (P5-178)

- Identify, protect and manage Environmentally Sensitive Habitat Areas (ESHAs) to ensure their long-term integrity and the biological productivity of these habitats. (G5-12)

  - Monitor, study and develop effective management programs for the City's parks and ESHAs. Endeavor to reduce conflicts between environmental protection and use of public and private property within ESHAs. (O5-36)

    - Maintain and enhance the resource value of environmentally sensitive habitat areas in consultation with a qualified biologist and in coordination with the California Department of Fish and Game. Remove any non-native, invasive vegetation from sensitive habitats. (P5-159)

  - Reduce the introduction and spread of invasive horticultural species into and within identified ESHAs. (O5-37 excerpt).

  - Provide beach users with information about Carmel Beach, its vegetation, facilities, amenities, and limitations (rules). (O4-4 excerpt)

  - Establish a uniform signage program for the beach and bluffs to better inform beach users of regulations governing activities on the beach. (O4-5)

    - Post "beach access/pedestrians only" signs at the top of pedestrian easements to help visitors locate these access routes including North Dunes access routes and the easement from San Antonio through Sand and Sea. (P4-29)

- Install signage along Scenic Road to direct traffic and indicate beach parking hours. (P4-30)

- Use as few signs as possible to accomplish the desired purpose. Rely on design features and/or public education to influence behavior first. Establish standards for the total number of informational signs along the shoreline. (P4-31)

- Consider locating signs at the bottom of the bluff if appropriate. (P4-32)

- Use signs that are aesthetically pleasing, easily seen, minimal in size, brief in content, of muted color and uniform in design. (P4-33)

- Post educational/interpretive signs where appropriate along Scenic Road and in the North Dunes area. (P4-34)

- Use international symbols whenever possible, along with a brief explanation of prohibitions and Municipal Code Section citations. (P4-36)

- Maintain all signs to ensure that they are legible. Signs that are vandalized or defective shall be replaced or repaired as soon as possible. (P4-37)

- Maintain signs at each stairway indicating fires must be at least twenty-five feet from the base of the bluffs and that they are not allowed north of Tenth Avenue. (P4-38)

- Use trash containers as a location for educational and regulatory signs. (P4-39)

- Provide signage prohibiting fires in the dunes area. Consider using doors on restroom stalls for posting beach rules and regulations. (P5-40)

- New development shall minimize risks to life and property, assure stability and structural integrity over the life of the development, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area. (G5-1)

5 RECREATIONAL ACTIVITIES AND EVENTS

5.1 RECREATIONAL ACTIVITIES

Carmel Beach and its shoreline area provide opportunities for a wide variety of recreational activities. Beach visitors participate in swimming, surfing, diving, jogging, walking, sandcastle building, volleyball, picnics, and other beach-related activities.

Several City facilities and amenities enhance these beach activities. The main beach restroom, at the Ocean Avenue/Del Mar parking lot, offers restroom facilities and changing areas. Four of Carmel's beach access stairways have foot wash-off stations (Eighth, Eleventh, Thirteenth, and Santa Lucia Avenues). Two parking spaces marked white for "loading," located on Scenic Road near Eighth and Eleventh Avenues, enable people to move supplies to and from their vehicles.

5.1.1 *Regulated Shoreline Activities*

Some recreational activities have significant impacts on the surrounding environment and are dealt with by City ordinance.[59]

Recreational Fires

Recreational fires have long been part of the Carmel Beach tradition. Histories of Carmel's earliest days are full of tales of writers and artists enjoying fires on the beach and dunes. As the City's popularity and population grew, it became clear that coals and ash from the numerous fires were discoloring Carmel's characteristic white sands – portions of the beach and dunes were turning gray.

As described in Section 2, the beach is cleansed by the natural cycle that annually removes sand during winter and re-deposits sand the following spring. But this process cleans only a portion of the Carmel's shoreline. Beach sands located above the reach of high-energy storm waves, including nearly all of the City's dune sands, are not affected by this yearly cleansing. Any discoloration of these sands can remain for years.

[59] City ordinances that deal with activities along the Carmel shoreline are listed in section 9B.

In 1995, the City passed an ordinance to limit the location and size of beach fires.[60] Fires are now limited to portions of the beach south of Tenth Avenue and west of the high tide line, where white beach sands may be cleansed and/or renewed by daily or monthly tidal cycles, or by the annual onshore/offshore sand cycle. According to Carmel Police Department personnel,[61] this ordinance has reduced many problems associated with shoreline recreational fires:

- fires are no longer permitted in the dunes; and
- people no longer remove live wood from trees and bushes for use as fuel.

The City's current beach fire ordinance also restricts the building of fires closer than 25 feet from "any wall, vegetation or combustible material not intended to be used in the fire." This has significantly reduced the potential for beach fires to spread, endangering neighboring areas. In spite of the success of the 1995 ordinance, Carmel Beach sand south of Tenth Avenue remains discolored from spring through late fall.

The existing program represents a compromise between two competing values: the tradition of building recreational beach fires vs. the purity of Carmel's signature white sands. Extending the area where fires may be built would enhance one value at the expense of the other.

The City has attempted to use concrete fire rings at several sites, but these have not proven successful. The heavy rings were difficult to move when threatened with either burial by sand or inundation by seawater. They also tended to be used as receptacles for trash and broken bottles.

Other Activities

The City allows alcohol on Carmel Beach, but camping and overnight sleeping on the beach and dunes are prohibited, as is the use of unauthorized vehicles. Riding a horse, mule, or donkey, is lawful if it occurs seaward of mean high water, though access to the beach may be difficult.[62] Operation of motorized personal watercraft (including jet skis) anywhere in Carmel Bay is prohibited by Monterey Bay National Marine Sanctuary regulation.

Many people bring dogs to Carmel's shoreline area. On Scenic Road, dogs must be leashed, but on Carmel Beach they need only to be under voice

[60] Carmel Municipal Code Section 8.32.160
[61] Carmel Police Sergeant Terry Chandler (pers. comm.)
[62] The ordinance cited describes suitable beach access at Santa Lucia Avenue. In the years since that ordinance was approved, storm damage and the City's repairs have made Santa Lucia Avenue unsuitable for equine access.

control. As in all parts of the City, people must pick up and properly dispose of their dog's wastes. The City has installed dispensers for special plastic waste-disposal bags ("Mutt-Mitts") at near the top of each beach access stairway along the Pathway.

5.2 SPONSORED EVENTS

People may hold private events on Carmel Beach, including parties and weddings. Any event attended by more than 50 people, or that uses commercial- or City support, requires a Carmel Special Event Permit, as described below.

Every year, the Carmel shoreline becomes the site of several public events. All events are free admission and open to the public. Popular activities, including the Fourth of July and the Great Sand Castle Contest, intensify traffic and parking conditions and require enhanced City support services (e.g. additional trash collection services, increased removal of litter and trash from the beach, and placement, servicing and removal of a significant number of portable restrooms).

Each public event requires a Special Event Permit from the City. Event sponsors must make a presentation to the Special Events Committee, describing their event. Sponsors must also submit plans for parking, trash collection/recycling, portable toilets, and beach/vegetation monitoring. The City's Special Events Committee has oversight responsibility for each event and prepares an "after-event" impact analysis report.

A list of Carmel's annual Special Events appears in Table 3, following:

Table 3 - ANNUAL SPECIAL EVENTS

Event	Date	Location	Description/ Impact on Traffic and Parking
Resolution Run	January 1st	Scenic Rd, south of Eighth Ave.	A 5K-10K Walk-Run/ Minimal impact on traffic and parking
Kite Festival	Spring	Carmel Beach	Kite flying for children and adults/Increased traffic and parking.
Surf-About	Spring/Summer	Carmel Beach	Surfing contest/ Minimal impact on traffic and parking.
Fourth of July[63]	July 4th	Carmel Beach	Beach activities/ Restrictions on traffic and parking.[64]
Movies on the Beach	Summer	Thirteenth Ave. cove	Evening films/ Minimal impact on traffic and parking.
Great Sand Castle Contest	Fall	Carmel Beach	Sand castle building/ Increased traffic and parking.

[63] The Fourth of July celebration on Carmel Beach is not an organized/sponsored event. Use of fireworks on Carmel Beach is prohibited (CMC 8.32.170).

[64] During Fourth of July celebration ~~event~~ or during any ~~other~~ temporary event, if travel and parking are restricted on Scenic Road and on portions of Ocean, San Antonio, Carmelo, Eighth, Thirteenth, and Santa Lucia Avenues a Coastal Development Permit is required.

5.3 MANAGEMENT POLICIES

- Provide for a wide variety of passive and active recreational experiences for all beach users while protecting the resource values of beach environs. (G4-4)

  - Maintain the City's beach, park and open space resources in a manner to encourage use and enjoyment by residents and visitors. (O4-9)

    - Establish and maintain in public ownership the entire sandy beach on Carmel's shoreline from the north to the south City boundary. (P4-45)

    - Allow surfing, hiking, picnicking, horseback riding, and typical beach games, such as Frisbee and volleyball on the beach without restriction. Allow dogs on the beach when on a leash or under voice control. Require dogs on the Beach Bluff Pathway to be on a leash. However, if the dog policy combined with educational efforts does not promote a safe environment for beach users and dogs, a leash law for certain times should be considered. (P4-47)

    - Prohibit percussion instruments on Scenic Road, the Beach Bluff Pathway, and beach bluff without a permit. Prohibit sound amplifying equipment on the City Beach without a permit. (P4-49)

    - Prohibit sales or other commercial activities on Carmel Beach, along the bluff or in the Ocean Avenue/Del Mar parking lot. (P4-50)

    - Prohibit overnight camping on any portion of the beach and bluffs. (P4-51)

    - Allow alcohol consumption on the beach until 10:00 p.m. (P4-52)

    - Prohibit bicycles and skating on pedestrian access easements between Scenic Road and San Antonio Avenue and on the Beach Bluff Pathway. (P4-53)

    - Prohibit private dune buggies and motorized marine vehicles on the beach. (P4-54)

- Implement procedures and regulations for temporary events on the beach that will protect public access and environmental resources. (P4-56)

- Prohibit motorized vehicles and motorized recreational equipment on Carmel Beach, sand dunes and other City owned parkland. This prohibition does not apply to city and contracted maintenance vehicles or public safety vehicles. (P5-24)

- Restrictions on parking and traffic along Scenic Road, the Del Mar parking lot, San Antonio and the public rights-of-way west of San Antonio shall require a Coastal Development Permit.

- Allow beach users the opportunity to enjoy a fire for warmth or cooking, while protecting the sand from degradation. (O4-10)

  - Allow beach fires until 10:00 p.m. south of Tenth Avenue but at least twenty-five feet from the base of bluffs. Install appropriate signage to indicate this distance and time limit and to indicate methods for correct extinguishing of fires with water. (P4-57)

  - Continue Police Department enforcement of the no-fire regulation north of Tenth Avenue and especially in the North Dunes and Del Mar Dunes areas. (P5-41)

6 CARMEL SHORELINE EROSION AND RESPONSE

Like most of coastal North America, Carmel's shore has experienced significant erosion during at least the past century. Even though it is protected by granite headlands at each end, Carmel Bay faces toward the west-southwest, and receives nearly the full brunt of high-energy winter storm waves.

6.1 EROSION HISTORY

Johnson (1984) reviewed reports describing damage from Monterey Bay/central California storms that occurred between 1910 and 1983. Over the past two decades, Carmel's shoreline has been severely damaged by storms associated with the El Niño weather patterns. The most recent El Niño periods (Winters of 1982/83, 1986/87, and 1997/98) were characterized by extended periods of heavy rain, strong winds, and high surf. The extensive damage during these El Niño winters resulted, in part, from the nearly continuous battering of the shoreline by powerful storm waves and the weakening of water-saturated beach bluffs. During the 1982/83 El Niño period, severe winter storms struck Carmel nearly every ten days. More sand was removed from the beach than at any previous time in the memory of long-term residents or documented history.



Photo 8 – *Severe Erosion and Boulder Migration at Tenth Avenue (North) Stairway*

6.2 EROSION PROCESSES

Erosion of Carmel's shoreline can be divided into two distinct categories: beach erosion and coastal bluff and dune erosion.

6.2.1 *Beach Erosion*

Short-term Erosion

As described in Section 2, Carmel Beach experiences seasonal changes in sand volume. The "constructive" low-energy waves during the spring and summer months and the "destructive" high-energy waves, from late fall through early spring, combine to create the beach's annual onshore/offshore sand cycle. In this cycle, beach erosion during the winter is usually offset by beach-building ("accretion") during the summer. After a severe El Niño winter, more than a single year of accretion may be required before the beach returns to its "normal" level.

In contrast to its characterization, "short-term" beach erosion can have significant and long-lasting impacts on Carmel's shoreline. Low winter beach sand levels can make both vertical and lateral beach access difficult, hazardous, or even impossible (see Sec. 3). In addition, low beach levels reduce the ability of sand to absorb the impact of incoming storm waves. This allows waves to strike Carmel's shoreline bluffs, dunes, and structures (i.e. stairways, seawalls, storm water outfalls, etc.) without the buffering protection of beach sand. Finally, low winter sand levels may threaten seawalls, stairways, and other structures, by exposing their supporting base and footings directly to the tremendous power of winter waves.

Long-term Erosion

Along some shorelines, the annual onshore/offshore sand cycle becomes out-of-balance, resulting in a long-term sand deficit. This produces a beach that grows narrower and, in extreme cases, eventually disappears, leaving boulders, cobbles, and bedrock. Unlike the short-term erosion described above, this long-term erosion cannot be remedied by seasonal coastal cycles.

Long-term beach erosion may sometimes be caused by an interruption in the beach's sand supply. Though the full details of Carmel's sand supply are not well understood, long-term beach loss due to sand supply interruption is not likely.

A more common cause of long-term beach erosion is the loss of sand associated with seawalls and revetments. This phenomenon can best be explained by understanding that as an unprotected shoreline erodes, its beach width tends to remain roughly the same[65] – it is usually the bluffs and dunes behind the beach that erode (see below). Over time, the resulting beach appears to move farther inland. When encountering a hard (and less erodible) structure at the back of a beach, high-energy storm waves tend to erode the easily-moved sand grains in the immediate vicinity. Eventually, the area seaward of a hard structure will be denuded of beach sand. This "fixing" of the back-beach will occur whether the hard structure is a "natural" rock, an engineered rock revetment, or a reinforced concrete seawall. This is one of the reasons that broad beaches rarely form along rocky points. This process also accounts for the "peninsula effect," by which the hard, protected portion of a shoreline is left protruding seaward while the more-erodible adjacent areas are eaten away.

Long-term erosion via back-beach fixing has been reported along other shorelines, but has not yet been documented at Carmel. Storlazzi and Field (2000) analyzed aerial photographs from 1949, 1970, and 1990, and stated that Carmel Beach "has narrowed noticeably in the last 40 yr." Unfortunately, their study lacked important information (tidal conditions) required for a clear and accurate assessment.

Accurate information about whether Carmel Beach (or even a portion of the beach) is experiencing long-term erosion will be an important tool in the City's shoreline management program. Steps required to obtain the necessary data are discussed in Section 8.

Passive Erosion

Experts generally agree that where the shoreline is eroding and armoring is installed, armoring will eventually define the boundary between the sea and the upland. On an eroding shoreline fronted by a beach, the beach will be present as long as some sand is supplied to the shoreline and the beach is not submerged by sea level rise. As erosion proceeds, the beach also retreats. This process stops, however, when the retreating shoreline comes to a revetment or a seawall. While the shoreline on either side of the armor continues to retreat, shoreline retreat in front of the armor stops. Eventually, the shoreline fronting the armor protrudes into the water, with the mean high tide line fixed at the base of the structure. In the case of an eroding shoreline, this represents the loss of a beach as a direct result of the armor.

[65] This assumption is valid only if such factors as sand availability and wave intensity do not change.

In addition, sea level has been rising slightly for many years. In the Carmel Beach area, the trend for sea level rise for the past 25 years has been an increase resulting in a rate of nearly one foot per hundred years. Also, there is a growing body of evidence that there has been a slight increase in global temperature and that an acceleration in the rate of sea level can be expected to accompany this increase in temperature. Some shoreline experts have indicated that sea levels could rise as much as 3 feet by the year 2100[66]. Mean level affects shoreline erosion several ways and an increase in the average sea level will exacerbate all these conditions. On the California coast the effect of a rise in sea level will be the landward migration of the intersection of the ocean with the shore. On a relatively flat beach with a slope of 40:1, every inch of sea level rise will result in a 40-inch landward movement of the ocean/beach interface[67]. This too leads to loss of beach as a direct result of the armor. These effects are also known as "passive erosion".

6.2.2 *Coastal Bluff and Dune Erosion*

Coastal bluff erosion is both ongoing (i.e. long-term) and episodic. Unlike the beach sand, Carmel's coastal bluffs cannot easily be replenished by natural cycles. Bluffs and dunes that were built by meteorologic and geologic forces over millennia can be eroded or lost by storms lasting just days or even hours. Long-term coastal bluff erosion at Carmel was documented by Johnson (1984), who analyzed maps and aerial photographs spanning a 75-year period (1908 to 1983). He determined that Carmel's coastal bluffs had eroded at a rate of 0.4 feet/year in the north and 0.3 – 0.7 feet/year in the southern portion. Analysis of aerial photographs showed several periods of extreme bluff erosion, including the loss of at least 20 feet of bluff (near Thirteenth Avenue and near Martin Way) between 1968 and 1970.

The best-documented episodic erosion of Carmel's coastal bluffs occurred during the El Niño storms of 1982/83. Johnson (1984) recorded several areas of significant erosion:

- loss of 20 feet of bluff north of Eighth Avenue;
- loss of 25 feet of bluff between Tenth and Eleventh Avenues;

[66] Gary Griggs, as quoted in "Living on the Edge; a saga of seawalls, who wants them, who doesn't, and the fate of California's disappearing coastline" by Bruce Willey (in the "Good Times", February 27-March 5, 2003 issue). Mr. Griggs is quoted as also indicating that some estimates show that it will be higher than three feet, some lower, but that the three feet rise by 2100 is "probably the median".

[67] In other words, a one-inch rise in sea level can result in over 3 landward feet of dry sandy beach loss. For the 3 foot rise estimated by 2100, that would translate into a 120-foot landward movement of the wet-dry intersection on a beach sloped at 40:1.

- loss of 30 feet of bluff between Eighth and Ninth Avenues;
- loss of 30 feet of bluff near Santa Lucia Avenue; and
- loss of 40 feet of bluff between Ninth and Tenth Avenues.

Wave-caused Bluff Erosion

At Carmel, the primary cause of coastal bluff and dune erosion is wave attack. The same high-energy storm waves that remove sand from the winter beach are responsible for eroding the City's coastal bluffs and dunes. As described above, Carmel's bluffs become even more vulnerable to erosion once the beach sand has been scoured.

Not all locations along Carmel's shoreline are equally vulnerable to erosion. Factors such as sand level, rock type, and the presence of faults or joints, may increase the severity of erosion at specific sites.

An additional factor may be the orientation of exposed outcrops of sandstone bedrock on the beach. These large rocks are located seaward of the coastal bluffs. They are usually hidden under many feet of beach sand, and are only exposed during the harshest winters. Johnson (1984) noted that deep channels exist between some of these bedrock outcrops. These "re-entrants" lie perpendicular to the beach bluffs. They may act to direct and focus wave energy toward specific locations along Carmel's coastal bluffs, Scenic Road and City infrastructure, producing more severe erosion or damage.

Lateral Current-caused Bluff Erosion

Johnson (1984) also described a fast moving "inshore current" that flows laterally along the beach, eroding material from the base of Carmel's bluffs. This current apparently becomes trapped between the naturally occurring sand berm and the bluff face. It moves along the bluff face toward the south end of Carmel Beach, which is at a slightly lower elevation. City personnel have observed this lateral current causing severe erosion at certain locations along the Carmel shore. When present, the lateral flow also creates difficult or hazardous conditions for people attempting to use several beach access stairways.

Storm Water Drainage-caused Bluff Erosion

Another force known to cause significant shoreline erosion is excessive storm water runoff. During the 1982/83 El Niño storms, heavy rains overwhelmed the City's storm water system. Uncontrolled storm water flows washed away portions of the City's coastal bluffs and undermined beach access stairways.

The impact of storm water runoff on Carmel's coastal bluffs is described in more detail below.

6.3 RESPONSES TO EROSION

For over 40 years, Carmel has responded to threats of coastal erosion with a number of effective public works projects.

6.3.1 *Storm Water Runoff Control*

Carmel's shoreline is at the bottom of a large hill and receives storm water runoff from the City's streets and drains above. Before 1983, the City's storm water system actually contributed to coastal erosion. This became most evident during the 1982/83 El Niño storms:

- All of the existing storm water pipes were undersized;[68]
- In some areas, Scenic Road sloped away from its drain inlets, allowing water to pond along the seaward curb; and
- The high seaward curb (8-12 inches) had openings at each beach access stairway, allowing storm-water runoff to flow down stairs and then onto the beach or adjacent bluffs. This redirected storm water caused bluff erosion that undermined the stairways.

Between 1983 and 1988, the City remedied these problems during Phase I of the Carmel Beach Rehabilitation Project. Based on a storm water flow study by Carmel's City Engineer,[69] Scenic Road was re-paved and its seaward curb was redesigned to drain more efficiently. The entire Scenic Road storm water system was completely rebuilt, utilizing larger drainpipes and catch basins, and placing outfalls in locations where storm water runoff would not erode the bluffs or cause damage to access stairways.[70] The City's Department of Public Works instituted a beach area maintenance program that included the cleaning of debris from protective grates, ensuring that storm water would flow directly into the new drainage systems.[71]

[68] In one case, water in a large-diameter pipe flowed into a pipe of smaller diameter.
[69] 1983 Drainage Study for Carmel-by-the-Sea. Neill Engineers. The City's storm water drainage system was studied again by the City Engineer in 1995, and updated in 1997.
[70] Redesigning the City's storm water drain system was one of the most important features of the Carmel Beach Rehabilitation Project. During the 1997/98 El Niño storms, more rain fell than during the '82/83 storms, but without any damage caused by excessive runoff.
[71] The peak period for storm drain system monitoring and maintenance begins in late fall, prior to the winter storm season. Monitoring continues throughout winter.

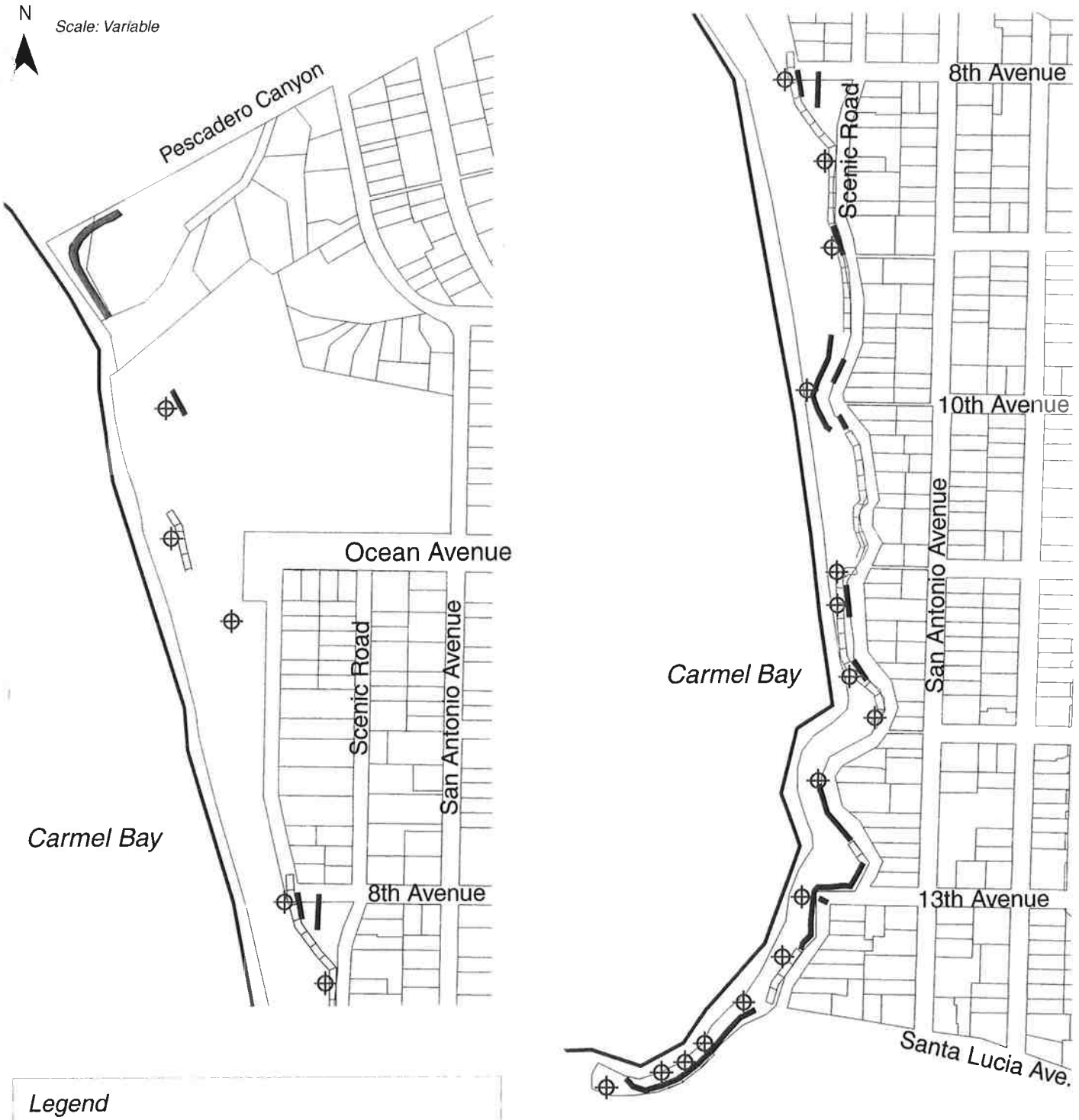

Figure 8
Coastal Protection Structures

Storm water runoff also eroded bluffs at locations where protective vegetation had been destroyed by people walking or climbing on Carmel's fragile coastal bluffs ("bluff-cutting"), instead of using the stairways. The City's program of building convenient beach access stairways and using plants, boulders, and guardrails in its landscaping significantly reduced the overall incidence of bluff-cutting, reducing the vulnerability of its coastal bluffs to erosion from storm water runoff.

As described in Section 3, pedestrian pathways along Ninth, Tenth, Eleventh, and Twelfth Avenues were designed to also carry storm water runoff between San Antonio Avenue and Scenic Road. Each pathway/drainageway directs runoff water into a drain inlet at Scenic Road. Near the western end of the Eleventh Avenue pathway/drainageway, a large Monterey cypress tree interferes with the efficient drainage of storm water. In response, the City installed a special drain inlet that can be opened prior to each rainstorm and then closed after the storm has passed. This task is performed by personnel from the Department of Public Works who also install a special barrier with hazard lights over the open drain inlet.

At least half the water captured by the City's storm water runoff system discharges onto Carmel Beach through 19 outfalls of varied design and composition (Fig. 8). To prevent erosion of beach sand and soft bedrock, the City has placed boulders under selected outfalls to dissipate the erosive energy of storm drainage water.[72]

Storm water runoff often transports debris into the ocean. In keeping with Federal requirements to remove all gross pollutants[73] and greatly reduce the amount of suspended solids that would otherwise flow into Carmel Bay, the City installed Continuous Deflection Separation (CDS) units into its storm water system. Since 2001, CDS units have been effectively removing debris from Carmel's two largest storm water outfalls: at the foot of Ocean Avenue and at the intersection of Fourth and San Antonio Avenues.

6.3.2 *Sand Redistribution*

Beach sand plays a critical role in the protection of Carmel's shoreline (Sec.s 2 and 6). Since the early 1960s, Carmel has used heavy equipment to redistribute beach sand, moving it from the lower beach to the upper beach. Originally, this procedure was used only along the beach below the Ocean Avenue/Del Mar parking lot. Sand was pushed up the hill during late spring/early summer, to compensate for sand that would be moved downhill by foot traffic. By the end of

[72] Many storm drain outfalls drain onto natural rock.
[73] Gross pollutants are defined as debris (including paper, plastics, cans, bottles, etc. and natural material) that is greater than five mm in size.

summer, a significant portion of the bulldozed sand was again returned back to the lower beach.

Since 1984, the City has expanded its sand redistribution program, using bulldozed sand to cover the numerous rock revetments (described below) installed along the shoreline. Covering revetments with sand achieves two goals. It enhances the aesthetic appearance of Carmel Beach by camouflaging a pile of hard-edged boulders under a thick layer of white beach sand.[74] It also returns to safe public use an area previously occupied by rocks and voids.

The covering of revetments is not ordinarily recommended. In his final report on the Carmel's Phase I Beach Rehabilitation Project, Johnson (1984) cautioned that:

> "(f)illing in the voids of the rip-rap will reduce the efficacy of the revetment somewhat. The voids absorb some of the wave energy that reduces wave runup and reflected wave energy. Generally, however, if the material filling the voids is not solid, e.g. concrete or tightly compacted soil, the waves soon remove the material and allow the (revetment) to function as designed."

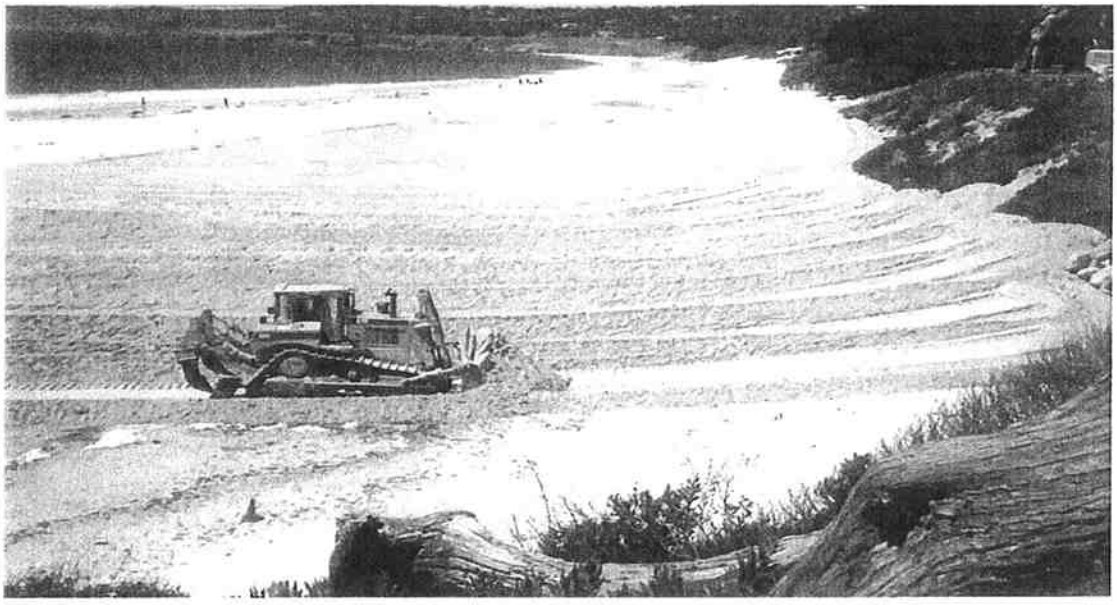

Photo 9 – *Sand Redistribution*

Carmel's use of sand to cover its revetments has, thus far, proven successful. From late spring through early winter, the public has regained the use of beach land that might have otherwise been lost. During severe winter storms, bulldozed sand is rapidly stripped from each revetment, allowing the structure's boulders and voids

[74] During its sand redistribution program, the City covers each revetment with at least three feet of sand.

to reflect and absorb the force of incoming waves. The California Coastal Commission has accepted Carmel's revetment camouflaging as mitigation that helps offset potential adverse impacts (i.e. loss of beach access) associated with revetment installation.

Recently, the City began using its sand redistribution program to address problems caused by ponded water on Carmel Beach.[75] In 2001, the City used a bulldozer to cut a channel through the berm, allowing ponded water to drain back out to the ocean. In areas where ponded water had gathered at the base of a stairway, preventing beach access, the water was drained and then sand was moved laterally to level-out these low areas, returning beach access to the public.

During recent years, the City has moved only sand that was located above the high tide line. The actual volume of sand moved each year varies according to several factors, including the amount of sand already on the upper beach, the degree of revetment cover needed, and the amount of lower beach sand available for movement. For example, the need for sand redistribution following a mild winter will be less than after a severe winter. The City estimates that the amount of sand moved varies between 50,000 – 100,000 cubic yards, depending on conditions. Carmel Beach sand redistribution usually requires two to three weeks to complete.

Because sand redistribution is conducted early in the natural beach-building process, removal of sand from the lower beach apparently does not contribute to any significant beach erosion. In fact, the amount of sand on Carmel Beach continues to build during the remainder of summer. By the end of the peak beach-use period (mid-September), some of the sand that had previously been bulldozed uphill will have returned back down to the lower beach where it will now be ready to absorb the impact of upcoming winter storm waves.

6.3.3 *Shoreline Armoring*

Since 1958, the City has built seawalls, retaining walls, and rock revetments to protect portions of its shoreline bluffs (see Fig. 8). Most of these structures are located along the southern half of Carmel Beach, from Eighth Avenue to the City limit south of Martin Way, where they line nearly the entire shoreline

Seawalls and Retaining Walls[76]

[75] Described in Section 2.2.3

[76] The City classifies a wall whose footing will be reached by seawater under normal tidal conditions, and whose purpose is to protect the bluff against direct wave impact, as a "seawall." A wall built higher on the bluff that is only exposed to ocean spray or wave splash, and that is designed to retain or support bluff soils, is classified as a "retaining wall."

Approximately 50% of the City's shoreline protection structures are seawalls. They are visible at all times, and contribute to the Carmel Beach visual experience. Some of Carmel's earliest shoreline walls were built of local "golden granite" rocks, held together by mortar. More recently, walls have been built of reinforced concrete and faced with golden granite. Many of the City's coastal walls are built upon a foundation sunk deep into the bedrock and some of these walls have "tie-backs" that anchor the wall into the bluff.

All coastal walls are outfitted with ample "weep holes" to promote drainage. This helps relieve the tremendous pressure caused by the build-up of water-laden soils behind the wall, which could cause the wall to lean or collapse.

In general, Carmel's seawalls and retaining walls have held up well under the onslaught of coastal storms. The City's only major seawall loss proved the need for solid design and construction. In 1978, a newly built seawall[77] was struck by storm waves. When built, this wall's footing was not founded into bedrock along its complete base. Waves first undermined the wall's base where it bridged over the sand; once this section failed, the rest of the wall was soon destroyed. All seawalls and retaining walls built since are completely founded into the underlying bedrock.

At the extreme north end of Carmel's beach lands is a privately owned seawall. It was originally constructed in 1983 to protect the owner's property against further wave attack and additional bluff erosion. Over the ensuing years, this wall was modified several times in an attempt to improve its structural stability and appearance.[78] In 1999, Carmel accepted, in fee title, beach lands seaward of this wall, legitimizing the prescriptive right of public access that existed across this area of the beach. The City is committed to maintaining unimpeded public access and use of the entire beach from the south to north City limits.

Revetments

Since 1978, the City has installed rock revetments to protect nearly one-quarter of its total shoreline. All of Carmel's rock revetments are located along the shore south of Ocean Avenue (see Fig. 8). Some early revetments consisted of rocks dumped up against the bluff face.[79]

[77] Located south of 12th Avenue Point.
[78] Copies of engineering and landscaping plans for this private seawall are recorded with the Carmel Department of Community Planning and Building.
[79] These have all been replaced by engineered revetments or seawalls.



Photo 10 – *Shoreline Armoring Along Carmel Beach*

In 1983, Carmel responded to extensive shoreline bluff damage (from the 1982/83 El Niño storms) by installing several engineered revetments.[80] These were designed by the City's consulting engineering-geologist, Rogers E. Johnson & Associates. Their size, shape, and slope were based on calculations that predicted the size of waves expected to strike the toe of each revetment. The lowest course of boulders was placed into a "keyway" dug into the bedrock at the base of each structure. Filter fabric was laid down before placing the boulders to allow the free flow of water in and out of the structure, and reduce the erosion of sand or bluff soils.[81] Within two summers, these structures were completely covered by sand as a result of the beach's natural sand deposition processes and the City's extensive sand redistribution-bulldozing efforts. In the years since their installation, these revetments have remained mostly hidden from view. During most years, few Carmel Beach visitors are aware of their presence.

Revetments are made of hundreds or more individual boulders, ranging from 700 lb. core stones up to larger "armor" stones typically weighing as much as five tons. A revetment's bluff protection abilities are due to a combination of factors, including the irregular surfaces of each boulder and the spaces ("voids") between them. As a wave strikes the revetment, its energy is quickly

[80] These engineered revetments were installed in 1983/84 during Phase I of the "Carmel Beach Rehabilitation Project."
[81] All work was conducted under the guidance of a certified engineering geologist.

dissipated by reflecting off the many boulder faces. At the same time, wave energy is absorbed by the void spaces between boulders.

A revetment's individual boulders eventually respond to the forces of wave action and gravity. Over time, boulders can be expected to change position. Some boulders may eventually "migrate" seaward, away from the revetment (Photo 8). Movement of the keystones (those boulders located at the base of a revetment) can drastically change the entire revetment structure and critically compromise its erosion-protection abilities – as well as public safety. Maintenance of the City's revetments is described in Section 8.

6.4 FUTURE PROJECTS

6.4.1 *Future Shoreline Armoring*

Carmel's seawalls are a collection of structures built in different years, using varied techniques. Because of their age, the earliest walls were built using materials and techniques that do not meet current standards.[82] It is reasonable to expect that some existing walls, especially the oldest ones, will need repair or eventual replacement. Because coastal erosion often damages unprotected bluffs and dunes adjacent to armor structures, it is also likely that the ends of some older seawalls may need to be extended at some future date. Consistent with the Coastal Act, new armoring will occur only if existing coastal structures, accesses or infrastructure become threatened by erosion.

Carmel's shoreline revetments were all built within the last two decades and all were engineered to meet current standards. Maintenance of existing revetments should be anticipated (see Sec. 8). After exposure to winter storm waves, some revetment boulders may need to be repositioned. And, as with seawalls described above, the unprotected bluffs adjacent to existing revetments may eventually require additional protection.

South of Eighth Avenue, only one area remains unarmored by either wall or revetment: the section between Twelfth Avenue and the Twelfth Avenue promontory. This area is characterized by high, steep bluffs that may be protected from direct wave attack (by the Twelfth Avenue point), but are exposed to scouring by the laterally flowing inshore current (described in Sec. 6). This area may be a future candidate for some form of shoreline armoring to protect the Pathway and beach access facilities from bluff erosion.

[82] Some of these early walls were built without engineering plans.

Accurate prediction of future events is not possible. In addition, there is no way to guarantee that existing walls and revetments will continue to protect against storms of unexpected intensity. Scientists who study coastal-related phenomena warn that higher sea levels and less predictable weather patterns may be expected during this century.

City policies allow permanent structures to be built on the beach only when required to protect existing structures in danger from erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. The design of new shoreline structures must be consistent with the aesthetic character established by existing structures. City policy also calls for the evaluation of the potential to replace its existing shoreline revetments with vertical seawalls and to reduce the amount of sandy beach covered by revetment structures.[83]

The City is committed to protecting the Carmel shoreline and its access facilities, along with Scenic Road, its houses and infrastructure. As new shoreline challenges arise, the City will evaluate each situation and respond with appropriate measures that are in keeping with its approved coastal policies.

6.4.2 *Beach Nourishment*

As discussed throughout this *Shoreline Management Plan*, Carmel's beach sand plays an essential role in protecting its shoreline from erosion. The City has always depended upon natural processes (see Sec. 2.2) to transport sand onto Carmel Beach.[84] During the past few decades, other coastal communities, however, have conducted "beach nourishment" programs to bring additional sand to their shores. Some use trucks to import sand from a different location, while others, like the nearby City of Santa Cruz, use dredges and pumps. There are even a few communities on the East Coast that bring up sand from offshore sand bars.

It is City policy[85] to explore the feasibility of beach nourishment if long-term shoreline monitoring determines that Carmel Beach is losing significant volumes of sand or that the beach is becoming demonstrably narrower.

To be considered successful, a beach nourishment program would need to match Carmel's characteristic beach sand. This task might be both difficult and expensive—but importing new sand that differs in color or texture from Carmel's native sand would be extremely unpopular.

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[83] City of Carmel Coastal Land Use Plan (approved June 2003) Policies P5-6, -11, -12, -15, and -17.

[84] Carmel's sand redistribution program moves sand that is already on the beach to areas where it can bring the most benefit; this process does not import any "new" sand to the shoreline.

[85] City of Carmel Coastal Land Use Plan (approved June 2003) Policy P5-20.

One possible source of suitable sand might be the subtidal sand bar understood to exist just offshore from Carmel Beach. This sand bar is thought to be the repository of the white sand that moves onshore and offshore during the beach's annual sand cycle. At present, there have been no detailed oceanographic studies that document the location, size, or dynamics of such a sand bar, but future study might help the City understand this potential sand source. Movement of any offshore sand onto Carmel Beach would, of course, be expensive, but might appear worthwhile if Carmel ever shows signs of permanently losing its beach sand.

Beach nourishment should also not result in environmental degradation, nor conflict with the goals and policies of agencies responsible for protecting local offshore habitat, including the Monterey Bay National Marine Sanctuary and the California Department of Fish and Game. At present, the environmental and recreational impacts of using nearshore sand for beach nourishment are not understood.

6.5 MANAGEMENT POLICIES

- Continue implementation of the *Shoreline Emergency Action Response Plan* to minimize the dangers to public safety and facilities that may be caused by winter storms or other natural disasters. (O5-5)

  - Prepare as-built plans showing the extent of all armoring in the SMP plan area in relation to the existing topography and other relevant features (including the top of bluff, base of bluff, sand-bluff interface, sandstone platforms, Scenic Road, Scenic Road pathway, and utilities in the Scenic Road rights-of-way, etc). The as-built plans shall indicate vertical and horizontal reference distances from the surveyed benchmarks to the survey points on each structure for use in future monitoring efforts. (P5-4)

  - Construct new shoreline armoring in areas previously unprotected only when required to protect existing structures in danger of erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply. Require any approved structures to include native landscaping (screening), be visually compatible with existing seawall designs, address drainage, incorporate visual mitigation, sand coverage for revetments, and golden granite facing for seawalls. (P5-6)

- Evaluate the storm-water outfall system for purposes of reducing impacts to the beach environment. Consider options to modify and/or remove outfalls from the beach and replace or retrofit storm drains with filters or treatment devices to reduce impacts on the shoreline environment. (P5-9)

- Runoff from storm water outfalls shall be conveyed onto Carmel Beach in a non-erosive manner (i.e. runoff shall be discharged so as to minimize erosive forces.) (P5-10)

- Prohibit any construction of substantial or permanent structures on the beach or within Carmel Bay except where required to protect existing structures in danger from erosion. Require design review for any structure proposed and minimize conflict with the scenic and aesthetic character of the shoreline environs through such review. (P5-11)

- Ensure that the design of seawalls and engineered revetments are consistent with the aesthetic character of established structures. Continue to use golden granite (or better materials) for exposed vertical seawalls in locations where shoreline protection has been determined necessary. If vertical seawalls are not feasible, but engineered revetments may be feasibly installed, minimize the seaward encroachment of these structures and reduce the visual impact by burying stone revetments with beach sand and/or topsoil and native landscaping. (P5-12)

- Evaluate the potential to replace existing revetments with faced vertical seawalls or sea walls designed to mimic the natural bluff face, to reduce sandy beach area coverage and the need for sand bulldozing. All replacement structures must be found compatible with the areas' aesthetic qualities. Recognize that physiographic conditions may dictate a better alternative (e.g. when a specific area of the beach is more susceptible to reflected wave energy and consequent accelerated scour). (P5-15)

- Any project (including but not limited to repair, maintenance, expansion, modification, or replacement) involving the shoreline armoring structure that extends along the Carmel Beach bluff southeast from the mouth of Pescadero Creek shall require the façade to use materials that are complementary to shoreline armoring structures located along the Carmel Beach bluff south of 8th Avenue. (P5-17)

- Maintain records of the volumes of sand moved and the volumes needed to cover each engineered revetment. When revetments fail or need to be substantially reconstructed or replaced, consider vertical seawalls as a preferred alternative unless monitoring data and/or engineering requirements favor an engineered revetment design. (P5-22)

- Where unavoidable, minimize and mitigate all impacts to both marine and terrestrial resources when performing sand redistribution. (P5-23)

7 PUBLIC SAFETY

Carmel's shoreline presents challenges to public safety that are unique to coastal areas. The very combination of ocean and shore that attracts so many people to the coast can also pose potential dangers.

7.1 RECREATIONAL HAZARDS

Carmel's white sand beach, clear waters, beautiful vistas, and proximity to town, combine to make this site one of central California's most popular coastal recreation venues. Throughout the year, many people engage in water sports, including wading, swimming, kayaking, surfing and wind-surfing. These activities are sources of enjoyment for residents and visitors alike; they also represent very real dangers.

Conditions at Carmel Beach are no more dangerous than those encountered at other open-coast central California beaches. The level of potential hazard depends upon an individual's experience, skill level and physical conditioning, as well as environmental conditions (i.e. water temperature, wave size and energy, presence of undertow or rip current, etc.). People engaged in these activities do so at their own risk.

The City of Carmel, like many other local coastal municipalities, does not provide on-site lifeguards. The City has posted warning signs on all beach-access stairways and sand ramps. These signs, approved by the State of California Attorney General's office, provide warning of hazardous shoreline and ocean conditions and notify visitors that the beach has no lifeguards.

When emergencies occur along the shoreline, a telephone call to 911 will alert the appropriate emergency personnel. With current technology, many emergency calls are made with mobile phones, but some parts of the Carmel shoreline have poor cell phone reception. In response, the City has recently installed emergency phone stations at two locations along the Carmel Beach Bluff Pathway: at Eighth and Thirteenth Avenues. These phones are connected directly to the Carmel Police Department dispatcher. Information about an emergency will then be forwarded to the Carmel Fire Department, which is the primary responder to any medical or rescue emergency on the beach. Emergency calls can also be made from a pay

telephone located outside of the City's public restroom near the Ocean Avenue/Del Mar parking lot.

In cases where a person in distress is beyond the surf line, City of Carmel personnel are prohibited by policy from entering the water to attempt rescue. Fire Department personnel follow the Monterey County *Coastal Incident Response Plan*[86] and may call in a rescue craft from Point Lobos State Reserve (California Department of Parks and Recreation) or a U.S. Coast Guard helicopter. During emergency situations, "four-wheel drive" vehicles can use the City's vehicle/equipment access ramp, located between Eighth and Ninth Avenues. If this ramp is not usable, emergency vehicles are authorized access to the beach via the dunes adjacent to the Ocean Avenue/Del Mar parking lot.

7.2 COASTAL STORM HAZARDS

From late fall through early spring, residents and visitors may also be exposed to dangers posed by coastal storms (heavy surf, powerful waves, high tides, strong winds, and erosion of Carmel's beach, dunes and bluffs). Under these conditions, pedestrian activity on the beach, bluffs, rocks, or stairways, may be dangerous. Extremely large waves have been known to carry individuals into the ocean at several locations in Monterey and Carmel Bays. In spite of posted warnings, some visitors purposely stand on shoreline bluffs, promontories, and/or stairs in order to experience the raw power of stormy seas. Rescue during stormy conditions is especially difficult.

To help protect the public when these unsafe conditions occur, the City has developed the *Beach Emergency Closure Plan*, which enables the Carmel Police Chief, in consultation with the Beach Emergency Action Committee (BEAC), to close Carmel Beach to the public. Beach closure will be undertaken based on information from City staff or from organizations such as the Monterey County Office of Emergency Services and the U.S. Weather Service, etc. Public Works personnel will then install standardized signs and erect suitable barricades at specified shoreline access points. The *Beach Emergency Closure Plan* appears in Appendix 9.3 of this *Shoreline Management Plan.*

[86] County of Monterey. 2001. Operational Area Coastal Incident Response Plan (Draft). Office of Emergency Services.

7.3 CARMEL SHORELINE HAZARDS

7.3.1 *Tripping Hazards*

Not all shoreline hazards are directly related to coastal storms. Pathways that become uneven and landscape plants that become overgrown may pose potential hazards for pedestrians. In addition, the dynamic and very harsh conditions that characterize seaside environments may increase the "wear and tear" on fasteners that secure guardrails, stairway planks and hand rails, etc.

At any time, foot traffic on Carmel's coastal bluffs may be hazardous. Some portions of these bluffs may be steep and slippery. Other areas may have poor footing, or be the site of unseen hollows that can develop as a result of wave impacts eroding coastal bluff soils behind retaining walls or revetments. To protect the public from these hazards (and to protect the fragile bluffs and vegetation from intrusive foot traffic), Carmel's Municipal Code prohibits walking on, or traversing, the City's shoreline bluffs.[87]

7.3.2 *Revetment Hazards*

Carmel Beach's numerous engineered rock revetments may at times represent a hazard to some beach visitors. As described in Section 6, these revetments consist of large boulders installed to achieve a specified angle of repose. Occasionally, some of these boulders may shift under the impact of high-energy storm waves. People who climb or play on the revetments may encounter dangerous conditions, including perched boulders and voids between rocks. In late spring or summer, when conditions allow, the City covers each revetment with at least three feet of sand as part of its annual sand redistribution program. In most years, storm waves can strip away much of Carmel's beach sand and bluff material, exposing the underlying revetment boulders. Under these conditions, climbing on Carmel's shoreline revetments is inherently hazardous, and is prohibited.

7.3.3 *Ground Squirrel Hazards*

As discussed in Section 2, Carmel's expanding population of California ground squirrels also pose potential public safety hazards, from spreading disease to undermining bluffs. Control of these rodents is discussed in Section 8.

[87] CMC 12.32.165

7.3.4 *Monitoring*

Most of the potential problems discussed above can be remedied through a program of regular monitoring and responsive maintenance. City of Carmel policy encourages all employees to watch for, and report, conditions that could be hazardous to public safety.[88] Regular monitoring and inspections are augmented with a series of Shoreline Assessments, performed twice per year (spring and fall). Each of these monitoring and maintenance activities is a vital component of Carmel's on-going commitment to protecting public safety. These programs are described in more detail in Section 8.

7.4 MANAGEMENT POLICIES

- To provide a safe environment for all beach users.
  - Educate the public about the danger of the beach and ocean environment and provide emergency response capabilities. (O4-4 excerpt)
    - Consider establishing and budgeting for the position of an educational officer who would patrol the beach and adjacent areas to educate people about beach usage and prevent damage to the environment. This person should have the authority to issue citations. (P4-25)
    - Maintain emergency 911 phones along the shoreline. (P4-28)
    - Post signs warning beach users about dangerous ocean conditions. (P4-35)

[88] According to the Guidelines for Emergency Beach Closure, "(a)ny City employee who becomes aware of an existing or potential shoreline condition (this includes any condition on Scenic Road or any property West of Scenic Road including, but not limited to, the beach slope), that threatens the public safety, health, or welfare of persons on the beach or shoreline, shall immediately notify their respective Supervisor." (Carmel City Council Policy C03-03, approved 1 Apr 2003)

8 CARMEL SHORELINE MANAGEMENT PROGRAMS

Like all coastal areas, the City of Carmel must deal with constantly changing conditions along its shoreline. The natural forces and human activities responsible for these changes have been described throughout this *Shoreline Management Plan*. In response, the City has implemented numerous projects and programs designed to protect its shoreline (and associated infrastructure) and enhance public access to the beach.

Clearly, Carmel will continue to be faced with challenges to its shoreline. To remain effective, the City's shoreline protection measures must be combined with effective monitoring, inspection, maintenance and repair programs.

8.1 MONITORING AND INSPECTIONS

There is a common perception that shoreline damage is usually the result of catastrophic and uncontrollable forces. But experience has shown that many problems encountered along our shore could be fixed with greater ease and less expense if dealt with at an early stage. This requires a program of regular and timely monitoring and inspections. Monitoring refers to "watching, checking, or keeping track of" on-going processes along the Carmel shoreline. Inspections involve detailed examinations of shoreline structures by engineers or other trained personnel.

8.1.1 *Shoreline Assessments*

The City contracts for a series of biannual independent shoreline assessments. These are performed by a specialist familiar with coastal processes in general, and the Carmel shoreline in particular. Each year, one assessment is conducted in the fall, before the beginning of the winter storm season, and the other is performed in early spring, after winter storms have abated.

Each assessment covers the complete shoreline within Carmel's city limits and includes evaluation of:

- the beach (from the tide line to the base of the dunes, bluffs, walls, or revetments);
- the dunes (including North Dunes) and bluffs;
- the Ocean Avenue/Del Mar parking lot;

- all seawalls, retaining walls, revetments, beach access stairways (including handrails) and sand ramps;
- all portions of the Carmel Beach Bluff Pathway and landscaping, including guardrails;
- all storm drains, drop inlets, grates, and access covers (especially following the Fall Catch Basin Cleaning by Public Works staff), and storm water outfalls; and
- all warning signs and other informational signs along the City's shoreline.

The pre-winter assessment focuses on steps needed to prepare the City's shoreline for the coming winter. This assessment also includes a report of long-range winter weather forecasts by the National Oceanic and Atmospheric Administration (NOAA). The post-winter assessment surveys each of the above-described areas, with a special focus on steps needed to repair any damage caused by the previous winter's storms. During each assessment, conditions determined to pose an imminent threat to public safety, shoreline facilities or to environmental resources are brought directly to the attention of the appropriate department directors or other responsible personnel.

Results of each assessment are reported to the directors of Carmel's departments of Public Works and Community Planning and Building, the City Forester, and the City Engineer.

8.1.2 *Shoreline Surveys*

A much longer-term element of the City's shoreline monitoring program is the development of baseline information and periodic surveys to document changes in beach width, sand volume, rates of bluff erosion, and any movement of seawalls, retaining walls, and revetment boulders. These data help supply information necessary on long-term shoreline trends. Questions such as "Is the shoreline losing sand?" "Is the beach becoming narrower?" "Are the seawalls and revetments contributing to local coastal erosion?" can only be answered through a program of accurate shoreline surveys, repeated over a period of years or decades.

The results of these surveys will be of great value to staff and consultants tasked with protecting Carmel's coastal assets. This information will also help answer questions raised by the California Coastal Commission during development of Carmel's Local Coastal Program.

Permanent Shoreline Benchmarks

To facilitate shoreline surveys, the City has installed seven permanent benchmarks along the upper shoreline, along with a set of associated survey

points on seawalls and revetments. The location of each benchmark was surveyed and described in accordance with Coastal Commission requirements.[89] They were placed by the City Engineer in October 2002, after consultation with the Director of Public Works and the City's consulting engineering-geologist.

Profiling the Beach

The Coastal Commission has required the City to conduct beach profile surveys along its shore to "facilitate future long-term trend evaluation."[90] These profiles are to measure changes in elevation along lines plotted from the bluff top out to the water's edge; all measurements are to be interpreted in relation to the permanent shoreline benchmarks described above.

City staff and consultants have selected a series of seven transect lines to be surveyed (Fig. 9). These cover a variety of shoreline conditions including open beach sand, revetments, and seawalls. (Some of the proposed transects include sites profiled in 1983 by the City's consulting engineering-geologist, Rogers E. Johnson and Associates, as part of the Carmel Beach Rehabilitation Project.) For comparison, the most northern of the proposed transect lines represents an area not affected by the City's annual sand redistribution program.

The City has committed[91] to profiling its beach four times per year:

- at mid-Winter when sand is at its lowest;
- at Spring, prior to sand redistribution activities;
- at early Summer, immediately following sand redistribution; and
- in the early Fall, before sand begins its retreat offshore.

Profiles are slated to be performed in 2003 and 2005 (to establish a baseline), then repeated at five-year intervals beginning in 2010.[92]

After each five-year period, the City will review all available data. Analysis of these profiles will document several important factors, including the

[89] California Coastal Commission required the City to establish a "series of permanent surveyed benchmarks inland of the bluff edge running the length of Carmel Beach ...."[89] These benchmarks were to be "... described in relation to National Geodetic Vertical Datum (NGVD) and identified through permanent markers, benchmarks, survey position, written description, reference numbers, et cetera." (from Special Condition 2(i)(1) of the City's Coastal Development Permit #3-00-140, approved April 13, 2001.)

[90] Special Condition 2(f) of Coastal Development Permit #3-00-140

[91] City of Carmel Coastal Land Use Plan (approved June 2003) Policy P5-19.

[92] City of Carmel Coastal Land Use Plan (approved June 2003) Policy P5-20.

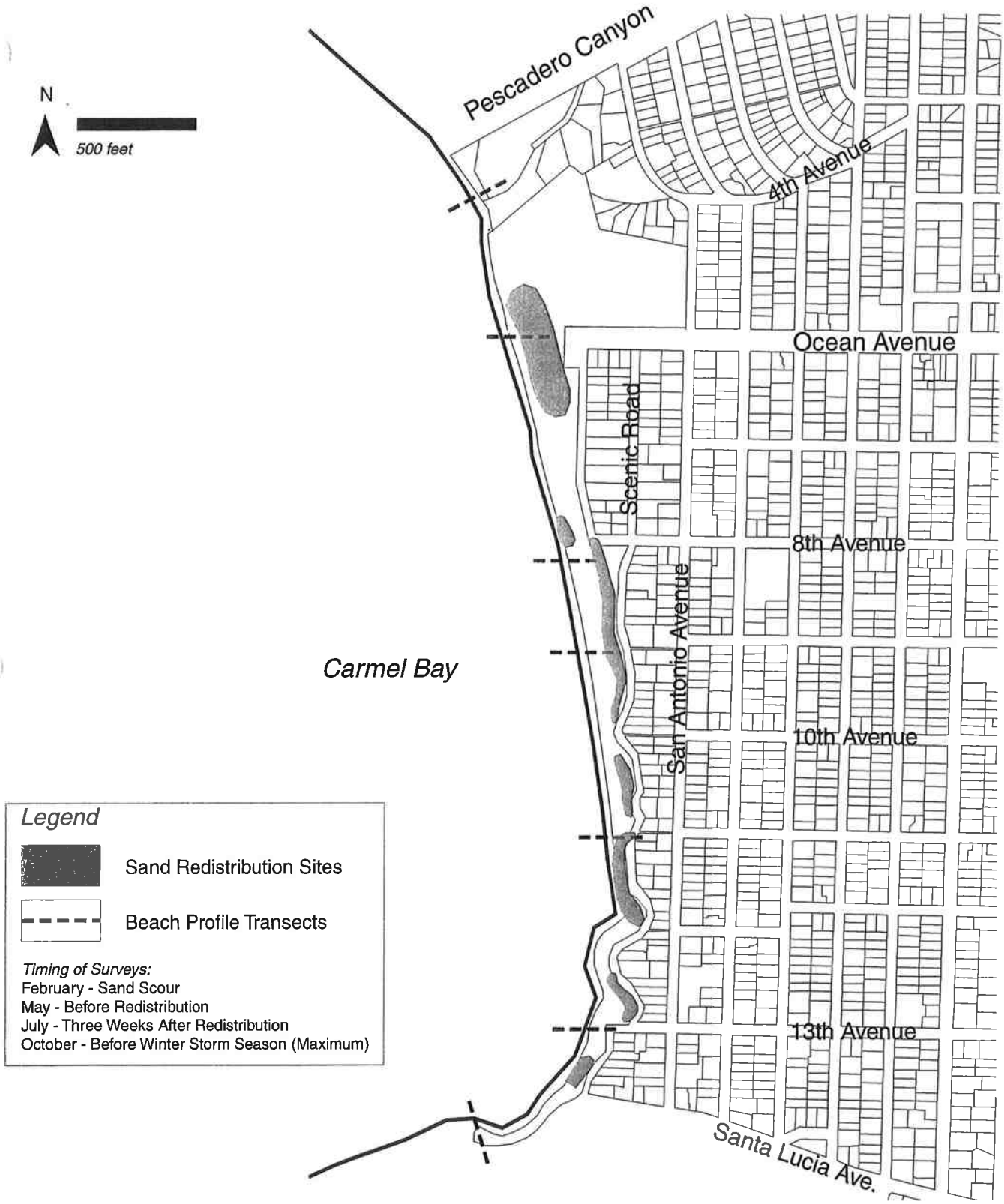


Figure 9
Sand Redistribution and Profile Transects

approximate volume of sand[93] on Carmel Beach at the period of maximum sand scour, the approximate volume of sand returned by the natural sand cycle, the pattern and approximate volume of sand redistributed by the City's sand redistribution bulldozing, and the approximate amount of sand moved back downhill by summer beach visitors.

Long-term beach profile surveys will enable the City to quantitatively assess the impact of its sand redistribution program. As described in Section 6.3.2, the City has been re-contouring sand on portions of Carmel Beach for nearly forty years, but has only anecdotal information about the program's impacts. Analysis of beach profile surveys could lend credence to the City's continued use of sand redistribution as an important shoreline management tool, or it could help the City modify the methods or timing of this critical program.

Analysis of beach profiles could also help answer questions related to the impact of hard shoreline protective structures on beach width and sand volume. As described in Sections 2.2.4 and 6.2.1, seawalls and rock revetments have been associated with long-term sand loss along other shorelines, but this phenomenon has not been documented at Carmel.

Beach profile information can be obtained in a number of ways, including aerial photogrammetry and ground-based surveys that use laser-measuring systems and/or GPS. Each technique varies in cost, accuracy, and applicability to Carmel's unique features.

The value of long-term profiling cannot be overstated. The benefits of this monitoring program will increase with time. The longer the period of profiling, the clearer any trends will be. It is reasonable to expect that new beach profile sampling and assessment techniques will become available in the future. The City should ensure that any new techniques will continue, whenever possible, to utilize previous data.

Monitoring Shoreline Armor Structures

The Coastal Commission has also required the City to establish survey points at several locations on all of its shoreline armor structures (walls and

[93] It is not possible to measure the exact volume of sand on Carmel Beach, but experienced shoreline surveyors using beach profile surveys to analyze beach dynamics, can estimate changes in sand volume over time. (In fact, some of the pioneering beach dynamics studies were based on surveys of transects conducted along Carmel Beach by noted oceanographer Willard Bascom in the mid-1940s.) When repeated over time, the impact of short-term temporal changes (such as those caused by severe storms, extremely high tides, etc.) can be modulated, and the usefulness of the studies increases.

revetments).[94] The City was further directed to survey the locations of these survey points (in relation to the permanent bluff top benchmarks) to determine if any portions of the revetments or walls have moved. These surveys of the City's armoring structures are to be conducted at five-year intervals, commencing in 2002, though City staff and consultants recommend more frequent surveys during periods of severe storm conditions.

8.1.3 *Monitoring by City Staff*

Perhaps one the most important forms of monitoring is that conducted by City staff during the course of their regular duties. Many of Carmel's Public Works and Forest, Parks, and Beach workers are very familiar with the City's shoreline. They are experienced and knowledgeable, and often spend many hours each week working along the shore. They are often the first to see signs of developing problems: fractures in concrete, water draining down stairways, plants growing onto walkways, cavities forming in bluff fill, trails and gullies being carved on coastal slopes. If ignored, these conditions will surely evolve into larger, more expensive, and, possibly, dangerous problems. The City must encourage and respond to reports of perceived problems by its field employees.

8.1.4 *Structural Inspections*

All of Carmel's shoreline structures require periodic detailed inspections by skilled specialists. These structures, including seawalls, retaining walls, revetments, and beach access stairways, are all subject to damage. Wave action, including run-up and overtopping, can damage walls, displace revetment boulders, and shift stairways. In addition, exposure to salt air rusts metal hardware and weakens stairs and safety rails.

Carmel's beach access stairways are inspected annually by the Director of the Department of Public Works and the City's Building Official. This inspection assesses the structural integrity of all stairways and handrails, examines cracks or displacement of concrete stairs and corroded hardware, loose or damaged boards in wooden stairways.

The City's shoreline storm water system is inspected each year before the on-set of winter storms. This inspection is conducted by the Department of Public Works Streets Supervisor, and includes all inlets, drain pipes, and outfalls.

[94] "... at least one survey point at both the upcoast and downcoast end of each structure, and at appropriate locations between each end." Special Condition 2(i)(1) of Coastal Development Permit #3-00-140.

No regularly scheduled inspection program of Carmel's seawalls, retaining walls and shoreline revetments has yet been established. These structures should be periodically reviewed by licensed engineers and/or certified engineering geologists.

8.2 MAINTENANCE

Of all City activities conducted along the Carmel shoreline, a strong commitment to timely maintenance must rank among the most important. The scenic Monterey cypress, the best designed beach access stairway, the efficient storm water system, and the most beautiful landscape, all will fail without a well-planned and fully implemented maintenance program. Maintenance of Carmel's shoreline must be an on-going, never-ending effort. Protection of shoreline visitors and the effectiveness of the City's programs and projects require no less.

Maintenance activities should meet all approved methodologies. Repairs should always strive to achieve equal or superior quality of design and materials. Modifications or changes to designs should be reviewed and approved by the responsible governing bodies of the City before implementation.

Maintenance tasks for Carmel's shoreline are described below. A checklist of these tasks is shown in Appendix 9.4. An effective maintenance program must be dependent upon regular monitoring and inspection programs (see Sec. 8.1) and prompt and timely responses. Anything less may compromise public safety and the integrity of the shoreline. Experience has shown that delays in addressing shoreline maintenance problems inevitably lead to remedies that are more difficult to accomplish and more expensive to build. Delay may also constrain the available options for addressing shoreline damage.

8.2.1 *Carmel Beach Sand*

The primary maintenance issues affecting Carmel Beach are related to keeping the beach sand clean and free of litter, trash, fire coals, and the occasional bodies of deceased wildlife, including birds and marine mammals (O5-6, P5-38, P5-39). This entails the timely emptying of beach trash receptacles and the cleaning of adjacent beach areas.

Beach maintenance also involves the annual redistribution of Carmel's beach sand. This activity is described in Section. 6.3.2.

8.2.2 *Dunes*

Since Carmel's dunes are not swept clean by waves and tides, manual control of litter, trash, garbage, etc. is essential. Sand from the dunes between Ocean and Ninth Avenues sometimes blows onto the City's roads, parking lots, and paths. These require timely clearing. Special attention must be paid to places where wind-blown sand covers walkways, curb-ramps, and other structures used by the physically disabled.

Maintenance tasks related to dune fauna and flora are discussed in Section. 8.2.6, below.

8.2.3 *Bluffs*

Prevention and repair of bluff damage caused by (illegal) "bluff-cutting" requires prompt and continuous maintenance. Repairs that involve re-vegetating trails, installation of guardrails, boulders, and/or signs, are strongly encouraged.

Timely maintenance is also needed to repair slumps and hollows that may form in shoreline bluffs. Investigation into the cause of a slump may uncover evidence of a broken or leaking water (or drainage) pipe.

Maintenance issues that deal with bluff vegetation and wildlife are discussed below.

8.2.4 *Beach Bluff Pathway*

Protection of public safety on the Beach Bluff Pathway can be enhanced by maintenance activities that keep the Pathway surface smooth and free of loose gravels, depressions, encroaching vegetation, and uneven interfaces (e.g. between Pathway and stairway landings). The Pathway will need to be resurfaced periodically.

8.2.5 *Structures*[95]

Beach access stairways must have handrails that are securely attached, and must be kept clear of encroaching vegetation or draining water that can make passage hazardous. Loose and/or perched revetment boulders must be repositioned or removed. Storm water structures must be kept clear of encroaching vegetation and debris, and the Continuous Deflection Separation (CDS) units must be maintained on an appropriate schedule. Plants and trees must be pruned to keep signs visible.

[95] Note that previous sections deal with monitoring and inspection of these structures.

Sign text must be kept legible through periodic refurbishment or replacement. Guardrails must remain secure. All components of the Pathway irrigation system should be regularly maintained for effective operation.

8.2.6 *Native Fauna and Flora*

Habitats for native biota must be kept free of competition from aggressive, invasive exotic plants. Maintenance and protection of Environmentally Sensitive Habitat Areas should be conducted in consultation with qualified specialists and in coordination with applicable state and federal agencies and policies.[96]

8.2.7 *Horticultural Plantings*

The Beach Bluff Pathway landscape plantings should be revitalized to better achieve the project's intended purposes (see below). Plants that encroach on the coastal viewshed, or on Carmel's shoreline cypress viewshed, must be pruned, removed, and/or replaced with appropriate species. Over time, areas of Hottentot-fig ice plant, acacia, and other aggressive invasive species should be replaced with plants from the approved list that complement the shoreline landscape. Young plants should be interspersed, over time, among mature plants, to ensure the continuation of this vital landscape.

8.2.8 *Trees*

Monterey cypress must be trimmed consistent with professional arboricultural standards to promote healthy growth and prevent structural damage during strong winds.

8.2.9 *Wildlife*

California Ground Squirrels

Control of Carmel's ground squirrel population can help protect citizens' health, welfare, and safety. When ground squirrel control is needed, the City will use population control techniques that are both effective and have no, or minimal, impact on other species. The City may also consider a public information program that explains the need for control, while describing the undesirable results that would follow if ground squirrel populations grow unchecked along the Carmel shoreline.

[96] City of Carmel Coastal Land Use Plan (approved June 2003) Policy P5-159.

Stranded/Deceased Marine Mammals and Birds

Like their human counterparts, many marine birds and mammals make annual visits to the central California coast. Other marine mammals (sea otters and harbor seals) live along our coast throughout the year. Occasionally, some of these animals may become stranded on Carmel Beach. At other times, their bodies may wash up onto the beach.

All marine birds and mammals are protected by Federal law. When these animals, or their bodies, appear on Carmel Beach, only certain government agencies or certified organizations are allowed to handle them. City personnel should contact the appropriate agency or organization listed below.

Stranded marine mammals should be protected from disturbance by people or dogs. Mammals that are injured or sick may feel vulnerable, and may act aggressively toward people or dogs that venture too close. Sometimes, sick marine mammals carry diseases that are transmissible to other species, including humans or dogs.

Contact List[97]

Sea Otters (alive or dead)	Monterey Bay Aquarium	648-4840[98]
Seals and sea lions (alive)	Marine Mammal Center	633-6298
Seals and sea lions (dead)	NOAA	1-877-466-9155[99]
Birds (live)	Monterey County SPCA	646-5534

8.3 EROSION RESPONSE

Successful management of the Carmel shoreline should be based on the following paradigm: coastal erosion will continue to occur. While the City's seawalls and revetments appear to have slowed the pace of erosion of Carmel's coastal bluffs, the impacts of storm and wave will continue to pose threats to the beach, dunes,

[97] This list should be updated annually.
[98] This is the Monterey Bay Aquarium's 24-hour security phone number. MBA sea otter resource personnel will be notified.
[99] Representatives from the National Oceanic and Atmospheric Administration (NOAA) have asked to be notified whenever seal or sea lion carcasses wash up on any portion of the Monterey National Marine Sanctuary, including the Carmel shoreline. This telephone number connects to the pager for NOAA's local law enforcement personnel. Once they have determined that the animal died of natural causes, then the City can dispose of the carcass. Carmel Department of Public Works personnel bury these carcasses with a sand cover of at least four feet. If a carcass is not too decayed, it may be buried under the beach near Pescadero Creek, where the sand is deeper and where there are fewer beach visitors.

and bluffs. By dealing with erosion threats, the City can enable the continued use and enjoyment of the Carmel shoreline far into the foreseeable future.

As described in Sections 8.1 and 8.2, the City's erosion control program must be based on effective monitoring, inspection, and maintenance of the shoreline's natural and structural elements, as conditions change throughout the seasons and over the years. Activities such as the timely trimming of trees, the clearing of vegetation and debris from storm water systems, the prompt repair of bluff-cut trails, and other maintenance actions recommended in Section 8.2 and listed in Appendix 9.4, can each help lessen the impact of winter storm damage.

If erosion is severe enough to require the construction of new shoreline protection structures or the modification of existing structures, then guidelines described in Section 6.4 and in City policies P5-5, P5-6, P5-11, P5-12, P5-15, P5-16, and P5-17 should be followed.

8.4 FUNDING

The steps described above involve continuous and often immediate action on the part of the City. This requires that adequate funding be available in the annual operating budgets of each responsible City department.

The City also has committed to establishing and sustaining adequate capital reserve funds to respond to both on-going and infrequent shoreline management projects. These include beach profile surveys, engineering inspections of all beach facilities and protective structures, and timely incremental rehabilitation of the Beach Bluff Pathway and landscaping. A minimum reserve level of $150,000 should be maintained (and adjusted annually based on the rate of inflation) to cover these expenses.

Significant funds are also set aside exclusively for the Carmel shoreline and Carmel Beach in the City's Capital Improvement Reserve Fund. These funds allow the City to respond to catastrophic events where the cost of restoration would place a major financial burden on the City's budget if reserves were not available. Historically, these types of damages inevitably occur along the shoreline as a result of severe winter storms. A minimum reserve level of $500,000 should be maintained (and adjusted annually based on the rate of inflation). These recommendations are in keeping with City policy.[100]

[100] City of Carmel Coastal Land Use Plan (approved June 2003) Policy P5-36

8.5 PERMITS

Inevitably, on-going management activities will result in changes to the Carmel shoreline. Erosion protection, facility maintenance, access improvement, and restroom construction all will require physical work. In each case, the City's first responsibility will be to determine whether a Coastal Development Permit is required. The *Shoreline Emergency Action Response Plan* (Appendix 9.2) can serve as a general guide and should be read in conjunction with ordinances on Coastal Development Permit procedures adopted in Title 17 of the Carmel Municipal Code. In cases when there is an urgent need to take action to protect public safety or forestall further damage to shoreline structures, infrastructure or environmental resources, an emergency permit can be issued. This allows for immediate but temporary action. Once the emergency condition is stabilized, a permanent remedy or improvement can be designed and permitted through normal Coastal Development Permit processes, including full public review.

8.6 MANAGEMENT POLICIES

- Establish and implement a comprehensive shoreline management program for the beach, bluffs and dunes that mitigates degradation caused by public use and natural forces. (G5-2)

  - Minimize erosion of the bluffs. (O5-1)

    - Obtain and maintain an accurate digitized map of the Carmel shoreline to develop the City's beach management and maintenance policies. Analyze historic beach trends using aerial photo analysis and other available tools. Update topographic information at least every 5 years and analyze shoreline changes to facilitate early identification of erosion hot spots, sand sediment losses/gains, migration of engineered revetments, and other long-term impacts. (P5-2)

    - Place a series of permanent surveyed benchmarks inland of the bluffs running the length of Carmel Beach. The surveyed benchmarks shall be described in relation to National Geodetic Vertical Datum (NGVD) and identified through permanent markers, benchmarks, survey position, written description, reference numbers, et cetera to allow measurements to be taken at the same location in order to compare information between years. (P5-3)

- Protect public access, Scenic Road, and the aesthetic character of the coast by maintaining existing seawalls and engineered revetments. When any existing seawalls or revetments need to be replaced or substantially reconstructed, review seawall and revetment design alternatives, as well as other beach management strategies and determine the best balance among objectives for access, aesthetics and protection of coastal resources (biological, geological, and recreational). Protect the natural character and features of the Del Mar and North Dunes by prohibiting the construction of any new shoreline protective structures unless required to protect existing structures in danger of erosion. For the beach and shoreline area, only consider the installation of new protective structures after careful review of alternatives and when required to protect existing structures in danger of erosion. Mitigate the impacts of shoreline protective structures on visual quality and beach dynamics using landscaping, sand management and prudent engineering. (P5-5)

- Encourage the use of existing stairs, trails, and pathways, and discourage off-trail "short cuts" on or over the bluff face. Install landscaping barriers at each "short cut" on the face of the bluffs and immediately restore damaged landscaping. (P5-7)

- Perform monitoring and maintenance of shoreline facilities and protective structures throughout the year including restoration of damaged vegetation, public facilities, infrastructure and access facilities. Restore sand levels annually and replace or repair damaged vegetation as needed. (P5-8)

- Prohibit the placement of loose rock on the beach except where such rock is placed as part of a revetment allowed to protect an existing structure in danger from erosion. When any part of a rock revetment migrates from an engineered structure reposition it to maintain engineering stability or remove it from the beach. (P5-13)

- Protect the flat area/tidal zone of the beach for recreational use and, to the extent feasible, avoid shoreline protective structures that reduce the amount of beach area available for public recreation. (P5-14)

- Modification of existing shoreline structures shall adhere to the same standards for establishing need, obtaining permits, as well as landscaping, visual impacts, drainage and design as new seawall projects. (P5-16)

- Explore alternatives to maintain the sand elevation at the foot of Ocean Avenue to ensure public access and to cover with sand all exposed engineered revetments along the length of Carmel Beach. (O5-2)

  - Each spring inspect the volume of sand at locations along the backshore and determine if it is appropriate and timely to re-establish the sand to a higher elevation. The use of heavy equipment is authorized for redistributing beach sand to rebuild the dunes and cover revetments. Minimize beach encroachment, impacts on public access and protect public safety during this process. (P5-18)

  - As described in the Shoreline Management Plan, sand and bluff profiles shall be surveyed in 2003 and again in 2005 to establish a baseline. Thereafter, a set of sand profiles shall be taken at five-year intervals (beginning in 2010) to establish an ongoing record of shoreline trends (i.e., volume and natural rate of accretion and/or loss of beach sand) on Carmel's beaches and bluffs. For each set of profiles measurements shall be taken (1) at mid-Winter when sand is at its lowest, (2) at Spring, prior to sand redistribution activities, (3) at early Summer, immediately following sand redistribution and (4) in the early Fall, before sand begins its retreat offshore. (P5-19)

  - After each five-year period of monitoring beach sand elevations (beginning in 2010 after data from 2003, 2005 and 2010 are available), review all available data and make preliminary determinations regarding the effects of seawall structures and sand redistribution activities. If the results of the City's beach monitoring program indicate that the beach has been losing sand over time investigate options for beach nourishment using offshore deposits or other sources that match Carmel Beach sand to replenish the beach and protect its width. The program shall at a minimum: 1) identify potential sources of beach quality sand; 2) include testing and screening for determining the acceptable quality and quantity of beach material; 3) identify placement locations; 4) establish placement methods and any restrictions on work timing or methods. (P5-20)

  - Maintain Carmel Beach as a public recreational resource. If the results of the City's beach monitoring program indicate that the beach has been losing sand over time, develop, implement, and then further monitor and evaluate a beach nourishment program to maintain or increase the available volume of sand. (P5-21)

Maintain the existing shoreline maintenance and emergency reserve account. Build fund balances over time, to the extent feasible, to handle future emergency repairs at the beach. (P5-36)

- Consider beach-related projects that address public safety and access as high-priority projects when preparing budgets. (P5-37)

- Keep the beach free of refuse. (O5-6)

  - Provide sufficient trash containers at the beach. Regularly patrol the beach and Del Mar area to remove all litter and excess charcoal from the sand, bluffs and parking lot. (P5-38)

  - Encourage volunteer programs for beach and bluff clean-up activities. (P5-39)

Shoreline Armoring Maintenance and Monitoring.

(1) Monitoring. The Permittee shall ensure that the condition and performance of existing seawalls and revetments are regularly monitored by a licensed civil engineer with experience I coastal structures and processes. Such monitoring evaluation shall at a minimum address whether any significant weathering or damage has occurred that would adversely impact its future performance, and identify any structural damage requiring repair to maintain the as-built revetment profile.

At a minimum, annual monitoring reports shall be prepared by a licensed civil engineer with experience in coastal structures and processes and shall contain recommendations, if any, for necessary maintenance, repair, changes or modifications to each existing revetment or the bedrock benches adjacent to and below it. All monitoring reports shall include photos of the structures and surrounding areas taken during low sand elevations in the winter months.

(2) Maintenance Activities. It is the Permittee's responsibility to maintain any shoreline armoring structures and all irrigation, drainage, and vegetation in a structurally sound manner and its approved state until such a time that the seawalls and/or revetments are removed or replaced. At a minimum, the Permittee shall:

a. Rock Retrieval. Any armor rocks that move seaward of the as-build seawall and/or revetments shall be immediately retrieved and either (1) restacked within the approved rock slope profile inland of the seawall; or (2) removed of the beach to a suitable disposal location. Any existing rock retrieved in this manner shall be recovered by excavation equipment positioned landward of the waterline (i.e. excavator equipment with mechanical extension arms).

b. Debris Removal. The Permittee shall remove all materials and/or debris that my fall from the bluff top area inland of the seawall onto the beach below.

c. Landscaping and Drainage Maintenance. The Permittee shall maintain all upper bluff drainage, vegetation, and/or irrigation elements above seawalls and/or revetments.

9 APPENDICES

9.1 OCEANOGRAPHIC INFORMATION
9.2 SHORELINE EMERGENCY ACTION RESPONSE PLAN
9.3 BEACH EMERGENCY CLOSURE PLAN
9.4 SHORELINE INSPECTION/MAINTENANCE LIST
9.5 CARMEL BEACH PROFILE MONITORING PROGRAM
9.6 CARMEL BEACH WATER STORAGE TANKS
9.7 REFERENCES CITED

9.1 OCEANOGRAPHIC INFORMATION[101]

One factor affecting beach scour and erosion of the bluffs at Carmel Beach is the stillwater level of the ocean. Stillwater level is influenced by several variables, discussed below:

Tidal Conditions
A mixed semi-diurnal tide characterizes the California coast. This means simply that we experience two high tides each day, of unequal height, and two low tides, also of unequal height. Normally, tidal heights are stated in feet, relative to mean lower low water (MLLW, the mean or average elevation of the lower of the two low tides each day). According to the 1973 and 1974 Tide Tables (National Ocean Survey, 1972 and 1973), tide levels in Carmel Bay vary from a high tide of +6.9 feet above mean lower low water (MLLW) to a low of -1.7 feet MLLW. The average tide level is +3.0 MLLW. Tides above 6.0 feet MLLW occur about 13 percent of the time.

Atmospheric Storm Surge
Another factor that influences the height of the still water level is storm surge. During large storms, onshore winds push water toward shore where the water "mounds," raising sea level. Similarly, large low atmospheric pressure systems associated with these storms allow sea level to raise above normal levels. During the oceanic storms of 1983, surges at the Golden Gate reached heights of 2.0 feet above predicted levels. Thus, sea levels have probably reached elevations of 9.1 feet (MLLW) at Carmel Beach and might be expected to raise to even higher levels under more extreme conditions.

Short-Term Increases (Due to Wave Pile-Up)
Short-term increases in stillwater depth due to mass onshore transport of water from breaking waves is estimated to be approximately 1.5 feet. We base this estimate on our observation during the 1982 and 1983 storms.

Long-Term Sea Level Rise
Tide records show that a world-wide rise in sea level has occurred in historic time. Thompson (1977) states:

> "The sea-level history determined from the tide measurements made at the N.O.S. reference tide station at San Francisco can be considered representative of Monterey Bay. At San Francisco, the sea-level rise derived from the 19-year running mean of 113 years of tide data from 1859 to 1972 (unpublished N.O.S. data) was about 0.73 feet (21.9 cm). Local sea level has not changed at a constant rate nor has it risen continuously over this 113-year period. It rose 0.35 feet (10.5 cm) from 1859 to 1887 (28 years), remained stationary from 1887 to 1929 (42

[101] Supplied by the City's consulting engineering-geologist Rogers E. Johnson and Associates

> years), then rose 0.35 feet (10.5 cm) from 1929 to 1972 (43 years). Long-term shoreline erosion rates should be expected to reflect this trend. Sea-level rise as a primary controlling factor in coast erosion is only now gaining general recognition among coastal experts."

Emery and Kuhn (1982) state:

> "Mean annual sea levels of 247 tide-gauge stations of the world exhibit a general rise of relative sea level of about 3mm a year during the previous 40 years."

They caution against drawing conclusions regarding sea level changes from the analysis of short-term (5 and 10 year) records because of the influence climatic cycles and poor tide gauge distribution may have on short-term records.

Future changes in sea level cannot be accurately predicted but it is obvious that sea level will probably continue to slowly rise due to melting of the polar ice caps, most probably caused by the greenhouse effect. The greenhouse effect is from the general increase of the earth's temperature that is the result of increased CO_2 levels in the atmosphere. The present rate of rise is 1 foot per 100 years (Environmental Protection Agency, 1983 [quoted in *Science*]).

Design Stillwater Level Summary	
Extreme high tide	+7.1 feet MLLW
Atmospheric storm surge	+2.0 feet
Short-term increases	+1.5 feet
Long-term sea level rise	+0.4 - 2.0 feet
Design Stillwater Level	***11.0 - 12.6 feet MLLW (8.2 - 9.8 feet MSL)***

Tsunamis

Tsunamis are among the most destructive natural phenomena to affect coastal areas. Common causes of tsunamis are tectonic displacement of the sea floor associated with large earthquakes; sea floor landslides; rock falls into bays and oceans; exploding volcanic islands and underwater nuclear explosions (Wiegel, 1970; Furneaux, 1964; Galanopoulos, 1969). Rupture along the San Gregorio fault, just off the Carmel coastline, could create tsunami conditions. Carmel also could be affected by tsunamis generated by large earthquakes occurring anywhere along the Pacific Northwest coastline.

A tsunami is a long-period wave whose speed and wavelength decreases as it approaches a shoreline. The energy within the wave is "crowded" into progressively less water, resulting in a wave with a significant run-up height. Waves that were 3 feet high in the open ocean may reach heights in excess of 60 feet during run-up. Factors that significantly affect the height of a tsunami wave near the shore include local sea floor bathymetry and the shape of the shoreline. Understanding the geometry of the sea floor

and coastline aides researchers in predicting how waves will refract, reflect, and form secondary waves and high-amplitude resonant waves, generally adding to the complexity of runup predictions.

Although most coasts of the Pacific Ocean basin have a long history of tsunami-caused death and destruction, tsunami damage to coastal California is relatively slight in historical time. The only tsunami to cause appreciable damage along the California coast occurred on March 27, 1964, as a result of the great Alaska earthquake (Magoon, 1965). Even though earlier tsunamis produced little damage in California, extensive development of some of the affected coastline over the last 100 years has increased the potential risk of death and property damage.

Recent work by Steven Ward (2001), a geophysicist at the University of California, Santa Cruz, suggests that submarine landslides, perhaps triggered by an earthquake, within the Monterey submarine canyon could generate a tsunami 50 to 80 feet high on the Monterey side of the bay.

Ward's work is based on computer modeling and he cautions that, at least to date, no geologic evidence has been found along the shores of Monterey Bay that a major tsunami has ever swept ashore from the canyon.

9.2 SHORELINE MAINTENENCE AND EMERGENCY ACTION RESPONSE PLAN

INTRODUCTION

Erosion along the Carmel shoreline presents hazards to public safety and threatens City infrastructure. The shoreline is vulnerable to damage from the effects of direct wave action, lateral (along shore) water flow, subsurface soil saturation, slumping, and uncontrolled storm water drainage from the bluffs above the beach.

This *Shoreline Maintenance and Emergency Action Response Plan* recommends actions to be taken by the City before, during, and after severe storm events. These recommended actions are designed to provide immediate stopgap measures to protect Carmel's shoreline from further damage. Long-term solutions must be taken through the City's formal design review and permit processes before implementation. Steps described in this *Shoreline Maintenance and Emergency Action Response Plan* must be used in conjunction with the corresponding sections of the *Shoreline Management Plan.*

Part A describes shoreline monitoring and response actions. It describes the responsibilities of personnel from the Forest, Parks and Beach Department, the Department of Public Works, and contract coastal specialists. Actions (shown in CAPITAL LETTERS) will minimize potential public safety hazards and will reduce the level of damage to the shoreline.

Part B contains notes regarding repairs to various shoreline structures, including seawalls, revetments, beach access stairways, and bluffs. These notes should serve as a guideline for repairs.

Part C lists equipment and material, which might be used to repair shoreline damage. These may be stored at City facilities or be available from local sources. A resource list is also included.

As noted in Chapter One, the majority of the actual beach and base of the bluff area at Carmel Beach (including the revetments and the seawalls) is located within the California Coastal Commission's retained coastal permitting jurisdiction. As a result, the majority of development associated with this emergency action response plan will require a coastal development permit from the Coastal Commission. The City intends to submit a coastal development permit application to the Commission by June 2004 for routine long-term maintenance activities in the Beach area (e.g. revetment, seawall, and stair way maintenance), and will

continue to coordinate with the Commission on non-routine development (e.g. Emergencies and new structures), including by obtaining emergency permits from the Commission as necessary.

A. MONITORING and RESPONSE

PROCEDURE	*RESPONSIBILITY*	*SCHEDULE*
1. BEFORE STORM SEASON		
• Conduct fall shoreline assessment	Coastal consultant	Fall: Oct/Nov
• Inspect fill areas along the upper shoreline bluff, the tops of masonry walls (10th, 13th, Santa Lucia to Martin Way) for signs of soil fractures, cracks, developing hollows, or soil subsidence. Monitoring should be performed visually by walking the bluffs above the seawalls and along the Pathway and beach access stairways. **ACTION:** IF NECESSARY, VOIDS SHOULD BE FILLED WITH ADDITIONAL COMPACTED CLEAN FILL MATERIAL OR SAND. SLUMPS SHOULD BE EXCAVATED AND AN ENGINEERED REVETMENT CONSTRUCTED AND COVERED WITH COMPACTED FILL, CONTOURED, AND LANDSCAPED.	Forest, Parks and Beach Dept	Early Fall/ Early Spring
• Inspect bluffs vegetated by overhanging ice plant which becomes laden with water during storms and can cause saturated bluff soils to slump. **ACTION:** OVERHANGING ICE PLANT SHOULD BE REMOVED AND REPLACED WITH NON-INVASIVE NATIVE PLANTS.	Forest, Parks and Beach Dept	Early Fall/ Early Spring/ Major Storms
• Inspect concrete stairway structures for holes or cracks, which might allow water to penetrate, and eventually weaken, the stairway. **ACTION:** WHEN DETECTED, THESE DEFECTS SHOULD BE REPAIRED WITH APPROPRIATE FILL MATERIALS.	Public Works Dept	Early Fall/ Early Spring/ Major Storms
• Inspect stairways for overgrowth of plants, especially ice plant, which represents a safety hazard as well as a water trap.	Forest, Parks and Beach Dept	Early Fall/ Early Spr Mid-Summer

ACTION:
ALL VEGETATION SHOULD BE TRIMMED IMMEDIATELY.

2. DURING STORM SEASON

• Inspect all storm drains, gutters, grates, manholes, drop inlets, culverts and outfalls for plugs and damage, which may interfere with water drainage systems from 4th Ave. to Martin Way **ACTION:** ALL COMPONENTS OF THE STORM DRAIN SYSTEM (INCLUDING ALL STORM DRAINS, GUTTERS, GRATES, MANHOLES, DROP INLETS, CULVERTS, AND OUTFALLS) SHALL BE INSPECTED ON A REGULAR BASIS AND SHALL BE MAINTAINED AT LEAST TWICE YEARLY (1) BETWEEN OCTOBER 1st AND OCTOBER 15TH AND (2) BETWEEN APRIL 15TH AND MAY 1ST. SUCH MAINTENZNCE SHALL INCLUDE CLEAN-OUT, REPAIR AND/OR REPLACEMENT AS NECESSARY TO ENSURE THAT THE STORM DRAIN SYSTEM EFFECTIVLY FILTERS AND TREATS RUNOFF TO REMOVE TYPICAL URBAN RUNOFF POLLUTANTS. (SEE SMP Fig. 8)	Public Works Dept	Regularly During Storm Season
• Inspect storm drain grates and drop-manhole covers to ensure that they are securely in place. **ACTION:** SECURE IF NECESSARY.	Public Works Dept	Regularly During Storm Season
• Inspect eastside catch basin at Scenic Road and 11th Avenue. **ACTION:** JUST PRIOR TO RAINSTORMS, THE UPPER GRATE SHOULD BE LIFTED AND THE OPENING PROTECTED WITH A SPECIALLY DESIGNED DRAINAGE DEVICE (WITH TRAFFIC HAZARD WARNING LIGHTS), STORED AT THE DEPARTMENT OF PUBLIC WORKS FACILITY. THIS PROTECTIVE DEVICE SHOULD BE REMOVED WHEN DRAINAGE FLOWS SUBSIDE.	Public Works Dept	Prior to Storm Events
• Inspect bluff areas directly below storm drain outfalls for damage (slumping, liquefaction) caused by defective drain pipes. **ACTION:** IF DAMAGE IS DETECTED, INSTALL ARMORSTONE TO DIFFUSE DRAINAGE AND MAKE NECESSARY DRAIN SYSTEM REPAIRS AS SOON AS PRACTICAL.	Public Works Dept	After Storms

• Inspect stairway structures, including handrails. During periods of low sand level, focus attention on structural safety and undercutting of superstructure. **ACTION:** STAIRWAYS SHOULD IMMEDIATELY BE CLOSED TO PUBLIC USE BY INSTALLING WARNING DEVICES AND BARRICADES WHEN UNSAFE CONDITIONS ARE DETECTED. REPAIRS SHOULD BE MADE AS SOON AS POSSIBLE (see *Beach Emergency Closure Plan* in Section 9.3).	Public Works Dept	Regularly Winter/ Immediately After Major Storms
• Inspect beach sand and soils covering rock revetments for signs of slumping or gaps between granite boulders, which may represent a safety hazard. (SMP Fig. 8) **ACTION:** PRIOR TO ANNUAL SAND REDISTRIBUTION PROJECT, CLEARLY MARK POTENTIAL HAZARDS WITH WARNING SIGNS, BARRIER TAPE AND BARRICADES.	Forest, Parks and Beach Dept	During Major Storms & Surf
• Inspect exposed revetments for signs of loose, perched, or migrating boulders. **ACTION:** ANY ROCK OR BOULDERS FOUND TO BE LOOSE OR UNSTABLE, OR TO HAVE MIGRATED AWAY FROM ANY EXISTING SEAWALL OR REVETMENT SHOULD BE RETRIEVED IMMEDIATELY AND EITHER RESTACKED WITHIN THE APPROVED ROCK SLOP OR REMOVED FROM THE BEACH TO A SUITABLE DISPOSAL LOCATION. ANY EXISTING ROCK RETRIEVED IN THIS MANNER SHALL BE RECOVERED BY EXCAVATION EQUIPMENT POSITIONED LANDWARD OF THE WITERLINE. IF IMMEDIATE REPAIRS ARE NOT POSSIBLE, DOCUMENT CONDITIONS PHOTOGRAPHICALLY & SCHEDULE REPAIRS AS SOON AS POSSIBLE.	Public Works Dept	Winter/ Prior to Sand Redisribution
• Inspect the top and ends of each seawall for signs of erosion at the bluff/wall boundary. **ACTION:** WHEN IDENTIFIED, ERODED AREAS SHOULD BE REPAIRED WITH FILL, CONCRETE GROUT, BOULDERS, OR OTHER APPROPRIATE MATERIALS	Public Works Dept	Early Fall/ Early Spring

COMPLEMENTARY TO THE STRUCTURE BEING REPAIRED.

• Inspect the beach for logs or other large heavy driftwood and debris, which could act as a battering ram causing damage to slopes, walls, stairways, and other structures. **ACTION:** DRIFTWOOD OR DEBRIS SHOULD BE REMOVED ENTIRELY FROM THE BEACH SURF ZONE AND MOVED TO HIGH GROUND. IF NOT FEASIBLE, CUT INTO SMALL PIECES.	Forest, Parks and Beach Dept/ Public Works Dept	Prior to Storms/ After Storms/ or As Needed
• Spills **ACTION:** NOTIFY "NATIONAL RESPONSE CENTER" (800) 424-8802	All Dept.s/All Staff	Respond Immediately

B. SHORELINE REPAIR

During the past fifty years, the Carmel shoreline has been protected by the construction of seawalls and retaining walls, rock revetments, the bulldozing and redistribution of sand, and the deposition of fill material. Even with these protective measures, the shoreline continues to be vulnerable to erosion.

The City's shoreline can be divided into four distinct areas, based on the type of structure or material that protects the beach bluffs: reinforced seawalls and retaining walls, rock revetments, natural consolidated material (sandstone, siltstone, mudstone), and unconsolidated beach and dune sand. Responses to erosion of each area must be specific for the type of material listed.

1. REINFORCED SEAWALLS/RETAINING WALLS

Reinforced seawalls/retaining walls protect approximately 30% of the Carmel shoreline. These massive engineered walls provide substantial protection against both direct wave action and lateral water flow; their built-in drainage systems help control storm water and subsurface hydrostatic drainage problems. These walls may be susceptible to storm damage:

1) In some locations, seawalls/retaining walls create a solid reflective surface that may focus wave energy onto adjacent, unprotected portions of the shoreline; and
2) Because seawalls are made of harder material than the native bedrock, the wall foundations are vulnerable to undercutting by winter wave action when sand levels are low.

In areas where reflective damage occurs, adjacent unprotected sites should be closely monitored for signs of bluff erosion. If necessary, repairs should be made as soon as practical.

*NOTE: Modifications to existing seawalls are not recommended unless accompanied by an analysis of wave action and water flow dynamics. Professionally engineered plans for seawall-modification should incorporate the information described in the Carmel Beach Rehabilitation Project - Phase I Geology Report, and must be in conformance with the Carmel General Plan and Local Coastal Program (LCP), as well as with the California Environmental Quality Act (CEQA).

2. ROCK REVETMENTS

All existing revetments along the Carmel shoreline include a keyway excavated into the underlying bedrock. Because the bedrock is relatively "soft," the keyway is vulnerable to damage, resulting in rock migration. Depending upon conditions, at least three modes of repair should be considered:

1) A deeper keyway could be cut at the original location. Overlying rocks would have to be moved, then replaced after the toe rocks are re-installed; or
2) Repair existing keyway. This would require moving and replacing overlying rock, similar to #1, above; or
3) Replace existing revetment with a vertical seawall.

All existing revetments also include a layer of filter fabric installed between bluff soils and overlying revetment rocks. This fabric prevents loss of sand and bluff material through the structure.

3. NATURAL CONSOLIDATED MATERIAL

Approximately 15% of the Carmel shoreline is protected by sandstone, siltstone, or mudstone. These natural "soft" rocks are very vulnerable to wave erosion.

As described above, these portions of the shoreline should be monitored for signs of undercutting or erosion along their boundary with seawalls, retaining walls, revetments, and the adjoining bluff material. Where damage is substantial, repairs involving seawall or revetment extensions should be considered. Plans for these structures should incorporate the information described in this Shoreline Management Report, the Carmel Beach Rehabilitation Project Phase I Erosion Protection Report, and must be in conformance with the Carmel General Plan and Local Coastal Program (LCP), as well as the California Environmental Quality Act (CEQA).

4. UNCONSOLIDATED MATERIAL

The remaining portions of the Carmel shoreline are protected by unconsolidated material (sand, fill material). Carmel's white sand is world famous, attracting both residents and visitors. In addition to its value as a visual resource, the sand helps protect the beach slopes from wave impacts. The amount of sand on the beach is affected by wave action, and varies throughout the year: during the late fall through early spring, steep, short-period waves move sand from the beach out to underwater offshore sandbars; during the late spring through mid-fall, long-period waves move sand from the offshore bars back onto the beach. During the winter, enough sand may be removed from the beach to expose the underlying bedrock and expose footings of seawalls, revetments, and stairways. When severe sand scour occurs, these structures will be vulnerable to wave damage.

Portions of Carmel's shoreline bluffs, especially from Ninth Avenue to the south City limits, have been built from fill material deposited by the City. This fill contains a variety of materials, including rock, dirt, and sand. In the past, these materials have been eroded by wave action, uncontrolled drainage, trampling, and other forces.

Both the white beach sand and the fill materials will need replacement from time to time. During early summer, the Forest, Parks and Beach Department has been responsible for contracting the City's sand redistribution program: the movement of sand from the lower beach to cover rock revetments along the upper beach and bluffs. Sand redistribution helps replace sand dragged downslope by numerous beach visitors and camouflages unsightly shoreline revetments. This activity also introduces temporary public access impacts and could lead to a disruption of shoreline habitat and loss of beach sand.

The City is monitoring beach profiles to better understand what, if any, impact its sand redistribution program is having on beach sand. If the results of the City's beach monitoring program indicate that the beach has been losing sand over time, the City is prepared to investigate options for beach nourishment using offshore deposits or other sources that match Carmel beach sand to replenish the beach and protect its width.

C. EMERGENCY CONSTRUCTION MATERIALS

Material	Amount	Where Stored
Sand Bags (burlap)	500	Dept of Public Works
Slurry Bags	20	Dept of Public Works
Boulders		(see list of rock sources)

ROCK SOURCES:

1. Kaiser - Santa Margarita Quarry
   P.O. Box 850
   Atascadero, CA 93422

This quarry supplied most of the armorstone and corestone used during the Phase I project. According to Rogers Johnson & Associates (memo to Carmel Beach Task Force, 17 November 1983): "The Santa Margarita rock is technically classified as DIORITE. It is not true granite; however, it is close in color and composition @-o granite. Diorite is composed mainly of the minerals quartz and plagioclase (both light colored) while - granite is composed of quartz, plagioclase, and orthoclase (a pink-colored mineral). The Santa Margarita rock also contains BIOTITE, which is a black, platy mineral, and this gives the rock its darker hue." According to this memo, the Santa Margarita rock is ideal for use in riprap seawalls.

2. Granite Rock Co. - Logan Quarry
   P.O. Box 151
   Watsonville, CA 95077

This quarry supplied approximately 15% of the rock used during the Phase I project. According to Rogers E. Johnson & Associates (memo to Carmel Beach T-ask Force, 17 November 1983): "The Logan (Aromas) rock is technically classified as a QUARTZ GABBRO, which is composed of the minerals plagioclase Hand pyroxene with minor quartz. The plagioclase is white to light gray; the pyroxene is the distinctive, dark green, elongate mineral seen in the rock. The pyroxene gives the rock a greenish hue while the Santa Margarita diorite is blacker due to the biotite (the color difference is only slightly detectable.")

According to this memo, the Logan Quarry rock is also ideal for use in rip-rap seawalls, but some concern was expressed regarding the tendency of this rock to fracture (though observations made during rock delivery indicated that Logan Quarry rock did not break up any more than did rock from Santa Margarita).

9.3 BEACH EMERGENCY CLOSURE PLAN

GUIDELINES FOR EMERGENCY BEACH CLOSURE[102]

Any City employee who becomes aware of an existing or potential shoreline condition (this includes any condition on Scenic Road or any property West of Scenic Road including, but not limited to, the beach slope), that threatens the public safety, health, or welfare of persons on the beach or shoreline, shall immediately notify their respective Supervisor. The Supervisor shall notify his/her respective Department Director who in turn will notify the Chief of Police. Upon notification to the Chief of Police, the Chief will promptly convene a meeting of the "Beach Emergency Action Committee" (BEAC), which is comprised of the following Department Directors or their representative(s):

Assistant City Administrator	City Forester	Police Chief
Fire Chief	Public Works Director	

The role of BEAC is to assess the information and circumstances causing concern for the public and possible beach closure. Typical sources of information or agencies BEAC might consult include but are not limited to any of the following:

National Weather Service	831-656-1725
California Coastal Commission	831-427-4863
County Offices of Emergency Services	831-755-5120
County Office of Health Department	831-647-7650
County Office of Water Resources Agency	831-647-7600 ext. 4860
Other Governmental Agencies as Appropriate	

Media

Monterey Herald.....831-646-4353

Carmel Pine Cone.....831-624-0162

[102] Approved by Carmel City Council (Resolution No. 2003-43); adopted by April 1, 2003.

ACTIVATION:

If, in the opinion of BEAC the beach or parts of the beach should be temporarily closed in the interest of public safety, health, and welfare, a recommendation to activate the Emergency Beach Closure Plan ("PLAN") shall be made to the City Administrator, or his designee. The Police Chief shall maintain a file containing the supportive documents or information relating to the recommendation to close the beach. Upon approval by the City Administrator, the PLAN shall be activated as follows:

1. The City will take reasonable action(s) to ensure the public is notified of the beach closures by:

   a). The Police Chief, or his designee, notifies the Public Works Department to post the beach closed as recommended by BEAC. Public Works will post standardized temporary signs, markings, or other devices in a manner and location that are approved by BEAC. Additional information concerning the locations for posting signs is contained at the end of this document.

   b). The Police Chief, or his designee, prepares and distributes a press release that notifies the public and all City Staff (via Email), of the decision to close the beach.

2. As time permits, all field personnel from the Police Department and with the assistance of the Fire Department and Public Works Department, will periodically monitor the beach and enforce the beach closure by authority of 409.5 California Penal Code.

3. All field personnel from the Police, Fire, and Public Works Departments will as time permits monitor the beach closure area to ensure signs and markings are maintained to the best extent possible. Signs, markings, etc, that are down, obscured, or otherwise missing, shall be promptly reported to Public Works for repair.

4. Notify the central coast office of the California Coastal Commission of recommendation of the BEAC to close the beach prior to action being taken by the City to preserve public safety, health and welfare. If it is not possible to contact the Coastal Commission prior to action, then the City shall contact the Coastal Commission immediately following action.

DEACTIVATION:

The Police Chief and other members of BEAC will monitor the status of the beach closure and meet as necessary to discuss deactivation of the emergency beach closure plan. If, in the opinion of BEAC, the need for maintaining a beach closure no longer exists, the Police Chief will make a recommendation to the City Administrator, or his designee, to deactivate the PLAN. Upon approval of PLAN deactivation, the Public Works Department will remove beach closure signs, markings, and other devices.

VEHICLE ACCESS POINTS:

The primary vehicle access point to the beach is located at Scenic and 8th. If the beach is inaccessible at this location due to high surf or other hazardous conditions, an alternative access point will be staged at Del Mar Beach.

SIGN POSTING LOCATIONS:

In the event the PLAN is approved to initiate an entire beach closure, the following locations represent the desired minimum sites where standardized BEAC approved signs and/or barricades are to be posted. If a localized part of the beach is identified for closure, the above referenced signs will be posted at locations to be determined appropriate by the BEAC.

Minimum sites to be posted for full beach closure:

1. 4th Ave. access easement at Sand and Sea
2. W/S San Antonio 75 feet south of 4th Ave.
3. Del Mar parking lot (3) placed west of the lot pavement evenly spaced between restroom and the pump station at the south end of the lot.
4. 8th Ave. stairway
5. Emergency access south of 8th Ave.
6. Handicap access south of 8th
7. 9th Ave. stairway
8. North 10th Ave. stairway
9. South 10th Ave. stairway
10. 11th Ave. stairway
11. 12th Ave. stairway
12. 13th Ave stairway
13. Santa Lucia stairway
14. Martin Way stairway

9.4 SHORELINE INSPECTION AND MAINTENANCE CHECKLIST

This Appendix provides a list of ongoing maintenance and repair tasks that are required based on past experience. Protection of public safety is paramount; at all times City personnel should be observant of changes that occur along the shoreline and should respond to new repair and maintenance issues as they arise.

Throughout the checklist below, specific items that typically require a Coastal Development Permit are identified. Items not so identified generally do not require a Coastal Development Permit. For proposed development in the shoreline area, both the City Planning Director and the Coastal Commission should be contacted for a determination of what development does and does not require a coastal development permit and from which entity. The city shall submit a Coastal development permit application to the California Coastal Commission by June 2004 to implement the inspection and maintenance activities identified within this document.

Carmel Beach

Goal: Maintain the unique white sand beach that is kept free of litter, garbage and other waste.

Inspection and Maintenance Issues:

Beach Cleaning:

__ Remove litter (trash and garbage) from trash receptacles and surrounding beach, dunes and bluffs.

__ Support volunteer groups that regularly remove beach litter.

__ Increase number of trash containers and, when necessary, frequency of trash removal services during special events.

__ Remove and/or dispose of dead marine mammals and birds.

Revetments

Goal: Ensure stability, structural integrity of all revetments; annually maintain sand coverage to camouflage revetments, ensure public safety and expand maximum beach access.

Inspection and Maintenance Issues:

__ Reposition migrating, perched, and/or loose boulders to maintain revetment's design slope. *NOTES: Pay special attention to the revetment protecting the Ocean Avenue storm water outfall. See section 9.4 for coastal permitting requirements.

__ Rebuild revetments if the shape has been significantly altered. NOTE: Rebuilding a revetment requires a Coastal Development Permit and an evaluation of all reasonable alternatives to shoreline armoring including replacement with vertical seawalls and consideration of "soft" options.

__ Camouflage existing revetments with sand pursuant to the provisions in 17.20.20.O. Sand redistribution shall avoid over-excavation the beach berm and use the minimum amount of sand necessary to cover existing revetments.

__ Post signs to warn of dangerous conditions when revetments are exposed.

__ Repair "boundary" erosion (at top and sides of revetments) Consider adding additional armor stones or other alternative. See the Introduction section for coastal permitting requirements.

__ Maintenance and monitoring of shoreline structures shall be carried out consistent with section 17.20.19.E.

Seawalls and Retaining Walls

Goal: Ensure stability and structural integrity of all walls.

Inspection and Maintenance Issues:

__ Repair undermined footings, pitted or weathered mortar joints, loose facing-rocks, or structural cracks using approved methods.

__ Repair "boundary" erosion (at top and ends of walls) with combinations of compacted fill, re-vegetation, guardrails, boulders, signage, or other approved methods. Consider adding additional armor stones or other alternative. NOTE: The addition of new boulders to a seawall or retaining wall requires a Coastal Development Permit.

__ Clear drain ("weep") holes when necessary to ensure proper drainage.

__ Retrieve loose rock from failed seawalls during periods of low tide and low sand elevation.

__ Maintenance and monitoring of shoreline structures shall be carried out consistent with section 17.20.19.E

Sand Redistribution

Goal: Ensure complete sand coverage of all revetments; re-establish and re-grade all sand ramps south of Eighth Avenue and the dune slopes at Ocean Avenue.

Inspection and Maintenance Issues:

__ Conduct sand redistribution consistent with section 17.20.20.O of Title 17. NOTE: The sand redistribution program requires a Coastal Development Permit.
__ Use the minimum amount of sand necessary to maintain public safety and cover existing revetments.
__ Schedule an observer to ensure public safety.
__ Establish a marked safety zone around worksite.
__ Avoid disturbance of inter-tidal sand.
__ Closely monitor revetment-covering process to prevent formation of voids and hollows.
__ Level borrow areas on bluff side of sand berm.
__ Drain ponds by breaching beach sand berms; back fill low areas once drained.

Beach Accessways

Goal: Provide safe convenient access to and from the beach.

Inspection and Maintenance Issues:

Stairway Safety:

__ Clear stairways of any obstructions that impede safe passage, including low-hanging limbs and ice plant that encroaches on stairway treads.
__ Keep stairway treads and landings level and stable.
__ Eliminate water flows that create unsafe slippery conditions and stimulate algal growth.

Stairway Structural Integrity:

__ Repair or replace deteriorating or rusty stairway hardware.
__ Repair undercutting of all stairways using approved methods.
__ Repair misalignment or instability of wooden.
*NOTE: Pay special attention to all support members.
__ Re-point deteriorating mortar joints in masonry stairways.

Handrails:

__ Firmly secure all handrails.
__ Keep all surfaces smooth and eliminate sharp corners and rough edges.

Sand Ramps:

__ Maintain gradual gradients of slope and even transitions to Pathway and street interfaces.

__ Cover exposed logs.

Disabled Access:

__ Ensure that all Pathway access ramps ("curb cuts") have even transitions between the Pathway and ramp materials.

__ Clear sand from all disabled-access surfaces.

*NOTE: Pay special attention to areas adjacent to open sand – e.g. Pathway access ramps between Eighth and Ninth Avenues and the paved walkway that connects City's main beach area restroom with the curb ramp at the foot of Ocean Avenue.

Shoreline Bluffs

Goal: Ensure that bluffs are stable and can support the beach bluff Pathway, landscape and all other infrastructure.

Inspection and Maintenance Issues:

Bluff Trails ("bluff-cutting"):

__ Respond immediately by re-vegetating trails, installing guardrails, boulders, signs, or other aesthetically compatible techniques that discourage further bluff-cutting. NOTE: Introduction of new guardrails, boulders or signs to any area requires a Coastal Development Permit.

Bluff Hollows:

__ Repair by clearing overlying vegetation to determine cause; repair and backfill with sand.

*NOTE: Check bluffs behind seawalls and retaining walls.

Bluff Slumping:

__ Repair slumping bluffs by adding clean backfill material (clay) and compact.

*NOTES: Examine adjacent areas and bluff tops for further slumping, ground cracks, and/or slurried soils. Adding backfill requires a Coastal Development Permit if there is significant slumping over a wide area.

Rodent Control:

__ Control any rodent populations that expand their range to the bluffs from Eighth Avenue southward.

Bluff Outfalls:

__ Repair bluff erosion, undermining, and broken/separated pipes using approved methods.

Bluff Top Structures:

__ Ensure that structures near the edge of bluffs (stairway landings, trash enclosures, patios) are stable, level and square.

Vegetation:

__ Re-establish approved vegetation on barren slopes.

__ Remove acacia and *Myoporum* to prevent encroachment into shoreline viewsheds.

__ Remove ice plant.

Irrigation/Drainage breaks:

__ Repair immediately.

*NOTE: Pay special attention to saturated soils and wet stairway.

Storm Water System

Goal: Provide unimpeded storm water flows from the City's streets and storm water systems. Safely discharge storm water without causing shoreline erosion or damage to infrastructure.

Inspection and Maintenance Issues:

__ Clear debris from all storm water inlets, grates, CDS units and pipes prior to each storm event. All components of the storm drain system (including all storm drains, gutters, grates, manholes, drop inlets, culverts, and outfalls) shall be inspected on a regular basis and shall be maintained at least twice yearly: (1) between October 1st and October 15th, and (2) between April 15th and May 1st. Such maintenance shall include clean-out, repair, and/or replacement as necessary to ensure that the storm drain system effectively filters and treats runoff to remove typical urban runoff pollutants.

__ Clear vegetation from all storm water inlets and outfalls prior to storm season.

__ Repair structural defects in storm drain system, including drain pipes, drop inlets, Continuous Deflection Separation (CDS) units, and outfalls and outfalls.

__ Modify storm drain outfalls where drainage causes shoreline erosion using boulders or other suitable material to diffuse the force of discharging water. Repair separated outfall pipe sections. *NOTE: Pay special attention to Fourth Avenue perched outfall, wall, attached guardrails and pipe. Placement of any material including boulders at the toe of the bluff or on the beach requires a Coastal Development Permit.

__ Open the drain inlet grate located at the western end of the Eleventh Avenue pathway/drainageway prior to each rainstorm and install the specially designed barrier with hazard.

__ Ensure stability of protective armor stones and gabion-rock bedding at Ocean Ave outfall.

Beach Bluff Pathway

Goal: Provide for safe and visually pleasing pedestrian travel along the City's shoreline bluff including interconnections to the beach access stairways, sand ramps, and disabled-access Pathway ramps.

Inspection and Maintenance Issues:

Pathway Safety:

__ Regularly clean loose gravels from all hard surfaces, including stairways, landings, and patios.

__ Repair localized erosion (ruts, rills, gullies, and depressions) in decomposed granite surface using approved DG formula described in Section 3. *NOTE: When conditions warrant, schedule a complete resurfacing of the Pathway.

__ Keep interfaces with rock curbs, patios, stairway landings, trash enclosures, manhole covers, irrigation system components, and Pathway access ramps smooth and even.

__ Maintain pitch or gradient of the decomposed granite surface to facilitate drainage and prevent ponding of water.

__ Clear Pathway of any vegetation or other obstructions that impede safe passage.

Landscape

Goal: Maintain an aesthetically pleasing landscape that includes healthy plants and associated elements, which control erosion, define pedestrian travel routes, and complement rather than disrupt coastal viewsheds.

Inspection and Maintenance Issues:

Landscape Design Plan:

__ Review the approved landscape plan, its design features and intended purposes with the City's shoreline maintenance staff.

__ Update and document changes to the landscape plan on a regular basis. The landscape palette shall include only native, non-invasive and drought-tolerant plants. *NOTES: Changes to the number or location of boulders, benches, signs or guardrails requires a Coastal Development Permit. Changes to the number or location of plants do not require a Coastal Development Permit as long as species on the approved plant palette are used. Maintain documentation of the Pathway and landscape design including number, species and locations of all plants and all boulders, guardrails, benches and signs. Periodically review the design with the Forest and Beach Commission.

__ Remove invasive and non-native plant species and replant with appropriate non-invasive native plants where new plants are (1) from the approved SMP Table 2 plant list forth areas inland of the sandy beach, (2) dune species endemic to the Carmel Beach area for areas on the Sandy beach, and (3) riparian and wetland species native to Pescadero Creek for the Pescadero Canyon mouth area.

Tree Trimming and Shrub Pruning:

__ Schedule trimming of Monterey cypress trees using professional standards that will promote healthy growth and prevent structural damage from wind storms.

__ Trim trees and prune shrubs that encroach on the silhouettes of mature cypress to eliminate conflicts with cypress viewshed.

__ Prune shrubs to promote healthy plant growth and protect coastal viewsheds.

__ Remove acacia thickets to protect coastal views, deter transient activities, and prevent encroachment onto other plant habitats. *NOTE: Monterey pines and native plant communities in the North Dunes.

Shrubs and Groundcovers:

__ Plantings should conform to the approved Pathway Landscape Design Plan.

__ Replacements should be planted near mature specimens to avoid large-scale die-offs when plants reach the end of their life span. *NOTE: This work can be scheduled in increments.

Aggressive, Invasive Exotic Plants:

__ Eliminate ice plant or acacia on or near bluff top; replace with species from the approved plant list that complement landscape.

Irrigation System:

__ Assess effectiveness of irrigation system components (including water storage tanks, pumps, spray heads and bubblers).

__ Adjust, repair or replace broken or ineffective components immediately.

__ Supply adequate water to maintain healthy growth of landscape plants.

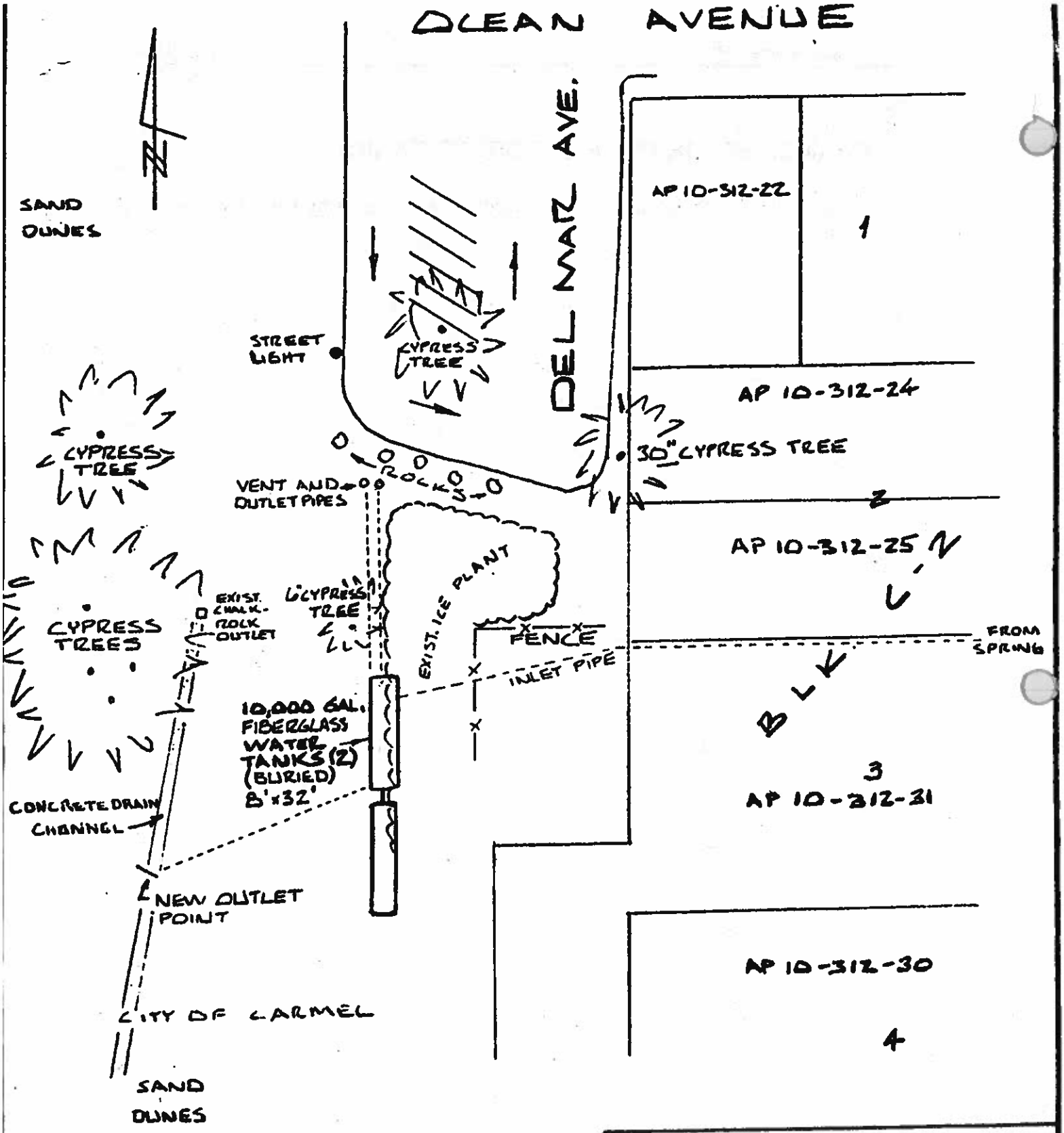
__ Expand the irrigation system only if existing system will not be compromised.

9.5 CARMEL BEACH PROFILE MONITORING PROGRAM

A series of benchmarks and beach profile transects have been established to monitor changes along the Carmel Shoreline (see Figures below). Note: *If you are viewing this document in electronic format the figures will not appear. A complete set of these figures is available from the Carmel Department of Community Planning and Building.*

9.6 CARMEL BEACH WATER STORAGE TANKS

A map illustrating the location of the underground water tanks by Del Mar Avenue is shown below.



NEILL ENGINEERS, Inc.
Consulting Engineers
CARMEL MONTEREY

PLAT SHOWING
UNDERGROUND WATER TANKS
DEL MAR AVENUE
CARMEL-BY-THE-SEA, CALIFORNIA

SCALE: 1"=40'
DATE DEC. '84
W.O. 6555

Clayton B. Neill Jr.
Registered Civil Engineer 12605

9.7 REFERENCES CITED

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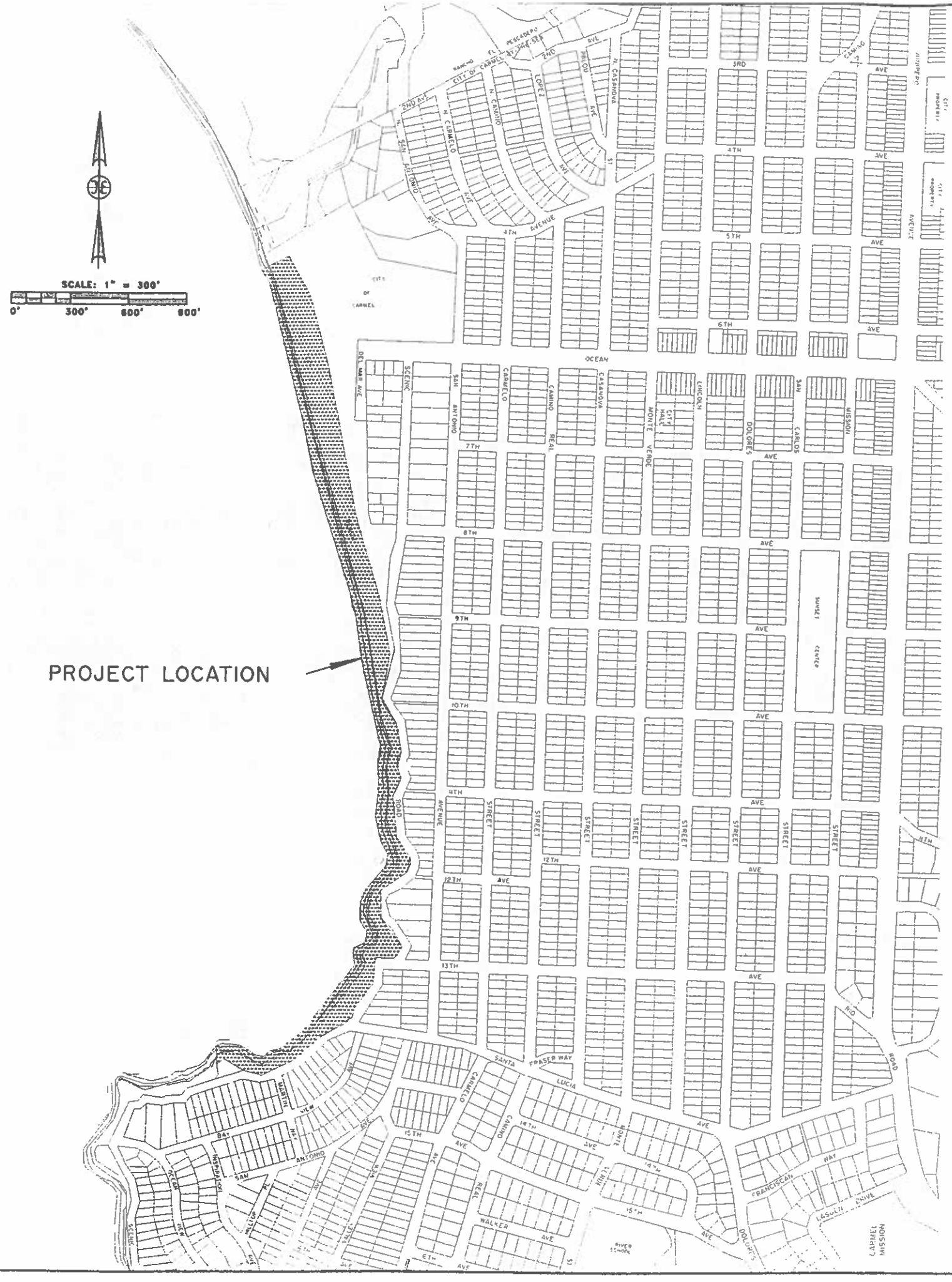
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0'
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PROJECT LOCATION
OCEAN
SCENIC
CARMELO
CASANOVA
LINCOLN
DOLORES
CARLOS
MISSION
MONTE VERDE
CITY HALL
CAMINO REAL
SAN ANTONIO
SAN CARLOS
SAN ANTONIO
SAN CARLOS
DEL MAR AVE
CITY OF CARMEL
N. CARMELO
N. CASANOVA
OCEAN AVENUE
7TH AVENUE
SAN ANTONIO
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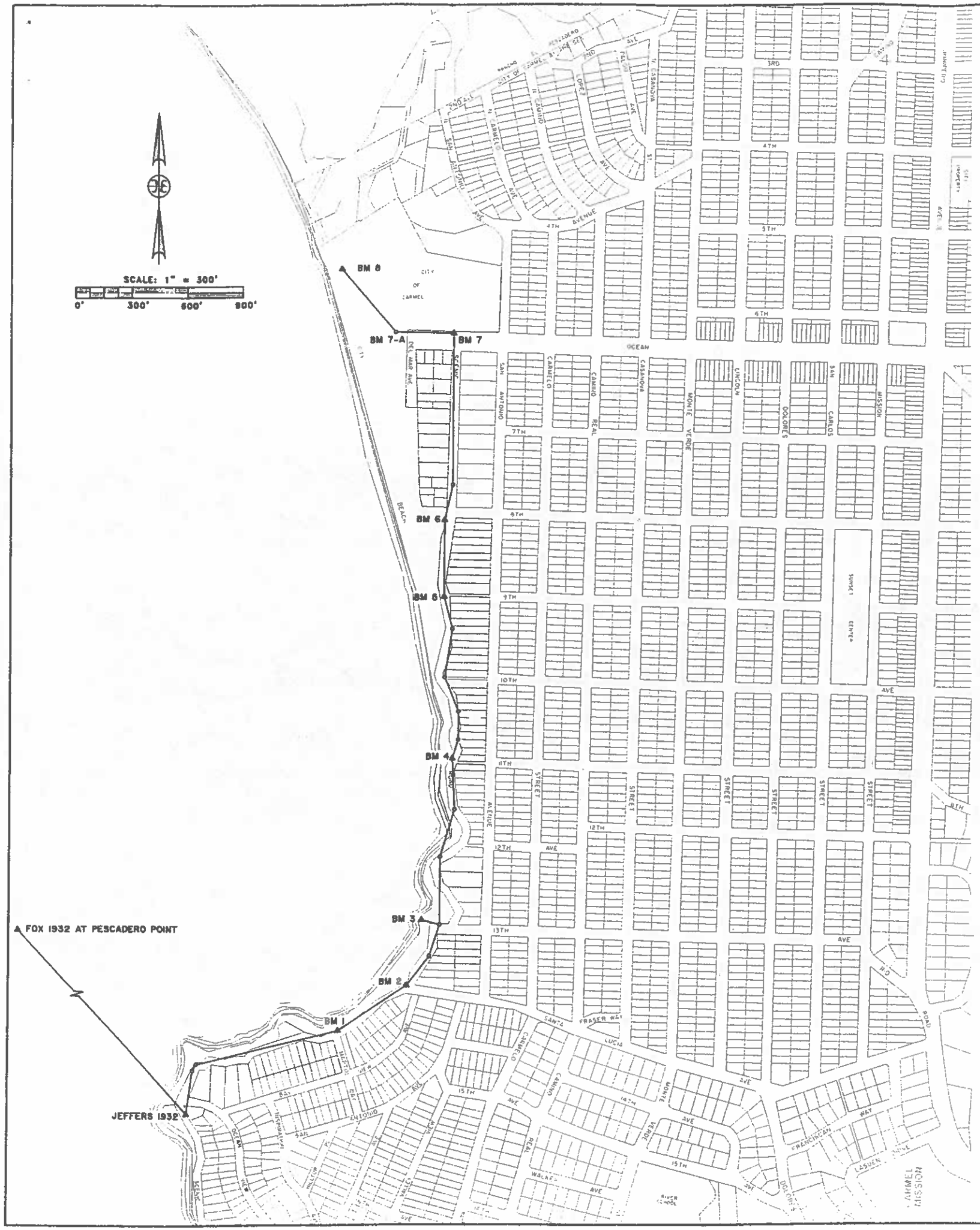


BENCHMARK DESCRIPTIONS:

JEFFERS 1932	USC&GS BRASS DISC IN CONCRETE MONUMENT ON EAST SIDE OF SCENIC ROAD 80 FEET SOUTH OF OCEAN VIEW AVENUE.
FOX 1932	USC&GS BRASS DISC IN ROCK OUTCROPPING ON PESCADERO POINT
BM 1	BRASS DISC IN WHEELCHAIR RAMP WEST SIDE OF SCENIC ROAD AT MARTIN WAY
BM 2	BRASS DISC IN WHEELCHAIR RAMP WEST SIDE OF SCENIC ROAD AT SANTA LUCIA AVENUE
BM 3	BRASS DISC IN STONE BENCH ON POINT WEST OF SCENIC ROAD AT 13th AVENUE
BM 4	BRASS DISC IN CURB WEST SIDE OF SCENIC ROAD ABOVE STAIRS AT 11th AVENUE
BM 5	BRASS DISC IN CURB WEST SIDE OF SCENIC ROAD ABOVE STAIRS AT 9th AVENUE
BM 6	BRASS DISC IN SIDEWALK WEST SIDE OF SCENIC ROAD AT 6th AVENUE
BM 7	BRASS DISC IN SIDEWALK NORTH SIDE OF OCEAN AVENUE AT SCENIC ROAD
BM 7-A	BRASS NAIL AND WASHER IN WALL AT END OF OCEAN AVENUE
BM 8	BRASS DISC IN TOP OF STORMDRAIN ENDWALL AT NORTH END OF BEACH

BENCHMARK	NORTH	EAST	ELEVATION
JEFFERS 1932	463711.93	1136797.04	31.18
FOX 1932	460366.66	1132958.18	40.87
BM 1	464151.23	1139608.81	26.10
BM 2	464387.56	1139973.96	27.28
BM 3	464736.29	1140066.70	26.62
BM 4	465609.94	1140226.36	37.61
BM 5	466467.72	1140191.54	35.03
BM 6	466905.70	1140196.38	41.38
BM 7	467916.15	1140265.60	65.42
BM 7-A	467923.38	1139949.51	48.61
BM 8	468271.01	1139665.75	23.34

HORIZONTAL POSITIONS SHOWN ABOVE ARE BASED ON THE NORTH AMERICAN DATUM OF 1927. ELEVATIONS ARE BASED ON NATIONAL GEODETIC VERTICAL DATUM OF 1929. CROSS SECTION MEASUREMENTS WERE TAKEN JULY 1 THROUGH JULY 3, 2002.

NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

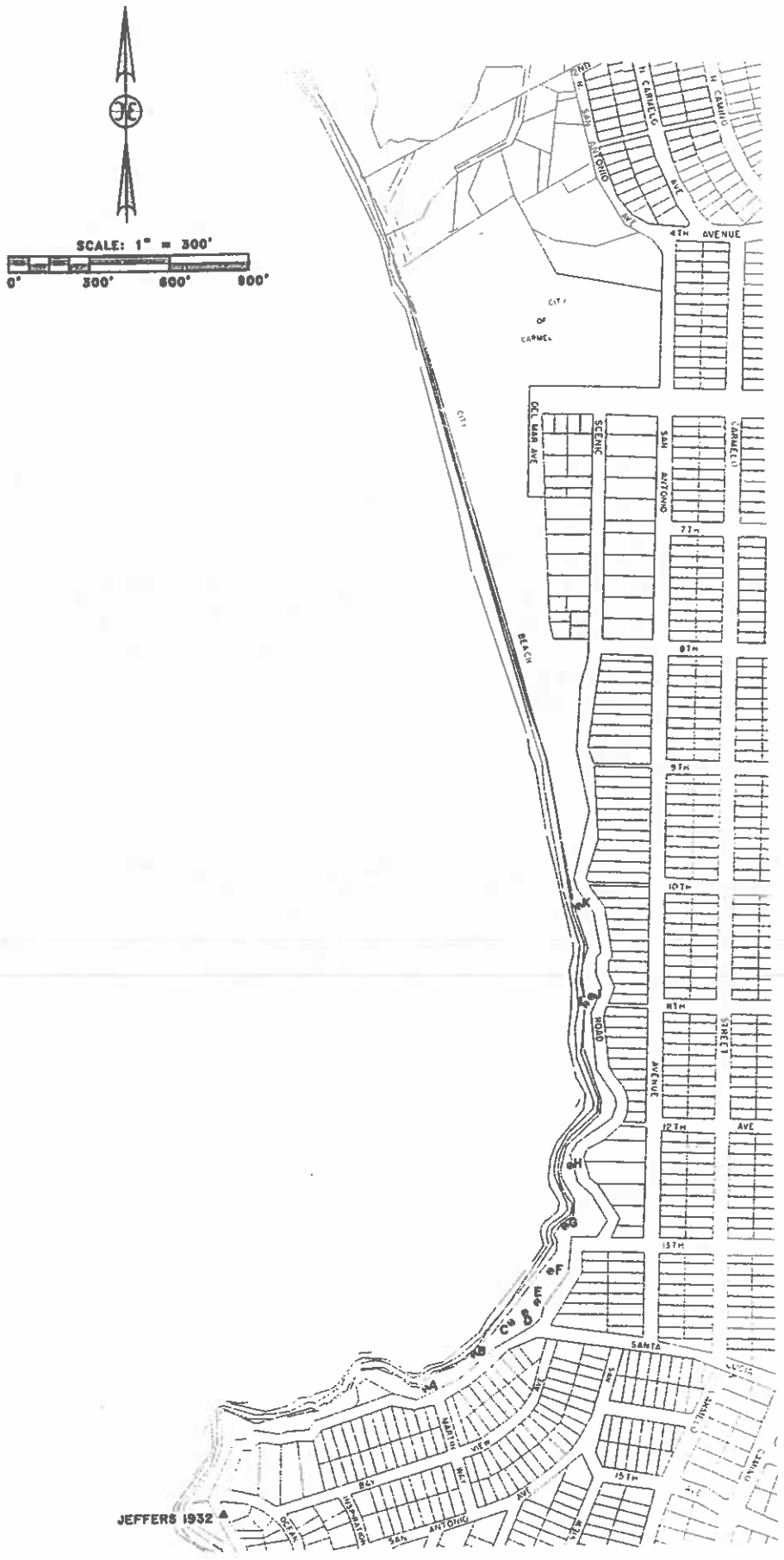
KEY MAP AND CONTROL DIAGRAM

CARMEL BEACH

BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

W.O. 7995 JULY 2002 SCALE: 1" = 300'



POINT DESCRIPTIONS:

A	BRASS NAIL AND WASHER IN TOP OF OLD WALL NORTHWEST OF MARTIN WAY, 3 FEET SOUTH OF MULTI-PRONG CYPRESS TREE.
B	BRASS NAIL AND WASHER IN TOP OF NEW WALL NORTHEAST OF MARTIN WAY, SOUTH OF SANTA LUCIA AVENUE.
C	BRASS NAIL AND WASHER IN TOP OF OLD WALL ABOVE CULVERT, SOUTH OF SANTA LUCIA AVENUE.
D	BRASS NAIL AND WASHER IN TOP OF NORTH END OF NEW WALL NEAR SANTA LUCIA AVENUE.
E	BRASS NAIL AND WASHER IN CONCRETE AT BOTTOM OF NORTH SIDE OF STAIRS, NORTH OF SANTA LUCIA AVENUE.
F	BRASS NAIL AND WASHER IN TOP OF NEW WALL AT BEND, BETWEEN SANTA LUCIA AVENUE AND 13th AVENUE.
G	BRASS NAIL AND WASHER IN NORTHWEST EDGE OF BOTTOM LANDING AT 13th AVENUE STAIRWAY.
H	BRASS NAIL AND WASHER ON FOOTING LEDGE 50 FEET SOUTH OF NORTH END OF WALL NEAR 12th AVENUE.
I	CHISELED 'X' ON TOP OF HIGHEST ROCK ABOVE PIPE OUTLET, APPROXIMATELY 10 FEET BELOW MANHOLE AT 11th AVENUE.
J	BRASS NAIL AND WASHER IN TOP OF ROCK WATER FAUCET ENCLOSURE AT 11th AVENUE STAIRWAY.
K	BRASS NAIL AND WASHER IN CORNER OF STONE WALL AT LOWER LANDING OF 10th AVENUE STAIRWAY.

POINT	NORTH	EAST	ELEVATION
A	454160.53	1139554.96	16.03
B	454283.66	1139736.18	15.89
C	454400.35	1139873.49	20.98
D	454459.44	1139903.26	18.45
E	454462.97	1139961.33	10.10
F	454590.80	1140021.14	17.72
G	454793.37	1140043.69	8.06
H	454984.64	1140100.93	15.46
I	455591.16	1140171.90	21.39
J	455620.11	1140191.18	27.53
K	455961.97	1140152.32	19.29

HORIZONTAL POSITIONS SHOWN ABOVE ARE BASED ON THE NORTH AMERICAN DATUM OF 1927. ELEVATIONS ARE BASED ON NATIONAL GEODETIC VERTICAL DATUM OF 1929.

NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

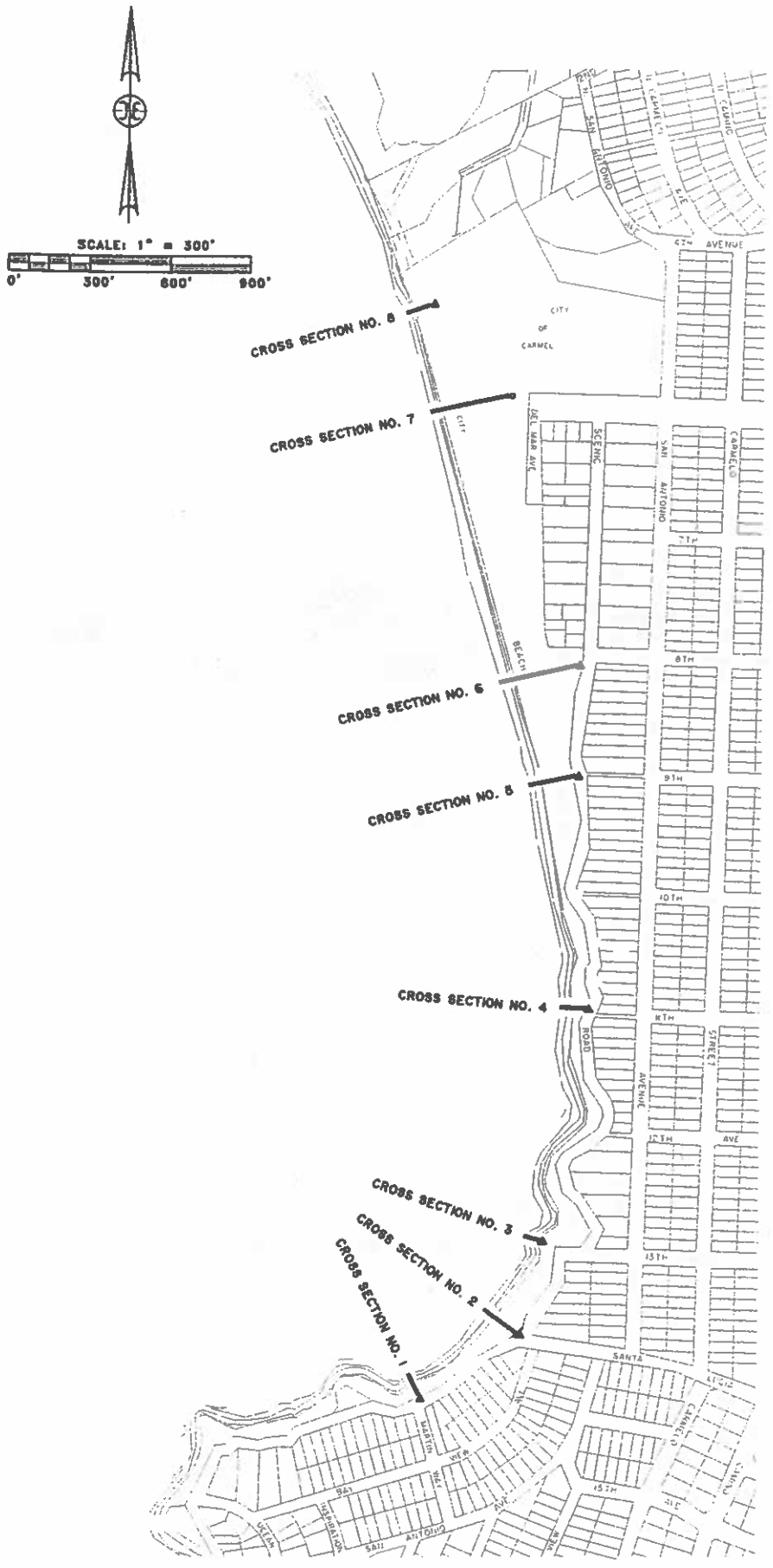
BEACH MONITORING POINTS

CARMEL BEACH

BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

W.O. 7995 JULY 2002 SCALE: 1" = 300'



EACH CROSS SECTION ORIGINATES AT A CORRESPONDING BENCHMARK, DESCRIBED BELOW, AND EXTENDS PERPENDICULAR TO THE SHORELINE, ENDING AT WATERLINE.

BENCHMARK DESCRIPTIONS:

JEFFERS 1932	USC&GS BRASS DISC IN CONCRETE MONUMENT ON EAST SIDE OF SCENIC ROAD 60 FEET SOUTH OF OCEAN VIEW AVENUE.
FOX 1932	USC&GS BRASS DISC IN ROCK OUTCROPPING ON PESCADERO POINT
BM 1	BRASS DISC IN WHEELCHAIR RAMP WEST SIDE OF SCENIC ROAD AT MARTIN WAY
BM 2	BRASS DISC IN WHEELCHAIR RAMP WEST SIDE OF SCENIC ROAD AT SANTA LUCIA AVENUE
BM 3	BRASS DISC IN STONE BENCH ON POINT WEST OF SCENIC ROAD AT 13th AVENUE
BM 4	BRASS DISC IN CURB WEST SIDE OF SCENIC ROAD ABOVE STAIRS AT 11th AVENUE
BM 5	BRASS DISC IN CURB WEST SIDE OF SCENIC ROAD ABOVE STAIRS AT 9th AVENUE
BM 6	BRASS DISC IN SIDEWALK WEST SIDE OF SCENIC ROAD AT 8th AVENUE
BM 7	BRASS DISC IN SIDEWALK NORTH SIDE OF OCEAN AVENUE AT SCENIC ROAD
BM 7-A	BRASS NAIL AND WASHER IN WALL AT END OF OCEAN AVENUE
BM 8	BRASS DISC IN TOP OF STORMDRAIN ENDWALL AT NORTH END OF BEACH

BENCHMARK	NORTH	EAST	ELEVATION
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NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

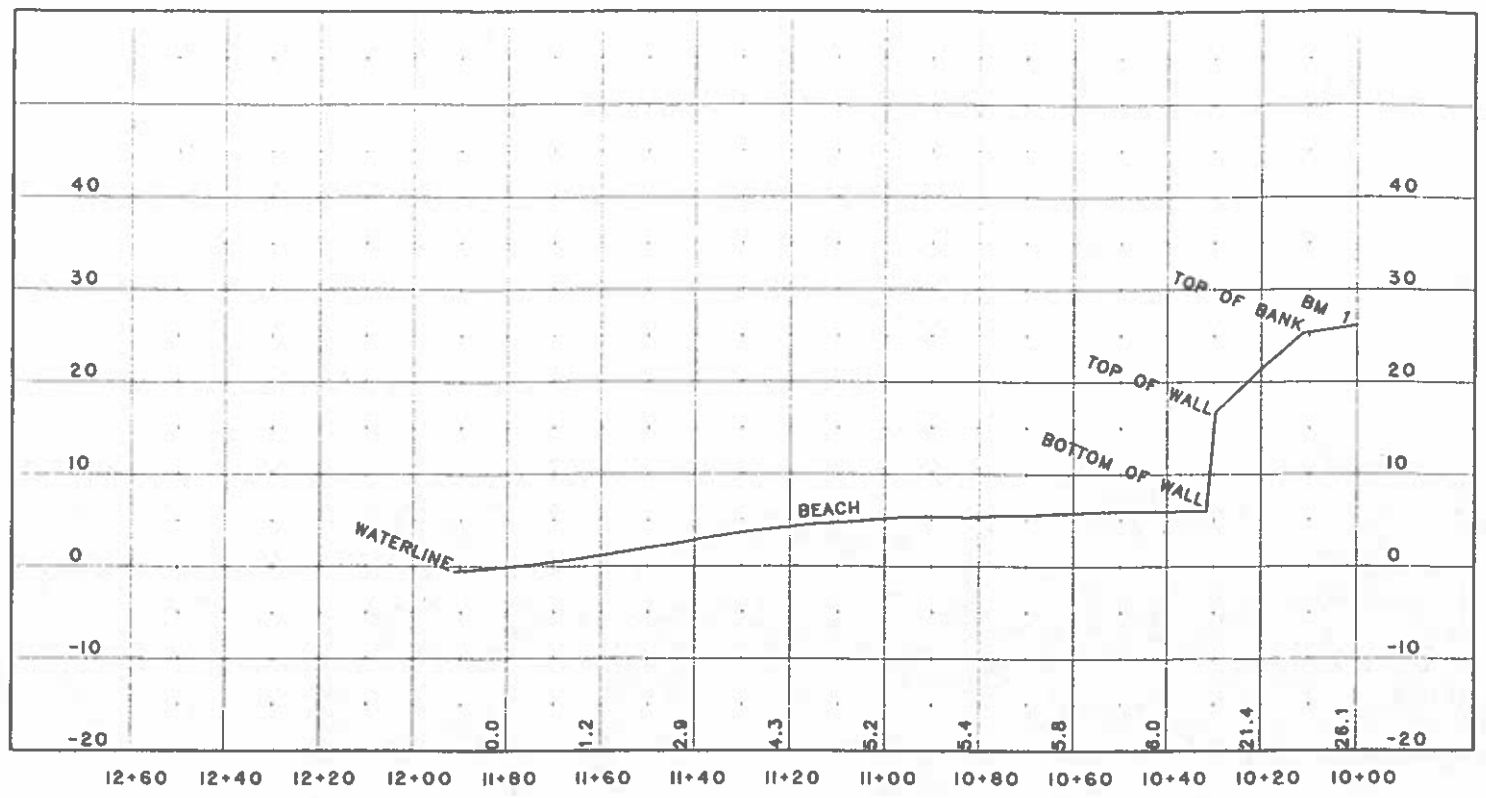
BEACH CROSS-SECTIONS

CARMEL BEACH

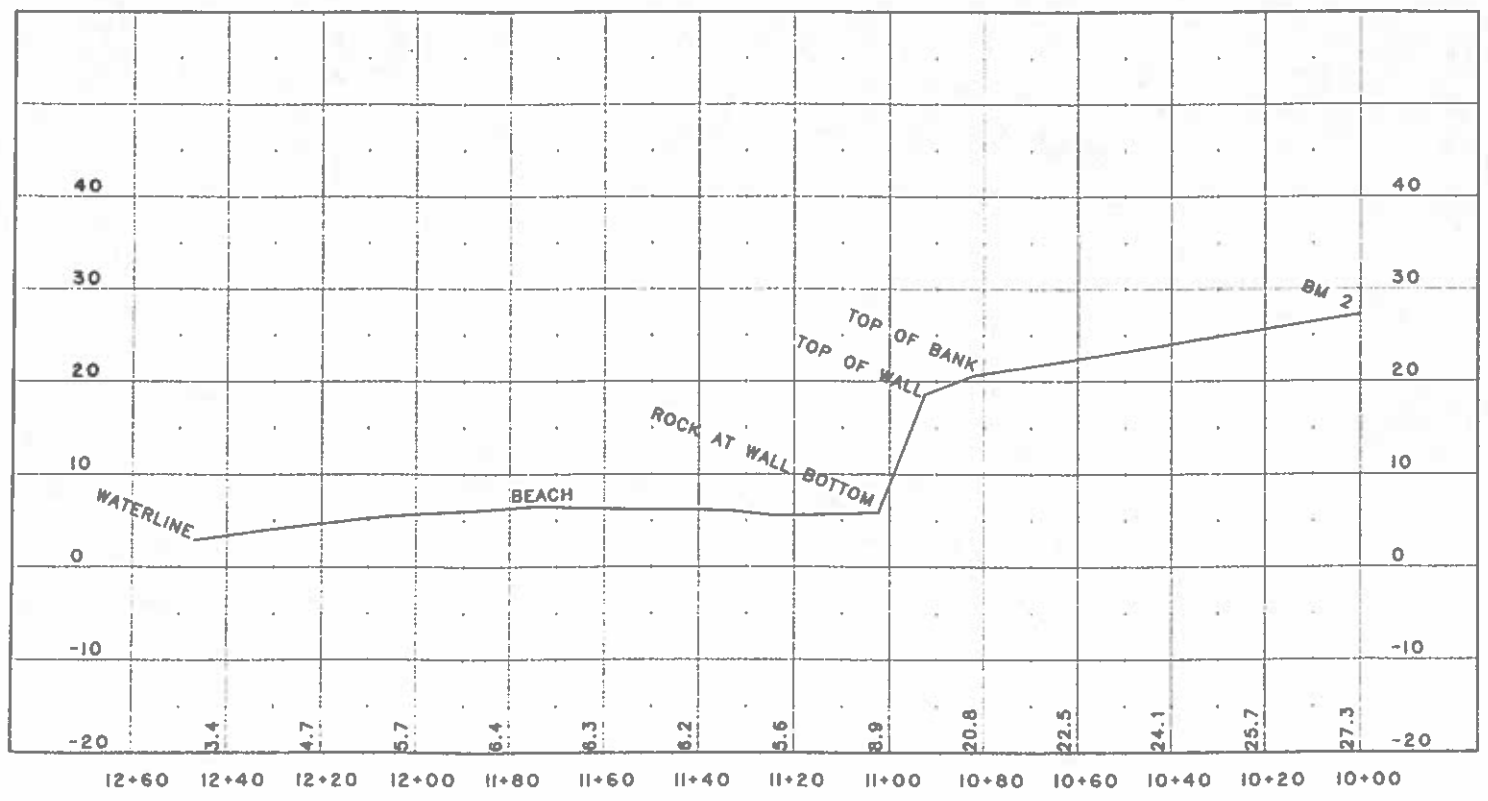
BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

W.O. 7995 JULY 2002 SCALE: 1" = 300'



CROSS SECTION 1
NEAR MARTIN WAY



CROSS SECTION 2
NEAR SANTA LUCIA AVENUE

NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

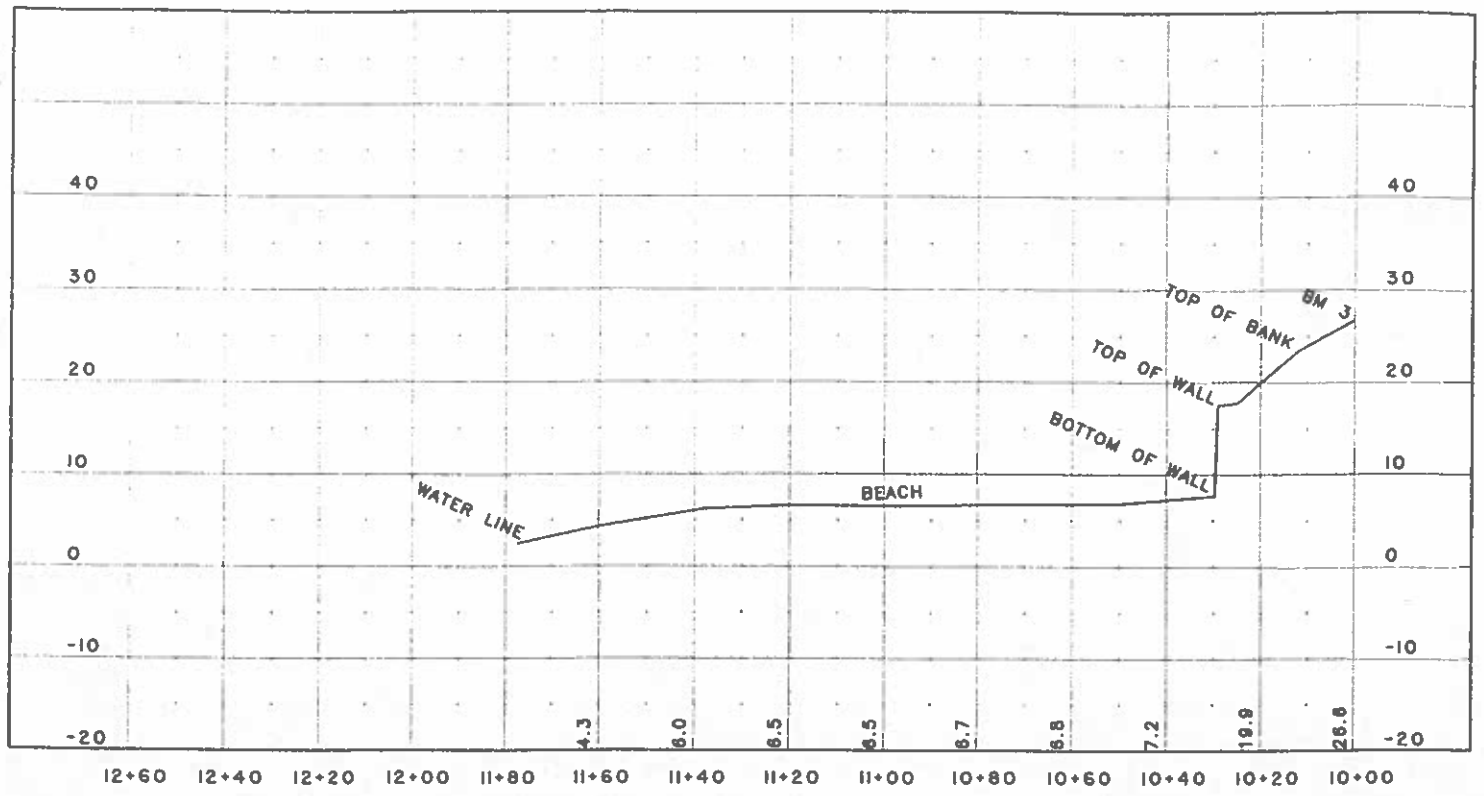
BEACH CROSS-SECTIONS

CARMEL BEACH

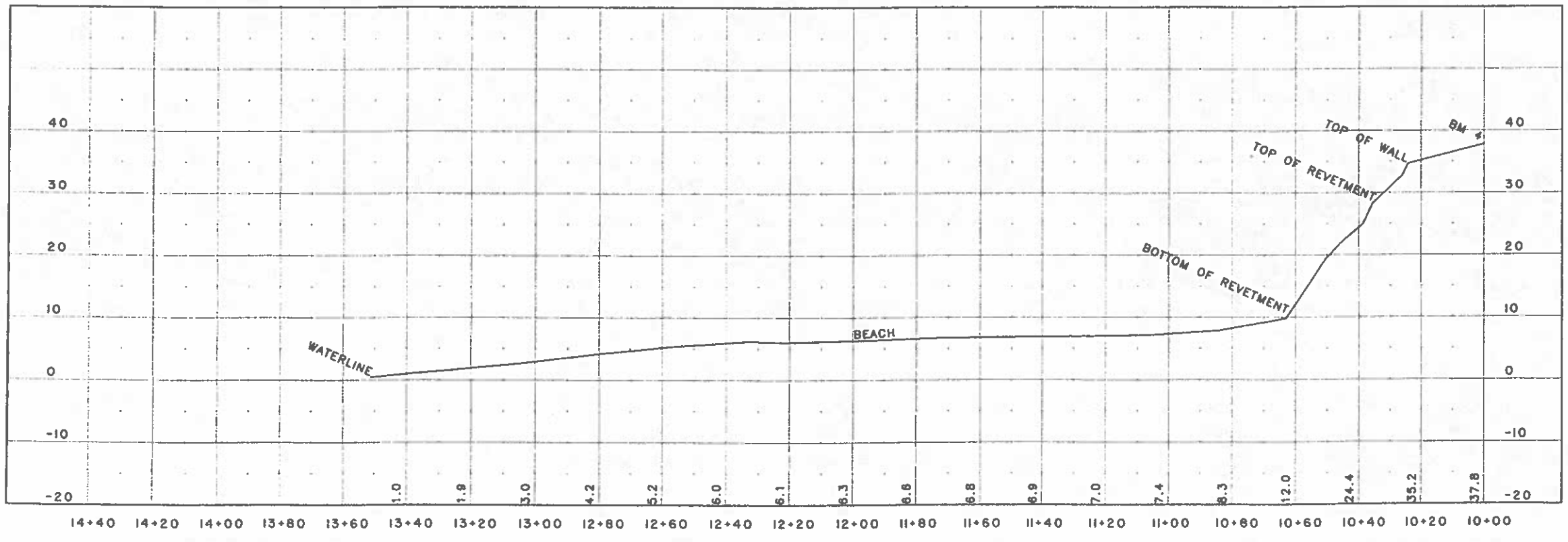
BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

W.O. 7995 JULY 2002 SCALE: 1" = 20'H
1" = 10'V



CROSS SECTION 3
NEAR 13th AVENUE



CROSS SECTION 4
NEAR 11th AVENUE

NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

BEACH CROSS-SECTIONS

CARMEL BEACH

BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

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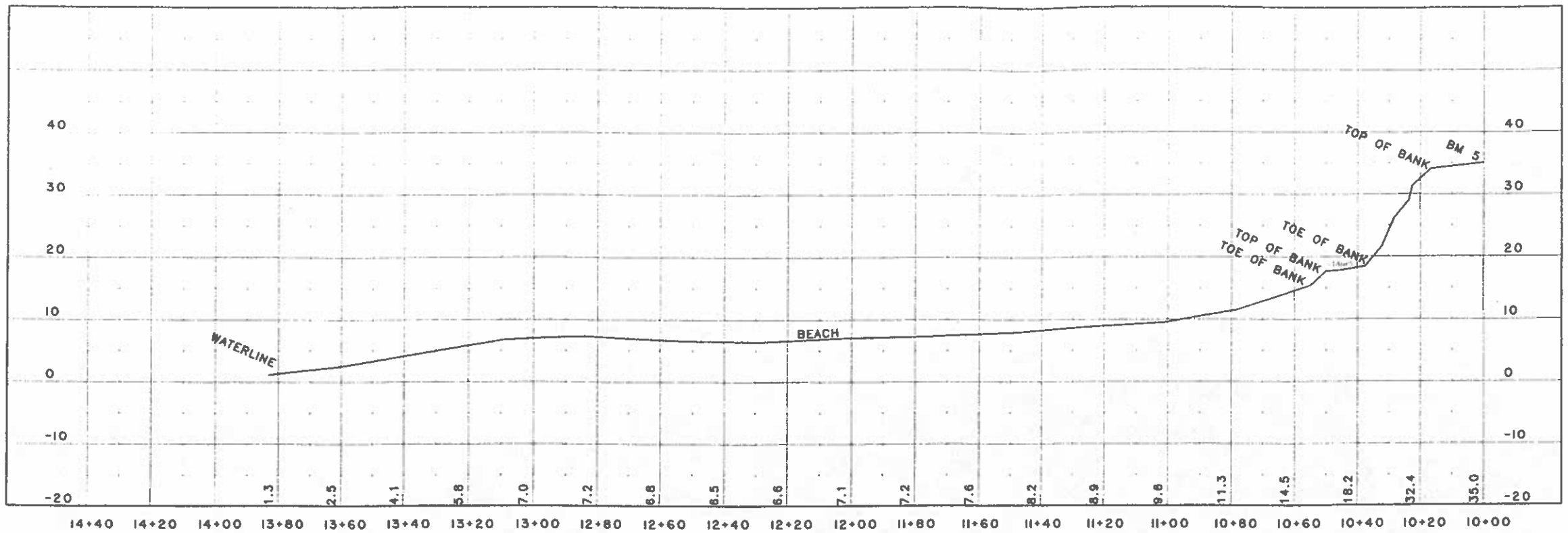
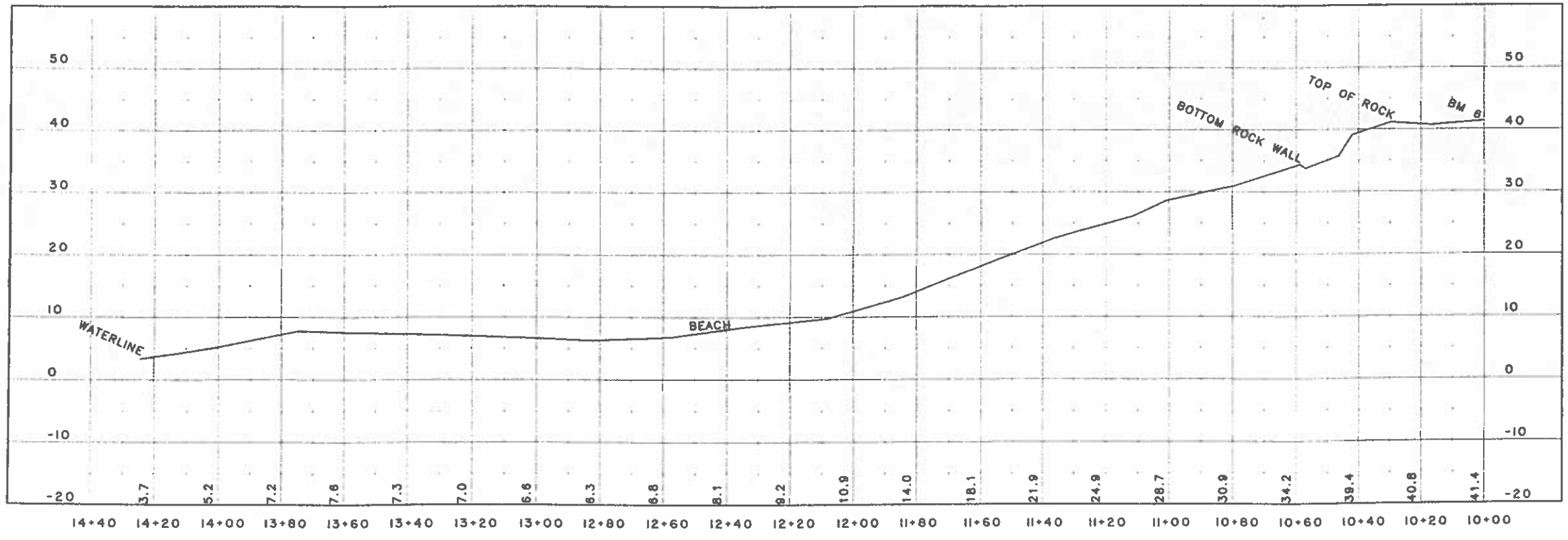


CROSS SECTION 5
NEAR 9th AVENUE



CROSS SECTION 6
NEAR 8th AVENUE

NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

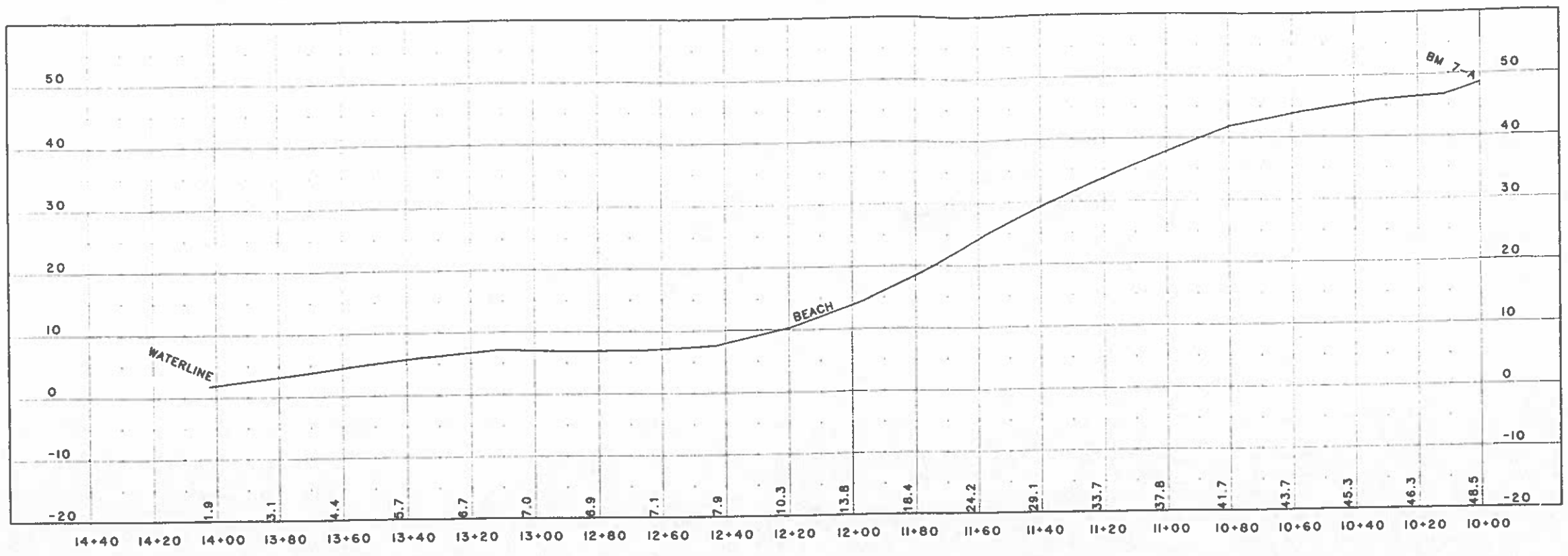
BEACH CROSS-SECTIONS

CARMEL BEACH

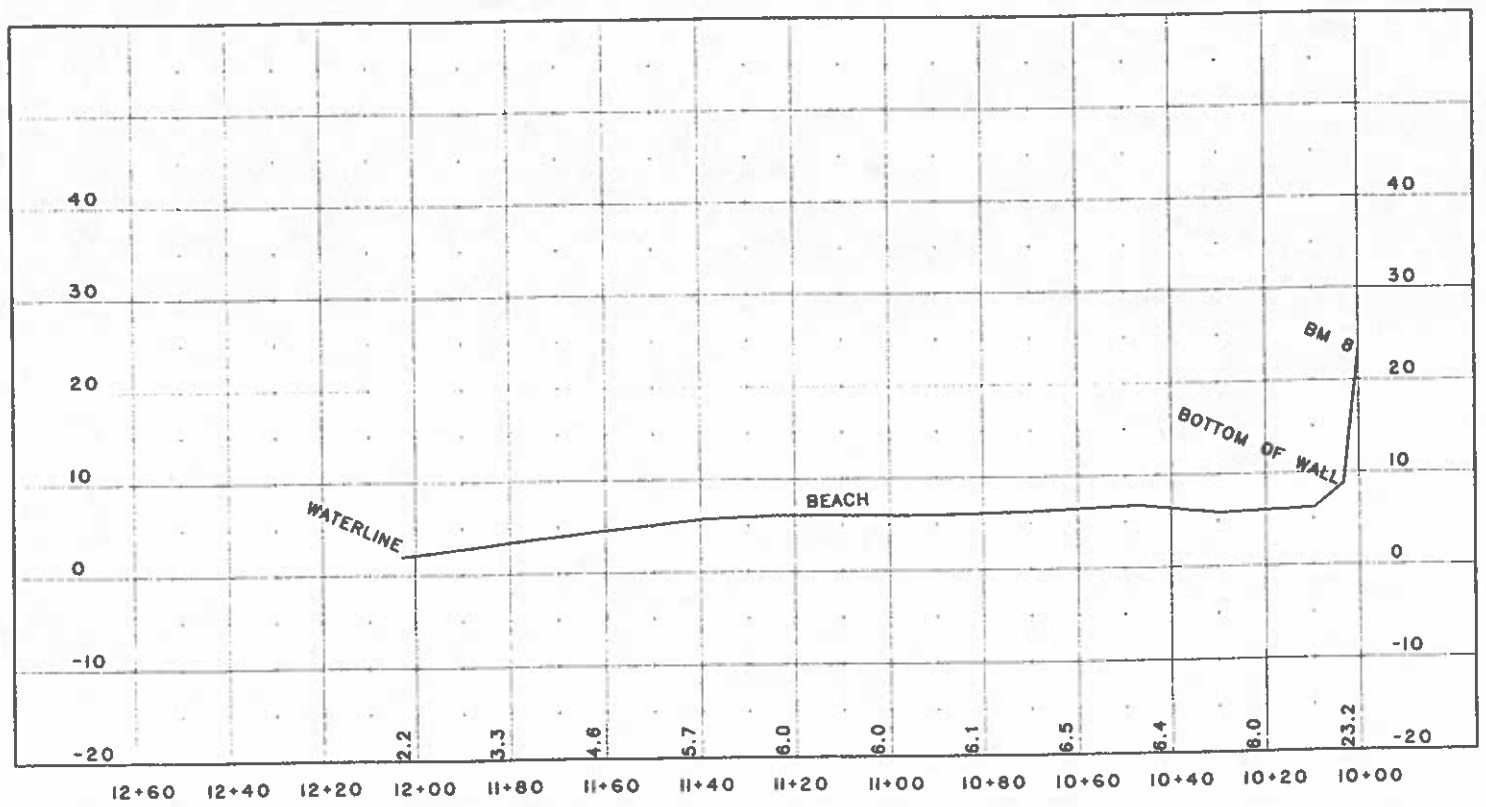
BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

W.O. 7995 JULY 2002 SCALE: 1" = 20'H
1" = 10'V



CROSS SECTION 7
NEAR OCEAN AVENUE



CROSS SECTION 8
NEAR STORM DRAIN AT NORTH END BEACH

NEILL ENGINEERS CORP. CARMEL, CALIFORNIA

BEACH CROSS-SECTIONS

CARMEL BEACH

BEACH AREA MONITORING PROGRAM

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA

W.O. 7995 JULY 2002 SCALE: 1" = 20'H
1" = 10'V

From: **Scott Lonergan** <[redacted]>
Date: Thu, Aug 13, 2026 at 12:09 PM
Subject: August 2026 Revetment Condition Input
To: <nromero@ci.carmel.ca.us>, <cityclerk@ci.carmel.ca.us>
Cc: Greg D'Ambrosio [redacted]

Hi Nova - Could you forward this to the Planning and F&B Commissioners please?

Thank you,

Scott

Hello Planning Commissioners and Forest & Beach Commissioners:

An incremental revetment condition assessment to HKA's is attached that may be helpful as part of Carmel's ongoing monitoring program.

If you would like me to make a 3-minute comment or otherwise provide a brief presentation of this to answer any questions you may have, please let me know.

Thank you.

Scott
[redacted]

Carmel Revetment Condition Assessment
2026 Update

Greg D'Ambrisio *(principal in the mid-1980's revetment intallation)*
Scott Lonergan *(former Carmel Climate Committee member)*

Carmel-by-the-Sea, 13-August-2026

Basis for 2026 Update

- *Part of a **long-term monitoring requirement***
- ***Input from a principal** of the mid-1980's revetment installation (Greg D'Ambrosio)*
- ***Significant sand scour** exposed revetment beyond that visible during HKA's 2023 assessment **

***** ***70% of Carmel's revetment** (R4, R5, & R6) was flagged by HKA to **"monitor when exposed"** due to insufficient visibility during their 2023 assessment. This 2026 update addresses that gap.*

12th Ave with significant sand scour



2026 Revetment Update Summary

Keyway in 12th Ave cove revetment



- *All revetment installed in the mid-1980's, over 90% of the Carmel's total, was **engineered** including placement over filter fabric and toe protection (aka keyways) to anchor into the bedrock.*

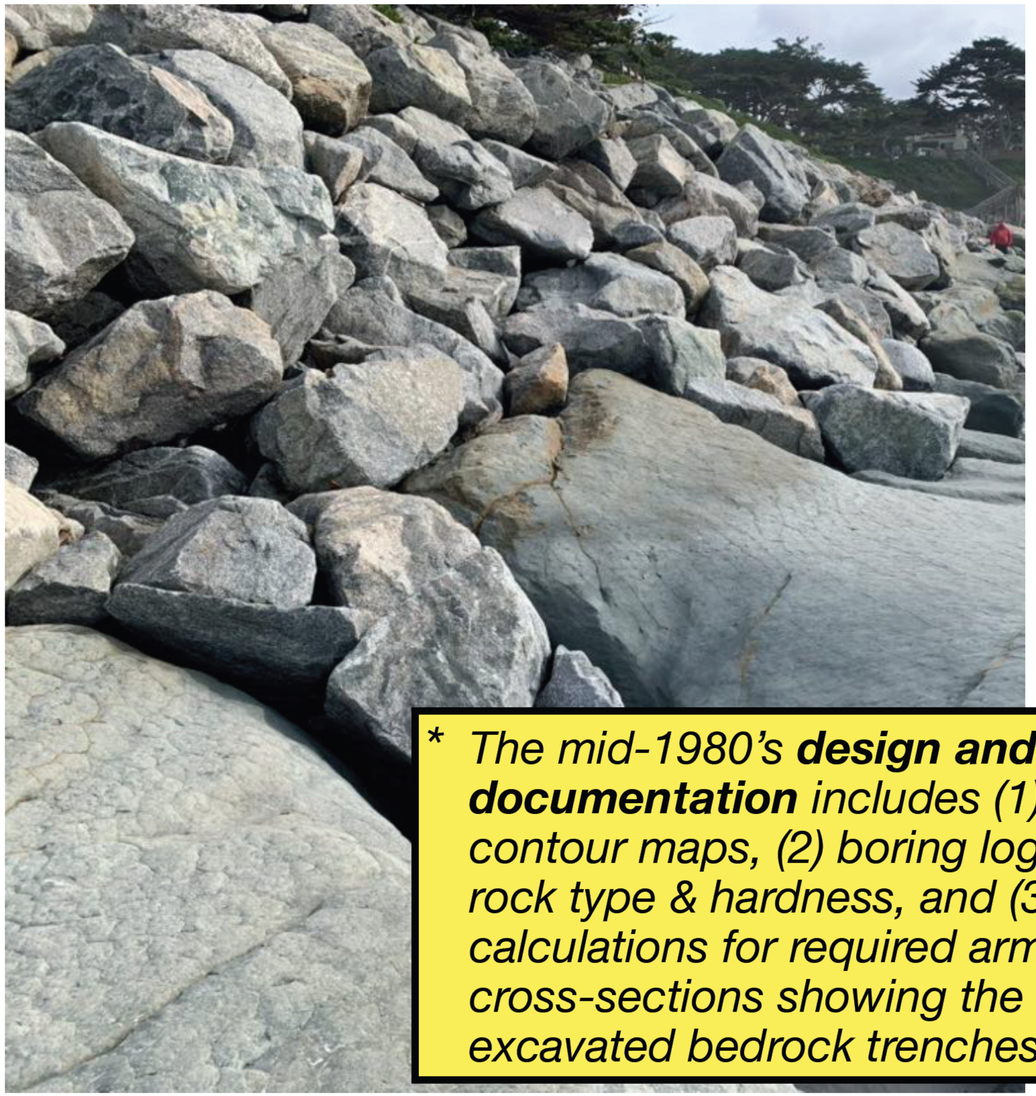
- *Revetment status:*
  - *R1 & R3 HKA condition assessments **need to be revisited***
    - *R1 (Santa Lucia), determined too steep by HKA, was an **intentional design** decision to preserve unique beach sandstone features and appears stable*
    - *R3 (12th Ave Cove) with atypical stacking has not moved in over 50 years.*
  - *R2 (13th) needs repair **as concluded by HKA***
  - *R4, R6, and R5 not fully assessed by HKA, **appear stable** following assessment with the benefit of significant sand scour*

- *Independent of existing revetment condition, **overtopping** will occur in the future if no other action taken*

*3% **(50 linear feet)** of Carmel's revetment needs repair*

Mid-1980's Revetment (92% of total) was Engineered*

Revetment placed over filter fabric with toe protection (aka keyways) used to anchor



Rock staged between 10th and 12th Avenue for the mid-1980's revetment installation



* *The mid-1980's **design and engineering documentation** includes (1) bedrock profile & contour maps, (2) boring logs of bedrock detailing rock type & hardness, and (3) toe keyway stability calculations for required armor stone weight and cross-sections showing the width & depth of the excavated bedrock trenches.*

Revetment Condition Summary Table

Key:
Primary 2026 Updates

	HKA 2023 Assessment			2026 Update	
Revetment	**Linear Feet**	**Repair Needed?**	**Issue/Notes**	**2026 Update**	**Repair Feet**
R1 (Santa Lucia)	**118**	Yes, 1/3	**Too steep**	**Revisit - is repair needed?** (steepness was design decision & remains stable)	**?**
R2 (13th)	**50**	Yes	**Undersized stone & failing**	**No change to HKA assessment**	**50**
R3 (11th - 12th)	**406**	Yes, 1/4	**Poorly stacked**	**Revisit - is repair needed?** (Despite atypical stack, has not moved in over 50 years)	**?**
R4 (10th - 11th)	**336**	?	Undersized stone; **monitor when exposed**	**No undersized stone; appears stable** ('undersized' stone is debris, not part of revetment)	**0**
R5 (8th - 10th)	**815**	?	Unable to access; **monitor when exposed**	**Revetment appears stable** (confirm stability at repaired 9th Ave stair area)	**0**
R6 (Ocean Ave)	**136**	?	Unable to Access; **monitor when exposed**	**Revetment appears stable**	**0**
Total Revetment	**1,861**				**50**
% of Total	**100%**				**3%**

*HKA was **unable to complete assessment** for 70% of Carmel's revetment due to lack of access / sand scour*

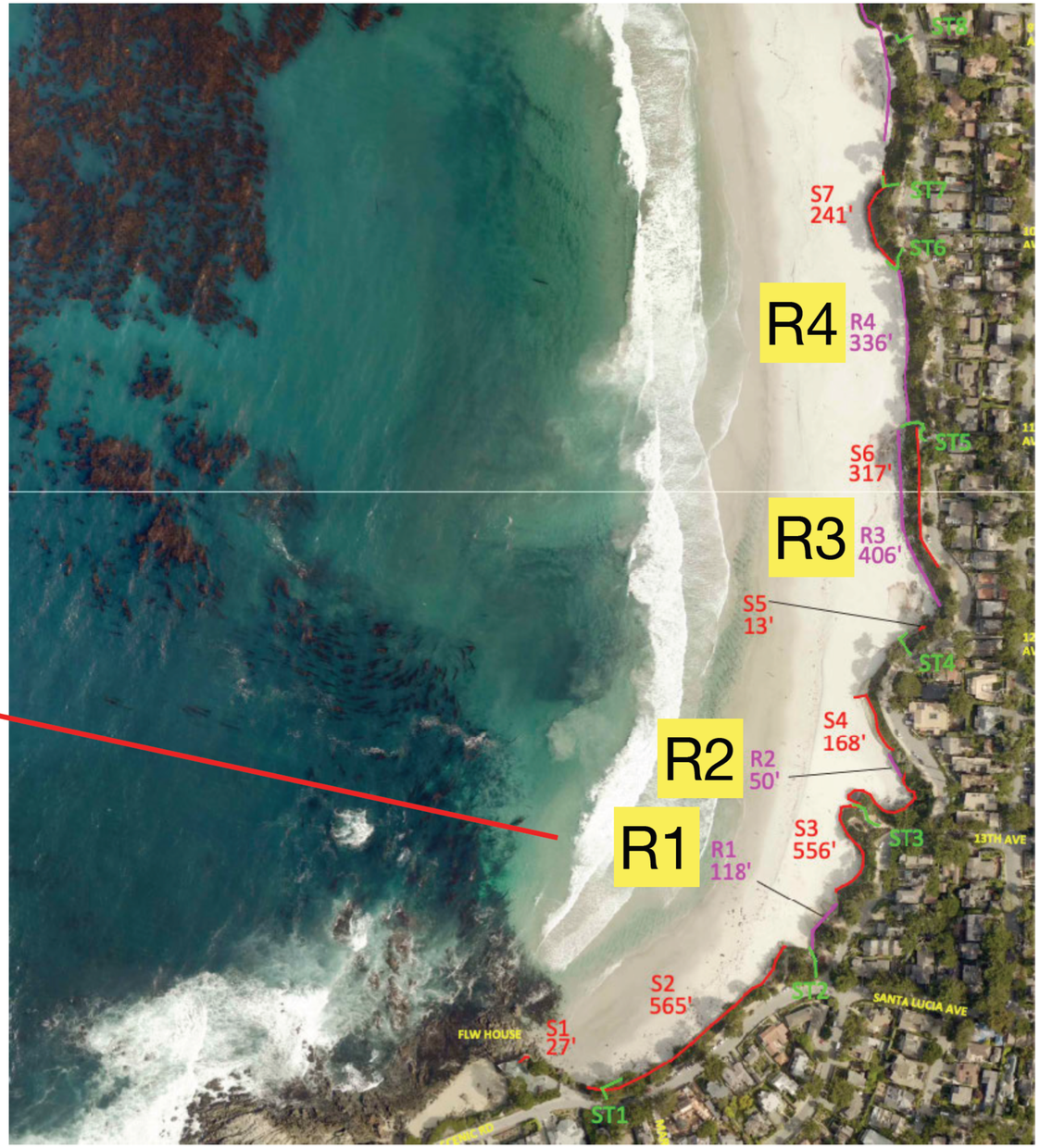
*3% of Carmel's revetment **needs repairs***

2026 Update by Revetment Section R1 to R6

R1 (Santa Lucia)



Carmel Beach - South End



R1 (Santa Lucia)

*R1 assessed as being 'too steep' by HKA. This pitch was a **design decision** using deep keyways to reduce coverage of the unique sandstone*

R1 following significant sand scour



R1 has deep keyways behind sandstone



R1 (Santa Lucia)

Unique sandstone formations that extend into R1 revetment location



R1 (Santa Lucia)

Observation following significant sand scour indicates R1 is stable after over 4 decades — is repair needed?

R1 following significant sand scour



R1 has deep keyways behind sandstone



R1 (Santa Lucia)

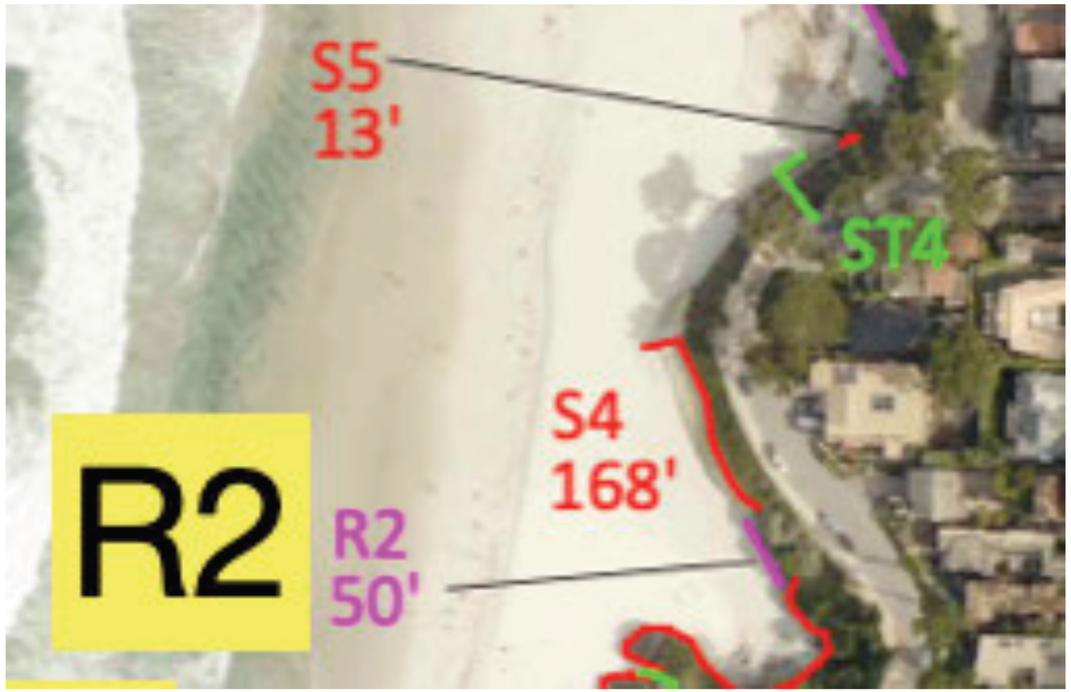
2003



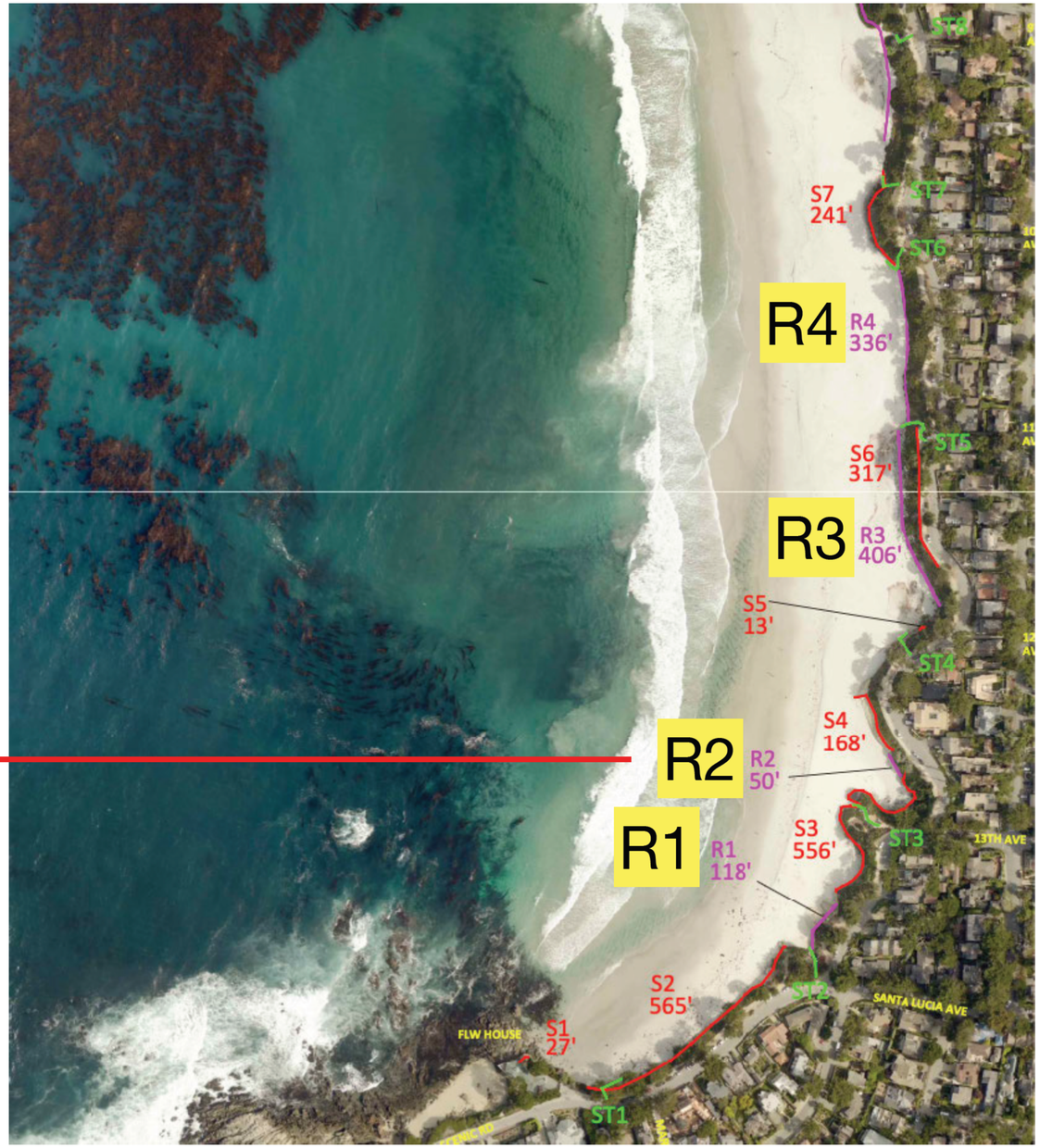
Historically, R1 was seasonally covered with sand through the City's sand redistribution program

Covering revetment with sand is recommended
- Integral Consulting, Final May 2026 Report, p 2-3, 2-4

R2 (13th Ave)



Carmel Beach - South End



R2 (13th Ave)

R2 (constructed in the 1970's) determined to be undersized stone and failing as part of HKA 2023 assessment, and in need of repair as a ***high priority.***

Considerable debris from previously destroyed seawalls and stairs litter the cove.

No change from 2023 HKA report

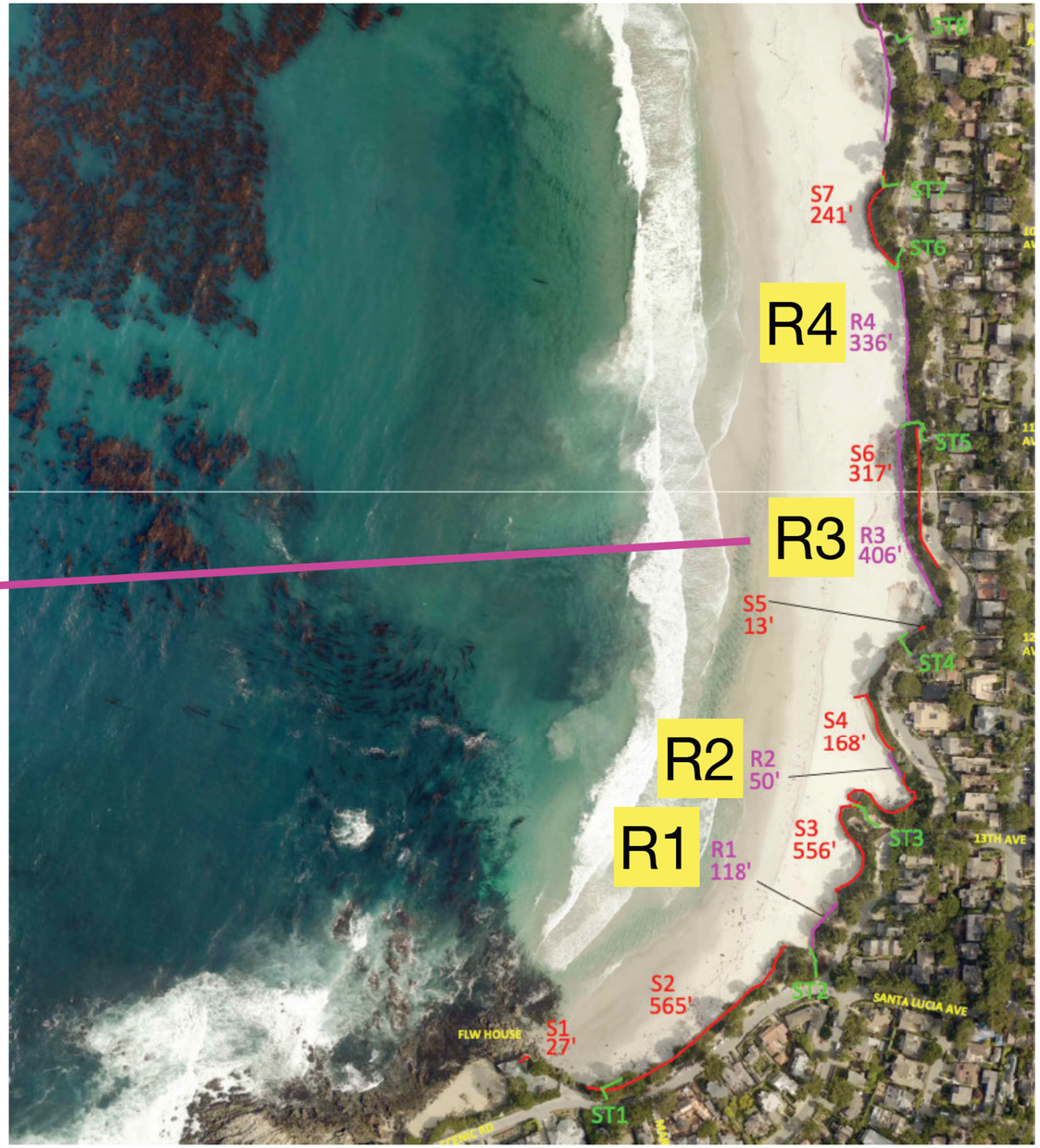
R2 following significant sand scour



R3 (11th - 12th)



Carmel Beach - South End



R3 (South End / 12th Ave Cove)

South end of R3 (constructed in the 1970's) determined to be poorly stacked as part of HKA 2023 assessment, and in need of repair as a medium priority

Installed under the guidance of an engineer to diffuse wave run and overtopping along the sandstone cliff, this revetment has not moved in over 50 years.

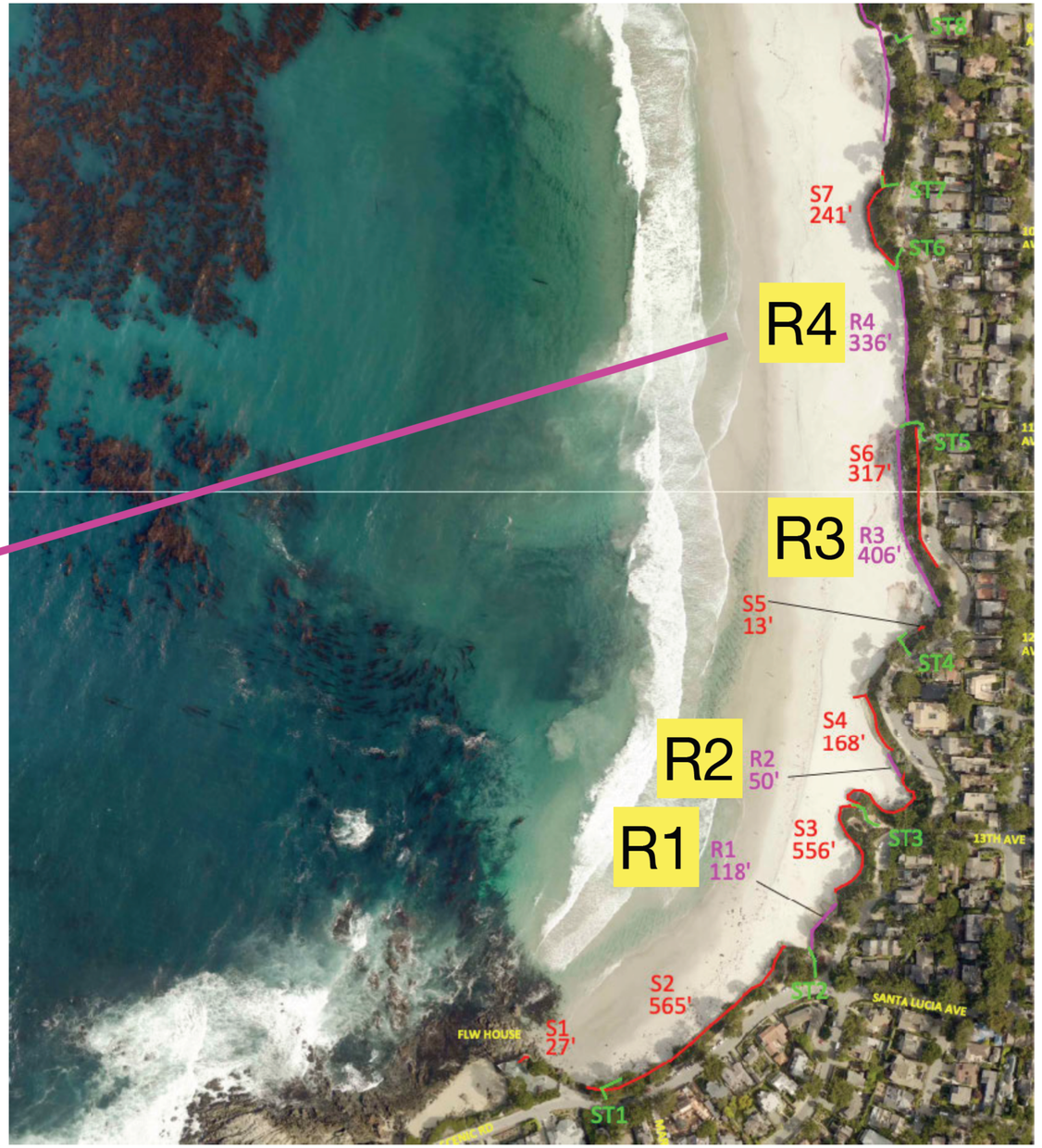
Is repair necessary?



R4 (10th - 11th)



Carmel Beach - South End



R4 (10th - 11th; north end)

*HKA assessment noted 'undersized' rock at the toe of the revetment and recommended **'monitor when exposed'**. Some of this small rock is known to be debris from stairs and a ramp destroyed in the 1982/83 storm event.*

R4 following significant sand scour

Observation following significant sand scour indicates R4 is stable



R4 (10th - 11th; north end)



‘Undersized’ rock at toe of engineered R4 is debris and unrelated to revetment

1983



1983 bluff erosion and destroyed pedestrian ramp at location of future R4

R4 (10th - 11th)

North end of R4 anchored into 10th Ave stairway



South end of R4 anchored into sandstone cliff near the 11th Ave stairway



R5 (8th - 10th)

Carmel Beach - North End





R5 (9th - 10th Section)

R5 was not assessed by HKA due insufficient visibility



R5 (Northside of 10th Ave Seawall)

*There is **no 'fugitive' revetment** as some inferred - the white rock at R5 toe was temporarily used during 1982/1983 emergency and later moved aside (undesirable composition) as the revetment and small seawall was installed*

R5 following significant sand scour



R5 (Northside of 10th Ave Seawall)

1983

Emergency rock used to temporarily protect bluff following the 1982/83 storm event



R5 (8th - 9th Section)

*Revetment compromised as part of 9th Ave stair installation to create base has since been repaired **

R5 9th Ave stair area following significant sand scour



* *following a displaced boulder shifting and temporarily trapping a boy (retrieved unhurt)*

R5 (8th - 9th Section)

South of 8th Ave sand ramp following significant sand scour



R5 (8th - 9th Section)

South of 8th Ave sand ramp where revetment bends east under the 8th Ave sand ramp



R5 (8th Ave Sand Ramp)

***Revetment at 8th Ave sand ramp is against bluff and not visible**; Integral's Final 2026 report recommends maintaining the sand ramp through sand management*



R5 (8th Ave Sand Ramp - Integral Recommendation)

Integral Consulting, Final May 2026 Report, p 2-3, 2-4

*It is important for the City to **reinvest in beach and dune management** activities as an immediate and near-term adaptation strategy. Some of the specific beach and dune management actions include the following:*

- ***Movement of sand back onto the sand ramps** (including 8th Ave sand ramp/revetment)*
- ***Dune vegetation planting with guided access for dune stability and erosion reduction***
- ***Covering of revetments***
- ***Enhancement in the safety of the vertical access landings***
- ***The integration of driftwood and vegetation with sand into nature-based approaches***

Beach and dune management actions will likely play a role at all stages of the adaptation pathway future to maximize access and recreation, regardless of what other mid- and long-term strategies are adopted.

R5 (8th Ave Sand Ramp - Integral Recommendation)

*8th Ave **Immediate Strategy Recommendation** (p 2-19)*

Perform sand management and sediment redistribution to ensure continued, safe use and reduce potential future beach scour and erosion

*Note: It has been affirmed by the Monterey Fire Chief (per City Administrator, Brandon Swanson) and the Carmel Public Works Director (Ken Wysocki) that the **8th Avenue sand ramp is not needed for emergency vehicle access***

R5 (8th Ave Stairs & Outfall)

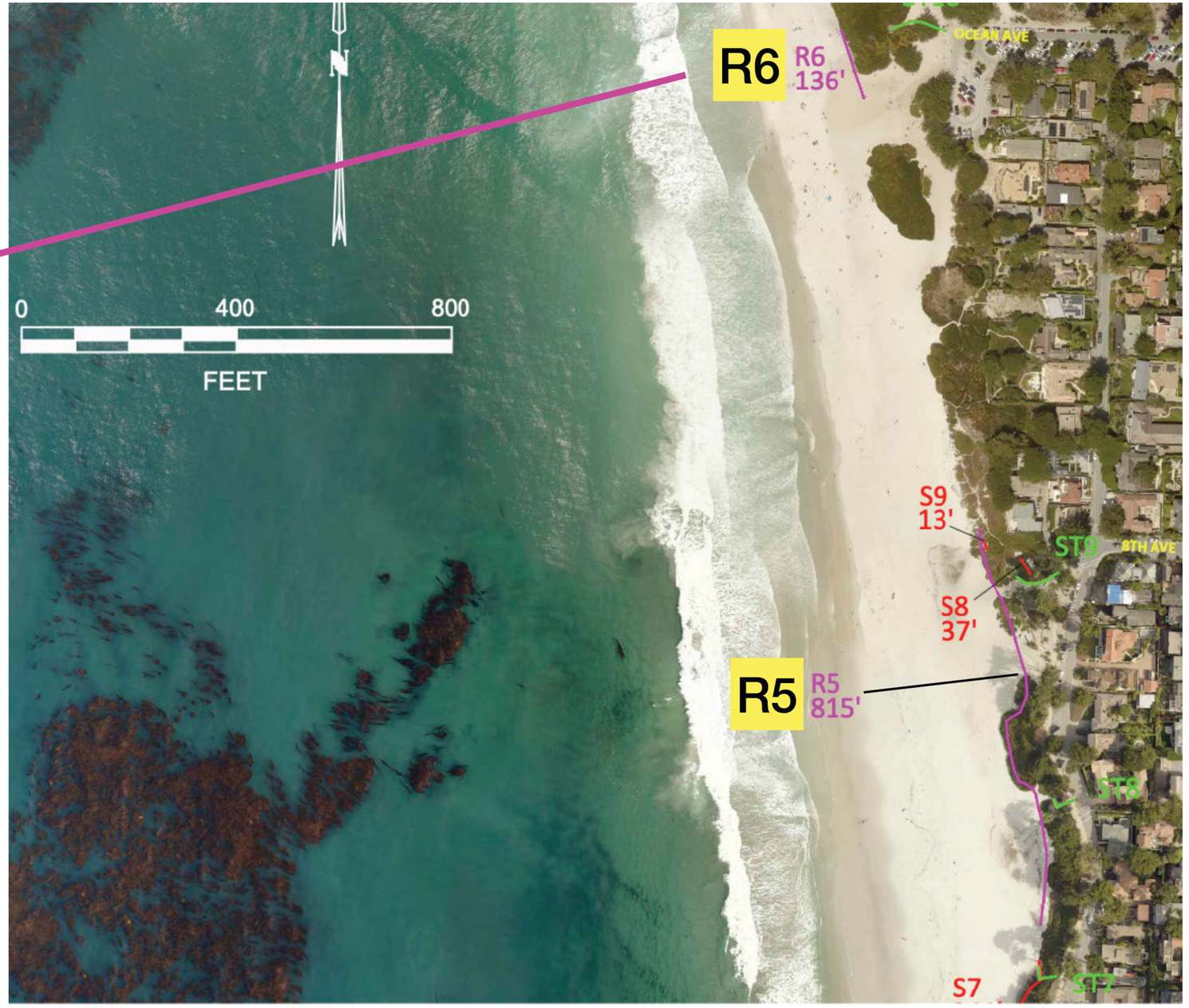
North end of R5 following significant sand scour



R6 (Ocean Ave)



Carmel Beach - North End



R6 (North Dunes at Ocean Ave Outfall)

R6 was not assessed by HKA due insufficient visibility

