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While a USACE-issued report, many of the data were from outside references, and those references are cited in the report.

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Photos on Cover:
Clockwise, from upper left: Honolulu Deep Draft Harbor; Waikiki Beach; North Shore, Oahu, along the Kamehameha Highway; Makapu’u Beach

Authors’ Note: This report primarily uses the units of measurement that were reported in the references used to develop the report text (i.e., inches, feet, and miles); however, metric units are used where references were reported in metric and conversion would not have been true to the reported information.
PREFACE

Seventy percent of Hawaii’s beaches have been and are continuing to erode, which has enormous implications for Hawaii’s economy and way of life, environmental resources, and infrastructure. Climate change and sea level rise significantly compound the regional and local issues on what management steps are needed to establish resilient shorelines. Overcoming the barriers to beach nourishment and shoreline management is critical, with the recognition that there are insufficient funds to protect every shoreline and nourish every beach.

This report, under the National Shoreline Management Study, provides an assessment of the effects of erosion and accretion upon socio-economics, upon the environment, and what management actions are being taken or are needed to maintain resilient shorelines.

Quick Report Tour

The report is organized as follows:

- Section 1 is the Executive Summary.
- Section 2 is the introduction, which includes an overview of the report.
- Section 3 describes the physical and geological characteristics of the shorelines of Hawaii.
- Section 4 describes the extent of erosion and accretion along the shorelines, based upon the U.S. Geological Survey and University of Hawaii at Manoa studies published in 2012.
- Section 5 describes the coming impacts of climate change and sea level rise on the Hawaiian Islands and state government actions that are underway to address the issues.
- Section 6 presents the economic and social impacts of shoreline change caused by erosion and accretion.
- Section 7 provides case studies to demonstrate the complexities of shoreline management issues and the variety of situations that need to be addressed.
- Section 8 summarizes environmental and ecological resources along the shoreline and the potential implications of erosion and accretion on those resources.
- Section 9 presents the ongoing shoreline management approaches that have been used to date, such as armoring, beach nourishment, and sediment management.
- Section 10 presents the USACE navigation and flood risk reduction programs in Hawaii, including actions in the Honolulu District’s Regional Sediment Management Program.
- Section 11 provides a discussion of the challenges and opportunities for beach restoration, nourishment, and shoreline protection.
- Section 12 is a brief summary of the management and governance structure for shoreline management at the federal, state, and county levels.
- Section 13 presents the findings and conclusion of the report.
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## ACRONYMS USED IN THIS REPORT

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<thead>
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<th>Description</th>
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<tr>
<td>BMP</td>
<td>Best Management Practices</td>
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<td>CDUP</td>
<td>Conservation District Use Permit</td>
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<td>CIP</td>
<td>Capital Improvement Project</td>
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<td>Cm</td>
<td>Centimeter</td>
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<tr>
<td>COEMAP</td>
<td>Coastal Erosion Management Plan</td>
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<td>CRAMP</td>
<td>Coral Reef Assessment and Monitoring Program</td>
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<td>CSA</td>
<td>Combined Statistical Areas</td>
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<td>CWA</td>
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<td>CWB</td>
<td>Hawaii Department of Health, Environmental Management Division, Clean Water Branch</td>
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<td>Cy</td>
<td>Cubic Yard</td>
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<td>CZM</td>
<td>Coastal Zone Management</td>
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<td>CZMA</td>
<td>Federal Coastal Zone Management Act</td>
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<td>D2P</td>
<td>Diamond Head to Pearl Harbor</td>
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<td>Department of Accounting and General Services</td>
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<td>DBEDT</td>
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<td>ENOW</td>
<td>Economics: National Ocean Watch</td>
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<td>ENSO</td>
<td>El Niño–Southern Oscillation</td>
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<td>MPRSA</td>
<td>Marine Protection, Research, and Sanctuaries Act</td>
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<td>NAGPRA</td>
<td>Native American Graves Protection and Repatriation Act</td>
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<td>NAICS</td>
<td>North American Industry Classification System</td>
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<td>NED</td>
<td>National Economic Development</td>
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<td>National Environmental Policy Act</td>
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<td>National Pollutant Discharge Elimination System</td>
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<td>NWHI</td>
<td>Northwestern Hawaiian Islands</td>
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<td>O&amp;M</td>
<td>Operations and Maintenance</td>
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<td>OCCL</td>
<td>Office of Conservation and Coastal Lands</td>
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PacIOOS  Pacific Islands Ocean Observing System
PBRA  Poipu Beach Resort Association
PED  Preconstruction and Engineering
PMRF  Pacific Missile Range Facility Barking Sands
POH  U.S. Army Corps of Engineers Honolulu District
R2R  West Maui Ridge 2 Reef Initiative
RSM  Regional Sediment Management
SHPD  State Historic Preservation Division
SLC  Sea Level Change
SMA  Special Management Areas
SSA  Shoreline Setback Areas
SSBN  Small Scale Beach Nourishment
UH  University of Hawaii at Manoa
USACE  U.S. Army Corps of Engineers)
USGS  U.S. Geological Survey
WAPPA  Waikoloa Anchialine Pond Preservation Area
WBA  Waikoloa Beach Association
WKWWRF  Wailuku-Kahului Wastewater Reclamation Facility
WQC  Clean Water Act Section 401 Water Quality Certification
WRDA  Water Resources Development Act
WWRF  Wastewater Reclamation Facility
1 EXECUTIVE SUMMARY

Most of Hawaii’s beaches and shorelines are eroding, threatening the economy, environmental resources, and infrastructure. A 2012 assessment found that over the last century, 70 percent of the beaches were eroding on Kauai, Oahu, and Maui and 13 miles of beaches had been lost.

Beaches are the lifeline of Hawaii’s economy and a major contributor to the national economy. Tourism and recreation in the Hawaiian Islands rely heavily on sandy beaches and clean water, drawing visitors from the U.S. mainland but also from the Pacific Rim countries. Sandy beaches are also an important part of Hawaii’s culture and heritage. The ocean-based economy and shoreline resources of Hawaii are worth upwards of $9 billion annually. Shoreline erosion and associated beach loss have the potential for substantial negative impacts to the economy, the high quality of life residents and visitors enjoy, cultural resources, and coastal ecosystems.

Coastal habitats and water quality are critical to the natural environment, society, and the economy of Hawaii. Hawaii’s reefs are particularly important habitat as they provide the critical first line of defense against wave-driven coastal erosion by absorbing wave energy. Preserving Hawaii’s reefs is key to coastal protection and should be approached in a holistic fashion, linking the activities in the islands’ watersheds and near shore waters to potential impacts to the reefs.

Climate change and sea level change are compounding the challenges of and need for effective beach and shoreline management. The State of Hawaii, led by the Department of Land and Natural Resources, is investigating impacts of sea level rise on increased coastal erosion and inundation for a statewide Sea Level Rise Vulnerability and Adaptation Report (due December 2017) required by the Hawaii Climate Adaptation Initiative (State Act 83, 2014).

There have been state and county laws, regulations, and policies in place since the 1970s to protect shorelines, beaches, and beachfront properties from the effects of erosion. Those policies have proven insufficient in most areas, as development pressures have resulted in dense development and associated infrastructure (e.g., roads, wastewater facilities) built too close to the shoreline in many coastal communities, exacerbating the impacts of erosion.

Historically, government agencies approved and permitted seawalls, revetments, and other coastal armoring structures to defend against erosion. In addition, there are many unpermitted structures from past decades on the shoreline. However, over the last two decades, the science and understanding of the impacts of coastal armoring has increased, and we now know that in many cases, shoreline hardening can increase erosion of adjacent shorelines. In more recent times, “soft” erosion control measures, including beach nourishment, have been utilized. These soft approaches are frequently limited in their viability due to a number of challenges, including:

- The limited availability and cost of sand supplies that are compatible with existing beaches;
- Concerns about potential adverse impacts to state marine waters and coral reefs (e.g., state regulations designate sand as a pollutant);
- Technical logistics and costs associated with delivering and placing sand on a beach;
- Timely environmental permitting, especially Clean Water Act (CWA) Section 401 certification; and
- Lack of funding.

Managed retreat of shorelines and erosion-based building setbacks (e.g., Kauai or Maui) are sustainable long-term strategies for shoreline management, but retreat is more difficult to implement where shorelines are already developed.
Governance and funding of shoreline erosion mitigation and beach management has traditionally been a function of federal, state, county, and city governments. This is changing due to declining federal funding and tremendous budgetary pressures on state, county, and city governments. In order to maintain these functions, the private sector will need to step forward and participate in public-private partnerships (e.g., Waikiki Beach Special Improvement District), including generation of funds, for short- and long-term shoreline management efforts.

Federal, state, and local governments should collaboratively establish priorities for protecting and maintaining beaches and shorelines and finding innovative financing approaches using public-private partnerships and alternative financing options. Short- and long-term planning is essential and should include a wide range of stakeholders, particularly considering the increasing challenges for coastal management in an uncertain future with changing climate and sea level rise.
2 INTRODUCTION

This assessment of Hawaii, which is part of the National Shoreline Management Study (NSMS), contributes to ongoing efforts to provide an accurate description of the status of the United States shoreline and provides information for future shoreline management policy discussions and management actions. The U.S. Army Corps of Engineers (USACE) was authorized to undertake the NSMS under Section 215(c) of the Water Resources Development Act of 1999 (WRDA, P.L. 106-59), which defined key areas to include, specifically:

- A description of (1) the extent of, and economic and environmental effects caused by, erosion and accretion along the shores of the United States; and (2) the causes of such erosion and accretion.
- A description of resources committed by federal, state, and local governments to restore and nourish shores.
- A description of the systematic movement of sand along the shores of the United States.
- Recommendations regarding: (1) appropriate levels of federal and non-federal participation in shore protection; and (2) use of a systems approach to sand management.

This assessment describes economic and environmental effects that result from natural and anthropogenic influences on sediment processes along the shorelines of Hawaii, including erosion and accretion. The State of Hawaii encompasses the volcanic Hawaiian Archipelago, which comprises hundreds of islands spread over 1,500 miles (2,400 kilometers (km)). At the southeastern end, the eight "main islands" are (from the northwest to southeast) Niihau, Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii Island. This report focuses upon the four largest and most populated islands, Oahu, Maui, Kauai, and Hawaii Island (the Big Island).

2.1 The 1971 National Shoreline Study

In the late 1960s, the public and Congress expressed concerns about shoreline erosion problems and the need to protect the nation’s shorelines (Stauble 2004). In Section 106a of the 1968 River and Harbors Act (RHA, P.L. 90-483), the 90th Congress authorized USACE to conduct a national assessment of coastal erosion and an evaluation of the existing federal shoreline protection program. In response, USACE published the National Shoreline Study. The main goals of the National Shoreline Study were to identify shorelines threatened by erosion and to develop recommendations regarding sediment management, shoreline restoration, and minimizing damages in coastal areas affected by erosion.

The National Shoreline Study was the first nationwide look at coastal erosion and the federal shore protection program. The study produced 12 documents in total, including individual reports on the topics of Shore Management Guidelines (USACE 1971a), Shore Protection Guidelines (USACE 1971b), the Report on the Shoreline Management Study (USACE 1971c), and a series of nine regional inventories. The National Shoreline Study concluded that 20,500 miles of the nation’s shoreline were undergoing “significant erosion” (USACE 1971c) (Error! Reference source not found.). The qualitative criteria for identifying “significant erosion” were based on rate of erosion, economic factors, industrial use, recreational use, agricultural use, navigational needs, demographic distributions, and ecological impact.
The National Shoreline Study assessment sub-divided areas experiencing “significant erosion” into 2,700 miles of “critical erosion” and 17,800 miles of “non-critical erosion” (USACE 1971c). Areas of “critical erosion” were places where actions to halt erosion may be justified. Critical erosion areas were determined based on predictions of population and land use into the year 2020, environmental effects of past erosion, ownership, land use regulations, and an overall judgment that prevention of erosion would justify the prospective damage prevented and benefits from tangible and intangible values. Non-quantitative methods and criteria were used to develop the conclusions of the 1971 National Shoreline Study; therefore, the results do not allow for quantifiable comparisons to present-day erosion rates (Stauble 2004).

Major needs identified in the National Shoreline Study (USACE 1971c) included:

1. Coordinated action by federal, state, and local governments in concert with action by corporate and private owners to arrest erosion of some parts of the national shorelines.
2. Coordinated and comprehensive planning and management to ensure use of the national shoreline in the national best interest.
3. Intensified research and investigation of the processes contributing to shoreline erosion.
4. Identification and development of improved technologies and methods for controlling erosion.

In the 40 years following the National Shoreline Study, the nation’s coasts have undergone a substantial transformation with respect to the regional geomorphology, ecology, development, land use, population, and management practices. With these changes comes a need for an overview of the present and future status of the shoreline. Also, since the 1971 National Shoreline Study was published, there have been major advancements in our understanding of coastal processes, how coastal climate impacts erosion, and how sediment moves along the shoreline. There has been extensive research and publication by various federal and state agencies, private consultants, and academia to provide detailed information on the changing shoreline. Improved technologies such as LiDAR (Light Detection and Ranging)\(^1\) and GPS/GIS (Global Positioning System/Geographic Information System) allow for a much more accurate measurement and analysis of shoreline erosion and accretion. There is knowledge of accelerated climate change and the potential impacts upon shorelines.

Previously published NSMS (under the Water Resources Development Act (WRDA) of 1999) assessment reports include the North Atlantic Regional Pilot (2011, draft), a California regional assessment (2014, draft), and a first phase National Assessment (December 2010, draft) that examined the analytical

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\(^1\) LiDAR is an active remote sensing system that can be operated in either a profiling or scanning mode using pulses of light to illuminate the terrain. LiDAR data collection involves mounting an airborne laser scanning system onboard an aircraft along with a kinematic Global Positioning System (GPS) receiver to locate an x, y, z position and an inertial navigation system to monitor the pitch, roll, and heading of the aircraft. By accurately measuring the round trip travel time of the laser pulse from the aircraft to the ground, a highly accurate spot elevation can be calculated.
factors relative to the four eastern regions of the U.S. shoreline: North Atlantic, South Atlantic, the Gulf of Mexico, and the Great Lakes. In addition to the North Atlantic and California reports, detailed regional assessments (such as this document on Hawaii) are planned for all the remaining U.S. coastal regions, including: South Atlantic, the Great Lakes, the Gulf of Mexico, Oregon and Washington, and Alaska.

The NSMS series has produced a wealth of information on economic and environmental effects of erosion and accretion along U.S. shorelines, and the use of systematic approaches to managing sediments and associated impacts. Available documents can be found on the NSMS website: http://www.nationalshorelinemanagement.us/index.cfm.

2.2 Purpose and Objectives of the NSMS Assessment of the Hawaiian Islands

The purpose of this Assessment of the Hawaiian Islands is to describe the physical, environmental, and economic aspects of erosion and accretion of the shoreline for the four islands, and to describe how shorelines are being managed by federal/state/local authorities with an emphasis upon systems approaches to sediment and shoreline management. The study objectives are to:

- Describe characteristics including shoreline habitat, coastal and sediment processes, and specific features of the Hawaiian Archipelago and each of the individual islands.
- Identify the changes to beaches and shorelines from erosion and accretion and the resulting economic, social, and environmental effects.
- Describe the current shoreline management approaches, including the use of systematic approaches to sediment and shoreline management.

General descriptions of the islands are included in the report. This document does not provide specific details for every reach of the coastal littoral zone. Several case-study examples are included for illustrative purposes. More specific information and detailed analyses are provided in the references identified in the text.

This assessment of the Hawaiian Islands provides information to be used in the development of recommendations for improved shoreline and sediment management, and identifies appropriate levels of federal and non-federal participation in shore protection and use of a systems approach to sediment management. The information in this report is intended to contribute to ongoing and future shoreline management policy discussions at the national, state, and local levels.
2.3 **Overview of Erosion/Accretion Issues and Shoreline Management in Hawaii**

The objectives of this NSMS report\(^2\) are to document the physical, economic, environmental, and social impacts and management challenges of shoreline change in Hawaii.

### 2.3.1 The Setting

Life in the Hawaiian Islands is enhanced by beaches, and, of course, those spectacular ocean views, beautiful island scenery, healthy environment, and outdoor adventuring. The economy in Hawaii is heavily dependent upon tourists coming to see and play on the spectacular islands and to enjoy the wide sandy beaches.

Natural erosion of Hawaii’s coasts and shorelines has been ongoing for millions of years. The islands are primarily made of basalt lava from the volcanoes that formed the islands. The shorelines of the Hawaiian Islands are made up of materials of either volcanic origin or from sand from the breakdown of the fringing reefs and biological organisms associated with those reefs. As the islands evolved to what they are today, beaches formed as carbonate sand was deposited along the shoreline. In some areas, dunes also were formed where sand accumulated landward of the shoreline. Those sandy shorelines provided a reservoir of sand supplies to maintain the width of the beaches as the shoreline advanced or retreated due to natural forces (Fletcher et al. 2010).

With the arrival of many more people over the years, homes and commercial buildings were built, and infrastructure, such as roads, was constructed, many of which were built without recognition of the short and long term impacts of shoreline erosion.

### 2.3.2 Eroding Beaches and Shorelines

Hawaii’s beaches and shorelines are eroding, threatening the economy, environmental resources, and infrastructure.

- In 2012, a comprehensive assessment of Hawaii’s beaches found that over the last century 70% of the beaches had eroded on Kauai, Oahu, and Maui (Fletcher et al. 2012) and over 13 miles of beach had been completely lost to erosion.
- Shoreline retreat, averaging 1 foot per year (0.3 m/year) statewide, wetland migration, and cliff collapse due to erosion are occurring now on many of Hawaii’s coastlines. Shoreline retreat threatens the existence of residential and commercial structures (e.g., large tourist hotels), the natural beach environment, as well as critical infrastructure, such as roads and public utilities.

Beaches are the lifeline of Hawaii’s economy, and a major contributor to the national economy.

- Tourism and recreation in the Hawaiian Islands rely heavily on sandy beaches, including tourists from the U.S. mainland but also from the Pacific Rim countries. Sandy beaches are also an important part of Hawaii’s culture and heritage.

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\(^2\) The Congressionally-authorized National Shoreline Management Study (NSMS) is the first undertaking in nearly a half-century to document the physical, economic, environmental, and social impacts of shoreline change across each region of the U.S. Under the leadership of the **Institute for Water Resources** of the U.S. Army Corps of Engineers (USACE), NSMS is providing government policymakers, coastal engineers and scientists, and stakeholders with information about the coastal regions most in need of resilience planning.
Beyond tourism and recreation opportunities, the shoreline of Hawaii is where the most valuable property and land are located, as well as critical infrastructure that supports transportation of visitors and residents alike.

2.3.3 The Economics of Shoreline Management

The ocean-based economy and shoreline resources of Hawaii are worth upwards of $9 billion annually; shoreline erosion and associated beach loss has the potential for substantial negative impacts to the economy, the high quality of life residents and visitors enjoy, cultural resources, and coastal ecosystems.

- Ocean-based sectors have proven their resilience in Hawaii and the coastal United States. Since the economic recession, the ocean-based economy experienced increases in GDP higher than GDP growth across all industries both in Hawaii and the mainland. Ocean jobs made a strong recovery between 2010 and 2013 in Hawaii, with increases of 9 percent, as compared to all industries, which increased jobs by 5.3 percent.
- Sandy beaches are the basis for tourism and recreation, and over 8 million tourists from the U.S. mainland and the Pacific Rim countries visited Hawaii in 2014, each spending approximately $200 per day. Waikiki Beach is the largest draw for many of these tourists and it accounts for nearly half of statewide tourism expenditures and a significant portion of all civilian jobs in the state.
- Recreational opportunities associated with the shore abound in Hawaii and when studied, the positive economic impacts are immense. For example, there are over 700,000 surfers in Hawaii, second in the nation only to California, and they surf on average 144 days out of the year, expending on average $66 per trip. Major international surfing competitions are held regularly along Oahu’s North Shore, where one event in 2011 was estimated to have brought $20.9 million in direct and indirect revenue to the State.
- As an important part of Hawaii’s culture and heritage, water-based recreation like surfing and outrigger canoeing has been practiced as sport and culture on the Hawaiian Islands for hundreds of years. The shoreline is the center of Hawaiian traditions, most notably burials, which occurred both at sea and in dunes. Certain traditional practices and sites, such as fishponds (for aquaculture) and fishing shrines still exist today, although rising seas and eroding beaches are threatening their future.
- In addition, the most valuable property and land are located along the shoreline, as is critical infrastructure that supports transportation of visitors and residents alike. Median prices for waterfront single family homes in Kailua and Honolulu, Oahu, are the fifth and sixth highest in the nation ($4.5 and 3.8 million respectively). The landscape of the Hawaiian Islands limits where roads and highways can be built—interior routes are not always feasible—meaning that many island communities are connected by only one coastal road. The Hawaiian Islands are 2,000 miles from the nearest significant landmass, making the state port system a critical factor in the state’s sustainability. Ten commercial harbors on six major Hawaiian Islands transported over 30 million tons of cargo in 2013.

2.3.4 Environment and Erosion

Coastal habitats are critical to the natural environment, society, and economy of Hawaii. Hawaiian coastal habitats support a rich variety of terrestrial and marine species, including dozens of migratory and resident birds, thousands of fish and marine species, and threatened or endangered turtles and marine mammals. Coastal erosion directly threatens these habitats. Hawaii’s reefs provide the critical first line of defense against wave-driven coastal erosion. Coral reefs not only provide protection from
wave energy but also are a source of sand for beaches. Fundamental to shoreline management is protection of Hawaii’s reefs in a holistic fashion (Fletcher et al. 2010).

- Coastal planning should consider future habitat needs in the face of chronic erosion and sea level rise. Important species, like endangered sea turtles, monk seals, or bird species, rely on beach habitats. As beaches erode, these habitats are lost.
- The current suite of shoreline management efforts can have positive and negative impacts, and are site-specific based on local environmental conditions and shoreline management options. Beach nourishment can create or improve habitat for some marine organisms (e.g., birds, sea turtles, monk seals). If done incorrectly (e.g., by not following best practices), beach nourishment may have impacts such as on local water quality, or incompatible material can have negative impacts on aquatic habitats. Hawaii’s Department of Land and Natural Resources Office of Conservation and Coastal Lands Small Scale Beach Nourishment Guidelines provide best management practices for protecting water quality and aquatic habitats in small beach nourishment efforts (which are applicable to larger projects as well). Benthic habitat monitoring after the 2012 Waikiki Beach Restoration did not find significant negative impacts associated with beach nourishment activities.
- While breakwaters, seawalls, and groins can protect coastal development (e.g., infrastructure, cultural sites), these engineered structures interfere with the littoral zone sediment supply and natural transport mechanisms, thereby exacerbating the loss of certain habitats (e.g., beaches and dunes) and forage sites.
- USACE’s Engineering with Nature initiative seeks to maximize the potential habitat benefits of hard structures, and in Hawaii, some shoreline protection structures have been shown to create habitat for marine species (e.g., Iroquois Point). However, the effects on species assemblages and biomass need more study.

2.3.5 Climate Change and Sea Level Rise
Climate change and sea level rise are compounding the challenges of beach and shoreline erosion management.

- Sea level has been rising in Hawaii for the past century or more. Rates of sea-level rise in Hawaii ranged from 1.5 cm (0.6 Inches) on Oahu and Kauai, to 3.3 cm (1.3 inches) on Hawaii Island per decade over the last century. Current rates are 1.41 mm per year for Kauai and Oahu, 2.04 mm per year for Maui, and 2.95 mm per year for the Island Hawaii.
- Hawaii is expected to see increased frequency and intensity of storms, and an increased frequency of tropical cyclones as the storm track may shift northwards towards the Central North Pacific.
- The State of Hawaii, led by the Hawaii Department of Land and Natural Resources (DLNR), is investigating impacts of increasing coastal erosion and inundation for a statewide Sea Level Rise Vulnerability and Adaptation Report (due December 2017) required by the Hawaii Climate Adaptation Initiative (State Act 83, 2014).

2.3.6 Approaches to Shoreline Protection
Over the past century, various approaches have been utilized to mitigate the impacts of erosion to property, structures, and infrastructure that are located along the shoreline. On Oahu, 27 percent (29 km) of the shoreline has been armored to stabilize the shoreline (Romaine 2013a). On Maui, 15.6 of 56 miles of Maui’s shoreline surveyed in 2003 (County of Maui Department of Planning 2003) were identified as hardened (i.e., seawall, revetment, grouted revetment, sandbags, or groins).
While arming may protect the backshore, natural reservoirs of sand are impounded behind coastal structures, leading to further sand deficits on eroding beaches, and ultimately beach loss fronting many structures. Shoreline arming with seawalls, bulkheads, and revetments also may result in increased erosion of adjacent shorelines, which increases pressure for additional arming of the shoreline.

Shoreline erosion is expected to worsen and likely accelerate as sea levels continue to rise. A combination of short- and long-term solutions is needed to manage and mitigate current and projected future erosion in Hawaii. The suitability of the following options will vary from one coastal setting to the next. Coastal managers and stakeholders need to consider a wide range of environmental, cultural, and socio-economic issues in selecting the best option for an area.

1. **Armoring.** Bulkheads, seawalls, and revetments have been successful in protecting the shoreline from erosion but often lead to further beach narrowing, beach loss, and loss of lateral public access along the shoreline. Shoreline arming is restricted in Hawaii by State Coastal Zone Management Policy and Conservation District Rules with exceptions.

2. **Groins.** Groins have also been successful in stabilizing beaches and protecting the shoreline. These are most often used in combination with beach nourishment. Groins can have negative impacts on down-drift beaches if not designed and sited properly.

3. **Managed Retreat.** Shoreline setbacks provide a buffer that allows shorelines to retreat naturally. Proper siting (and in some cases, relocation or removal) of buildings and infrastructure at appropriate distances from the shoreline avoids the risk of damage from erosion for a number of years, thereby avoiding the need for shoreline arming.

4. **Beach Nourishment and Engineering with Nature.** Beach nourishment is an effective short- to medium-term approach for restoring beaches, and typically requires periodic re-nourishment. Engineering with nature approaches are the intentional alignment of natural and engineering processes for sediment management within a littoral cell.

5. **Natural shoreline change.** This approach allows sediment and the shoreline to migrate naturally in the absence of engineered structures or beach nourishment. This approach can be beneficial when a natural shoreline is desired.

6. **Land Acquisition.** Purchasing land along the shoreline is an option, best utilized for undeveloped land, which in turn allows for natural/managed retreat of the shoreline. Acquisition of developed land may be increasingly necessary to preserve key “legacy” beaches.

7. **Natural Infrastructure.** Natural infrastructure (i.e., healthy ecosystems and also known as living shorelines), such as wetlands and salt marshes, coral reefs, mangroves, sea grasses, and dunes, is well known to mitigate beach erosion and flooding. This approach is limited by the specific local physical shoreline conditions, and can be used in combination with engineered structures, as noted below.

8. **Hybrid Solutions.** Combinations of natural and built engineered infrastructure can provide important storm protection and coastal flooding benefits to coastal communities, and can be designed to balance the need for shoreline, beach, and habitat protection.

Looking back over several decades, local government agencies approved locations for structures and roads to be built without proper consideration or understanding of the risks from shoreline erosion. Historically, government agencies approved seawalls, revetments, and other coastal arming structures as the first line of defense. Over the last two decades, science and understanding of the negative impacts of coastal arming has increased and, in recent times, agencies have generally approved coastal arming only after a comprehensive review of the alternatives.
2.3.7 The Challenges of Beach Nourishment

Beach nourishment is a vital element in Hawaii's current and future management efforts to restore beaches and to combat erosion. However, beach nourishment is used infrequently given the regulator and on-the-ground challenges. Federal and state nourishment projects completed since 2007 have totaled about $35 million.

The barriers noted below need to be overcome by concerted efforts of federal and state authorities for success in increasing beach nourishment projects. These barriers include:

1. The limited availability and cost of sand supplies that are compatible with existing beaches. Most beaches in Hawaii lack abundant offshore sand sources. The primary source of sand on a chronically eroding shoreline is the dune system located along its landward edge. However, historically, these have not been protected by management authorities, and residential developments, roads, and commercial buildings were built too close to the shoreline on the dunes;
2. Concerns about potential adverse impacts to state marine waters and coral reefs (e.g., state regulations designate sand as a pollutant);
3. Technical logistics and costs associated with delivering and placing sand on a beach (e.g., the USACE hopper dredge, Essayons, lacks the capability to pump sand to the beach);
4. Limited monitoring and understanding of localized beach dynamics;
5. Few implemented examples for lessons learned;
6. Lack of funding; and
7. Timely environmental permitting, especially Clean Water Act (CWA) Section 401 certification, and a streamlined inter-agency programmatic permit for small-scale beach nourishment projects.

2.3.8 Governance of Shorelines

There have been state and county laws, regulations, and policies in place since the 1970s that have had the intention of protecting beaches and beachfront properties from the effects of erosion, including state Coastal Zone Management policy (Hawaii DLNR 205A), state Conservation District rules and policies, and county policies. In spite of these rules and policies, development pressures have resulted in a legacy of dense development and roadways built too close to eroding shorelines in many coastal communities.

Governance and funding of shoreline erosion and management has traditionally been a function of federal, state, county, and city governments. This is changing due to less federal funding available which, unfortunately, coincides with tremendous budgetary pressures on state, county, and city governments. The private sector will need to step forward and participate in public private partnerships (e.g., Waikiki Special Improvement District), including generation of funds, for short- and long-term shoreline management.

The USACE missions related to shoreline management include navigation dredging and flood risk management. The USACE navigation mission includes two elements related to dredging, one being maintenance dredging to ensure that channel depths are at authorized depths (i.e., O&M), and the other is new work or deepening dredging to dredge existing or new channels to authorized depths. Flood risk management goals are to reduce overall flood risk, including reducing the risk of loss of life, reducing long-term economic damages to the public and private sector, and improving the natural environment.
USACE in Hawaii has responsibility for 19 deep and shallow draft harbors and 10 shore protection projects. Through the Regional Sediment Management Program, the USACE is working to deliberately manage sediments on a regional or littoral cell basis instead of project by project. The USACE will continue its role in working with state, county, city governments, the academic community, the private sector, and other stakeholders (e.g., conduct comprehensive assessments of Hawaii’s sediment management needs and where regional sediment actions could be conducted).

Implementation of these missions is being enhanced by three USACE ongoing initiatives, including: (1) regional sediment management, (2) engineering with nature, and (3) green infrastructure.

State and county governments are key to shoreline management in Hawaii. Erosion and related shoreline management within the State of Hawaii is split between the Coastal Lands Program in the DLNR Office of Conservation and Coastal Lands and the Coastal Zone Management (CZM) Program in the Office of Planning. In practice, DLNR handles all the day-to-day shoreline management in the state. State CZM is more involved in long-range coastal resource management planning and inter-agency coordination through county-administered CZM policy (e.g., Special Management Areas). In addition, the Hawaii Department of Health, Clean Water Branch is responsible for issuance of Clean Water Act (CWA) Section 401 certifications, ensuring that projects will not violate state water quality standards.

Unique to Hawaii, HRS 205A grants individual counties with regulatory authority over designated areas of concern, i.e., Special Management Areas (SMA). From a spatial context, the SMA generally extends from the shoreline inland to the nearest highway. Within the SMA, the Counties have established rules that govern the immediate shoreline area, such as shoreline setbacks and procedures for variances. Under State legislation, the four counties are required to establish a “shoreline area” with setbacks no less than 20 feet and no more than 40 feet inland from the shoreline wherein no development is allowed.

The counties of Maui and Kauai have established more stringent shoreline setback requirements. Maui’s program was established initially in 2003, and has a setback requirement with the intention of protecting coastal structures from erosion for 50 years with an additional 25 foot buffer (Maui 2003), whereas Kauai’s setback rules are targeted to 70 years. For example, Kauai’s formula for the setback distance is 70 times the annual erosion rate plus 40 feet. These formulas to determine setbacks do not account for future accelerated sea level rise. In 2014 Kauai updated its regulations and added additional setback requirements to account for future accelerated sea level rise; however, this is a ‘stop gap’ measure of an additional 20 (twenty) feet setback until the erosion rates are updated to account for sea level rise. The City and County of Honolulu and the County of Hawaii have adopted a standard 40-foot minimum shoreline setback.

Of particular note, the University of Hawaii and its Sea Grant College Program both provide scientific research support and technical and policy analyses to state and county governments on erosion and shoreline management issues.

### 2.3.9 Future Challenges to Shoreline Management

The bottom line for the Hawaiian Islands is not a simple offering. Seventy percent of Hawaii’s beaches have been and are continuing to erode, which has enormous implications for Hawaii’s economy and way of life. Climate change and sea level rise significantly compound the regional and local issues on what management steps are needed to establish resilient shorelines. Overcoming the barriers to beach nourishment and shoreline management is critical, with the recognition that there are insufficient funds to protect every shoreline and nourish every beach (Fletcher et al. 2010).
State and local governments understand that coastal erosion is threatening critical natural resources as well as homes and infrastructure, and also understand that beaches are a valuable part of Hawaii’s economy and way of life. State and local governments approved the location of most residential and commercial facilities along the shorelines. It is important to note that most existing development was sited too close to the shoreline over the past 50–60 years because erosion and flooding hazards were not well understood and/or these hazards were not given proper consideration. Beaches are public trust resources are protected by the State constitution, CZMA policy, and Conservation District Rules. Thus, a managed approach taking all of these concerns into account is how the state and counties have been attempting to balance public and private interests. This is recognized as a significant challenge, especially in view of climate change and sea level rise.

Federal support is needed to help facilitate regional and local efforts to identify local shoreline management issues, develop shoreline management plans, and provide the basis for action. Federal, state, and local governments should collaboratively establish priorities for which beaches and shorelines will be maintained, finding innovative financing approaches using public-private partnerships and alternative financing options. Short- and long-term planning is essential to sustainable and resilient shorelines, and should include the wide range of stakeholders.

2.3.10 Report Organization

The report is organized as follows:

- Section 1 is the Executive Summary.
- Section 2 is the introduction, which includes an overview of the report.
- Section 3 describes the physical and geological characteristics of the shorelines of Hawaii.
- Section 4 describes the extent of erosion and accretion along the shorelines, based upon the U.S. Geological Survey and University of Hawaii at Manoa studies published in 2012.
- Section 5 describes the coming impacts of climate change and sea level rise on the Hawaiian Islands and state government actions that are underway to address the issues.
- Section 6 presents the economic and social impacts of shoreline change caused by erosion and accretion.
- Section 7 provides case studies to demonstrate the complexities of shoreline management issues and the variety of situations that need to be addressed.
- Section 8 summarizes environmental and ecological resources along the shoreline and the potential implications of erosion and accretion on those resources.
- Section 9 presents the on-going shoreline management approaches that have been used to date, such as armoring, beach nourishment, and sediment management.
- Section 10 presents the USACE navigation and flood risk reduction programs in Hawaii including actions in the Honolulu District’s Regional Sediment Management Program.
- Section 11 provides a discussion of the challenges and opportunities for beach restoration, nourishment, and shoreline protection.
- Section 12 is a brief summary of the management and governance structure for shoreline management at the federal, state, and county levels.
- Section 13 presents the findings and conclusion of the report.
2.4 References for Introduction

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Romine, Bradley, Historical Shoreline Changes on Beaches of The Hawaiian Islands with Relation to Human Impacts, Sea Level, and Other Influences on Beach Dynamics, A Dissertation Submitted to the Graduate Division of the University of Hawaii at Manoa in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Geology and Geophysics. May 2013a.


Chapter 3: Geological Description of the Hawaiian Islands and Their Shorelines

The Hawaiian Islands stretch across approximately 1,700 miles of the Northern Pacific Basin. All of the islands were formed by one or more large basalt shield volcanoes (Clague and Dalrymple 1987). The Hawaii hot spot that formed the Hawaii Island Archipelago and its northern arm (i.e., the Emperor Seamount) is in the mantle just south of the Island of Hawaii. The trail of islands increases in age with distance from the hot spot, as a result of the speed and direction of the Pacific Plate for the last 75-80 million years. The Pacific Plate is migrating at a rate of about 10 cm per year to the northwest (Fletcher et al. 2008).

The State of Hawaii consists of eight main islands—Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, Niihau—and 124 small volcanic and carbonate islets offshore of the main islands (Fletcher and Feirstein 2009). Each of the islands is the top of one or more shield volcanoes that extend thousands of meters below the surface. Above the surface, Mauna Kea on the Hawaii Island stands 4,200 meters. From seafloor to summit, it is 9,450 meters (Fletcher et al. 2008).

3.1 Fringing Coral Reefs

The Hawaiian Islands are mostly surrounded by fringing coral reefs. Figure 2 shows the life of a typical mid-Pacific island. The islands initially grew from volcanic activity and then erosion of the island results in a shallow shelf, where coral reefs have developed. During the early stages of volcanism, lava flows prevent formation of coral reefs; contributing also may be rapid subsidence and erosion of island coasts during this stage (Fletcher et al. 2010). For example, corals are not forming near the actively growing shorelines below Kilauea Volcano on Hawaii Island. On the west side of the island, corals are beginning to form where the rate of lava accumulation has slowed, but much of the west side of Hawaii Island is still prone to volcanic activity from Mauna Loa and Hualalai.

Corals in Hawaii’s fringing reefs consist primarily of stony or hard coral. The reefs are comprised of coral and coralline algae skeletons (Fletcher and Feirstein 2009). The coralline algae deposit calcium carbonate on the reef, leaving fossil skeletons on the reef when the algae die. The reefs break down by mechanical erosion (i.e., waves and currents) and by bioerosion, which is the breaking down of the reef by marine organisms.

One of the marine organisms that breaks down reefs is the Parrotfish (Uhu) (Figure 3). Parrotfish have teeth that form a parrot-like beak that is used to feed on the calcareous algae, reef organisms, and corals from the reef. While feeding, Parrotfish grind up the corals and algae, ingest the particles, and after digestion, excrete the excess as calcium carbonate sand. One Parrotfish can produce approximately 200 pounds of sand per year (National Geographic 2014, To-Hawaii.com). This sand, along with the mechanically-eroded reef sediments, provides an important source of sand for Hawaii beaches.

Land-based pollution has resulted in a decrease in bioerosion (Wolanski, et al 2009) and thereby production of sand; also, overfishing of parrotfish is a significant concern (Environment Hawaii 2015). Additionally, studies by University of Hawaii (Harney and Fletcher 2003) suggest that much of Hawaii’s beach sand is old and likely deposited during a late Holocene sea level high stand 500 to 4,000 years ago. This suggests that the modern production of sand may be a minor contribution to the overall sand budget, and it is important to conserve and manage existing beach sand supplies. Harney et al. (2000) concluded that understanding the age of sand on the beaches and stored on the reefs and coastal plain can aid in the interpretation of sediment production, transport, and residence time in preparation of sediment budgets and associated management actions (Harney et al. 2000).
Figure 2. Eight stages in the geological history of a volcanic island in the central Pacific. (H.T. Stearns 1946).
The Hawaiian Islands are built of shield volcanoes\(^3\). The shorelines are typically made of volcanic bedrock, alluvial deposits of solidified tephra (material ejected during volcanic eruption) from the volcanic interior of the islands, and carbonate (limestone) deposits, which can include unconsolidated carbonate sands, reef and beach rock, and consolidated aeolian sediments (Fletcher et al. 2012). Unlike the beaches of the continental United States, shorelines in Hawaii do not have a significant source of quartz sand. Beaches of the Hawaiian Islands consist primarily of white calcareous sand (i.e., mostly containing calcium carbonate) produced by marine organisms and, to a lesser extent, black, red, and green sands derived from the erosion of volcanic headlands and deposition of fluvial terrestrial sediments from rivers and streams. The white calcareous sand is composed of carbonate shells and skeletons of marine organisms, such as corals, algae, molluscs, and echinoderms (e.g., sea urchins and sand dollars). Depending upon which island and which beach, the sands can be mostly white sands made by marine organisms or black sand of volcanic origin. In general, about 5 percent of sand on the beaches is from volcanic rocks, which means 95 percent of sand is from calcareous, reef-derived material. Every beach is unique and has its own source and type of sand (Harney website).

While various beaches have beach sands that range from coarse- to fine-grained, most beach sands in Hawaii are generally medium in size. The fine-grained sands are generally on the eastern windward beaches that face persistent trade winds, abrading the size of the sediment particles and effectively sorting the particles as well (Moberly and Chamberlain 1964). Beach sand on north and west shores tends to be coarser due to exposure to high waves in winter months, which tends to remove finer grain

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\(^{3}\) A shield volcano is a type of volcano usually built almost entirely of fluid lava flows. They are named for their large size and low profile, resembling a warrior’s shield lying on the ground. This is caused by the highly fluid lava they erupt (http://en.wikipedia.org/wiki/Shield_volcano).
material offshore. Southern shores receive the biggest waves in summer months and tend to have medium grain sizes.

Not only affecting particle size, wave events and storms significantly impact the characteristics and width of beaches. North and west-facing beaches tend to have wide and gently sloping profiles in the summer months and steep narrow profiles in the winter (Fletcher et al. 2012).

The littoral system for sediment movement includes both the beaches and offshore beach sand reservoirs. Sand accumulates in channels and depressions on offshore reef surfaces, which in many cases are active components of beach sand and offshore sand exchanges. In some cases, these offshore deposits can provide a sand source for beach nourishment, but sand can also be lost from the littoral system through channels over the reef edge into deeper water. In general, sand supply is limited, and for that reason, beaches in the Hawaiian Islands are typically narrower than mainland beaches.

Sediment budgets in Hawaii should account for the volume of sediment stored in reef channels and holes, the volume in the coastal plain, the likely loss of sediment due to natural processes of dissolution, attrition, and transport offshore, as well as the volume moving on and off the beaches, any sediment provided by landside runoff, and production by coral reefs and encrusting coralline algae. Creation, destruction, and storage of carbonate sands is controlled by a combination of wave energy, water quality, and biological productivity (Fletcher et al. 2008). Sediment budgets based upon detailed study of these sources and sinks can provide improved shoreline management to combat shoreline retreat and beach losses (Harney and Fletcher 2003).

### 3.2 Waves and Fringing Reefs

The power of waves to erode shorelines is dependent upon a number of local factors, such as storm frequency and intensity, wave height, period, and direction during high surf events, local bathymetry, the orientation and exposure of the shoreline, the morphology of the shoreline, shoreline sediment types, and presence or lack of fringing reefs. For areas with shallow nearshore waters, the relative power of waves to attack the shoreline is dissipated by waves breaking and running up to the shore. For deeper nearshore waters, the power of the waves is focused directly on the shoreline. Wave energy can be largely dissipated by fringing reefs, but depending upon reef characteristics and the energy of wave characteristics, the power of waves can still impact the beach and shoreline (Fletcher and Feirstein 2009).

Depending upon their depth and width, fringing reefs can dissipate the energy from waves heading toward the shoreline. Beaches fronted by shallow fringing reefs tend to be narrower, less steep, and finer grained than beaches fronted by deeper water due to differences in incident wave energy. At the reef’s edge and crest, most energy from the waves is expended over a short distance, primarily due to bottom friction. This is not unlike wave run-up to shorelines with shallow and low sloping bathymetry, but many reefs are a distance from the shoreline and are likely more effective at energy dissipation. Most energy is lost in the fringing reef from the action of the bottom of the wave hitting the coral reef edge and crest, breaking, and reforming. Some waves form again and reach the beach, but with much less energy than when they arrived at the reef. Depending upon the tidal range, most energy can be dissipated at low tide, but at high tide, waves can pass over the fringing reefs with less loss of energy. The primary factors in wave energy loss and fringing reefs are the depth of submergence of the reef, the size of wave, and the width of the reef (Pe' quignet et al. 2011) (Hopley 2011). Figure 4 and Figure 5 provide examples of wave dissipation at the reef edge and reef crest.
Figure 4. Tunnels Beach, Kauai, showing wave dissipation by fringing reefs.

*Source: Julian Fong via flickr*

Figure 5. West and southern Maui. Examples of fringing reefs and wave dissipation.

*Source: USGS. http://www.soest.hawaii.edu/coasts/publications/hawaiiCoastline/maui.html*
3.3 Wind, Waves, and Tides

The four dominant wave regimes that impact the Hawaiian Islands are the trade winds, north Pacific, southern Pacific, and Kona storms (Fletcher and Feirstein 2009). Figure 6 shows the direction of waves and the height of those waves, based upon data acquired at the wave buoys shown in the Figure.

- The trade winds are dominant about 75 percent of the year, with average wave heights of 2 meters (m), up to 5 m on occasion.
- In the winter, the North Pacific swell is generated from storms in the northwest Pacific Ocean, with average annual maximum wave heights of 6.8 m but can be up to double that during certain events.
- The Southern swell arrives in the summer from storms south of the equator, tracking south of Australia, New Zealand, and the South Pacific Islands with wave heights of averaging 2.5–3 m.
- Kona storms are synonymous with bad weather in Hawaii. They are associated with low-pressure areas generated northwest of Hawaii moving to the east, with southerly winds typically resulting in waves of 3–4 m. Kona storms commonly include high winds and rain, exposing typically leeward southern and westerly facing shorelines to damage from erosion. Kona storms occur every year, and major Kona storms occur about every 5–10 years.
- Infrequent but occasionally damaging waves can also occur in summer months from tropical storms and hurricanes.

The effects of storms, winds, and waves is somewhat dependent upon the tides, due to the natural protection provided by shallow coral reefs, whereas storms hitting at low tides usually cause less erosion and flooding than if they arrive during high tides. Tide ranges are relatively similar and small for all of the islands, which for Honolulu is a mean spring tide range of 0.6-0.8 meters. Spring tides average about 1 meter. These levels vary depending upon wind set-up, atmospheric pressure, El Niño–Southern Oscillation (ENSO) cycles, and other oceanographic factors (Fletcher et al. 2010, Fletcher et al. 2012; Fletcher and Fierstein 2009). Hawaii is also prone to passing “meso-scale eddies.” These are slowly rotating water masses that pass through the islands on an irregular basis and can temporarily elevate tide levels by several inches.

![Figure 6. Hawaii dominant swell regimes.](image)

3.4 Description of the Shoreline

3.4.1 Kauai

Kauai has 75 km of sandy beaches along a total shoreline of about 180 km. Two volcanoes may have created Kauai or it could have been one volcano, as scientific investigation is continuing. The highest points on the island are at Mt. Kawaikini at 1,598 meters and Mt. Waialeale at 1,569 meters. Rain gauges at Mt. Waialeale, which traps moisture from the trade winds, measure an average of 11.4 m of rainfall per year (Blay et al. 2013 and University of Hawaii Manoa website).

![Map of Kauai](source: University of Hawaii Manoa Coastal Geology Group website)

In general, the shoreline consists of rugged volcanic cliffs and pockets of beaches with intermittent beach rock and some lithified sand dunes on the south coast. Most beaches are calcareous sand but some contain eroded materials from inland brought to the coast by streams and rivers. Depending on the time of year, the Kauai shoreline is exposed to North Pacific waves, southern swell, the trade winds, and Kona storms, all of which have the potential to cause coastal erosion and accretion. Kauai’s unique round(ish) shape and lack of nearby islands make it highly exposed to waves from all directions, which can refract (wrap) around much of the island.

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4 Much of the information describing the shorelines of Kauai, Maui, Oahu, and Hawaii in this section was derived from the University of Hawaii Manoa Coastal Geology Group website. Specific information from other references is cited.
The Mana Coastal Plain shown in Figure 7 is an area of convergence of longshore transport receiving sand from trade wind waves, southern hemisphere swell, and North Pacific swell refracting around the west side of the island (Fletcher and Feirstein 2009).

The north shoreline is primarily characterized by embayments, fringing reef systems, and beautiful white sandy beaches backed by rugged mountains. The beaches tend to be steep, with coarse-grained calcareous sand. In winter, the beaches fronting the Princeville cliffs are typically inundated by northern swells. Hanalei Bay is a deep bay with an overall accreting beach according to long-term shoreline change studies, similar in that respect to Kailua Bay on Oahu.

Kauai’s northwestern shoreline is extremely rugged, which includes the Na Pali Coast State Park, a stretch of 24 km of steep ridges and cliffs and deep erosional valleys. Pockets of sand beaches exist along the shoreline although the calcareous sand is eroded to become boulder beaches in the winter.

Further along the shoreline to the west and south, the shoreline transitions to the Mana Plain, which is a sand-rich beach plain with extensive dunes in the north. The Mana Plain was formed over thousands of years by converging longshore currents from the north and south. It extends 5 km inland with gently sloping wide beaches backed by an extensive dune system. This area includes Kauai’s longest stretch of sandy beach, 24 km long, and up to 90 meters in width in the summer.

The southwestern coast contains long, moderately narrow beaches that receive sediments from runoff from the interior of the island. Lacking a shallow nearshore reef in the Waimea area, the beaches are relatively wide and steep. Waimea Canyon, “Grand Canyon of the Pacific,” is the largest source of terrestrial sediment in Hawaiian Islands. Of interest, the beach at Waimea-Kikiaola is mostly dark volcanic sand and transitions to light carbonate sand at Oomana Point to the east.

The southern part of Kauai includes a coastal plain that extends into the ocean with rocky headlands, and pocket beaches. Poipu is the major resort center of Kauai, and it has suffered from chronic erosion and struggled to recover from damage from Hurricane Iniki. There are extensive lithified sand dunes (eolienite) east of Poipu (Mahaulepu).

Kauai’s eastern coast is fronted by extensive fringing reefs, composed of coarse- to fine-grained sandy beaches separated by rocky points interspersed with boulder coastlines and numerous embayments.

![Image of Kauai shorelines](image-url)

*Figure 8. Kauai shorelines.*

*Source: University of Hawaii Manoa Coastal Geology Group website.*
3.4.2 Oahu

Oahu has 180 km of generally irregular shoreline with 107 km of sandy beaches, and is the third largest and most populated of the Hawaiian Islands, having 900,000 of the state’s 1.2 million residents. Oahu consists of two eroded shield volcanoes separated by the Schofield Plateau. The North Shore has long sandy beaches, rocky reef rock points, and beach rock outcrops that are frequently exposed during the winter months. The North Shore is famous for large waves reaching breaking heights of 15 meters and more. The South Shore is well developed including Honolulu, Waikiki Beach and Pearl Harbor. Pearl Harbor contains about 50 km of shoreline, and includes the wetlands at Pearl Harbor National Wildlife Refuge.

Most of the coast is characterized by a gently sloping coastal plain. The shoreline is composed primarily of calcareous sand and limestone rock (fossil reef, beach rock, and lithified sand dunes) (Fletcher, 2010). The coast becomes more rocky and narrow around Kaena Point (northwestern point of Oahu) and Makapuu Point (southeastern point of Oahu).

Figure 9. Map of Oahu.

Source: University of Hawaii Manoa Coastal Geology Group website, Fletcher 2011
3.4.2.1 South Oahu

The southern shorelines of Oahu are gently sloping and protected by a wide and shallow fringing reef. The exceptions to the gentle shoreline are Diamond Head and Koko Head. The southern shore (Honolulu) is Hawaii’s most populated area, and the center of Hawaii’s tourism, business, and military sectors. Waikiki Beach in Honolulu was originally a wetland with a narrow beach. It has been extensively engineered over the past century and is now full of hotels, offices, and restaurants; the beaches are experiencing chronic erosion and are in need of regular sand nourishment. The shoreline is exposed to the alongshore trade winds year round, strong southern waves in the summer, and Kona storms. A series of seawalls, revetments and groins have been installed to maintain the beaches and to protect the development from erosion. Sections of Waikiki Beach have also undergone beach nourishment dating back nearly 100 years.

The shoreline from Barbers Point in the west and to Makapuu Point in the east is the most densely populated and urbanized area of Oahu (including Waikiki Beach and downtown Honolulu), and is fronted by one of Hawaii’s widest and shallowest offshore fringing reefs. East of Pearl Harbor is mostly armored, and the west side of Pearl Harbor is natural except for Barbers Point industrial areas, Iroquois Point groin field, and extensive seawalls at Ewa Beach.

Between Diamond Head and Koko Head is Maunalua Bay, which other than the two prominent volcanic headlands, is characterized by narrow sandy beaches and historical fishponds that have been infilled (Wailupe and Niu) or dredged (Hawaii Kai) to support development. Hanauma Bay is near Koko Head, and home to the Hanauma Bay Nature Preserve, the most popular county park in the United States. Further to the east is the rugged Ka Iwi Coast and Makapuu Point interrupted by Sandy Beach State Park, a pocket beach famous for body surfing in the powerful surf.

Figure 10. Typical beach scene at Waikiki Beach.

Photo by Craig Vogt.
3.4.2.2  East Oahu

The shoreline of eastern Oahu, from Kahuku Point in the north to Makapuu Point in the southeast corner, is generally moderately developed with single-family homes, with the exceptions of preserve areas at Kahuku, Kaneohe Marine Corps Base, and large recreation areas at Kualoa and Waimanalo (Bellow Beach). In many locations along the east coast of Oahu, roads and homes were built too close to the shoreline, and the shoreline has extensive coastal armoring. Much of the shorefront coastal highway north of Kaneohe Bay has been armored, resulting in extensive beach loss and high wave damage along the critical roadway. The shoreline, which is mostly a low-lying coastal carbonate sand-rich plain with shallow fringing reefs, is exposed to the trade wind swell year round and refracted North Pacific swells during the winter months. North of Kaneohe Bay, beaches are typically narrower and fringed by a shallow reef, whereas beaches south of Kaneohe Bay are generally wider with a deeper fringing reef. The protected back-reef shoreline of Kaneohe Bay is characterized by narrow gravel and mud beach and rocky shoreline and includes areas of mangrove, wetlands, and historical fishponds.

3.4.2.3  North Oahu

The North Shore of Oahu, from Kaena Point to Kahuku Point, is famous for the huge waves from strong Pacific Northern swell during the winter months and includes the area known as the “7-mile miracle” for the numerous world-class big wave surf breaks between Haleiwa and Sunset Beach. The north shore beaches host world championship surf contests in the winter and are among the most popular recreation sites for visitors and Oahu residents. The area generally has flat and wide beaches in the summer with relatively calm waters. In the winters, beaches are steeper and narrower. However, shoreline change is highly variable along the shoreline with some areas accreting sand in winter months and eroding in summer months with shifts in predominant wave direction.

3.4.2.4  West Oahu

West Oahu is the least developed of Oahu’s shoreline. The shoreline is characterized by sandy beach embayments and basaltic and fossil reef limestone headlands. Most beaches are lined by single-family homes, undeveloped land, and parks. The beaches are subject to erosion from refracted North Pacific waves, Kona storms, and southern swells, depending upon the season. Though erosion rates are high, beach loss has been less pronounced on West Oahu compared to other sides of the island due to extensive beach parks on the seaward side of the coastal highway, providing a buffer from erosion and high wave inundation.
3.4.3 Maui

The island was formed by two volcanoes, West Maui Volcano (extinct) and Haleakala Volcano (dormant). The two volcanoes are shown in Figure 13, one on each side of the island with a low-lying central isthmus between. The highest point on Maui is the summit of Haleakala Volcano at an elevation of 3,055 meters. Maui has about 90 km of sandy beaches out of a total shoreline of about 193 km.

Maui has undergone extensive development over the past several decades, with the population of Maui tripling since 1970 (Fletcher 2011). Most development is concentrated along the coastal areas with beaches, which is in West Maui and South Maui; there is less dense development on the north shore and east Maui is rural, where much of the land is either undeveloped or used for agriculture. More information is available in the Maui Island Plan, adopted in 2012 (Maui County 2012).
3.4.3.1 North Shore Maui

The north-exposed shore of Maui extends from Kahakaloa to Keanae with a wide variety of shoreline types including steep and rocky volcanic coastline, clay bluffs, sandy beaches, and cobble beaches. The eastern portion of the region is marked by rocky headlands bordering small coastal embayments with cobble beaches from stream deposits. This region is famous for surfing very large waves, including the famous Peahi (Jaws) Break, that shoal over the deep reef towards the coastline. Sand mining is believed to have been widespread on the north shore of Maui and elsewhere to support the sugar cane industry as well as cement production.

To the west, the shoreline transitions to bluffs comprised of volcanic soil and clay along with rocky headlands and sandy pocket beaches. This region is dominated by consistent trade winds that blow parallel to the shore as well as broad fringing reefs that break large swells. This coast is considered one of the best windsurfing areas in the world. Like Oahu, the north shore of Maui is famous for big wave surfing in winter months as well as windsurfing, particularly the breaks around Hookipa and Paia. Trade winds on Maui are enhanced (accelerated) on the north and south shores as the winds are funneled through the central isthmus.

The central part of the region around the Maui isthmus has long sandy beaches made up of coarse, calcareous sand mixed with coral rubble and basalt rock. One example is the nearly continuous beach from Spreckelsville to Kahului Harbor. A fringing reef provides some protection from the direct impact of North Pacific
swell during the winter. The trade winds contribute to well-developed coastal dunes. Industrial and commercial activity has resulted in a well-developed shoreline, and widespread chronic erosion. Beaches in this area are prone to high seasonal variability with large waves from the northwest predominant in winter months and from the northeast predominant in summer months.

Erosion has led to narrowing beaches and resulted in some armoring of the shoreline to protect coastal development. Some of the coastal dunes are degraded from human activity (i.e., sand mining) and no longer provide natural hazard mitigation, or can be sand sinks through sand blowouts that transport sand inland and out of the active beach system. Further to the northwest, the coastline becomes very rugged with pocket sandy beaches. The beaches from Paia to Spreckelsville, including the well-known Baldwin Beach Park, were mined for sand and coral from 1907 to the late 1970s. The beach sand was used to manufacture hydrated lime for sugar plantation uses, to build railroads and airstrips, plus to produce cement during wartime. Shoreline recession at Baldwin Park is, in part, the result of sand mining operations for a now-defunct lime kiln (Fletcher et al. 2012). By the 1920s, beach erosion along Stable Road was a concern, and in 1925, a 400-foot long concrete seawall was constructed fronting residential properties in order to protect the shoreline. Before 1940, approximately 14 rock groins were constructed in front of this seawall and downdrift of it through Kanaha Beach Park further to the southwest to prevent beach loss. A comprehensive assessment was completed in 1954, “The Spreckelsville Beach Problem,” that recommended ceasing sand removal from these beaches (Cox, 1954). Beach sand mining continued for another 25 years. By 1997, the beach in front at the east end of the downdrift seawall was lost (Stable Road 2012).

3.4.3.1 West Maui

West Maui is dominated by rocky headlands and narrow calcareous sandy beaches. Key features of West Maui include numerous pocket beaches between Napili and Kahana/north Kaanapali, extensive beaches at Kaanapali (main tourism center on Maui), and narrower low-lying beaches, cobble, and seawalls from Lahaina to the south. This region is known for its favorable weather conditions and attractive beaches so it has become a well-developed tourist destination, including the historic town of Lahaina and the Kaanapali resort area. Overall, this region is highly developed with condos and hotels, the most developed tourism area of Maui, second only to Waikiki on Oahu.

The generally west facing coastline receives wave exposure from northwest swells in the winter that wrap into the region, south swells in the summer, and occasional Kona storms that approach from the south. This region is partially shielded from the full energy of northwest swells by the islands of Molokai and Lanai. With wave exposure from two directions (north and south), the sandy beaches exhibit high seasonal variations. The region overall is considered sand starved, owing partly to a limited sand supply in the upper part of the coastal plain where the geology transitions from sand to volcanic sediment types. As a result, while fringing reef in many areas provides protection from wave energy, chronic erosion and narrowing beaches have led to shoreline armoring to protect the extensive tourist and commercial facilities. This armoring is associated with loss of beaches along parts of the region, including Lahaina and Honokowai.
Many beaches have eroded to expose beach rock and seawalls (particularly north of Kaanapali). Seawall failure has been rampant in this area in the past decade due to improperly built structures. In addition to widespread chronic erosion, beaches from Kaanapali to Napili are particularly prone to seasonal changes with sand typically driven to the north end of beaches from southerly swell in summer months and toward the south end of beaches from northerly swell in winter months.

The coastal highway south of Lahaina is a critical transit corridor that was built directly behind low-lying beaches and is prone to erosion and overwash during high waves.

3.4.3.2 South Maui

From Maalaea to Makena-Wailea, the shoreline is generally characterized by long stretches of sandy beach and is a well-developed shoreline characterized by condos, hotels, and single-family homes. It is the second largest tourist area on Maui.
As the southern coast of Maui Island, the region receives wave exposure from the south during summer south swells and from Kona Storms. Since the orientation of the coastline is west facing, sand transport from waves in generally from south to north. Consistent summer trade winds blow parallel to the shoreline downcoast from north to south due to a funneling effect of wind between the West Maui Mountains and Haleakala. As a result, there is also a significant wind-blown (aeolian) sand transport pattern opposite of wave transport that creates well-developed coastal dunes. The Maalaea small boat harbor at the north end is a manmade facility protected by breakwaters. Going south, the shoreline is characterized by narrow beach backed by the Kealia Pond, a large wetland. This transitions to the well-developed Kihei area with many condominium complexes used as vacation rentals fronted by relatively narrow beaches. Continuing south into the Wailea area, resort development dominates behind sandy pocket beaches between rocky, basalt headlands. South of Wailea is Makena, with a combination of expensive single-family homes and important recreational areas with long, sandy beaches, including the famous Big Beach. This area is relatively protected from trade winds. In addition to extensive chronic erosion problems, the beaches from Kihei south are particularly prone to erosion damage from large south swells and intermittent southerly Kona storms.

### 3.4.3.3 East Maui

The shoreline from Nahiki to Kaupo is mostly undeveloped shoreline at the base of Haleakala Volcano characterized by steep rocky headlands, and basalt points formed by geologically young lava flows. The Hana coastline consists of steep rocky headlands, shallow sloped bays, and pocket beaches. The wide exposure of the Hana coast to wind and waves approaching from the north, east, and south, make the dynamic hazards associated with storms and waves relatively severe.

![Kaupo](image)

**Figure 17. Shoreline at Kaupo.**

*Courtesy Bob Cella*
3.4.4 Hawaii Island (Big Island)

Hawaii Island (Big Island) has approximately 428 km of shoreline and is the largest and youngest of the Hawaiian Islands. The island consists of five volcanoes, three of which—Mauna Loa, Kilauea, and Hualalai—are still considered active, plus the active volcano, Loihi, on the Big Island’s submerged southeastern flank. The summit of Mauna Kea, the island’s tallest mountain, has an elevation of 13,796 feet (GoHawaii website). Measured from the seafloor, Mauna Kea is the tallest mountain on Earth. Mauna Loa and Kilauea have erupted frequently during recent historical times (Peterson and Moore 1987).

The sediment characteristics of Big Island beaches are highly variable from one area to the next. White carbonate sand beaches are found in areas where fringing reefs are established on older lava flows, particularly on the west (Kona to South Kohala) coast, while black (as well as red and green) sand pocket beaches are found where the primary source of sediment is from eroded lava rock.

As stated by Peterson and Moore (1987), the geological history of Hawaii Island can be summed up in a single sentence:

“Hawaii has been built of adjacent and partly overlapping mounds of basaltic lava flows and small amounts of tephra, which originated on the ocean floor and successively grew above the sea to form the five distinct volcanoes that compose the still-evolving island.”

Peterson and Moore were quick to point out that the summary sentence is well over-simplified in that it misses the related processes and conditions that shaped the island, such as changes in composition of magma, shifts in vent locations, variations in inactive cycles, and interactions with the magma and the sea. The first detailed description of Hawaiian volcanic activity was by two missionaries that traveled around the island in 1823, William Ellis and Joseph Goodrich.

As a result of the journey, Ellis described Hawaii Island as follows:

“The whole island of Hawaii, covering a space of four thousand square miles, from the summits of its lofty mountains down to the beach, is, according to every observation we could make, one complete mass of lava, or other volcanic matter, in different stages of decomposition. Perforated with innumerable apertures in the shape of craters, the island forms a hollow cone over one vast furnace, situated in the heart of a stupendous submarine mountain, rising from the bottom of the sea.” (Peterson and Moore 1987)

Island building continues on the Big Island, as in the second half of 2014, lava flowed from the volcano, Kilauea, towards the village of Pahoa. Kilauea’s east rift zone has been erupting continuously from the Puu Oo vent since 1983. Figure 18 shows the lava flows.

Figure 18. Island building continues.

Due to its relatively young age and ongoing volcanism, the Big Island has fewer fringing reefs and thus fewer white calcareous sand beaches compared to Kauai, Oahu, and Maui.

The Puna area on the southeastern coast of the Big Island including Cape Kumakahi, shown in Figure 19, is characterized by steep cliffs, intertidal benches and anchialine pools (i.e., an enclosed coastal pond with underground connection to the ocean), and few pocket beaches. To the northwest of Cape Kumakahi is the urban area of Hilo, which is heavily populated and home to one of the two deep-draft harbors on the Big Island. A 3-kilometer offshore breakwater protects developments along the eastern and central parts of Hilo Bay (Figure 20).
In 1946 and again in 1960, Hilo was hit by devastating tsunamis that claimed 220 lives and destroyed hundreds of buildings. On April 1, 1946, tsunami waves were generated by an earthquake in the Aleutian Islands, and on May 22, 1960, an earthquake on the coast of Chile generated tsunami waves of 25-35 feet. Hilo’s two tsunamis leveled a wide swath of homes and businesses in the bay front area, which was never redeveloped. Almost the entire area fronting Hilo Bay is open grassland (Tsunami Museum website).

The Hamakua Coast north of Hilo is characterized by steep, rocky shorelines with basaltic headlands, sea cliffs, coves, and embayments. Beaches in this area consist primarily of black volcanic pebble and cobblestone. There are no calcareous sand beaches in this area as fringing reefs have yet to develop. In the area of Waipio Valley further to the northeast, spectacular coastal bluffs and cliffs up to 400 meters high are present with a few beaches consisting of black volcanic sand.

Further to the northeast and around Upola Point, the shoreline is characterized by steep basaltic headlands with intermittent black sand beaches. Shorelines from Upola Point to Kawaihae Bay are characterized by rocky headlands with a few cobble and boulder beaches. Kawaihae Bay is the other deep draft harbor on the island and is protected by a breakwater and fringing reefs. South of Kawaihae Bay, the Waikoloa coastline is Hawaii Island’s most popular tourism destination with several large white calcareous sand beaches and healthy offshore fringing reefs. This area has more carbonate pocket beaches than other areas, though the area is still characterized primarily by rocky shorelines. Numerous anchialine pools are also a unique coastal environmental feature.

The shoreline along the historic lava flows from the Hualalai Volcano is characterized by low rocky headlands, pocket beaches of white and black sands, and offshore fringing reefs. A large portion of the local population is centralized in Kailua-Kona, which is a central hub for tourism on the Big Island. Shorelines further south along the Mauna Loa Volcano are characterized as rocky, low sea cliff shorelines backed by numerous wetland areas supported by groundwater flows. Olivine beaches are prevalent as coastal erosion processes produce green sand from the shoreline basalt headlands. There are some small carbonate pocket beaches but overall the shoreline is characterized by rocky lava coast (rocky intertidal, low cliffs, benches).

From the southernmost point of the Big Island at Ka Lae Point (South Point), the shoreline to the north is characterized by steep rocky headlands that eventually transition to low-lying coastal plains near Honuaupō Bay. Kīlauea Volcano remains very active, with lava flows threatening the village of Pāhoa as recently as 2014. In addition to ongoing erosion along the shoreline, the southern coast of the Big Island is also subject to episodic bench failures. The shoreline from Ka Lae Point to Cape Kumakahi is generally characterized by recent volcanic flows from Mauna Loa and Kīlauea with steep volcanic cliffs and occasional volcanic (black, red, green) sand beaches. The volcanic vent Pu‘u O‘o on Kīlauea's eastern rift zone has been active since 1983, continuously building new land and prone to faulting, slumping, and collapsing of newly formed lava benches. No carbonate beaches are found on this shoreline.
Figure 20. Hilo Bay.
Photo credit Jessica Podoski.

Figure 21 shows common shoreline characteristics on the Big Island. All photos are from the University of Hawaii Manoa website.

Figure 21. The rocky shoreline of the Big Island.
Source: University of Hawaii Manoa Coastal Geology Group website.
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4 EROSION AND ACCRETION ALONG HAWAII BEACHES AND SHORELINES

The Hawaii shoreline is typically areas of non-continuous beaches with short headlands dividing the coast into small embayments and beaches, or lengths of rocky shoreline with pockets of short beaches. Overall, Hawaii beaches are characterized by a dominant trend of erosion. However, localized trends of shoreline change are highly variable within individual beaches and littoral cells. Fletcher et al. 2012 and Romine 2012 found that:

- The long-term erosion rate for the beaches of Oahu, Maui, and Kauai is 0.11 m per year; 70 percent of the shorelines that were measured were found to be eroding.
- On the three islands, a total of 22 km or 9 percent of the total length of beaches were completely lost to erosion and shoreline armoring over the last century.
- Maui has lost 11 percent or 7 km of beach over the last century, with long-term average erosion rates of 0.17 m per year and 85 percent of Maui’s beaches eroding.
- Kauai has lost 8 percent or 6 km of beaches, with an average long-term rate of erosion of 0.11 m per year with 85 percent of Kauai’s beaches eroding.
- Oahu has lost 8 percent or 9 km, with an average long-term rate of erosion of 0.06 m per year and 60 percent of beaches eroding.

Areas of erosion and accretion are often separated by hundreds of meters on neighboring beaches or on sections of the same beach. On developed coasts, localized erosion and accretion trends are often attributed to manmade structures (e.g., seawalls, groins) affecting alongshore sand transport. The overall trend of erosion is important knowledge for policy considerations, but local erosion and accretion rates are the basis for current and future management of shorelines by State and county agencies at the scale of individual beaches and littoral cells. The overall condition is that all islands are experiencing chronic erosion and many beaches are degraded. In some cases, this has reached a critical point where beaches are being lost and there is no longer enough beach sand to buffer against seasonal high waves and episodic events; development is being threatened. While there are some cases of accretion, this is not the overall trend and it is most often due to interruptions in longshore transport by manmade structures.

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5 See Fletcher et al. 2012 and Romine 2013 for the additional details regarding the erosion and accretion measurement methods and statistical basis and range of uncertainty for these erosion rates.

6 The information and data in this subsection 4.1 of the report are from Fletcher et al. 2012 and Romine 2013, unless otherwise referenced, and therefore these references are not repeated in the text.
Figure 22 shows Waikiki Beach before and after the beach nourishment project that replenished sand on the eroded 1,700-foot long shoreline between the Royal Hawaiian groin and Kuhio Beach Park.

![Figure 22. Waikiki Beach before (above) and after (below) beach nourishment. Credit: Top photos: University of Hawaii Sea Grant College Program. Bottom photo: Hawaii DNLR.](image)

In combination with factors such as waves, sediment supply, littoral processes, and human influences, sea level rise is having significant impacts on erosion of beaches on all the main islands. In Maui, over the last century, beaches have experienced significantly more erosion than Oahu. This has been attributed, in part, to a rate of sea level rise which is 65 percent greater than Oahu, because of subsidence or rebound of the earth’s crust (and therefore the islands) and/or variations in the upper ocean water masses (Romine et al. 2013). Projected increases in rates of sea level rise will cause more extensive and severe erosion in the coming decades. Studies predict a doubling of erosion rates by mid-century due to future sea level rise (Anderson et al. 2015).

### 4.1 The USGS and University of Hawaii Study of Historical Shoreline Change

Published in 2012, this was a comprehensive assessment of historical shoreline change on the three most populated islands in Hawaii: Oahu, Maui, and Kauai as part of the USGS National Assessment of Shoreline Change project. The objectives of the assessment were to (1) develop and implement improved methods of assessing and monitoring shoreline movement and (2) improve the current understanding of the processes controlling shoreline movement. The assessment was a compilation of research efforts funded by federal, state, and county agencies and conducted by University of Hawaii researchers (Fletcher, et al. 2012).
The erosion rates were noted with uncertainties and possible variations in reported values, such as seasonal and annual variability inherent in the shoreline assessed. An example of the time-span of the historical assessment of shoreline positions is shown in Figure 23. For the most part, one historical shoreline position is available for each decade or so, going back to the early 1900s. Historical depictions of shorelines represent a point in time, and those were used to represent a decade or more in the historical data set for a particular shoreline. Thus, the results need to recognize the natural variability of the shoreline, as well as measurement errors inherent in the methodology. Uncertainties resulting from shorter-term fluctuations in shoreline locations were assessed using data from seasonal beach profile surveys collected over several years around the islands. See Fletcher et al. 2012 and Romine and Fletcher 2013 for details regarding the methodology and uncertainties7.

The assessment mapped and analyzed historical shoreline change on the three islands, resulting in over 12,000 individual shoreline change measurements at a spacing of every 20 meters along the beaches over the last century. Historical shoreline positions were mapped from photos and previous topographic studies. The study results were organized geographically by individual island and island region as shown in Figure 24, Figure 25, and Figure 26.

7 For example, Fletcher et al. reported the results as -0.11 ± 0.01 m per year as the average long-term rate for Oahu, Kauai, and Maui. This document lists that result as 0.11 m per year.
Figure 24. Kauai beach study regions.

Source: Fletcher et al. 2012

Figure 25. Oahu beach study regions.

Source: Fletcher et al. 2012
Results of the Assessment

The results show that erosion was occurring in the long term at an average rate of 0.11 m per year with 70 percent of transects showing a trend of erosion. Accretional trends were shown at 28 percent of transects. Two percent of beaches only had two historical shorelines available, so those were not sufficient to include in the weighted linear regression methodology for those areas. As noted earlier, while these averages and total percentages of shoreline trends provide useful information on a regional basis, these values mask the other key finding that shoreline trends are highly variable along the shoreline when viewing the data at the scale of individual beaches. Alongshore variability is shown in Figure 27. The historical shoreline change data are available for county and state decision-making regarding shoreline management and available in historical erosion maps and tables. The University of Hawaii maps and rates are used by the counties of Kauai and Maui and for State Conservation District Lands for calculating shoreline construction setbacks and for hazard assessment and beach management. Maps and rates are available at the UH Coastal Geology Group website (http://www.soest.hawaii.edu/coasts/erosion/) and an online mapping tool developed with PacIOOS (http://oos.soest.hawaii.edu/pacioos/regions/hawaii.php).
Figure 27. Variability in erosion and accretion along the shorelines of Oahu.  

*Credit: Brad Romine.*  

Table 1 summarizes the findings of the assessment. Beach loss in the table means that the beach was completely lost to erosion over the timespan of the study. In nearly all cases where the beach was lost, the shoreline is now characterized by waves breaking directly against seawalls or other coastal armoring.
Table 1. Beach loss and erosion rates for Kauai, Oahu, and Maui.

Source Romine and Fletcher 2013

<table>
<thead>
<tr>
<th>Region</th>
<th>Beach Loss in km</th>
<th>Beach Loss in %</th>
<th>Erosion Rate in meters per year</th>
<th>Percent Eroding in %</th>
<th>Percent Accreting in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauai</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>North</td>
<td>1.7</td>
<td>8</td>
<td>0.11</td>
<td>76</td>
<td>23</td>
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<td>East</td>
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<td>78</td>
<td>19</td>
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<tr>
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<td>1.9</td>
<td>14</td>
<td>0.01</td>
<td>63</td>
<td>34</td>
</tr>
<tr>
<td>West</td>
<td>1.5</td>
<td>7</td>
<td>0.13</td>
<td>64</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>6.0</td>
<td>8</td>
<td>0.11</td>
<td>71</td>
<td>27</td>
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<tr>
<td>Oahu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>0.2</td>
<td>1</td>
<td>0.11</td>
<td>73</td>
<td>25</td>
</tr>
<tr>
<td>East</td>
<td>5.5</td>
<td>13</td>
<td>0.01</td>
<td>50</td>
<td>47</td>
</tr>
<tr>
<td>South</td>
<td>3.0</td>
<td>11</td>
<td>0.04</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>West</td>
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<td>0</td>
<td>0.25</td>
<td>83</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>8.7</td>
<td>8</td>
<td>0.06</td>
<td>60</td>
<td>38</td>
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<tr>
<td>Maui</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>0.9</td>
<td>6</td>
<td>0.26</td>
<td>87</td>
<td>12</td>
</tr>
<tr>
<td>Kihei</td>
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</tr>
<tr>
<td>West</td>
<td>3.8</td>
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<td>0.15</td>
<td>85</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>6.8</td>
<td>11</td>
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<td>85</td>
<td>14</td>
</tr>
<tr>
<td>Total all beaches</td>
<td>21.5</td>
<td>9</td>
<td>0.11</td>
<td>70</td>
<td>28</td>
</tr>
</tbody>
</table>

4.1.1 Kauai Beaches

Shown in Table 1, Kauai beaches were erosional overall, losing 6 km of beaches over the last century or so. The overall average erosion rate was 0.11 m per year. As with Oahu, erosion trends are highly variable along the shoreline.

- The highest average rate of erosion was for East Kauai beaches at 0.15 m per year, but the highest measured rates were in west Kauai at Major’s Bay at 1.6 m per year. Extensive areas of erosion and beach loss (due to seawalls) were found along the residential area of Kapaa.
- About 14 percent of south Kauai’s beaches were lost to erosion. Beach erosion and loss was concentrated around Poipu and Pakala in the southern region. The County of Kauai funded a study to explore beach restoration alternatives for the Poipu resort area.
- A notable exception to the overall trend of erosion was at Hanalei Bay on the north shore, where the beach is accreting at an average of 0.11 m per year. Like the other islands, beaches
along Kauai’s north shore are prone to high seasonal variability with massive winter waves leading to seasonal erosion and high wave run-up.

- Accretion over the last few decades was found at several other locations, the maximum rate of 2.8 m per year at Polihale Beach, the width of which varied widely with the season.
- The west side of Kauai, particularly between Kekaha and Barking Sands, is highly variable with shifting seasonal wave directions resulting in temporary changes in beach width of 100 m or more from one month to the next. Shifting sands along West Kauai recently threatened the beachfront highway. A harbor at Kikiaola near Waimea blocks natural sediment transport leading to erosion on the downdrift side, which has threatened several private properties.

### 4.1.2 Oahu Beaches

Oahu beaches were erosional overall with 60 percent of beaches showing erosion, whereas 38 percent were accreting sand. A total of 9 km of sandy beaches were lost over the last century leaving Oahu with 107 km of sandy beaches.

- The west region of Oahu was the most erosional with rates of 0.25 m per year and 83 percent of the beaches eroding. Though the west side has the most erosion, there was little beach loss because of few seawalls along beaches and sufficient setback/buffer between development (including the coastal highway) and beaches. There are exceptions to this, such as at Makaha Beach Park, which has major seasonal erosion problems next to the highway. Historical erosion at some West Oahu beaches is attributed in part to sand mining in the early-mid 1900s.
- North Oahu’s winter poses significant risks of seasonal or intermittent erosion due to the large winter waves, and 73 percent of beaches were eroding chronically (over the long-term). A series of beach front properties suffered land loss and damage to homes during severe seasonal erosion over the winter of 2012/2013.
- The results for East Oahu indicate relatively stable shorelines, overall. Beach accretion was notable in portions of several deep bays, Laie, Kailua, and Waimanalo. The northern part of east Oahu was characterized by extensive beach erosion and beach loss fronting residential properties and the coastal highway. Extensive areas of beach erosion and beach loss were also found at Lanikai and Waimanalo on the southeast coast.
- The south shore showed about equal erosion and accretion with an overall trend towards erosion. This may be a result of efforts to stabilize the shoreline using such actions as seawalls in many locations throughout the region as well as groins and beach nourishment at Waikiki. At Waikiki Beach, accretion was noted on the updrift side of groins, and erosion and beach loss on the downdrift side of groins (Romaine et al. 2013).
- The highest erosion rate was 1.8 meters per year at Kualoa Point in east Oahu. The highest rate of accretion was 1.7 m per year at Pokai Bay in west Oahu on the updrift side of a harbor breakwater.

### 4.1.3 Maui Beaches

- Eighty-five percent of Maui’s shorelines are experiencing long-term erosion. Maui’s beaches have the highest rates of erosion of the three islands addressed in the 2012 USGS report (Fletcher et al. 2012). Recent University of Hawaii research examining 100 years of data indicates that Maui has the highest rates of erosion and is losing beaches to erosion faster than Oahu and Kauai due to locally higher rates of sea level rise. About 7 km or 11 percent of beaches have been lost to erosion over the last century or so, leaving about 90 km of sandy beaches. Only 14 percent of beaches were accretional, and are largely in association with manmade structures that interfere with sand transport and impound sand locally. North Maui had the
highest rates of erosion at 0.26 m per year, with 87 percent of beaches eroding. Extensive erosion was found east of Kahului Harbor, at Kanaha among a series of groins, and at Baldwin Park, which had the highest erosion rates on the island. The shoreline at Baldwin Park has retreated more than 100 m, where sand mining until the 1970s contributed to the retreating shoreline.8

- The west Maui and Kihei (southwest Maui) regions had similar rates of erosion. The rates were not as high as north Maui, but relatively high compared to Oahu or Kauai. Serious erosion and beach loss were found near Maalaea Harbor and in Kihei fronting Kanaha Beach Park and the Halama Street neighborhood. Beaches also were lost fronting Lahaina and the resort areas between Kaanapali and Napili in west Maui due to extensive seawall construction. The county and State are exploring beach restoration options at Kaanapali and west Maui.

- The highest accretion rate of 1.6 m per year was found at Kawillilipoa near Kihei, at the location between two fishponds where sand has accumulated due to interruption of longshore transport by the manmade structures.

Summary of the USGS and University of Hawaii Study

The conclusions of this work are that 70 percent of Hawaii’s beaches are eroding (represented by the three islands studied) and that 22 km of sandy beaches have been lost. While these average figures smooth out the differences between beaches, a limited number of which are accreting sand, it is expected that beach erosion will continue to threaten infrastructure, industrial and commercial facilities, and valuable real estate at an increasing rate. This will add increasing pressure on regulatory agencies and landowners working to address the impacts of beach erosion. Beach erosion and retreat will accelerate in the coming decades with projected increasing sea level rise; the information and data found for individual beaches in the 2012 study is valuable to shoreline management decisions at the local level. The State of Hawaii and University of Hawaii researchers are investigating future impacts of sea level rise and beach erosion for the Hawaii Climate Adaptation Initiative and statewide Sea Level Rise Vulnerability and Adaptation Report (State Act 83, 2014).

4.1.4 Hawaii Island Beaches

Hawaii Island’s geologic youth has resulted, in general, in a lower degree of beach formation along its rough volcanic coastline. White calcareous beaches make up a relatively small component of the shoreline largely because of poor reef development due to recent active coastal volcanism (University of Hawaii, Coastal Geology Group).

Hawaii Island is the largest mountain on earth (measured from the seafloor) and, as a result, is actively subsiding into the earth’s crust under its own weight from the growing volcanic edifice. In 1986, Campbell reported an annual subsidence rate of 2.4 mm per year for Hawaii, and that the subsidence has remained relatively constant for 600,000 years. In earlier work, Moore reported that Hilo, Hawaii, was subsiding at a rate of 4.8 mm per year (Campbell 1986).

The Hawaii coastline is subject to long-term subsidence but also localized episodic subsidence due to earthquakes. The 1975 Kalapana slumping along newly formed (geologically speaking) coastal areas. The

8 It was reported in 1963 that the chief use of beach sand in construction activities in Hawaii was in production of concrete. The quality of beach sand is such that it works well when used in concrete. Other uses included mortar and as a drainage course under paved roads. Sources of this type of construction sand are limited in Hawaii as river sands are almost non-existent in Hawaii, and use of basalt rock needs crushing and thorough washing and screening. The 1963 report predicted that beach sand will continue to be used in future construction projects in Hawaii, and it also cautioned that removal of sand from one beach should not exceed the normal supply at that location (Moberly et al. 1963).
1975 earthquake resulted in measured subsidence of 0.8 feet at Kalapana, which has resulted in frequent inundation of areas along the shoreline. Other reports state that subsidence varied from 3.5 m at Keahou Landing to 0.24 m at Kapoho. The subsidence due to the 1868 earthquake was as high as 2 m at Apua Point and 0.8 meters at Kaimu (Hwang 2007).

At Kapoho (Figure 28), subsidence rates have been reported more recently, in 2007, relative to Hilo of between 0.7 and 1.6 cm per year (+/-0.6 cm per year). Combined with measured sea level change, the relative sea level rise rate for Kapoho was estimated to be 0.8 to 17 cm per year, the vast majority of which is due to subsidence.

Development at Kapoho did not take into account that the area is subsiding, and thus, the risk of coastal inundation is increasing. In fact, several blocks of the Kapoho neighborhood are temporarily flooded by ocean water during annual high tides. Hwang (2007) stated that it would be hard to find a coastal area in the State of Hawaii that has greater risk of storms and wave action, as well as risk of major catastrophic events.

![Figure 28. Location of Kapoho.](http://www.hawaiiparadisevacationrentals.com)

Shoreline management in Kapoho is different from other areas of the Hawaiian Islands because the shoreline is dominantly cliffed or rocky, and therefore there is less risk of beach erosion and loss. Current management efforts are considering constructing seawalls or increasing the height of existing seawalls, requiring new buildings to be elevated, and at one point considerations of government land acquisition or exchange programs, or through other organizations such as the Trust for Public Lands and The Nature Conservancy (Hwang 2007). Though the high rates of relative sea level around Kapoho are due largely to local geologic processes, the area provides an example of how increasing rates of global (eustatic) sea level rise will affect low-lying coasts throughout Hawaii and beyond with increasing coastal inundation and threats to homes and infrastructure.
4.2 References for Erosion and Accretion


Interagency Climate Adaptation Committee, Sea Level Rise Vulnerability and Adaptation, Information Brief, Hawaii Climate Adaptation Initiative, October 2015.

Moberly, Jr. Ralph, Cox, Doak, Chamerlain, Theodore, McCoy, Jr., Floyd, and Campbell, J.F., Coastal Geology of Hawaii, Hawaii’s Shoreline, Appendix I, HIG Report No. 41, Coastal Zone Information
5 THE EFFECTS OF CLIMATE CHANGE AND SEA LEVEL RISE ON HAWAIIAN SHORELINES

Hawaii has over 750 miles of coastline comprised of a diverse mixture of environments, including sandy carbonate beaches, steep bluffs, densely-developed lowlands, lava benches, marshes and fishponds. Hawaii’s coastal communities and ecosystems are exposed to a wide variety of coastal hazards including high wave events, hurricanes, tsunamis, and extreme tides.

The impacts of erosion and flooding events are being exacerbated by rising sea level and may be further amplified by increasing numbers of events with changing storm patterns with climate change (Pacific Islands Regional Climate Assessment (PIRCA) website). The combined effects of these phenomena can cause shorelines to retreat, bluffs and cliffs to catastrophically fail, and low coastal areas to become inundated. While projections of sea level rise vary, the impacts will undoubtedly be increased by erosion and flooding statewide, exposing Hawaii’s coastal communities to greater hazards.

5.1 Sea Level Rise on the Hawaiian Shorelines

Sea level change is a very important consideration in Hawaii, given the characteristics of the islands and their shorelines. Recent USACE guidance addresses sea level change such that USACE missions, operations, programs, and projects are designed to be resilient to coastal climate change effects, with a focus upon sea level change (USACE 2014). At any location, changes in local relative sea level reflect the integrated effects of global mean sea level change plus local or regional changes of geologic, oceanographic, or atmospheric origin.

The sea level around Hawaii has risen about 1–2 millimeters (mm) per year over the last century. The average global sea level rise is about 4 mm per year, doubling since 1990 based on satellite altimetry observations. The local rate of sea level rise is influenced by a number of factors, including oceanographic patterns, basin scale weather including winds and ocean currents, and subsidence or uplift of the islands. Most of the Hawaiian volcanoes (including the above sea level islands) have undergone extensive subsidence, which continues today. About 2–4 km of vertical height is estimated to have been lost due to subsidence (Moore 1987).

Depending upon the distance from the Big Island, the rates of sea level rise vary, given the subsidence of the Big Island and its influence upon the underlying oceanic crust of the Pacific Plate. Closest to the Big Island, Maui’s rate of sea level rise is 2.04 mm per year, whereas Oahu’s is 1.41 mm per year and Kauai’s is 1.41 mm per year. These differences are because the weight of the Big Island is causing a downward flexure out as far as Maui, as shown in Figure 29. Romine et al (2013) found that local rates of sea level rise are an important factor in beach erosion trends, on an island-wide basis. Maui has higher rates of erosion than Oahu due to differences in relative rates of sea level rise (Maui’s is approximately 65 percent higher) (Romine 2013a, http://tidesandcurrents.noaa.gov).

9 Unless specifically referenced, the text in this subsection 5 is directly extracted from either of two references:
Figure 29. Lithospheric flexure under the massive volcanic accumulation that is the Big Island of Hawaii cause compensatory arching at a radius of approximately 400 kilometers (248 miles) resulting in the uplift of the island of Oahu.


Figure 31 includes four graphs that show the sea level trends on four islands in Hawaii, as found on the NOAA Tides and Currents website: https://tidesandcurrents.noaa.gov/sltrends/sltrends.htm.

5.1.1 Nawiliwili, Kauai

The mean sea level trend is 1.41 mm/year with a 95 percent confidence interval of +/- 0.45 mm/year based on monthly mean sea level data from 1955 to 2015, which is equivalent to a change of 0.46 feet in 100 years.
5.1.2 Honolulu, Oahu

The mean sea level trend is 1.41 mm/year with a 95 percent confidence interval of +/- 0.21 mm/year based on monthly mean sea level data from 1905 to 2015, which is equivalent to a change of 0.46 feet in 100 years.

5.1.3 Kahului, Maui

The mean sea level trend is 2.04 mm/year with a 95 percent confidence interval of +/- 0.42 mm/year based on monthly mean sea level data from 1947 to 2015, which is equivalent to a change of 0.67 feet in 100 years.
5.1.4  Hilo, Hawaii Island

The mean sea level trend is 2.95 mm/year with a 95 percent confidence interval of +/- 0.31 mm/year based on monthly mean sea level data from 1927 to 2015, which is equivalent to a change of 0.97 feet in 100 years.

![Sea level trends on four islands in Hawaii](https://tidesandcurrents.noaa.gov/sltrends/sltrends.htm)

As reported in 2009–2011, the global acceleration in sea level rise has not been observed in Hawaii as it has in the western tropical Pacific areas, which is likely due to the intensification of the trade winds over the last several decades (Merrifield 2011).

Ongoing research into the impacts of climate change and sea level rise are being conducted by the U.S. Global Change Research Program. Key messages from the third report in 2014 of that Program are shown in the text box.

### Key messages from the 2014 Third National Climate Assessment (Leong et. al, 2014)

- Warmer oceans are leading to increased coral bleaching events and disease outbreaks in coral reefs, as well as changed distribution patterns of tuna fisheries. Ocean acidification will reduce coral growth and health. Warming and acidification, combined with existing stresses, will strongly affect coral reef fish communities.
- Freshwater supplies are already constrained and will become more limited on many islands. Saltwater intrusion associated with sea level rise will reduce the quantity and quality of freshwater in coastal aquifers, especially on low islands. In areas where precipitation does not increase, freshwater supplies will be adversely affected as air temperature rises.
- Increasing temperatures, and in some areas reduced rainfall, will stress native Pacific Island plants and animals, especially in high-elevation ecosystems with increasing exposure to invasive species, increasing the risk of extinctions.
- Rising sea levels, coupled with high water levels caused by storms, will incrementally increase coastal flooding and erosion, damaging coastal ecosystems, infrastructure, and agriculture, and negatively affecting tourism.
- Mounting threats to food and water security, infrastructure, health, and safety are expected to lead to increasing human migration, making it increasingly difficult for Pacific Islanders to sustain the region’s many unique customs, beliefs, and languages.
The 2014 Global Change report (Leong et al. 2014) stated that over the current century, the sea level in the Pacific is expected to rise at the same rate as the projected rate in global sea level rise, with some variations regionally given ocean circulation changes and other changes due to other large-scale changes, such as melting glaciers. The report noted that global sea level rose about 8 inches since 1900, and that the rate of rise is increasing, with 1.3 inches per decade for the last two decades.

The National Research Council’s 2012 report on sea level rise for the coasts of Oregon, Washington, and California projected total increases of 3-9 inches by 2030, 0.6 to 1.6 feet by 2050, and 1.6 to 4.6 feet by 2100; these rates were presumed to be representative for Hawaii (NRC 2012). The projections in that report have been updated and expanded by NOAA’s 2017 report as shown in Table 1a. For 2050, increases of 0.16 to 0.54 meters are predicted for Hawaii, whereas in 2100, the increased sea level is predicted to be 0.30 to 2.0 meters. NOAA stated that “Long-term sea level rise driven by global climate change presents clear and highly consequential risks to the United States over the coming decades and centuries.” (NOAA 2017)

Table 1a. Global Mean Sea Level Rise scenarios, heights in meters for a base year of 2000 Source: NOAA 2017

<table>
<thead>
<tr>
<th>Year</th>
<th>Low in meters</th>
<th>Intermediate in meters</th>
<th>High in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>2020</td>
<td>0.06</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
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<td>7.5</td>
</tr>
</tbody>
</table>

Hawaii’s sea level rise is projected to be similar, but potentially higher as noted below, to those in Table 1a.

- Sea level has been rising in Hawaii over the past century or more. Rates of rise vary amongst the islands due to differing rates of subsidence that vary with distance from actively-growing Hawaii Island. Rates of sea level rise in Hawaii ranged from 0.6 inches (1.5 cm) on Oahu and Kauai, to 1.3 inches (3.3 cm) on Hawaii Island per decade over the last century (PICEP 2016). Based upon modeling, Spada et al. (2013) found that Hawaii and the central western Pacific Ocean will likely experience about 1 ft–2.5 ft (0.3 m-0.8 m) higher than global average sea level rise by the year 2100.
- Hawaii is expected to see increased frequency and intensity of storms, and an increased frequency of tropical cyclones as the storm track may shift northwards towards the Central North Pacific (PIRCA website).
- Hawaii is famous for large winter waves. During strong El Nino years, storms can be more powerful than usual with associated large waves with high intensity (PICEP 2016a). The Pacific
Islands Climate Education Partnership in 2016 cautioned that these larger waves “erode shorelines and beaches, undermine roads and seawalls, flood homes and buildings, and snarl traffic.” The PICEP went on to recommend that landowners and public agencies prepare for these problems as they get worse with El Niño years and sea level rise (PICEP 2016b).

- Sea level rise is expected accelerate over the coming decades and continue for centuries due to global climate and ocean warming. If greenhouse gases are emitted at the same rate as the past few decades, some studies have shown that the West Antarctic Ice Sheet may collapse and sea level rise may be twice as much as currently predicted (PICEP 2016b).

- Anderson et al. (2015) found that historical erosion trends are likely to double by mid-century.
  - Determined by sediment availability and local coastal slope, sediment-deficient low-lying coastal areas will experience enhanced erosion and inundation.
  - Beaches will be further shaped by changes in sediment transport patterns as a result of higher water levels over fringing reefs, climate-related degradation in reef geomorphology and sediment production, and changes in storminess and wave climate (Anderson et al 2015).

Sea level rise has been shown to be an important driver in the overall trend of beach erosion in Hawaii. Differing rates of relative sea level rise around Oahu and Maui remain as the best explanation for the difference in overall shoreline trends between the islands after examining other influences on shoreline change including waves, sediment supply and littoral processes, coastal geomorphology, and human impacts (Romine et al. 2013). More background information on climate change and sea level rise in Hawaii can be found in Fletcher et al. 2010.

Chronic erosion in front of developed lands has historically led to seawall construction, resulting in beach loss; approximately 8 percent of beaches on Oahu have been lost or narrowed due to seawall construction. Losses are similar on Kauai and Maui (average rate of erosion is 0.3 to 0.5 feet per year). On Kauai, for example, 71 percent of beaches experience chronic erosion. In nearly all locations where the beach was lost, the shoreline is now characterized by waves breaking against seawalls or other coastal armoring.

Over the longer term, sea level rise of this nature will lead to chronic coastal erosion, coastal flooding, and drainage problems, all of which Hawaii currently experiences. This long-term trend will be increased short-term fluctuations on coastal sea levels due to oceanographic and climate variability and episodic flooding and erosion along the coast with extreme tides.

Sea level rise threatens Hawaii’s nearshore ecosystems, critical infrastructure, and community infrastructure, accelerating erosion of previously stable beaches. Erosion is caused principally by waves, currents, and human impacts to sand availability (e.g., seawalls cutting off sand dunes from the beach). There is also evidence that historical beach mining on Oahu and Maui has led to accelerated erosion rates at localized scales. Continued sea level rise will increase marine inundation of coastal roads and communities and intensify salt-water intrusion in coastal wetlands and groundwater systems, taro loi, or field ponds, and estuaries. Extreme tides presently cause drainage problems in developed areas. Communities facing intensifying storm runoff and rising ocean waters will be subject to increased flooding. Figure 31 provides a graphic overview of the impacts of sea level rise, and needed adaptation strategies (PICEP 2016a).
As a modern day analogue of sea level rise in present-day Honolulu, the Mapunapuna industrial district of Honolulu (Figure 32) offers a glimpse of Hawaii’s sea-level future. When heavy rains have fallen during monthly high tides, portions of the Mapunapuna area flooded because storm drains were backed up with high ocean water. Even absent a heavy rainfall event, the area flooded with seawater at high tide as it surged from storm drains into the streets; marine fauna including young hammerhead sharks have been observed in pools created by such flooding. Recent construction of one-way drainage vents prevent now seawater from entering the storm drain system and tidal flooding has been mitigated in most situations (University of Hawaii website).

5.2 Socio-Economic Impacts of Sea Level Rise

A 2008 economic impact analysis of the potential complete erosion of Waikiki Beach on Oahu suggests the economic impact on total hotel revenue alone could be as much as $661.2 million annually (Hospitality 2008). This same report estimates that nearly $2.0 billion in overall visitor expenditures could be lost annually due to a complete erosion of Waikiki Beach if no other economic sector replaces tourism there. In addition to potential direct impact on visitor expenditures, the estimated decline in room demand due to beach erosion could also result in the hotel industry losing 6,352 jobs based on the analyses and data provided by the State of Hawaii. This is just one local example of the potential economic impact to one sector due to climate change. Similar studies in the U.S. and about the value of surfing in Australia found costs of inaction could exceed the cost of mitigation and adaptation (Lazarow et al. 2008). The University of Hawaii is in the process of updating the economic inputs into the 2008 study to determine a new economic estimate.
5.3 **Hawaii Climate Adaptation Policy (Hawaii Office of Planning website)**

In passing major climate change legislation in 2007 known as Act 234, and consistent with the scientific consensus, the Hawaii State Legislature concluded that “climate change poses a serious threat to the economic well-being, public health, natural resources, and the environment of Hawaii.” The focus and general purpose of Act 234 was to achieve cost-effective greenhouse gas emissions reductions at or below Hawaii’s greenhouse gas emissions estimates of 1990 by January 1, 2020. However, it was recognized that even if emissions are reduced to 1990 levels, Hawaii will be significantly impacted by climate change well into the future.

In 2012, Hawaii’s legislature passed Act 286, HRS §226-109 (Hawaii Act 286), amending the Hawaii State Planning Act to incorporate climate adaptation into county and state actions, including land use, capital improvement, and program decisions, acknowledging that Hawaii can best respond to climate change by adapting to its impacts. The State Office of Planning is implementing the policy with other agencies and organizations through the Ocean Resources Management Plan. Because the policy is an amendment to the Hawaii State Planning Act, all county and state actions must consider the policy in its land use, capital improvement, and program decisions.

<table>
<thead>
<tr>
<th>Climate change adaptation priority guidelines (§226-109) (Hawaii Act 286)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority guidelines to prepare the state to address the impacts of climate change shall:</td>
</tr>
<tr>
<td>• Ensure that Hawaii’s people are educated, informed, and aware of the impacts climate change may have on their communities;</td>
</tr>
<tr>
<td>• Encourage community stewardship groups and local stakeholders to participate in planning and implementation of climate change policies;</td>
</tr>
<tr>
<td>• Invest in continued monitoring and research of Hawaii’s climate and the impacts of climate change on the state;</td>
</tr>
<tr>
<td>• Consider native Hawaiian traditional knowledge and practices in planning for the impacts of climate change;</td>
</tr>
<tr>
<td>• Encourage the preservation and restoration of natural landscape features, such as coral reefs, beaches and dunes, forests, streams, floodplains, and wetlands, that have the inherent capacity to avoid, minimize, or mitigate the impacts of climate change;</td>
</tr>
<tr>
<td>• Explore adaptation strategies that moderate harm or exploit beneficial opportunities in response to actual or expected climate change impacts to the natural and built environments;</td>
</tr>
<tr>
<td>• Promote sector resilience in areas such as water, roads, airports, and public health, by encouraging the identification of climate change threats, assessment of potential consequences, and evaluation of adaptation options;</td>
</tr>
<tr>
<td>• Foster cross-jurisdictional collaboration between county, state, and federal agencies and partnerships between government and private entities and other nongovernmental entities, including nonprofit entities;</td>
</tr>
<tr>
<td>• Use management and implementation approaches that encourage the continual collection, evaluation, and integration of new information and strategies into new and existing practices, policies, and plans; and</td>
</tr>
<tr>
<td>• Encourage planning and management of the natural and built environments that effectively integrate climate change policy.</td>
</tr>
</tbody>
</table>
5.4 Hawaii Climate Adaptation Initiative Act of 2014

Through Act 83 in 2014, the Hawaii State Legislature unmistakably stated that climate change and sea level rise pose an urgent and long term threat to the State’s economy, sustainability, security, and way of life. The Act called for the establishment of an Interagency Climate Adaptation Committee (ICAC), co-chaired by the Board of Land and Natural Resources and the Director of the Office of Planning in DLNR. The first task of the Interagency Climate Adaptation Committee is to develop a statewide Sea Level Rise Vulnerability Assessment and Adaptation Report by December 31, 2017 (Hawaii Climate Adaptation Portal). This SLR Report is the first state-wide assessment of the impacts of sea level rise on Hawaii’s coastal areas.

The information brief published by the Interagency Climate Adaptation Committee in October 2015 clearly recognized the threats of climate change and sea level rise to Hawaii, stating that sea level rise will have many impacts on the coastal zone, including (ICAC 2015):

- Land loss due to flooding and inundation;
- Land loss due to erosion;
- Increased flood damage through extreme sea level events (e.g., extreme tides, storm surges);
- Saltwater intrusion into surface waters and groundwater impeding drainage; and
- Wetland loss and change.

The Interagency Climate Adaptation Committee has been directed to focus on climate impacts related to sea level rise. To achieve this goal, the Interagency Climate Adaptation Committee will: (1) develop, update, and use knowledge of climate risk to recommend improvements to policies, programs, projects, and business practices that reduce risk, and (2) share information and data and develop innovative sector-specific and cross-cutting recommendations to adapt to a changing climate.

The SLR Report will serve as a framework for the State and Interagency Climate Adaptation Committee to address other climate-related threats and climate change adaptation priorities, ultimately leading to a Climate Adaptation Plan for the State of Hawaii, which will be prepared by the Office of Planning.

The SLR Report will expand upon ongoing collaborations with the University of Hawaii School of Ocean and Earth Science and Technology (UH SOEST), the University of Hawaii Sea Grant College Program (UH Sea Grant), the Pacific Islands Ocean Observing System (PACIOOS), and the Pacific Islands Climate Change Cooperative (PICCC).

As part of the efforts to prepare the Sea Level Rise Vulnerability Assessment and Adaptation Report, a workshop was conducted with a broad range of stakeholders on January 31, 2017 (Hawaii Climate Adaptation Portal). An excellent workshop guide was produced to prepare workshop participants for discussion, entitled Workshop Guide, Sea Level Rise Vulnerability and Adaptation Workshop II, A Road Map for Sea Level Rise Adaptation in the 21st Century (Hawaii Climate Adaptation Portal).

- The workshop participants focused upon sea level rise adaptation recommendations, which were defined as proposed changes in the policy, planning, regulatory, funding, and governance environment needed to increase the capacity to adapt to or reduce the impact of sea level rise at state, county, and community levels.
- The range of recommendations to be developed in the Report due December 31, 2017, include: policy, planning, natural and cultural resources management, emergency/floodplain management, design and construction, financing and incentives, and governance.
5.5 **USACE Policy on Evaluation of Changes due to Sea Level Change**

In June 2014, USACE issued policy for addressing adaptation to changing sea levels. As shown in Figure 33, the overview states (USACE 2014):

*USACE missions, operations, programs, and projects must be resilient to coastal climate change effects, beginning with sea level change (SLC). This ETL (Engineer Technical Letter) addresses adaptation to changing sea levels for every USACE coastal activity as far inland as the extent of estimated tidal influence. It includes a broadly applicable method encompassing four USACE mission areas and provides insight into use for multipurpose projects. The information presented here is applicable to the full range of USACE projects and systems, from simple to complex, from small to very large, and over the full life cycle. This ETL integrates the recommended planning and engineering to understand and adapt to impacts of projected SLC through a hierarchy of decisions and review points that identify the level of analysis required as a function of project type, planning horizon, and potential consequences.*

**Figure 33. USACE Policy on Adaptation to Changing Sea Levels. USACE 2014.**
The key elements of the policy include:

- **USACE projects, programs, and activities often involve the development and management of long-lived systems.** The longer the life of engineered systems and their related socioeconomic and ecological systems, the more important it becomes to evaluate the sustainability and resiliency of these combined systems in the face of climate change effects. This document outlines the recommended planning and engineering approach at the project level for addressing impacts of projected SLC at USACE projects. The goal of this document is to provide a method to develop practical, nationally consistent, justifiable, and cost-effective measures, both structural and nonstructural, to reduce vulnerabilities and improve the resilience of our water resources infrastructure to SLC.

- **Because of the uncertainty and variability of future SLC, the approach outlines a robust framework that is flexible and adaptable to multiple future scenarios.** Emphasis is placed on both how the project operates within a larger system and how project decisions now can influence future impacts.

- **The project approach framework conveys to the field the level of detail required as a function of project type, planning horizon, and potential consequences.** An essential task is to identify the potential for adaptation throughout the project life or project phasing.

- **The purpose of the framework is to define the strategic importance of potential impacts on SLC in both time and space.** *SLC rates* will inform the timeline, while the *SLC magnitude* will inform the vulnerability and viability over that timeline. For ecosystem projects, the *rate* of change will affect vulnerability.

- **Being able to adequately express the potential impacts of a wrong answer, in both economic and operational terms, is very important.** The connectivity within the system, as well as the potential for cumulative or system effects, will help in assessing the potential level of impacts.

- **While the actual methods and the level of detail will vary widely for each USACE project, depending on the size and scope, the underlying framework developed favors a staged approach with the results guiding the level of effort for each subsequent stage.**

### 5.6 Management and Governance Challenge of Sea Level Rise: Takings

Climate change and resulting sea level rise is presently impacting Hawaii’s coastal and shoreline areas and such impacts are expected to become more severe in the future. Sea level rise in particular is expected to increasingly affect coastal areas in Hawaii, including inundation of low-lying roads and other developed areas, and increased erosion will further threaten beaches and shoreline homes and properties.

Government regulatory action, such as shoreline setbacks and hardening policies, will form an integral part of the community’s response to the threats posed by climate change. Beaches and shoreline public access are protected by the Hawaii State Constitution and policy such as the Federal and State Coastal Zone Management Act. State CZMA prohibits coastal hardening with certain exceptions. The inherent tension between existing regulations and private property rights, as exemplified by the Constitutional prohibition against unpermitted takings, may intensify, assuming the impacts from climate change demand stronger and more comprehensive regulation.

Codiga et al. in 2011 summarized the issues related to shoreline protection verses takings, saying that interpretation of takings claims may influence the application and enforcement of coastal development regulations. In a number of cases, property owners are resisting the government regulations regarding armoring or setbacks, on the grounds that enforcement violates the Constitutional takings prohibition.
As of 2017, these cases are increasing. These issues have not yet been tested in court. Some legal reviews suggest regulations in the interest of public safety and environmental protection may not qualify in court as regulatory takings, and regulatory agencies may be more liable for damages by allowing new development in hazard-prone areas.

Codiga concluded that Hawaii’s current regulatory regimes related to climate change impacts in coastal areas may generally be expected to withstand anticipated takings claims (Codiga, et al. 2011).

5.7 References for the Effects of Climate Change and Sea Level Rise on Hawaiian Shorelines


Codiga, Douglas; Hwang, Dennis; and Delaunay, Chris. Climate Change and Regulatory Takings in Coastal Hawaii. Center for Island Climate Adaptation and Policy. Honolulu, HI. 2011.

Fletcher, Charles; Boyd, Robynne; Neal, Williams J.; and Tice, Virginia; Living on the Shores of Hawaii, Natural Hazards, the Environment, and Our Communities; University of Hawaii Press, Honolulu, 2010.


Hospitality Advisors LLC, Economic Impact Analysis of the Potential Erosion of Waikiki Beach, Waikiki Improvement Association, September 3, 2008.


Pacific Islands Climate Education Partnership (PICEP); Climate Change in Hawaii, 2016b.

Pacific Islands Climate Education Partnership (PICEP), Pacific Climate Variability. 2016.
Pacific Islands Climate Education Partnership (PICEP); Sea Level Rise in the U.S. Affiliated Pacific Islands (USAPI), 2016a.


USACE, Global Changes Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation; Date (30 March 2019); ETL 1100-2-1; 30 June 2014.
6 SOCIOECONOMIC IMPACTS OF COASTAL CHANGE

This section reviews the socioeconomic impacts of coastal change and contains information and data on the impacts of erosion and accretion on the Hawaiian economy. This overview summarizes the documented costs associated with addressing erosion and accretion in the Hawaiian Islands and explores the benefits of doing so. In particular, it investigates impacts on the largest non-military economic sector in the state: tourism and recreation. Tourism and recreation in the Hawaiian Islands relies heavily on sandy beaches and clean waters. Sandy beaches are also an important part of Hawaii’s culture and heritage. Water-based recreation like surfing and outrigger canoeing has been practiced as sport and culture on the Hawaiian Islands for thousands of years. Beyond tourism and recreation opportunities, the coast of Hawaii is where the most valuable property and land are located as is critical infrastructure such as power, water and wastewater that supports visitors and residents alike.

6.1 Background—Demographics and the Ocean Economy

Since 2000, Hawaii has seen an 18 percent population increase from 1.2 to 1.4 million people, nearly double the percent increase that the entire United States experienced (10 percent) during that time. The City and County of Honolulu (the Island of Oahu) is the smallest of the four counties in geographical size, but contains 70 percent of the state's population (U.S. Census, 2015; Hawaii Department of Business, Economic Development and Tourism (DBEDT), 2014, and Figure 34). Oahu is home to popular tourist destinations like Waikiki Beach, Pearl Harbor, and the North Shore.

![Figure 34. Hawaii population by county (DBEDT, 2014)]
In 2013, Hawaii’s economy was worth close to $74 billion, with government and financial activities accounting for half of that figure (BEA, 2016). Leisure and hospitality\textsuperscript{10} make up 9 percent of the economy; however, this $6.9 billion in GDP does not fully represent the tourism and recreation sector, a sector that is heavily dependent on the beach and nearshore water. As shown in Figure 36, tourism-related industries are found across many of the sectors, and in reality make up over 20 percent of the Hawaiian economy or approximately $14 billion\textsuperscript{11} (HTA, 2014; Tian et al., 2011). A 2010 study calculated both the direct and indirect contribution of Hawaii’s tourism to GDP and found that visitors to Hawaii infuse an average of $40 million daily into the state’s economy, and for every $1 million in direct visitor expenditures, tourism supports 11.2 jobs (HTA, 2014; Tian et al., 2011).

\textsuperscript{10} Includes arts, entertainment, recreation, accommodation, and food services. Some establishments that provide cultural, entertainment, or recreational facilities and services are classified in other sectors.

\textsuperscript{11} The North American Industry Classification System (NAICS) classifies “tourism” as a sector and not an industry. Therefore, tourism-related industries, such as “tour operators” or “scenic and sightseeing transportation,” are captured by other industry categories beyond the “leisure and hospitality” supersector.
Figure 36. Hawaii economy by NAICS supersector, 2013 (BEA, 2016).

Ocean-dependent businesses and industries represent an important economic contributor to the economy, especially those that support the recreation and tourism sector. Other ocean-dependent sectors such as ship and boat building, offshore mineral extraction, commercial fishing and seafood marketing, and the dredging of harbors employ thousands of other workers.12

The National Oceanic and Atmospheric Administration’s (NOAA’s) Economics: National Ocean Watch (ENOW) data focus on six ocean-based sectors (see text box) and allow users to explore employment, wages, and GDP associated with those sectors. The Hawaii ocean-based economy was

12 National Oceanic Atmospheric Administration (NOAA) Economics: National Ocean Watch (ENOW) sectors:

Tourism and recreation includes eating and drinking establishments, hotels, marinas, boat dealers, campsites and RV parks, scenic water tours, manufacture of sporting goods, amusement and recreation services, recreational fishing, charter boats, zoos, and aquariums.

Marine transportation includes deep sea freight, marine passenger transportation (excluding charter boat fishing, which is included in Tourism and Recreation), pipeline transportation, marine transportation services, search and navigation equipment, and warehousing.

Marine construction includes beach nourishment and harbor dredging.

Living resources includes fish hatcheries and aquaculture, commercial fishing, seafood processing, and seafood markets.

Offshore mineral extraction includes exploration and production of oil, gas, sand, and gravel from offshore sources.

Ship and boat building includes the construction and repair of ships and boats.

Ocean economy: ocean-based economies focus on ocean-based sectors within shoreline-adjacent counties. Sectors include construction, living resources, minerals, ship and boat building, tourism and recreation, and marine transportation (NOAA ENOW, 2015).
worth $7.0 billion in 2013, approximately 9 percent of the total state GDP, with ocean-based tourism and recreation accounting for $6.2 billion of the total ocean economy (Figure 37). Ocean-sector jobs accounted for 12 percent (109,000) of the total employment within the state (860,000). Hawaii’s population may only account for one percent of the United States’ total coastal county population of 123 million (U.S. Census, 2015) yet the state’s ocean economy accounts for 2 percent of the entire United States’ ocean economy and 6 percent of the United States’ ocean-based tourism and recreation GDP (NOAA ENOW, 2016).

Between 2005 and 2013, Hawaii experienced a 7.5 percent increase in overall GDP\textsuperscript{13} and the ocean-based economy experienced a slightly higher 8 percent increase\textsuperscript{14} (BEA, 2016; NOAA ENOW, 2016). However, the change in ocean sector GDP from the end of the recent recession through 2013 equals 23 percent, more than a tripling of the GDP change experienced across the entire economy in Hawaii. The trend is similar nationally where GDP across all industries has risen 6.5 percent since 2009 as compared to the ocean economy, which experienced a 10 percent improvement. Ocean-based sectors have proven their resilience over the last decade both in Hawaii and across the United States. Employment numbers for the ocean economy nationally and in Hawaii experienced similar trends over the last 10 years, decreasing by 4 percent and 6 percent respectively during the recession of 2008 and 2009, while all sectors across both Hawaii and the United States experienced losses of 3 percent. Ocean jobs made a strong recovery between 2010 and 2013 in Hawaii and the national level, with increases of 9 and 9.6 percent, respectively, as compared to all industries, which increased jobs by 5.3 percent in Hawaii and 5.4 percent nationally during the same period (Figure 40; Table 2).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure37.png}
\caption{Hawaii ocean economy GDP (NOAA ENOW, 2016).}
\end{figure}

\textsuperscript{13}2009 chained dollars
\textsuperscript{14}2005 dollars
Figure 38. Hawaii ocean economy wages GDP (NOAA ENOW, 2016).

Figure 39. Hawaii ocean economy employment (NOAA ENOW, 2016).
The Hawaii ocean economy grew 8 percent between 2005 and 2013, despite a 16.5 percent decrease in GDP during the 2007-2009 recession (ENOW, 2016; Table 2). Overall, the average per person output of the ocean economy in Hawaii in 2013 was $5,000 compared to the U.S. mainland ocean economy output of $1,100 per person. Tourism and recreation accounted for 88 percent ($6.2 billion) of total Hawaii ocean-based GDP in 2013 ($7 billion) and 91 percent of employment—providing jobs for 99,000 people in marinas, restaurants, hotels, and boat dealerships. By comparison, tourism and recreation only accounted for 28 percent of the national ocean economy in 2013, employing 2.2 million people (of 3 million total ocean economy employees). Marine transportation was a distant second place to tourism and recreation in Hawaii, making up 7 percent of the ocean economy ($104 million). Ship and boat building was the next largest sector for employment and wages, creating 5,000 jobs and producing $413 million in wages (NOAA ENOW, 2016). The tourism and recreation sector is critical to Hawaii’s economic health, which means Hawaii’s economic health is also dependent on the shoreline’s health.
Table 2. Tourism and recreation real GDP across Hawaii coastal counties and nationally. (NOAA ENOW, 2016)

<table>
<thead>
<tr>
<th>Year</th>
<th>Employment</th>
<th>Real GDP (Billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S.</td>
<td>Hawaii</td>
</tr>
<tr>
<td>2005</td>
<td>1,856,220</td>
<td>94,500</td>
</tr>
<tr>
<td>2006</td>
<td>1,894,409</td>
<td>96,348</td>
</tr>
<tr>
<td>2007</td>
<td>1,952,890</td>
<td>98,165</td>
</tr>
<tr>
<td>2008</td>
<td>1,962,291</td>
<td>95,736</td>
</tr>
<tr>
<td>2009</td>
<td>1,903,072</td>
<td>90,239</td>
</tr>
<tr>
<td>2010</td>
<td>1,928,141</td>
<td>90,007</td>
</tr>
<tr>
<td>2011</td>
<td>1,993,210</td>
<td>92,419</td>
</tr>
<tr>
<td>2012</td>
<td>2,077,189</td>
<td>95,705</td>
</tr>
<tr>
<td>2013</td>
<td>2,149,892</td>
<td>99,105</td>
</tr>
</tbody>
</table>

Figure 41. Tourism and recreation real GDP by county (NOAA ENOW, 2016).
Due to data suppression issues at the county level for the Hawaii ENOW analysis,\(^\text{15}\) it is difficult to characterize county-specific contributions to the tourism and recreation sector in the ocean economy. Tourism and recreation is the largest ocean economy sector across all the counties, with Honolulu and Maui’s ocean economies contributing the majority of GDP (78 percent) and employment (82 percent) to the state’s totals. Honolulu County is home to nearly one million people (70 percent of the state’s population) and contains the state’s capital, Honolulu, as well as the rest of Oahu, where popular tourist destinations such as Waikiki Beach and the North Shore are located. In 2013, the tourism and recreation sector of the ocean economy in the county generated $1.5 billion and employed 42,000 people (NOAA ENOW, 2016).

The estimates for the entire tourism and recreation sector (upwards of $14 billion) or the ocean-based tourism and recreation sector GDP ($6.2 billion) alone, represent the importance of visitors to the State of Hawaii, the majority of which (over 90 percent) partake in beach activities (HTA, 2014; Tian et al., 2011; NOAA ENOW, 2016). In the years that followed the recession of 2008 - 2009, ocean sector GDP in Hawaii grew by 23 percent, more than a tripling of the GDP change experienced across the entire economy in Hawaii, displaying a resilience not experienced in other economic sectors. This sector and the ocean economy generally are heavily reliant on the existence of beaches—which are under threat from erosion and rising sea levels. The following sections explore some of the benefits accrued from the existence of healthy beaches and nearshore environments, and the approaches used across the islands to address these threats and their costs where available.

### 6.2 Benefits of the shoreline

The natural environment in Hawaii is the main draw for visitors that bolster the tourism and recreation sector and is essential to the quality of life that residents enjoy. Sandy, accessible, and clean beaches are a critical component to the tourism and recreation sector and the over 200,000 visitors in the state on a typical day (DBEDT, 2015). Residents and tourists alike enjoy beach-based recreational activities, including walking, fishing, snorkeling, surfing, kayaking, and swimming. Beaches also provide important habitat for wildlife, including seabirds, marine mammals (seals and turtles), crabs, and invertebrates. The shoreline is also culturally significant and the center of Hawaiian traditions, most notably burials, which occur both at sea and along the beach. Fishponds (for aquaculture), historic homes sites, and artifacts can be found along the shoreline. Additionally, hotels, homes, and critical infrastructure to accommodate residents and visitors alike have all been built along the shoreline. The largest threat to the sustainability of these recreational activities, cultural sites, property, and infrastructure is coastal erosion.

Erosion has drawn significant attention in recent years due to the ongoing loss of some of Hawaii’s most popular and recognizable beaches. Over the last century, 70 percent of beaches experienced erosion including 9 percent (21 km) that were completely lost to erosion (Romine and Fletcher, 2013). On Oahu, home to Waikiki Beach, nearly 17.1 miles (or 24 percent) of sandy shoreline has been narrowed (10.7 miles) or lost (6.4 miles) since the 1940s despite efforts to maintain it through nourishment (Fletcher et al., 2012; DBEDT, 2006a). The response to erosion has garnered equal attention, as government agencies, private property owners, and the public attempt to stall erosion without interfering with the many uses of the shoreline. There has been no silver bullet for protecting shorelines from erosion in the Hawaiian Islands. Each potential option—whether armoring, nourishment, relocation, etc.—has its tradeoffs,

\(^{15}\) This study cannot publish some values without violating the confidentiality of one or more businesses. By law, these non-zero values must be suppressed in published data, although they are reflected in higher-level totals, such as can be seen with the line labeled “Hawaii (Total)” (NOAA, 2015).
supporters, and opponents. Hawaii’s resident and visiting population will continue to grow and coastal property values will continue to increase, adding greater pressure on property owners to protect their property from erosion and placing increasing strain and demand on the shoreline and its many benefits.

The benefits associated with activities and the cultural significance of the coast are not always quantifiable, e.g., cultural significance of an archaeological site. Although there are methods for quantifying the value of the beach to people, few studies have been completed for the beaches of Hawaii. Each section below discusses the value of shoreline-based activities and resources in Hawaii and includes explicit quantifications, if available. In some instances, there are completed studies that indicate an ecosystem service value that has not been considered as part of the ocean-based economy figures from NOAA ENOW. Although generally, few studies explore the ecosystem service values, including nonmaterial benefits associated with cultural, aesthetic, and spiritual experiences.

6.2.1 Beach tourism and recreation

Hawaii’s recreational beach opportunities include sunbathing, walking, bird watching, whale watching, and running. Beaches also provide easy access to the ocean for swimming, surfing, diving, snorkeling, scuba diving, parasailing, windsurfing, sailing, kayaking, and canoeing. However, there have been very few studies (Kaiser et al., 1998) that estimate the total economic value of Hawaiian beaches across all the islands (recreational, commercial, cultural, and environmental benefits) or studies that extract beach-related tourism and recreation from other tourism and recreation (e.g., forest-based).

![Figure 42. Tourism and recreational spending areas (HTA, 2015b).](image)

The State of Hawaii compiles tourism statistics on an annual basis, but it is difficult to discern which visitor expenditures can be directly attributed to the shoreline and which expenditures could be impacted by shoreline changes induced by erosion. In 2014, 8.3 million visitors came to the Hawaiian Islands, or eight visitors for each person in the state. Annual 2014 total visitor expenditures were $14.9 billion, which works to an average personal daily spending of $195 per person (HTA, 2015). Expenditures include lodging, food and beverage, shopping, entertainment and recreation, transportation, and supplemental business expenditures (Figure 42; HTA, 2015b).
Lodging costs, the largest expenditure category for visitors, are connected to proximity to the shoreline, especially along the world-renowned Waikiki Beach along the south shore of Oahu. Waikiki’s on-beach hotels achieved an average daily rate of $225 in 2007, whereas off-beach properties in the area reported an average room rate of $122 (Hospitality Advisors, 2008). In the same year, on-beach hotels reported $776 million in annual room revenue in comparison to $420 million from off-beach hotels, or about 85 percent higher (Hospitality Advisors, 2008). Assuming the beach is the main component driving this revenue difference, the beach’s value to the hotels of Waikiki in 2007 was more than $350 million. Between 2007 and 2009, statewide hotel occupancy rates declined to 65 percent, the lowest level since 1990. The strength of the Hawaii tourism market helped fuel a quick post-recession recovery as statewide hotel occupancy increased to 77 percent by 2014, similar to 2007 occupancy rates (DBEDT, 2015).

Waikiki Beach is a major tourism destination in Hawaii, as well as a popular recreational spot for visitors and residents. The Beach became the center of the surfing resurgence on Hawaii in the early 1900s in response to the booming tourism industry—around the same time the first seawalls and shoreline modifications were occurring to build and protect hotels and roads. The beach extends approximately two miles, fronting a number of major resorts and hotels (Wiegel, 2008). The recreational opportunities and general popularity of the beach make it one of the primary “economic engines” for the state. In a 2003 study by the DBEDT, Waikiki generated more than $5 billion (45 percent) of the $11.4 billion originating from annual tourism expenditures in Hawaii and the resorts alone were responsible for 73,000 jobs. Including indirect jobs, the one-square mile of Waikiki supported approximately 11 percent of all civilian jobs in the state and the 4,650 commercial parcels generated $55 million in property taxes for fiscal year 2002 (DBEDT, 2003). Despite the economic recession in 2008, visitor expenditures in Hawaii reached $14.3 billion in 2013 and if Waikiki’s share remained similar to 2003, the area generated upwards of $6.4 billion (DBEDT, 2014; Hospitality Advisors, 2008).

Although Waikiki Beach is the backbone of the tourism and recreation economy, there are 24 miles of safe, clean, accessible, and generally suitable-for-swimming sandy beaches across the six main islands and 184 additional miles of sandy shoreline in the state (Kaiser et al., 1998). Oahu’s beaches alone provide recreational services valued at roughly $700 million annually, including $32 million for Hanauma Bay. The value estimates are based on demand for beach visits and exclude such values as sightseeing, natural protection of shoreline property, and existence (Kaiser et al., 1998).

There have been limited studies attempting to value beach visits and specific recreational activities along the Hawaiian shoreline despite the economic significance of beach-based tourism and recreation.

Completed studies in other states that are year-round beach destinations, such as California and Florida, may be applicable here, although Hawaii surfing conditions are a unique draw and the reason for the state being an international surfing destination. In 2000, a survey completed by NOAA indicated that there were 3.3 million surfers in the United States, with 704,000 participants identified in Hawaii, second place to California (1.1 million) (Leeworthy and Wiley, 2001). Surfers in Hawaii surf on average 144 days out of the year and expend on average $66 per trip (Wagner et al., 2011). Two studies (2006 and 2011) evaluated the economic impacts of The Vans Triple Crown of Surfing, hosted each year along the north shore of Oahu. In 2011, the event drew 23,195 spectators who spent $178 per day on average during the competition. Along with the direct and indirect impacts, the study also took into account the boost the competition gives to Hawaii’s image or brand. The 2011 event brought $20.9 million to the state, nearly 40 percent more than what the event generated in 2006 (Reed, 2011).
An ideal day at the beach, with excellent sand and water, little congestion and ideal safety conditions, has been estimated to provide residents and tourists roughly $78.50 of value (Penn et al., 2012). Nearly 20 years ago, a survey of Oahu beaches estimated the total annual island beach attendance at 20.7 million (City and County of Honolulu, Dept. of Emergency Services, Ocean Safety Division; cited in Kaiser et al. 1998). For 20.7 million beachgoers, the perfect beach day in Hawaii translates to over $1.6 billion annually.

Many beaches in Hawaii are part of national, state, and county parks, providing numerous opportunities for tourism and recreation. Hawaii’s State Park System is composed of 50 state parks encompassing approximately 30,000 acres on five major islands, the majority (74 percent) of which are located along the shoreline or within close proximity to the shoreline. An estimated 10.1 million people visit Hawaii State Parks in a year. Twenty percent of all visitors indicate ocean activities as a motivating factor for their trip (OmniTrak Group Inc., 2007).

The 2014 National Park Visitors Survey demonstrated that 5 million visitors to Hawaii’s seven National Parks spent nearly $250 million, directly supporting 3,048 jobs (Coolinane et al., 2015).

Table 3. Hawaii National Park visits and spending. (Coolinane et al., 2015)

<table>
<thead>
<tr>
<th>Park Name*</th>
<th>Total Visits</th>
<th>Total Spending</th>
<th>Jobs Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haleakala</td>
<td>1,142,040</td>
<td>$70,290,100</td>
<td>837</td>
</tr>
<tr>
<td>Hawaii Volcanoes</td>
<td>1,693,005</td>
<td>$136,839,700</td>
<td>1,672</td>
</tr>
<tr>
<td>Kalaupapa (National Historic Park)</td>
<td>67,211</td>
<td>$3,769,500</td>
<td>49</td>
</tr>
<tr>
<td>Kaloko-Honokohau (National Historic Park)</td>
<td>154,206</td>
<td>$8,648,400</td>
<td>110</td>
</tr>
<tr>
<td>Puuhonua O Honaunau (National Historic Park)</td>
<td>401,807</td>
<td>$22,534,600</td>
<td>285</td>
</tr>
<tr>
<td>Puukohola Heiau (National Historic Park)</td>
<td>134,734</td>
<td>$7,556,400</td>
<td>95</td>
</tr>
<tr>
<td>Total</td>
<td>3,593,003</td>
<td>$249,638,700</td>
<td>3,048</td>
</tr>
</tbody>
</table>

* no data was available for Ala Kahakai Park

The National Park Service also operates the World War II Valor in the Pacific National Monument at Pearl Harbor. Pearl Harbor is a lagoon harbor on Oahu, Hawaii, west of Honolulu. In 2014, 1.6 million people visited the National Monument site, spending $90,000,000 and supporting 1,154 jobs (Coolinane et al., 2015). Much of the harbor and surrounding lands is a U.S. Navy deep-water naval base. It is also the headquarters of the U.S. Pacific Fleet.

16 http://dlnr.hawaii.gov/dsp/parks/
6.2.2 Recreational value of coral reefs

The beaches of Hawaii provide access to near shore waters important to scuba diving and snorkeling, which are both significant tourist draws, particularly on Maui and Hawaii. The night dives to view the Manta rays at Keahou Bay on Hawaii alone bring as much as $660,000 annually to the dive shops in West Hawaii (Kaiser et al., 1998). Each year, reefs along Maui’s Kihei coast contribute $34 million in gross sales, leading to $28 million in added value to the economy (Davidson et al., 2003). The fringing coral reefs that host the abundance of marine life that make diving and snorkeling popular and profitable activities were estimated to generate about $800 million in gross revenues annually or $364 million in added value (Davidson et al., 2003) (Table 4) and the overall asset value of Hawaii’s 410,000 acres of reef area in the main Hawaiian Islands is estimated at nearly $10 billion (Cesar and van Beukering, 2004).

Table 4. Coral reef values annually (Cesar and van Beukering, 2004).

<table>
<thead>
<tr>
<th>Value categories</th>
<th>Value (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation</td>
<td>$304</td>
</tr>
<tr>
<td>Amenity/property value</td>
<td>$40</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>$17</td>
</tr>
<tr>
<td>Fishery</td>
<td>$2.5</td>
</tr>
<tr>
<td>Total</td>
<td>$363.5</td>
</tr>
</tbody>
</table>

Recreational value represents the largest share of the overall value of Hawaii’s coral reefs. This implies that almost 85 percent of the value of the Hawaiian reefs is dependent on tourism, and tourism is driven by the condition of coral reefs and the marine life that inhabit them (Cesar and van Beukering, 2004). The estimate of Hawaiian reef value does not consider the possibility of reefs providing coastal protection by dissipating wave energy, a service estimated to be valued at $47,000 of property value per meter of reef (NOAA, 2015).

6.2.3 Real estate

The most expensive homes in the United States have waterfront locations and the properties in the Hawaiian Islands are no exception. The median prices for waterfront single-family homes in Kailua and Honolulu, Oahu, are the fifth and sixth highest in the nation ($4.5 and $3.8 million respectively) (Krause, 2014). In 1990, a study estimated that 29,000 people or 3 percent of the state’s population at the time lived within 500 feet of the shoreline in Hawaii (Heinz Foundation, 2000). The property values of condominiums, residences, and hotels within one block of the Hawaiian coast in 2001 totaled $19.5 billion (Table 5).

Table 5. Property values of residences and hotels within one block of the coast and total by island in 2002 (Cesar et al., 2002; Hawaii RPAD, 2002).

<table>
<thead>
<tr>
<th>Island</th>
<th>Value (one block of coast)</th>
<th>Value (total) (billions)</th>
<th>Coast value (one block) percent of total value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oahu</td>
<td>$14.9 billion</td>
<td>$55.1</td>
<td>27%</td>
</tr>
<tr>
<td>Maui</td>
<td>$1.6 billion</td>
<td>$12.6</td>
<td>13%</td>
</tr>
<tr>
<td>Hawaii</td>
<td>$2.1 billion</td>
<td>$7.0</td>
<td>30%</td>
</tr>
<tr>
<td>Kauai</td>
<td>$960 million</td>
<td>$4.4</td>
<td>22%</td>
</tr>
<tr>
<td>Total</td>
<td>$19.6 billion</td>
<td>$79.10</td>
<td>23% (average)</td>
</tr>
</tbody>
</table>
The properties within one block of the coast represented on average one-quarter of the net residential and hotel/resort real property tax valuation in 2001 across all the islands. Although updated estimates for property values within one block of the coast are not available for more recent years, the total residential and hotel net real property tax valuation\(^\text{17}\) for 2014-2015 totaled $210 billion across all the islands, an increase of more than double (166 percent) since 2002 (City and County of Honolulu, 2015). If shore-adjacent properties experienced a similar increase, they could be worth approximately $53 billion. The value of residential and resort property translates into revenue for the counties and state, which collected $1.1 billion in 2014-2015.

The estimated premiums for coastal amenities (recreational opportunities, ocean views, etc.) vary greatly, but it is unquestionable that despite the threat of flooding and erosion, coastal homes are sold for higher prices compared to inland properties (Plattner and Campbell, 1978; Gillard, 1981; Benson et al.; 1997; Major, 2003). Major (2003) found that ocean front properties in New Jersey were selling for 156 percent more than properties located three blocks or greater away from the ocean.

### 6.2.4 Infrastructure

#### 6.2.4.1 Roads

Across the Hawaiian Islands, roads are necessary for visitors and residents alike. Tourists alone spent $1.3 billion on transportation in 2014 (e.g., interisland travel, car rentals, ground transportation, and gas), the majority of that amount—nearly 70 percent ($860 million)—spent on vehicle rentals (HTA, 2015b, HTA, 2013). The landscape of the Hawaiian Islands limits where roads and highways can be built. Interior routes are not always feasible and many island communities are connected by only one road, for example the Honoapiilani Highway in Maui or Kamehameha V Highway on Molokai. Highways often are the only option in and out of an area. About 1,000 miles of highway are the responsibility of the State Department of Transportation, Highways Division. The majority of these highways are perimeter roads around the islands and, therefore, shoreline change is an important consideration in all major road work activities.

#### 6.2.4.2 Commercial and recreational harbors

The Hawaiian Islands are 2,000 miles from the nearest significant land mass making ocean transportation of cargo critical to the state’s sustainability. The statewide harbors system consists of 10 commercial harbors on six major Hawaiian Islands. The nationally ranked Hawaiian ports and their tonnage are shown in Table 6:

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\(^{17}\) Not including commercial, industrial, agriculture, and conservation properties.
Table 6. State ports ranked nationally for associated tonnage (USACE, 2013).

<table>
<thead>
<tr>
<th>Harbor name</th>
<th>Island</th>
<th>Tons (millions) 2013</th>
<th>Tons (millions) 2005</th>
<th>2013 rank nationally (tonnage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honolulu</td>
<td>Oahu</td>
<td>14.3</td>
<td>20.4</td>
<td>40th</td>
</tr>
<tr>
<td>Kalaepoa Barbers Point</td>
<td>Oahu</td>
<td>8.7</td>
<td>6.3</td>
<td>56th</td>
</tr>
<tr>
<td>Hilo</td>
<td>Hawaii</td>
<td>2.1</td>
<td>2.0</td>
<td>114th</td>
</tr>
<tr>
<td>Kawaihae</td>
<td>Hawaii</td>
<td>1.9</td>
<td>2.2</td>
<td>118th</td>
</tr>
<tr>
<td>Kahului</td>
<td>Maui</td>
<td>3.7</td>
<td>4.1</td>
<td>84th</td>
</tr>
<tr>
<td>Nawiliwili</td>
<td>Kauai</td>
<td>1.7</td>
<td>2.0</td>
<td>121st</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>32.4</td>
<td>37.1</td>
<td></td>
</tr>
</tbody>
</table>

In 2013, the port of Honolulu was ranked 40th in the United States by tonnage with 14.4 million tons (foreign and domestic). Barbers Point, also on Oahu, ranked 56th in the nation with 8.7 million tons. Between 2005 and 2012, the state harbors experienced a decrease in tonnage flows of 13 percent.

The Freight Analysis Framework (FAF), a partnership between Bureau of Transportation Statistics and Federal Highway Administration, integrates data from a variety of sources to create a comprehensive picture of freight movement among states and several combined statistical areas (CSA) around ports, including Honolulu. In 2012, domestic imports and exports into the port of Honolulu CSA were estimated at 9.6 million tons, 5 million tons less than the USACE reports (U.S. DOT, 2012). The discrepancy in tonnage aside, the nearly 10 million tons of cargo transported in and out of Honolulu Harbor in 2012 were estimated to be worth $7.3 billion (U.S. DOT, 2012).

In 2014, 12,033 recreational boats were registered in Hawaii, down from 13,367 boats in 2013. The spending on recreational boating in Hawaii was $87.4 million in 2012 (Mahoney and Cui, 2013). When the indirect economic impact of boating-related spending is considered, the industry has a total annual impact of $211 million (Mahoney and Cui, 2013).

When beaches erode or disappear in Hawaii, tremendous benefits and economic value are lost. The fact that a one-week surfing tournament can generate over $20 million in benefits for the state economy or that on-beach hotels can charge nearly double the rate of off-beach properties support the beach as a valuable asset. Unfortunately, often in Hawaii, protecting waterfront property or infrastructure from erosion is prioritized over preserving the fronting beach, which can be lost when hardened structures like seawalls or revetments are installed. The following sections discuss the impacts of erosion and the methods (and costs where available) used to address it.

### 6.3 Impacts of shoreline change and shoreline management costs

As discussed earlier in Section 4, erosion is the primary driver of shoreline change in Hawaii. A total of 22 kilometers (approximately 14 miles) of beach along Kauai, Maui, and Oahu, was completely lost to erosion over the past century (Fletcher et al., 2011). While sea level rise is an important factor in island wide erosion trends, natural sediment processes and human impacts are more important at the scale of individual beaches. The loss of sand from beaches and the erosion of upland areas can negatively affect shoreline access, beach recreation, property values, habitat, infrastructure, and water quality. There are different ways to respond to an eroding shoreline as will be discussed below. Unfortunately, armoring the shoreline with seawalls or rock revetments was historically the typical response of state agencies and homeowners in Hawaii, often with negative ramifications for the beach and neighboring properties.
Only 28 percent of beaches in Kauai, Oahu, and Maui have shown to have an accretion trend over the last century (Romine and Fletcher, 2013). When sand moves across harbor mouths, there can be accumulation of sand in shipping or navigation channels. Without periodic dredging, these harbors would become too shallow to access. Accretion rarely has damaging economic impacts to beaches, but for harbors, it does create the need for regular expenditures on maintenance.

6.3.1 Addressing Impacts of Erosion—Armoring

Historically in Hawaii, armoring has been the most common response to shoreline erosion. In 2003, Maui County conducted a survey and identified 16 miles of the 56-mile shoreline study area was hardened (County of Maui Department of Planning, 2003). A similar study in Oahu found approximately 27 percent of the 85-mile study shoreline was armored (Romine and Fletcher, 2012). On Kauai, 10% of the shoreline is armored covering approximately 11 miles (Bezore, 2013; Romine and Fletcher, 2012).

Historically, armoring has been a common choice by landowners in Hawaii to address erosion impacts. Hardened materials can stabilize and temporarily protect upland, infrastructure, homes, resorts, and any other assets upland from the armoring (see Maui Case Studies on Kahana Bay and shore-adjacent infrastructure). The Heinz Report (2000) estimated that by 2060, without any additional protection efforts, one in four houses within 500 feet of the coast will be lost to the sea (without including estimates of damage to structures not built yet). Residential properties and resorts along the Hawaii coast make up approximately one-quarter of the $1.1 billion in property taxes the state collects. However, with rising seas and increasing erosion, compounded by the general high costs of shoreline construction (Wiegel, 2008), Hawaii may face a future of building upland from the shoreline.

6.3.2 Impacts/Costs of Armoring

Estimated costs of shoreline armoring vary greatly due to differing site characteristics affecting design, construction, and maintenance. Private property armoring costs are mainly borne by owners, making expenditure information difficult to find and aggregate. Below (Table 7) are estimated construction costs for a range of armoring types used in Hawaii based on completed projects. Based on these costs and the total length of armored shoreline, a very rough estimate of expenditures (private and public) can be made. For example, 15.6 of 56 miles of Maui’s shoreline that were surveyed in 2003 (County of Maui Department of Planning, 2003) were identified as hardened (seawall, revetment, grouted revetment, sandbags, groin, etc.). If that length was hardened using the range of construction costs of concrete seawall per linear foot ($500 - $1,750), it totals between $42 and $148 million. If this estimate is expanded to the entire Maui shoreline, assuming that the percentage of shoreline armored (28 percent) is the same as the study shoreline, 33.6 miles of the 120-mile shoreline would be armored, with $88.7 - $310 million expended on construction costs alone.

Table 7. Cost estimates of armoring materials in Hawaii.

<table>
<thead>
<tr>
<th>Armoring technique</th>
<th>Construction Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawall (Sea Engineering, Inc.) Concrete seawall (HDOT)</td>
<td>~$2,000-5,000 per linear foot ~$500-1,750 per linear foot</td>
<td>Sea Engineering, Inc. (2015) DOT project no. 30C-01-11 and 30C-01-12</td>
</tr>
<tr>
<td>Rock groins or revetments</td>
<td>~$2,000-$4,000 per linear foot</td>
<td>Sea Engineering, Inc. (2013a)</td>
</tr>
<tr>
<td>ElcoRock bag</td>
<td>~$2,000-$3,000 per linear foot</td>
<td>Sea Engineering, Inc. (2012) Maui County (2016)</td>
</tr>
</tbody>
</table>
Coastal armoring has been most common along the densely developed shorelines of Oahu and Maui. Armoring can stabilize upland and prevent property loss, but unfortunately, armoring has many documented negative impacts. Armoring structures have exacerbated erosion fronting the armoring and on neighboring properties, and in some instances, led to the complete disappearance of beach. In Oahu, beaches fronting coastal armoring were reduced by an average of 36 percent annually in comparison to unarmored coasts where beach width remained stable (Romine and Fletcher, 2012).

Nearly 25 percent (17 miles) of Oahu’s beaches have been lost or significantly narrowed over this century due to hardening of the shoreline (Fletcher et al. 2012). Beaches on Maui have been found to be 50-70 percent narrower in front of seawalls (DBEDT, 2006b). In Kihei, which has grown in popularity as a prime tourist destination on Maui, 5,500 feet of shoreline has severely eroded over the last several decades, due to severe weather, construction of seawalls, and natural processes (HTA, 2003). Rock revetments, seawalls, and other hardened structures reduce public access and associated beach-related recreational benefits, threatening the foundation of the tourism and recreation sector of the state’s economy.

Oahu’s beaches are by far the most studied when it comes to impacts from erosion and the connection to tourism and recreation. Waikiki Beach is the most famous example of an eroding beach on Oahu (see Case Study). Despite past beach nourishment efforts and numerous engineered structures intended to slow erosion, sand continues to be lost from the sediment budget—approximately 77,000 m$^3$ was lost from the entire Waikiki shoreline between 1951 and 2001 (Miller and Fletcher, 2003). Waikiki with no beach creates the potential for huge economic impacts to Honolulu and the entire state’s economy, estimated at $2 billion per year (Hospitality Advisors, 2008).

Erosion of the shoreline affects critical infrastructure like coastal roads. The general response by the Hawaii Department of Transportation (DOT) to highway and road erosion has been armoring. In 2003, the DOT evaluated its 1,000 miles of highway and identified approximately 30 miles of problem areas where the roadway was either damaged or in disrepair due to erosion and wave overwash or is potentially endangered due to erosion. These areas were primarily located on Oahu and Maui (DOT, 2003). DOT has prioritized the shoreline protection study projects, some of which have already been completed. The estimated total expenditure over the next 25 years to address the damages from erosion and shoreline change at these sites is $165 million, $100 million on revetments and seawalls alone.

Figure 43. Kamehameha Highway (Oahu) damage from erosion due to big surf in February 2016. Credit Hawaii DOT
Table 8. DOT Shoreline Protection Study Projects (planned, underway, and completed). *(Source: DOT, 2014)*

<table>
<thead>
<tr>
<th>Project</th>
<th>Island</th>
<th>Recommended Plan</th>
<th>Estimated Total (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kawailoa Beach</td>
<td>Oahu</td>
<td>Seawall</td>
<td>$1,521</td>
</tr>
<tr>
<td>Hauula</td>
<td>Oahu</td>
<td>Revetment</td>
<td>$6,000</td>
</tr>
<tr>
<td>Punaluu</td>
<td>Oahu</td>
<td>EA recommends revetment instead of costlier beach fill</td>
<td>$7,900</td>
</tr>
<tr>
<td>Kaaawa</td>
<td>Oahu</td>
<td>Revetment</td>
<td>$11,400</td>
</tr>
<tr>
<td>Kaaawa-Kaolo Pt.</td>
<td>Oahu</td>
<td>Revetment &amp; Beach Fill</td>
<td>$13,356</td>
</tr>
<tr>
<td>Kualoa</td>
<td>Oahu</td>
<td>Highway Relocation</td>
<td>$7,805</td>
</tr>
<tr>
<td>Makapuu Pier</td>
<td>Oahu</td>
<td>Emergency work: drilled shaft and curb to channel water. Permanent work will be seawall with upper rock slope.</td>
<td>$3,784</td>
</tr>
<tr>
<td>Makaha Beach Park</td>
<td>Oahu</td>
<td>Highway Relocation</td>
<td>$9,234</td>
</tr>
<tr>
<td>Hanalei Bay</td>
<td>Kauai</td>
<td>Revetment</td>
<td>$2,773</td>
</tr>
<tr>
<td>Niapala Fishpond</td>
<td>Molokai</td>
<td>Revetment</td>
<td>$1,704</td>
</tr>
<tr>
<td>Waialua-Kumimi</td>
<td>Molokai</td>
<td>Revetment &amp; Beach Fill</td>
<td>$13,936</td>
</tr>
<tr>
<td>Kahului Bay</td>
<td>Maui</td>
<td>CRM Seawall &amp; Composite Slope</td>
<td>$4,945</td>
</tr>
<tr>
<td>Kealia Pond</td>
<td>Maui</td>
<td>Beach Fill</td>
<td>$6,542</td>
</tr>
<tr>
<td>Ukumehame-Section 1</td>
<td>Maui</td>
<td>Highway Relocation</td>
<td>$16,764</td>
</tr>
<tr>
<td>Ukumehame-Sec. 2</td>
<td>Maui</td>
<td>Highway Relocation</td>
<td>$11,575</td>
</tr>
<tr>
<td>Ukumehame-Sec. 3</td>
<td>Maui</td>
<td>Revetment (COMPLETED)</td>
<td>$7,500</td>
</tr>
<tr>
<td>Olowalu MP 14</td>
<td>Maui</td>
<td>Revetment</td>
<td>$17,500</td>
</tr>
<tr>
<td>Olowalu MP 16</td>
<td>Maui</td>
<td>Revetment</td>
<td>$3,500</td>
</tr>
<tr>
<td>Launiupoko</td>
<td>Maui</td>
<td>Soil nails (COMPLETED)</td>
<td>$6,500</td>
</tr>
<tr>
<td>Kekaha</td>
<td>Kauai</td>
<td>Drilled shafts (COMPLETED)</td>
<td>$6,500</td>
</tr>
<tr>
<td>Hilo Bayfront</td>
<td>Hawaii</td>
<td>Groin Field Only</td>
<td>$3,900</td>
</tr>
<tr>
<td><strong>TOTAL BUDGET</strong></td>
<td></td>
<td><strong>$164,639</strong></td>
<td></td>
</tr>
</tbody>
</table>

By mid-century, shoreline erosion rates may double on average, compared to historical rates, due to sea level rise (Anderson et al., 2015). Over the last few years, due to increased rates of erosion or damaging storm events, DOT has armored the coastal highway in Maui and Oahu in some locations using Emergency Proclamations. The Emergency Proclamations have allowed DOT to waive state and county statutes and associated permitting when addressing the road damage (see Maui Case Study on shore-adjacent infrastructure). This practice concerns the public given the erosion, water quality, and public access challenges that tend to accompany armoring projects. In the last three years along Honoapiilani Highway, $33-43 million has been spent or earmarked for emergency proclamation projects that involved hard armoring. DOT estimates that—depending on the length and damage—shoreline work from emergency projects due to erosion from hurricanes/tropical storms runs $1 to $10 million per project (personal communication). Unfortunately, emergency projects are often past the point where nourishment or other “softer” alternatives are possible.

The continuing armoring and/or raising of road beds may not be feasible in many locations in the future or may be deemed undesirable due to other impacts like beach loss. Reinforcing or protecting these
roads against dangers would help maintain reliable operations, while relocating roads where feasible would provide additional circulation and capacity. For example, Maui County has acquired land in West Maui to relocate the Honoapiilani Highway landward, between Ukumehame and Lahaina. One-hundred acres of coastal land has already been obtained for this purpose (Norcross-Nund et al., 2008). Hawaii DOT recently let a contract for building a mauka segment between Lahaina and Olowalu. However, realignment of the rest of the endangered road is not currently included in future DOT plans or budgets. In addition, on Oahu, DOT is exploring highway realignment to avoid erosion and coastal flooding hazards at Makaha Beach (estimated cost of $9 million) and Kualoa (estimated cost of $8 million) on Oahu (Table 8).

6.3.3 Addressing Impacts of erosion—Nourishment and Restoration

Beach loss and coastal erosion threatens shorefront homes, resorts, and critical infrastructure. While armoring contributes to further beach loss, beach nourishment, replenishment, or restoration involves supplementing existing sandy beaches with additional sediment placed on the beach or in the nearshore (see Section 9 for additional information). During a beach restoration project, beach-quality sand imported from another location is added to an eroding beach to return it to a former width or volume. Beach nourishment and beach maintenance are somewhat broader terms that have been used to describe both beach restoration, periodic maintenance, and the creation of new beach area. Most recent projects in Hawaii fall under the category of beach restoration, such as the 2012 Waikiki Beach Restoration Project (Romine et al., 2015).

Having available sand sources is key to implementing beach nourishment. Beach restoration projects use either (1) land-based sand resources (e.g. dune sand); (2) sand dredged from off-shore deposits; or (3) beneficial reuse of sediment, such as from a harbor or stream mouth clearing project. Sand imported from outside Hawaii is generally not permitted on state submerged lands.

In some settings, erosion control structures (e.g. groins, jetties, breakwaters) can be effective at retaining sand and slowing erosion when used in combination with beach nourishment. However, these structures should be designed and sited to mitigate impacts on adjacent beaches (Romine et al., 2015).

Nature-based techniques are being recognized federally and at the state level as effective methods for addressing shoreline erosion without compromising natural resources and processes. In Hawaii, these softer approaches may take the form of beach nourishment, dune restoration (including vegetation plantings), coir logs, or other biodegradable materials. Rather than interfere with coastal processes and natural sediment movement, these techniques seek to mimic and leverage natural processes. While these approaches are environmentally preferred, they are used less frequently than armoring by private property owners and state agencies, especially under emergency conditions (see Case Study on Kahana Bay). There are also challenges and tradeoffs when implementing these approaches, just as there are with installing hardened structures along the shore.

Natural approaches to shoreline protection are more aesthetically pleasing, allow continued access to the beach, and in some instances, installation is more affordable than traditional armoring. In one study looking at waterfront property in the southeast and Gulf of Mexico, beach nourishment was found to increase property values along the coast and several rows inland in contrast to shoreline armoring, which lowers property values (Kriesel and Friedman, 2003). The study found that when comparing waterfront homes to one another, those with an eroding shoreline (3 ft/year) lose around 25 percent of their value (half of which can be reclaimed if the beach is nourished). One person stabilizing their shoreline can achieve the same gain, but multiple people armoring their properties end up with values back to where they started with the eroding shoreline. The Kriesel and Friedman study also discusses
the importance of cost-sharing to address coastal erosion because nourishment has community-wide benefits (Kriesel and Friedman, 2003).

Dune restoration is similar to beach nourishment in that it is a softer alternative that focuses on adding sediment to the beach. It also involves planting of vegetation to stabilize newly created dunes. Dune restoration projects have taken place at many locations on Maui, including at the Hawaiian Islands Humpback Whale National Marine Sanctuary (2000-ongoing), Kanaha Beach (2001-ongoing; since 2001, a mile and a half of coastline at Kanaha Beach, with about 75 acres of coastal dunes and wetlands, has been restored using volunteer labor), and at Kamaole III Park (2005-ongoing) (Norcross-Nu’u et al., 2008). Planting vegetation to stabilize dunes is usually one of the lowest-cost alternatives to addressing erosion; however, these projects may not be as effective at preventing erosion in high energy wave areas and chronically eroding shorelines, especially while vegetation is becoming established (UH Sea Grant Extension Service and DLNR, 2004).

Beach scraping or “sand pushing” is a simple, sand management approach used on Hawaiian beaches. Generally, the approach involves moving existing sand on a beach by mechanical means to rebuild a backshore dune or berm as a temporary buffer to protect upland before a high wave season. These projects do not require any additional material and usually involve excavating sand from the lower beach or nearshore and placing it near the back of the beach (Eversole, 2010). These projects require sufficient sand in the existing beach, and therefore are not possible on many narrowed, eroding beaches. Recently, the DLNR and the City and County of Honolulu Parks Department (acting with joint authority per an Executive Order from the Governor) permitted beachfront property owners at Sunset Beach along Oahu to execute sand pushing (Romine, 2013). The Parks Department also conducts regular sand pushing operations fronting beach parks and shoreline access right-of-ways in response to seasonal beach erosion. Further study may be needed to better understand if this is a sustainable approach to erosion management on the North Shore and elsewhere. Beach scraping has been undertaken at Makaha, Ehukai, and Kailua, all successfully and at a very low cost. Sand-pushing operations have been successful at maintaining beach width and protecting beachfront properties from further land loss, however, it is only a temporary measure and not a permanent solution.

6.3.3.1 Impacts/Costs of Nourishment and Dune Restoration

In other parts of the coastal United States, beach nourishment is the preferred or required alternative to armoring. Sand and equipment availability, cost, sensitive cultural issues (e.g., dune burial sites), and regulatory barriers are some of the obstacles to be overcome in Hawaii for implementing beach nourishment projects. Therefore, Federal and state agencies, counties, and private parties have not used nourishment along the Hawaiian shoreline as commonly as it is used in other parts of the coastal United States to address erosion.

Beach sand in Hawaii is a finite resource generally limited to thin deposits overlying a narrow coastal plain, in low-lying dune systems, narrow beaches, and within depressions and channels on the nearshore reef. By comparison, some mainland settings have abundant silicate sands that may be found in extensive terrestrial dune systems and across a wide marine continental shelf. As a result, beach restoration projects in Hawaii are relatively small compared to the mainland.

Land-based sources of beach quality sand in Hawaii have become scarce, and some projects using inland sand need to process the sand to remove clay, silt, and organic debris, adding significant cost. Due to these issues, recent projects have identified offshore sand deposits, the Waikiki Beach Restoration Project as an example. However, using offshore sand has challenges, including compatibility, costs associated with dredging, environmental review, mobilizing equipment, and landing sands via barge, slurry through a pipe or other means is logistically challenging in shallow reef environments. There is a
need for detailed cost-benefit investigations to assist in identifying promising offshore sand sites where large scale recovery could be used for multiple beach restoration efforts. A large sand recovery and stockpiling project (over 100,000 cubic yards) has the potential to significantly reduce costs per cubic yard due to “economies of scale” (Romine et al., 2015).

Nourishment has occurred sporadically on all the main Hawaiian islands, but limited mostly to Maui and Oahu, and most frequently on Waikiki Beach.

Nourishment has most frequently been used on Waikiki Beach in Honolulu, which has been extensively engineered over the past century. A 2008 report on Waikiki Beach (Hospitality Advisors, LLC, 2008) estimated that the total loss of Waikiki Beach would result in an approximately $2 billion reduction in annual visitor spending. The study included expenditures on beach and water-based recreation including surfboard rentals, umbrella and chair rentals, canoe rentals, and snorkel gear rentals and estimated the spending impact to be $8.5 million. Fifty-eight percent of all westbound visitors (North American) indicated they would not consider staying in Waikiki if the beach was completely lost. The $2 billion reduction from loss of Waikiki beach would mean an 18 percent overall reduction in visitor expenditures for the state as a whole and a loss of 6,352 jobs (Hospitality Advisors, LLC, 2008). An earlier economic valuation study from 2002 indicated that a congested Waikiki Beach (due to beach narrowing) could result in a net decrease of approximately 250,000 annual visitors, or 3.6 percent of total visitors for the state in a year, at an estimated value of $181 million annually (Lent, 2002; Lemmo et al., 2013). This seems to indicate that a narrower and, therefore, more crowded beach would also have negative economic impacts for the state.

Given the popularity and economic importance of Waikiki, the issue of Waikiki beach erosion has been an ongoing concern and there have been various construction and nourishment efforts to prevent further beach erosion (Table 9; see Case Study) (Lemmo et al., 2013; Hospitality Advisors, 2008).

Expenditures on nourishment of Waikiki were only available for the most recent project (2012), when $2.4 million was spent on placing 27,000 cubic yards (cy) of sand. The cost of maintaining Waikiki Beach is approximately $1.4 million annually over the next 10 years (DLNR-OCCL, 2013)—a cost that when compared to the potential $2 billion loss in visitor spending, seems reasonable.

Table 9. Beach nourishment history Waikiki Beach (Lemmo et al., 2013).

<table>
<thead>
<tr>
<th>Beach</th>
<th>Year</th>
<th>Volume (CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuhio Beach</td>
<td>1939</td>
<td>7,000</td>
</tr>
<tr>
<td>Kuhio/Queens/Kapiolani Beach</td>
<td>1951-1957</td>
<td>130,000-160,000</td>
</tr>
<tr>
<td>Kuhio Beach</td>
<td>1959</td>
<td>19,000</td>
</tr>
<tr>
<td>Outrigger Canoe Club</td>
<td>1965</td>
<td>6,000</td>
</tr>
<tr>
<td>Fort DeRussy Beach</td>
<td>1970</td>
<td>82,000</td>
</tr>
<tr>
<td>Kuhio Beach</td>
<td>1972</td>
<td>12,000</td>
</tr>
<tr>
<td>Fort DeRussy Beach</td>
<td>1975</td>
<td>16,000</td>
</tr>
<tr>
<td>Kuhio Beach</td>
<td>2003</td>
<td>1,400</td>
</tr>
<tr>
<td>Kuhio Beach</td>
<td>2007</td>
<td>10,000</td>
</tr>
<tr>
<td>Waikiki Beach</td>
<td>2012</td>
<td>27,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>310,400 – 340,400</strong></td>
</tr>
</tbody>
</table>
Most small-scale nourishment projects on Maui have used sand mined from inland dunes. The fine-grained nature of dune sand may contain too high a fraction of fine and organic material if not processed (screened, washed) for placement on high energy beaches that typically have coarser sand (Norcross-Nu‘u, 2008). Because some sand dunes contain burial sites, sand should be acquired only from quarries designated free of cultural sites. Inland sand on Maui may also become more expensive as limited inland sand resources become depleted. Sand has been shipped off Maui, primarily to Oahu, for use by cement companies for decades (Norcross-Nu‘u et al., 2008).

Similar to gathering cost information on coastal armoring projects, expenditures on nourishment, dune restoration, and sand scraping projects are difficult to obtain. They are not available centrally because these projects are undertaken by numerous parties, including private property owners, parks and recreation departments, the state, or private-public partnerships. Table 10 displays costs of federal/state projects involving nourishment across all the islands, although the majority of the projects identified were on Oahu and Maui. Although there are costs provided per cy where possible, the project information provided did not necessarily distinguish between expenditures on the nourishment portion of projects as compared to other construction activities such as groin installation. The range of costs ($50- $400/cy) reflects the aggregation of all project construction expenditures in some cases. The projects with cost information available completed since 2007 total approximately $19.6 million.

Table 10. Recent beach nourishment and dune restoration projects (all islands) (Source: DLNR and Maui County).

<table>
<thead>
<tr>
<th>Beach</th>
<th>Island</th>
<th>Year</th>
<th>Volume (CY)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kapaa Beach Park</td>
<td>Kauai</td>
<td>2016</td>
<td>600</td>
<td>~$14,000</td>
</tr>
<tr>
<td>Poipu Beach Park</td>
<td>Kauai</td>
<td>2013</td>
<td>490</td>
<td>$23,000</td>
</tr>
<tr>
<td>Poipu Beach Park</td>
<td>Kauai</td>
<td>2005</td>
<td>500</td>
<td>ND</td>
</tr>
<tr>
<td>Brennecke Beach</td>
<td>Kauai</td>
<td>2000</td>
<td>1,500</td>
<td>ND</td>
</tr>
<tr>
<td>Poipu Beach Park</td>
<td>Kauai</td>
<td>1983</td>
<td>4,000</td>
<td>ND</td>
</tr>
<tr>
<td>Poipu Beach Park</td>
<td>Kauai</td>
<td>proposed</td>
<td>6,600</td>
<td>$2-3 million ($303/cy)</td>
</tr>
<tr>
<td>Kapaa Beach Park</td>
<td>Kauai</td>
<td>proposed</td>
<td></td>
<td>$7.4 million ($100/cy)</td>
</tr>
<tr>
<td>Kikiaola</td>
<td>Kauai</td>
<td>ND</td>
<td>60,000</td>
<td>Bypass</td>
</tr>
<tr>
<td>Laulea Cove (North Shore)</td>
<td>Maui</td>
<td>2008-2016</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Kamaole II Beach Park</td>
<td>Maui</td>
<td>2012</td>
<td>125</td>
<td>$11,925 for sand only</td>
</tr>
<tr>
<td>Kalepolepo Beach Park</td>
<td>Maui</td>
<td>2012</td>
<td>125</td>
<td>$11,925 for sand only</td>
</tr>
<tr>
<td>Sugar Cove</td>
<td>Maui</td>
<td>1995-2011</td>
<td>29,731</td>
<td><del>$50+/cy for sand only (</del>$1.5 million total)</td>
</tr>
<tr>
<td>Stable Road</td>
<td>Maui</td>
<td>2010</td>
<td>3,000</td>
<td>$1.2 million ($400/cy – includes installation of 4 groins)</td>
</tr>
<tr>
<td>Halama Street Altman Property</td>
<td>Maui</td>
<td>2009</td>
<td>~200-300</td>
<td>ND</td>
</tr>
<tr>
<td>Spreckelsville, Kahului</td>
<td>Maui</td>
<td>2007</td>
<td>500</td>
<td>ND</td>
</tr>
<tr>
<td>Mama's Fish House, Paia</td>
<td>Maui</td>
<td>2006</td>
<td>500</td>
<td>ND</td>
</tr>
<tr>
<td>Kanai A Nalu</td>
<td>Maui</td>
<td>2003</td>
<td>3,000</td>
<td>ND</td>
</tr>
<tr>
<td>Maui Bay Villas</td>
<td>Maui</td>
<td>ND</td>
<td>5,000</td>
<td>ND</td>
</tr>
<tr>
<td>Kaanapali Beach</td>
<td>Maui</td>
<td>proposed</td>
<td>75,000</td>
<td>$7.6 million ($101/cy)</td>
</tr>
</tbody>
</table>
### Beach Restoration Projects

<table>
<thead>
<tr>
<th>Beach</th>
<th>Island</th>
<th>Year</th>
<th>Volume (CY)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahana Bay</td>
<td>Maui</td>
<td>proposed</td>
<td>50,000 to 100,000</td>
<td>$7-11 million</td>
</tr>
<tr>
<td>Iroquois Point</td>
<td>Oahu</td>
<td>2013</td>
<td>85,000</td>
<td>$14 million ($147/cy – Included construction of 9 groins)</td>
</tr>
<tr>
<td>Waikiki Beach</td>
<td>Oahu</td>
<td>2012</td>
<td>27,000</td>
<td>$2.4 million ($89/cy - includes cost of groin removal)</td>
</tr>
<tr>
<td>Kuhio Beach, Waikiki</td>
<td>Oahu</td>
<td>2007</td>
<td>9,000</td>
<td>$475,000 ($52/cy)</td>
</tr>
<tr>
<td>Lanikai Beach</td>
<td>Oahu</td>
<td>2000</td>
<td>10,000-12,000</td>
<td>ND</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$19.6 million</strong></td>
</tr>
</tbody>
</table>

Most small-scale dune restoration projects that have taken place on Maui were privately funded and carried out without a thorough engineering study under the auspices of the Hawaii State Programmatic General Permit for Small-Scale Beach Nourishment and/or a County Special Management Area permit (Norcross-Nu’u et al., 2008). Additionally, these small-scale restoration projects often rely on volunteers to plant vegetation compared with larger beach nourishment or armoring projects that are more complex, highly engineered sites.

### 6.3.4 Impacts of Harbor Shoaling—Federal Dredging

Although less of a concern for Hawaii as compared to effects of erosion, accretion is still an issue for harbors and marinas that host commercial navigation and recreational boating activities. The 10 commercial ports in the Hawaiian Islands handled nearly 35 million tons of cargo in 2012 worth upwards of $7.3 billion. Many of these ports experience accretion of sand that collects in navigational channels and harbor basins, which can impede movement of ships. Dredging is the main tool used to address accretion in commercial harbors and marinas. The USACE, in partnership with the U.S. Navy and State of Hawaii, has been dredging Hawaiian Island harbors since the 1960s (Figure 44). Dredging efforts reached their peak in the 1980s at nearly 4.5 million cy, and then dropped significantly. The funding climate in the 1980s allowed for shorter dredging cycles and more projects to be completed.
6.3.5 Impacts/Costs of Dredging

Between 1999 and 2009, expenditures on dredging 1.3 million cy of sediment out of the harbors of Hawaii were slightly over $20 million total, averaging $1.8 million annually. Of that $20 million, 83 percent ($16.8 million) was spent on maintaining access to harbors in Oahu, where over 1 million cy was dredged (Error! Reference source not found.; Figure 45). In 2012, Honolulu Harbor minimally handled flows of goods worth $7.3 billion and the marine transportation sector in Hawaii the same year was worth $485 million (NOAA ENOW, 2016; U.S. DOT, 2012). Therefore, the average annual $1.8 million spent on dredging all harbors—even the $20 million expended on dredging to keep shipping channels clear since 1999—would appear to be a good investment.

<table>
<thead>
<tr>
<th>Project Site</th>
<th>Year</th>
<th>Volume (CY)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbers Point Deep Draft Harbor</td>
<td>2016</td>
<td>45,111</td>
<td>$1,505,000</td>
</tr>
<tr>
<td>Haleiwa Small Boat Harbor</td>
<td>1999</td>
<td>4,500</td>
<td>$1,429,292</td>
</tr>
<tr>
<td>Hilo Deep Draft Harbor</td>
<td>2016</td>
<td>118,275</td>
<td>$1,449,000</td>
</tr>
<tr>
<td>Honolulu Deep Draft Harbor</td>
<td>2016</td>
<td>8,939</td>
<td>$1,216,250</td>
</tr>
<tr>
<td>Kahului Deep Draft Harbor</td>
<td>2016</td>
<td>57,202</td>
<td>$2,396,500</td>
</tr>
<tr>
<td>Nawiliwili Deep Draft Harbor</td>
<td>2016</td>
<td>64,731</td>
<td>$2,394,000</td>
</tr>
<tr>
<td>Port Allen Deep Draft Harbor</td>
<td>1999</td>
<td>21,000</td>
<td>$360,182</td>
</tr>
</tbody>
</table>

Marine transportation includes deep sea freight, marine passenger transportation (excluding charter boat fishing, which is included in Tourism and Recreation), pipeline transportation, marine transportation services, search and navigation equipment, and warehousing.
<table>
<thead>
<tr>
<th>Project Site</th>
<th>Year</th>
<th>Volume (CY)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manele Small Boat Harbor</td>
<td>2004</td>
<td>9,000</td>
<td>$694,095</td>
</tr>
<tr>
<td>Pearl Harbor (not USACE)</td>
<td>2004</td>
<td>570,000</td>
<td>$7,810,593</td>
</tr>
<tr>
<td>Pearl Harbor (not USACE)</td>
<td>2006</td>
<td>208,128</td>
<td>$2,464,017</td>
</tr>
<tr>
<td>Haleiwa Small Boat Harbor</td>
<td>2009</td>
<td>6,500</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Waianae Small Boat Harbor</td>
<td>2009</td>
<td>2,000</td>
<td>$494,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1,272,128</strong></td>
<td><strong>$20,325,754</strong></td>
</tr>
</tbody>
</table>

Table 11. USACE dredging projects 1999-2016 (cost information limited for earlier projects).

There has so far been limited beneficial reuse of dredge material on Hawaii, e.g., topsoil manufactured from dredged marine sediments in Pearl Harbor was used for creation of recreational fields at a cost of approximately $20/cy (Krause, 2000). Unfortunately, the dredge used on Hawaii does not have the capability to pump material out to the shoreline as needed for beach nourishment. The hopper design of the existing ship requires it to be in at least 35 feet of water to dump sediment. The USACE estimated it would cost $20-40 million to retrofit the dredge to be able to pump sediment to the shoreline.

Figure 45. Dredging expenditure by county (USACE, 2016).

### 6.4 Cultural Significance of the Shore

Hawaiian daily life and culture is deeply connected to the shoreline and nearshore environment. Reefs and the nearshore environment are important fishing grounds. Fishponds, some still in existence today, are enclosed manmade lagoons, used to supplement fishing activities. For native Hawaiian people, the beach and coastal dunes are resources for subsistence as well as cultural, spiritual, and traditional practices, and as burial grounds for their ancestors. The shore was a spiritual center, where Hawaiians built shrines—heiau—practiced significant ceremonies, and buried the dead.
6.4.1 Traditional practices along the shore

Hawaiian fishponds, or loko ia, are traditional aquaculture systems that have been used across all the islands for 1,000 years. In areas where shallow fringe reefs existed close to shore or in small inlets/bays, ponds were easily formed by constructing semicircular stone walls (made from basalt and/or coral) out from the shoreline. These aquaculture systems were used to supplement nearshore and offshore fishing activities. loko ia are some of the most significant traditional Hawaiian cultural resources, representing the traditional integrated view of land and water stewardship. At the peak of Hawaiian aquaculture, 400 fishponds produced over 2 million pounds of fish per year in the islands, demonstrating the value Hawaiian culture places on excellence in sustainability, food sovereignty, and natural resource management (NOAA Fisheries, 2015).

Fishing shrines and altars were often built along the coast where first caught fish offerings were given to the gods. The shrines were also used as land markers for fishing grounds, making it possible for an angler out at sea to determine if they were fishing in their designated grounds (Aluli and McGregor, 1992; Greene, 1993). Beaches and the nearshore were also used for recreational activities much as they are today—swimming, canoe races, and surfing were all dependent on the shore and shore access.

For thousands of years, native Hawaiians were returned to the earth after they passed away—remains were laid to rest in a variety of ways including burials (iwi kupuna) in caves, at sea, and in sand dunes. Sand dunes were a preferred medium because sand was hygienic and offered a simpler option compared to the underlying basalt found across the islands. Bodies would be often buried in sand dunes with no surface markers. Native Hawaiians believe that the spirit of loved one often lingers near the bones, thereby making the area around the burial site sacred (Ayau, 1991).

6.4.2 Erosion Impacts on Current Practices

In Hawaii and other Pacific Islands, many of the lands vulnerable to erosion contain cultural features such as burials sites, historical artifacts, and ancient home sites (Kane et al., 2012). The eroding of beaches in combination with increasing shore development and loss of beach access has seriously threatened the ability of native Hawaiians to maintain their connection to the shore and sea and affected their traditional practices and activities.

Fishpond production dropped in the 1900s, and by 1970, the ponds only produced 20,000 pounds of fish—less than 1 percent of what they produced at their peak. Today, there are only an estimated dozen active ponds (NOAA Fisheries, 2015). The diversion of streams for agriculture, changing shoreline uses, and resort development along the coast over the last century have influenced aquaculture practices, with fishponds being destroyed by siltation from eroding upland soil or filled in to create more land for residential and commercial development (Greene, 1993). Mangroves were introduced to the coast of Molokai to prevent coastal erosion, but have instead intensified mud deposition. Nearly all of the 50 ancient Hawaiian fishponds on south Molokai have been infilled by mud and populated by the invasive mangroves (Feirstein and Fletcher, 2002). The Kuualli fishpond on Waikoloa Beach on the Big Island was damaged by the March 2011 tsunami generated by an earthquake in Japan. The tsunami breached the beach and infilled sand in the pond (Sea Engineering, 2015). In 2012, a group of non-profit organizations and government agencies began efforts to address the difficulties in the permitting process for fishpond repair and restoration. This resulted in a streamlined permitting application released in 2015 (DLNR, 2015).

Traditional sand dune burials are no longer occurring; however, historical burial sites are commonly discovered along the shores of all the islands during land development activities. This has created tension and controversy over the last several decades between native Hawaiians, the state, and land developers. The State Historic Preservation Division (SHPD) was created in the 1980s to protect Hawaii’s...
history, including burial sites, and has jurisdiction over all buried remains and burial goods 50 years and older on public and private property. After consulting lineal descendants, SHPD dictates whether the inadvertently discovered iwi kupuna and burial goods will be reinterred in its current place or relocated. The program was established in 1987 after the discovery of over 1,000 burials dating back more than 1,000 years in sand dunes along the northwest shore of Maui that were being developed into an $80 million beachfront hotel (Wills, 1989). Frustrated with developers’ past disregard of burial sites along the coast, organizations of native Hawaiians organized protests and exerted enough pressure on the state and developers to force the relocation of the resort off the dune sites. It also catalyzed the passing of the Native American Graves Protection and Repatriation Act (NAGPRA) of 1990, which enabled Hawaiians to reclaim remains, and the objects that were buried with them.

On the west end of Molokai, the Papohaku Dune system and beach is one of the last intact dune systems in Hawaii. The beach and dunes were at one point the site of a fishing village and burial sites. Two hills that bounded Papohaku beach housed two major heiaus and one was used in the burial process and the dunes in between were used as a burial place (DLNR, 2008). The dunes on the west end of Molokai were mined in the 1960s and 1970s and sand shipped by barge to Oahu to make cement for the building industry and for use on Waikiki Beach. The average rate of erosion along the Papohaku beach has been approximately 1-4 feet annually, with the highest rates found in areas that had been mined in the past for sand used in construction (DLNR, 2008).

Hawaiians are maintaining traditional ways of life to varying degrees in Hawaii. In particular, this connection continues to be maintained on Molokai, where 38 percent of the food acquired by Native Hawaiian Molokai families is through subsistence activities such as fishing and hunting (Matsuoka et al., 1993). However, even the shorelines and nearshore of Molokai with its strong native Hawaiian heritage is suffering. For example, the introduction of hooved animals and decades of destructive agricultural practices has led to erosion and transportation of silt to the sea, where it clogs traditional fishponds and chokes fringing reefs (Han et al., 2012). A 2012 survey found that 57 percent of subsistence activities involve fishing and diving and 32 percent involve gathering sea urchins, shellfish, and crustaceans (Han et al., 2012).

6.5 Need for additional and updated studies

There were several data and information gaps identified during this effort that would help comprehensively assess the expenditures to address erosion and accretion in Hawaii in the future:

- Recent studies addressing cultural uses of the beach/shoreline;
- Studies documenting impacts of erosion across all the islands—recent studies focus on Kauai, Maui and Oahu;
- Complete inventory of project costs and quantities for federal and state nourishment projects;
- Complete inventory of project costs and quantities for federal and state dredging projects;
- Comprehensive survey of shoreline type (armored v. unarmored);
- Studies exploring the impacts of nourishment and armoring on nearshore coral reefs;
- Studies exploring the impacts of nourishment on nearshore marine water quality;
- Historic expenditures on roadways impacted by erosion;
- Beach and nearshore valuation economic model to assess natural resource value; and
- Detailed cost-benefit investigations to assist in identifying promising offshore sand sites where large scale recovery could be used for multiple beach restoration efforts.
6.6 Conclusion

The beaches and the nearshore waters of Hawaii are the backbone of the state economy and the centerpiece of the Hawaiian culture and lifestyle. Beaches provide access to historic shrines, are visited for spiritual ceremonies, contain historic burial sites, and allow access to nearshore reefs for fishing and recreation. The coast is where ports, highways, and other critical infrastructure are located, and the shoreline provides valuable recreational opportunities and a uniquely beautiful setting that people travel thousands of miles to visit; the Hawaiian shore is where people want to live and tourists want to visit. The ocean-based economy and shoreline resources of Hawaii are worth upwards of $9 billion annually\(^\text{19}\) and shoreline erosion and associated beach loss would have substantial negative impacts to the economy, the high quality of life residents and visitors enjoy, cultural resources, and coastal ecosystems.

The limited information on federal, state, and private expenditures for nourishing beaches and dredging harbors reveals a comparatively small cost in addressing erosion and accretion given the value of the shore to the state economy. Approximately $20 million has been spent on dredging Hawaiian federal harbors since 1999, on average $1.8 million annually. To nourish beaches, the state and private property owners have been responsible for the majority of projects at a cost of roughly $2 million annually ($19.6 million total since 2007; Table 10). Only a handful of “Civil Works” U.S. Army Corps projects have occurred in the last 30 years in Hawaii, which involved shoreline armoring. Two of the largest projects—Kaumalapau Deep Draft Harbor (Lanai) in 2007 and Kalaeloa Barbers Point Deep Draft Harbor (Oahu) in 1985—totaled $87 million. Even without consideration of all the market and nonmarket values the beaches and shore provide, the annual tourism and recreation revenue associated with the shore alone ($6.2 billion; NOAA ENOW, 2016) is a good incentive to continue relatively small investments that address erosion and accretion.

Other expenditures to address erosion impacts (e.g., to roadways) may also appear relatively minor in comparison to the value of the shoreline-based tourism and recreation economy. For example, emergency proclamations were issued in 2012-2013 to repair and protect two stretches of the Honoapiilani Highway in Maui after damage from erosion. The cost totaled $13 million. Tourists alone spent $1.3 billion on transportation in 2014 (e.g., interisland travel, car rentals, ground transportation, and gas), with the majority of that amount, nearly 70 percent ($860 million), spent on vehicle rentals that use the many coastal highways and roads of all the islands. Given these facts, the cost of repair, protection, and even relocation projects that address longer-term concerns, like the re-alignment of Honoapilani Highway (estimated cost of $800 million), appear justifiable (HTA, 2015b, HTA, 2013).

The costs of armoring shorelines to protect infrastructure and property from erosion go beyond the construction and maintenance costs of hardened structures such as seawalls and revetments. While constructing a seawall along a stretch of shoreline to protect a resort from erosion may cost between $500 and $5,000 per linear foot, this cost does not include the indirect costs such as the potential narrowing or loss of beach in front of the structure leading to lost public access and recreational opportunities. Unfortunately, there are few Hawaii-specific studies exploring these potential losses, which are only likely to increase if armoring of the shore continues. Beach nourishment and dredging also have indirect costs associated with them, such as habitat disturbance and noise pollution.

Very few studies or reports exist exploring the nonmarket value of the shoreline in Hawaii, which means the economic picture of the impacts of erosion and accretion is incomplete. The lack of studies is

surprising given the importance of the shoreline’s market value across the islands. Even considering dated beach attendance numbers for Oahu, it can be estimated using nonmarket values from Penn et al. (2012) that if the beaches of Oahu are clean, with clean water, no overcrowding, and ideal safety conditions, they are worth minimally $1.6 billion annually. There are additional information gaps that, if filled, could allow for a more robust evaluation of the economic impacts of erosion. These gaps include complete inventories of projects costs, both state and federal, for beach nourishment, shoreline protection, and dredging; tourism and recreation studies for beaches across all the islands (beyond just Waikiki Beach); information on historic infrastructure expenditures to address erosion damage; and reports that examine the value of the shoreline to cultural practices. Active research at the University of Hawaii is investigating the current value of Waikiki beach by updating the 2008 study results. In addition, researchers are developing a new valuation model to assess the comprehensive natural resource value of Waikiki’s nearshore ecosystems including reefs.

Although in some parts of the coastal U.S., sand is available to replace eroding beaches thereby presenting a viable alternative to shoreline hardening, Hawaii presents a different case due to the limited availability of beach-compatible material.

The economy of Hawaii heavily relies on tourism and recreation, which in turn rely on the state of the beaches and shorelines. Diversification of the ocean economy would add stability to a state that depends on an eroding shoreline experiencing accelerating rates of sea level rise.

6.7 References


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7 CASE STUDIES: ECONOMIC AND SOCIAL IMPACTS OF SHORELINE CHANGE

Island: Kauai

Issue: Kikiaola Light Draft Harbor, Kauai

Figure 46. Kikiaola Light Draft Harbor (left, Sea Engineering, 2008) and nearby temporary erosion controls (right, DLNR OCCL, 2014).

Background:

The Kikiaola Light Draft Harbor is located between the towns of Waimea and Kekaha and services both the tourist industry (access to the Na Pali Coast) and local fisherman (Sea Engineering, 2008). The State of Hawaii completed construction of the harbor in 1959 and improvements were made over the next five years, including the addition in 1964 of a 150-foot-long spur at the harbor’s entrance to help shelter boats from the swell as they exit the harbor (Azambuja, 2013).

Since its completion, there has been consistent accretion along the eastern side of the harbor and erosion along the western side of the harbor due to the harbor’s interference with alongshore transport of sand from the Waimea River Mouth (DLNR OCCL, 2014). Effects are visible along the western breakwater root of the harbor itself, where the water line has eroded approximately 75 feet landward (Sea Engineering, 2008), and along beachfront properties to the west that experience erosion of up to 4 feet per year. Land loss and scarping became severe enough that in 2013, DLNR provided Emergency Permits allowing nearby property owners to construct geotextile sandbag revetments and other temporary fixes to help protect their land from further erosion (DLNR OCCL, 2014). In addition to erosion issues outside the breakwaters, the harbor itself has suffered from sedimentation, leading to dangerously shallow depths and reduced functionality for its users (Azambuja, 2013).

Cost:

In 2009, to address the harbor’s sedimentation, USACE dredged both an 11-foot-deep channel at the harbor’s entrance and a 7-foot-deep area in front of the harbor’s boat ramp. USACE also rebuilt 835 feet of breakwater, raised the breakwater’s height, and removed the spur at the harbor’s entrance (Azambuja, 2013). The dredging and construction cost a combined $18.8 million (USACE, 2016a).

In 2014, to address the erosion on the western side of the harbor, the State of Hawaii bypassed 60,000 cy of sand from Waimea Beach (east of the harbor) to the shoreline west of the Harbor at a cost of $50/cubic yard for a total of $3 million (USACE, 2016b).
Socio-Economic and Cultural Issues:

Despite the USACE’s improvements and the sand bypassing project, problems persist around and within the harbor. The removal of the spur along the eastern breakwater has led to increased wave action in the harbor making it dangerous to load and unload boats, and sand and silt has re-settled where it was previously dredged, again making it difficult for boats to get in and out of the harbor (Azambuja, 2013). Erosion is an ongoing problem to the west of the harbor. A study from the USACE (completed before the bypassing project) found that 5,000 cy of sand would need to be moved from east to west of the harbor annually to offset the erosion (Azambuja, 2013). Among property owners west of the harbor, the persistence of erosion issues has led to a prevailing sense that the harbor does not benefit all members of the community equally (University of Hawaii Sea Grant College Program, 2016).

References:


University of Hawai‘i Sea Grant College Program. (2016). Personal communication between Ruby Pap, University of Hawai‘i Sea Grant College Program, USACE, and Eastern Research Group, Inc.


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**Island:** Kauai  

**Issue:** Pacific Missile Range Facility Barking Sands erosion of beach and burial site exposure  

**Background:**

The Pacific Missile Range Facility Barking Sands (PMRF) is located along the Mana Coastal Plain, on the western end of Kauai. It is the world’s largest instrumented multi-environmental range. There are over 1,100 square miles of instrumented underwater range and over 42,000 square miles of controlled airspace. The base includes a 6,000-foot (1,800 m) runway with operations and maintenance facilities. The shoreline is characterized by wide sand beaches in the south and narrower beaches in the north fronted by extensive limestone beach rock and backed by vegetated sand dunes. Various levels of public access to the beaches and water areas along PMRF's 7-mile coastline have existed for decades. In 2012, PMRF relaxed beach access along its north and south boundaries to facilitate walk-in civilian beach use (CNIC, 2016; DOD, 2015).

The area is exposed to swells from the northwest and west during winter and spring months and swells from the west and southwest in the summer, which wrap around the arcuate coast creating some of the most variable beaches in the entire state. Kaumualii Highway, a two-lane highway that is the only route providing access to the west end of Kauai, the county landfill, the wastewater treatment plant, and the PMRF Facility, runs along the shoreline through the town of Kekaha. This section of the highway is protected by an Army Corps of Engineers’ constructed revetment. In 2012, the beach began eroding at a rapid rate leading to the complete disappearance of the beach in front of the revetment. Flanking erosion at the west end of the revetment threatened the highway. The Hawaii DOT opted to build a 300 foot drilled shaft wall extending from the edge of the revetment west to MacArthur Park to address the erosion. During the same time period, the northern end of the PMRF beach was experiencing unprecedented rates of accretion. The PMRF, local students, and scientists began working together to monitor the changing seasonal erosion patterns to better understand the erosion and accretion that was occurring. After four years of regular beach profiles conducted in the area between PMRF’s northern boundary and St. Theresa’s church in Kekaha, a clear seasonal pattern of sand distribution has emerged. Results show longshore currents bring sand from MacArthur Park northwest to Major’s Bay (PMRF) during the summer months when north winter swells weaken and southern swells strengthen. In the winter months, the beach moves back to MacArthur Park with high, north swells (Blay, 2016; personal communications). Indeed, just a couple months after the drilled shaft wall was constructed to protect the highway at MacArthur, the beach returned to its former width. If seasonal erosion data had been...
available to DOT at the time of the temporary erosion emergency, they may have considered other “softer” or less costly options to protect the highway (Blay, 2016).

**Cost:**

The original revetment fronting Kaumualii Highway was completed in May 1980 at a cost of $3,047,520 (Federal $1,374,996; non-Federal $1,672,524). Repair of Hurricane Iwa damages to the revetment in November 1982 was completed in October 1983 at a cost of $229,600. The drilled shaft wall installed by Hawaii DOT cost $6.5 million (HDOT, 2014).

**Socio-Economic and Cultural Issues:**

In addition to impacting Kekaha Beach and Kaumualii Highway, erosion along the PMRF shoreline has also historically and currently impacted burial grounds located in the Nohili Dunes on Barking Sands. Native Hawaiians considered Mana Plain a leaping or departing place of souls. Human remains have been found in the sand dunes of PMRF Barking Sands, from the north end of the installation to Waiokapua Bay. In the past, protests and arrests occurred as groups demanded access to the dunes and demanded the halting of a missile program in the early 1990s as disruptive to the burial sites (Kakesako, 1997). PMRF has worked with local Native Hawaiians and members of the Burial Council over the decades to help secure and support re-internment of human remains from this site in accordance with the applicable state laws and regulations (DOD, 2015; CNIC 2011). The area in Figure 48 is one example of a site that was encroached on by high surf that came up over the berm road in late February of 2016. This is a known site of human remains and it will continue to deteriorate even more rapidly with sea level rise and erosion.

A better understanding of sediment transport by surveys and monitoring will help anticipate erosion events and prepare for them and allow for more informed decisions regarding protection of burials sites, the highway, and the Kekaha beach.

**References:**


Personal Communication with PRMF.
Island: Kauai

Issue: Poipu Beach Renourishment

Background: Poipu Beach and Poipu Beach Park is located along the southern Kauai coastline. The small pocket beach formed between volcanic basalt headlands is one of the most popular beaches on Kauai for its many recreational assets—snorkeling, swimming, surfing, and picnicking. An intermittent sand bar or tombolo usually protects the beach and beachgoers from strong currents, making it ideal for swimmers and other water-based activities. It is also a favorite viewing site for the endangered Hawaiian monk seal and the Green sea turtle. The popularity of the beach has made the area a highly desirable resort area and it continues to face increasing development pressure.

The beach is chronically eroding and suffered serious damage after Hurricane Iniki hit the area in 1992. Large waves pulled several tons of sand offshore, leaving the beach diminished and scarped. Before the sand could naturally return to the beach, currents pushed it downdrift to the west. The stability of Poipu Beach depends on a healthy tombolo. However, since 1992 the tombolo has eroded several times, exacerbating the erosion on the rest of the beach and causing dangerous swimming conditions. Several drownings have occurred at Poipu and Waiohai beaches due to these dangerous currents.

In 2003 the County of Kauai started working to secure permitting for beach nourishment utilizing inland dune sand excavated from the Kawaiuleile bird sanctuary on the Mana Plain in Kekaha. Approximately 25,000 cubic yards of sand were excavated. Approximately 500 cubic yards of sand were placed at Poipu Beach in 2005, however there were issues with grain size compatibility and cementation. This added additional time and cost for...
future nourishment events due to the need to have the sand washed and processed to remove the fine grains (Chang, 2004).

A few years passed before further nourishment projects were pursued again. In 2009, with technical assistance from the University of Hawaii Sea Grant College Program Extension Faculty, it was estimated that 7,100 cubic yards would be needed to restore the beach and that this would be conducted in two phases: a small scale beach nourishment project of 500 cubic yards (requires less permit review) and a larger scale project of 6,600 cubic yards to be conducted with additional environmental review and funding. A multi-stakeholder partnership was forged with the hotel industry, funding for a long-term beach restoration study was obtained, the inland sand was washed, and the permit process was re-started to begin Phase I.

In 2013, Sea Engineering completed the Poipu Beach Restoration Study, which identified several off-shore deposits of potentially beach compatible sand and developed erosion mitigation options for the beach including a beach nourishment design that included restoration of the tombolo. The process for getting the study completed involved multiple organizations including the DLNR Office of Coastal Land, County of Kauai, Poipu Beach Foundation, PBRA, and the University of Hawaii Sea Grant College Program, and was funded by the Hawaii Tourism Authority and the County of Kauai (Sea Engineering Inc., 2013).

In mid-to-late January 2013, the sand bar/tombolo was washed out by a significant east swell and further erosion was experienced on Poipu beach. To address the worsening conditions of the beach, 500 cubic yards of replenishment occurred in 2014, completing Phase I. Phase II has yet to be completed.

Cost:

The County of Kauai has sponsored beach nourishment and a restoration study with significant assistance from Poipu Beach Resort Association (PBRA) (a non-profit organization comprising members from the business community) and Hawaii Tourism Authority (HTA). The 2005 nourishment event cost $10,000 (no washing was conducted). The 2014 500 cubic yard beach nourishment event cost approximately $23,000, including washing/processing the Mana Plain sand. The 2013 Poipu Beach Restoration Study cost approximately $300,000. All events were funded with assistance from PBRA and HTA (see below).

PBRA has spent an estimated $120,000 between 1999 and 2010 maintaining Poipu Beach and nearby Brennecke’s Beach. A clear indication that the business community recognizes the draw of the beaches and recreational opportunities to the overall economic health of the area and county.

Table 11. History of Poipu Beach Park Sand Replenishment funded by the PBRA.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Year</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach restoration at Brennecke’s Beach (part of Poipu Beach Park) in partnership with the County of Kauai. PBRA led the project including private donations, in-kind donations, partnerships, fundraising, permit applications, placement, etc.</td>
<td>1999-2000</td>
<td>$35,750</td>
</tr>
<tr>
<td>Hauling of 90 loads of sand to Brennecke’s Beach for placement by summer 2004.</td>
<td>2003</td>
<td>$12,000</td>
</tr>
<tr>
<td>Hauling of sand to Poipu Beach Park.</td>
<td>2005</td>
<td>$10,000</td>
</tr>
<tr>
<td>Washing and sifting of sand for Poipu Beach Park.</td>
<td>2006-2010</td>
<td>$12,000</td>
</tr>
<tr>
<td>Poipu Beach Shoreline Study in partnership with the Hawaii Tourism Authority and County of Kauai.</td>
<td>2010</td>
<td>$50,000</td>
</tr>
<tr>
<td><strong>Total Donated from PBRA:</strong></td>
<td></td>
<td><strong>$119,750</strong></td>
</tr>
</tbody>
</table>

*Source: PBRA*
According to the Restoration Study, the estimated cost for utilizing the off-shore sand and restoring the beach to its pre-Hurricane Iniki condition (approximately 6,600 cubic yards) is $2 to 3 million, with much of the cost involving equipment mobilization. A more cost effective approach would involve dredging a larger amount of sand (several thousand cubic yards were identified in the study) and stockpiling it for future use. To this date, recommendations of the study have not been pursued due to lack of funding, leadership, and a clear direction for moving forward. The other option would be to pursue using the Mana Plain sand; however, questions remain about its effectiveness and compatibility with the beach (Sea Engineering Inc., 2013).

Socio-Economic and Cultural Issues:

Kauai County and local associations have worked to protect the recreational value of the beach and associated development in the area. Neighboring Waiohai Beach, fronting several resort properties to the west, also suffers from erosion and beach loss and could benefit from beach restoration. The Poipu region has previously been studied by the Hawaii Regional Sediment Management initiative. The county, State DLNR, and local associations hope to start developing the third phase of the project, which involves further investigating the compatibility of the sand in the offshore areas as a long term sand source—an expensive proposition (Smith and Lillycrop, 2014).

Unfortunately, there may not be another choice. Erosion issues continue to persist at Poipu Beach. High surf often erodes the tombolo creating dangerous conditions for beachgoers. Recently, during a high surf event in the summer of 2015, the eroding tombolo created a dangerous rip current that closed the beach to swimmers (Penn, 2015). More days like this could be in the beach’s future.

References:


Personal communication with Ruby Pap, Coastal Land Use Extension Agent, UH Sea Grant College Program, 12/13/16.
Island: Oahu

Issue: Erosion and beach nourishment at Waikiki Beach

Figure 51. Royal Hawaiian Hotel seawall and beach before nourishment (left) and after (right).
Source: DNLR-OCCL and Sea Engineering, Inc.

Background:

In the past century, extensive development has transformed Waikiki Beach with a critical section of the shoreline fronting Moana Hotel to the Royal Hawaiian Groin—from a recreational area for Hawaiian royalty into the cornerstone of Hawaii’s tourism-based economy and the home of modern surfing culture. In addition to the development of commercial infrastructure, coastal engineering projects have significantly altered the shoreline for over 100 years. Such alterations date back to the late 1800s, when seawalls were first built along Waikiki Beach. Key interventions include the aforementioned seawalls, construction of the Royal Hawaiian groin beginning in 1927 (along with several other groins and breakwaters in the area), completion of the Ala Wai Canal in 1928, extensive beach nourishment, and numerous other projects ranging from dredging and storm drain installation to recent beach nourishments in the past decade (Wiegel, 2008). Today, it is suggested that not a foot of natural shoreline exists between Honolulu Harbor and Diamond Head (Sea Engineering, Inc., 2016).

Though Waikiki Beach has primarily experienced erosion since development began in the late 19th century (with beach nourishment projects dating back to 1939, 12 years after groin installation began), erosion trends along the shoreline are highly variable and seasonally influenced due to effects of multiple groins, where sand accretes on updrift sides and erodes on downdrift sides. Since the 1930s, approximately 300,000 cy of fill material have been placed on sections of Waikiki Beach. A beach restoration project in 2012 restored Waikiki Beach to its former 1986 width using sand dredged from a nearshore sand deposit. Future nourishment will be necessary to maintain the beach (DLNR-OCCL,
The beach was monitored for 2.7 years after the nourishment was completed. The objectives were to evaluate the behavior and stability of nourished beaches, determine an approximate schedule for future beach nourishments, and understand beach change and sediment behavior in view of wave energies in a reef environment. The monitoring found that seasonal patterns of beach recession and advance coincided with seasonal wave conditions. For example, Waikiki Beach generally experienced an overall advance in the summer months (Habel 2016). Feasibility studies and plans are currently underway by the Hawaii DLNR, to assess potential long-term strategies for beach management throughout Waikiki.

Cost:

The cost of maintaining Waikiki Beach is estimated at $1.4 million annually over the next 10 years (DLNR-OCCL, 2013). While seemingly high, that cost is small in comparison to the economic value of the beach. According to the Hawaii State Data Book (DBEDT, 2015), Waikiki District accounted for $7.3 billion in visitor expenditures in 2015, representing 42 percent of total visitor expenditures statewide. Waikiki Beach is an attractive destination for foreign travelers, with 1.3 million visitors from Japan alone in 2007 (Hospitality Advisors, 2008). Thus, in addition to state revenues, Waikiki Beach contributes substantially to the national GDP by bringing foreign dollars directly into the U.S. economy. The beach experience is a major factor in Waikiki’s allure: a report by Hospitality Advisors (2008) found that 58 percent of North American visitors and 14 percent of Japanese visitors would not visit Waikiki if the beach eroded away. Such decreased visitation would result in the loss of about $2 billion, $125 million in taxes, and 6,352 jobs annually.

Who pays for Waikiki Beach maintenance is a central issue. While the USACE has conducted numerous studies, its maintenance, improvement, and projects have been limited to beach work fronting the Fort DeRussy and Hale Koa Hotel, which is a military recreational area (Sea Engineering, Inc., 2016). The Hawaii DLNR has led the last two beach restoration initiatives in 2017 and 2012 (Fletcher, 2013). Also recently, there has been a move towards “collaborative funding,” which seeks to “address both public and private interests in restoring and preserving beach resources (DLNR-OCCL, 2013).” For example, funding for the $2.4 million Waikiki Beach Nourishment Project of 2012 came from a combination of the Kyoya Resorts ($500,000), the Hawaii Tourism Authority ($500,000), and the State of Hawaii Beach Restoration Fund ($1.5 million) (DLNR-OCCL, 2013). To help address this ongoing need, in May 2015, the Mayor of the City and County of Honolulu signed into law a County ordinance allowing the formation of a new beach improvement District known as the Waikiki Beach Special Improvement District Association (WBSIDA) to tax Waikiki businesses as part of the real property tax assessment semi-annually to provide private funds to match state efforts to address beach erosion (Cocke, 2015).

Socio-Economic and Cultural Issues:

Although no significant impacts were identified in the 2012 environmental assessment and most stakeholders support maintaining Waikiki Beach for its tourism-related economic and recreation value, beach nourishment can cause concern for other uses, which include surfing, fishing, coral reef conservation, hotels (noise), and native Hawaiian culture. For example, prior to the 2012 nourishment project, concerns were raised by the local community that the sand to be excavated for the beach nourishment was from the site of Native Hawaiian sea burials, which included the ashes of swimming and surfing legend Duke Kahanamoku (DLNR-OCCL, 2013). To address this issue, the contractor conducted a pule (blessing ceremony) (DLNR-OCCL, 2013). The surfing community argued that the nourishment project could potentially impact the quality of the world-famous surfing waves at Waikiki by changing the wave breaks on the nearshore reef. This concern was addressed by sourcing (recycling) fill material from offshore, so as not to add sand to the overall littoral system and reef environment.
References:


Island: Oahu

Issue: Public-Private Partnership Transforms Shoreline and Provides Multiple Benefits

Figure 52. Iroquois Point before and after rock groin construction (2015). Source: Sea Engineering, Inc. Photo showing T-groins—Credit: Chip Fletcher.

Background:

Located between Pearl Harbor Naval Base and a military firing range, Iroquois Point has supported military housing since the 1960s. The Navy owns Iroquois Point, but began leasing a 363-acre subdivision to a private developer in 2003. The primary purpose of the project was to leverage private financing to redevelop residential units for military families, while allowing the developer to market some units to the public and provide other amenities to enhance the area. The project was facilitated by the combination of one landowner (Navy), one buyer (the real estate developer), the presence of high quality sand nearby, and fewer state and county permits than would be required in a non-military area.

In 2012, the “Kapilina” community was created, transforming Iroquois Point into a mixed military/civilian community. In addition to housing, Navy used the influx of private capital to combat chronic erosion. Over the years, the shoreline had receded 300 feet, leading to the loss of 16 homes and the sedimentation of Pearl Harbor navigation channels (Sea Engineering, Inc., 2015a). The shoreline restoration project, funded in part by a credit given to the developer during lease negotiations, involved constructing nine new groins, dredging 95,000 cy of readily available sand from the navigation channel, and nourishing the beach. Considered the largest beach nourishment project in Hawaii at that time (KITV4, 2013), a 4,000-foot long, 7-acre recreational beach was restored. The nine rock groins also provided habitat for marine life (Sea Engineering, Inc., 2015b; AECOS, Inc., 2015). As a result of these
improvements, Iroquois Point became a destination for those living inside and outside the community, who enjoy the recreational amenities created by this private-public partnership.

Cost:

The total project cost, excluding permitting costs, was between $14 and $15 million (including the credit Navy provided to stabilize the shoreline and improve the beach) (Sea Engineering, Inc., 2015a).

Socio-Cultural Issues:

This is an example of a successful private-public partnership. Stabilization and development of the shoreline benefits 5,000 military and civilian residents, as well as the general public who—with parking passes from the Navy—are able to access the beach, community center, and the area’s other recreational resources (such as snorkeling in the no-fishing zones established along the groins). Iroquois Point also hosts events on New Year’s Eve, Independence Day, and at other times during the year, providing additional social benefits for this previously underutilized military property (Sea Engineering, Inc., 2015a).

References:


Island: Oahu

Issue: Kailua Bay erosion management and accretion claims

Figure 53. Erosion scarp at Kailua Beach Park (2008). Source: Sea Engineering, Inc.

Background:

Kailua Bay is a 2.25-mile long embayment on the windward (east) coast of Oahu, situated between Kapoho Point to the north and Alala Point to the south. Sand beaches and calm waters support a variety of recreational activities along the bay including swimming, windsurfing, boating, and more, making the area a popular destination for residents and visitors alike (Sea Grant, 2010; Sea Engineering, Inc., 2008). Approximately 120 privately owned lots, which directly abut Kailua Beach, are concentrated in the northern and central sections of the bay, leaving the southern section accessible to the public through the 35.2-acre Kailua Beach Park (Sea Grant, 2010).

Studies of historical shoreline change for Kailua Bay find the beach is accreting in the northern and central sections of the bay and eroding along the southern shoreline (Fletcher et al., 2014), leading to vastly different strategies for shoreline management. Whereas property owners and public beach users along the northern and central sections of Kailua Bay have benefited from an accreting shoreline, and have not needed to consider any shoreline stabilization measures (McAvoy 2010), interventions aimed at limiting erosion along Kailua Beach Park in the south date back to the 1970s (Sea Engineering, Inc., 2008). Toppled trees, erosion scarps, and exposed irrigation pipes remain visible along the shoreline at Kailua Beach Park (Sea Engineering, Inc., 2008). In the past, sand grabbers—small, hollow tile structures intended to dissipate wave energy—were used in a limited capacity for shoreline stabilization at Kailua Beach Park, but these have been removed as a part of efforts to find more effective, longer-term options. Since 2013, alternatives have been attempted, including re-nourishing the shoreline using sand back-passed from the adjacent Kaelepulu stream and restoring the natural dune system as the preferred defense against erosion (Sea Grant, 2010).

Cost:

Given the long-term trends of erosion and accretion at Kailua Bay, there are costs and benefits associated with shoreline change in the area. Costs include expenses related to stabilizing the eroding shoreline in Kailua Beach Park and benefits are accrued in the northern and central sections of the bay as private property owners claim accreted beachfront as their own. Potentially offsetting these benefits, however, is a court ruling (following a lawsuit brought by private property owners) that the state can claim the accreted property and must only compensate private owners if the beach accreted before 2003 (any subsequent or future growth can be claimed by the state without any compensation) (Levine, 2010; HRS 501-33).
Socio-Economic and Cultural Issues:

Although adverse effects of shoreline change are most presently felt in the southern section of Kailua Bay, challenging jurisdiction issues persist in the central and northern sections. Private land ownership north of Kailua Beach Park dates back to the 1920s and, for decades, land owners claimed adjoining accreted beachfront lands as their own through common law provisions. The State Land Use Law defined all “lands seaward of the shoreline [as of October 1964] within the State Conservation District,” but as natural accretion moved the shoreline seaward, no provision was made to adjust the Conservation District regulatory boundary and the original 1964 line was not consistently enforced (Sea Grant, 2010).

Issues of land ownership and jurisdiction materialized in 1985 when a new state regulation required that property owners prove the accreted land they claimed was natural and fixed for 20 years. The state later amended this measure to declare that all accreted lands belonged to the state unless they restored previously eroded portions of private beachfront property (Sea Grant, 2010). Litigation filed by private landowners seeking to retain the accreted land moved through the Hawaii court system and parties ultimately filed a petition with the U.S. Supreme Court (Supreme Court of the United States, 2010). The Supreme Court, however, chose not to hear the case, thus establishing the Hawaii Court of Appeals’ decision as law: “the state must fairly compensate oceanfront property owners if it takes any sand that piled up on beaches before 2003, but the state can take any subsequent or future beach growth without any compensation” (Levine, 2010).

References:


Island: Oahu

Issue: Erosion of private property at Rocky Point - Sunset Beach, Oahu North Shore

Figure 54. Private property at Sunset Beach after erosion and now.

Background:

The North Shore of Oahu is one of the most iconic destinations for surfers worldwide. In the winter months, huge swells produce world-class surfing waves in the area known as the “seven mile miracle,” which includes Banzai Pipeline, Waimea Bay, and Sunset Beach. The Triple Crown of Surfing, a series of world-class professional surfing competitions, is held annually on the North Shore. The 2011 event brought an estimated $20.9 million to the state (Reed, 2011).

While the waves are highly valued for surfing, the huge winter swells from the northwest, coupled with smaller summer swells from the northeast, cause localized erosion and flooding impacts that threaten valuable beachfront properties and coastal highway. Most recently, about 15 homes at Rocky Point – Sunset Beach have been threatened by shoreline erosion, exemplifying the risk of seasonal and chronic shoreline erosion in this area. In October 2013, beach erosion driven by predominant summer northeast trade wind waves threatened a stretch of about eight homes adjacent to Sunset Beach. In December-January of that winter, large winter waves from the west to northwest led to dramatic erosion of the shoreline along an adjacent stretch of about 15 homes at Sunset Beach—Rocky Point (DLNR-OCCL, 2016).

Under Hawaii State law, coastal lands are public and managed by the DLNR-OCCL up to the certified shoreline. Recently, the DLNR and the City and County of Honolulu Parks Department (acting with joint authority per an Executive Order from the Governor) have permitted beachfront property owners at Sunset to conduct “sand-pushing,” a tactic in which sand is bulldozed to restore dunes to provide a temporary, erodible buffer to protect homes from erosion threats while maintaining the natural character of the beach (Romine, 2013). The Parks Department also conducts regular sand pushing operations fronting beach parks and shoreline access right-of-ways in response to seasonal beach erosion. Further monitoring and study of the beach and dune dynamics may be needed to better understand if this is a sustainable approach to erosion management on the North Shore.

Beach erosion and seasonal wave run up is an ongoing hazard on the North Shore and throughout Hawaii. Sea level rise will increase the occurrence and severity of erosion impacts. The state is working to address these increasing hazards through the development of a statewide Sea Level Rise Vulnerability and Adaptation Report (State Act 83). In addition, there have been several legislative attempts to develop a localized beach management plan for the North Shore to address these problems at the state and county, though funding has not been allocated to date. Most recently, the DLNR worked with the USACE to develop a “Technical Note” for the Regional Sediment Management Program, providing more in-depth investigation of sediment processes along the North Shore.
Cost:

No documented costs are available for interventions funded by private landowners. As described above, these repairs largely consist of a combination of authorized sand pushing and unauthorized armoring as stopgap measures that might lead to more expensive repairs in the future. Estimates range from $5,000 to $10,000 per sand-pushing operation (which would benefit several homes) (DLNR-OCCL, 2016).

Socio-Cultural Issues:

Sand-pushing operations at Sunset Beach have been successful at maintaining beach width and temporarily protecting beachfront properties from further land loss. However, there is still substantial pressure from landowners to provide increased protection to shoreline property. Homeowners at Rocky Point (and elsewhere in Hawaii) have made significant financial investments in their beachfront properties (many of which are vacation rentals), increasing pressure to protect the property from erosion with seawalls and other structures, even though the practice is generally prohibited, with few exceptions (Hawaii Revised Statues 205A). The state is challenged by a mandate to conserve natural shoreline and public access, while also protecting public safety. On the islands of Kauai and Maui, local governments have developed coastal erosion-rate based setback policies to move new construction back from the shoreline, out of erosion hazard areas. The City and County of Honolulu, which includes the North Shore, has yet to adopt a similar policy and requires a minimum setback of only 40 feet and a 60 foot setback for new subdivisions. While helpful at protecting new development, the erosion-based setbacks do not apply to existing development, like the homes at Sunset Beach that are already threatened. Improved regional shoreline management planning and adaptation tools are needed to address increasing erosion hazards on the North Shore and throughout Hawaii for new and existing development.

References:


DLNR-OCCL (Department of Land and Natural Resources - Office of Conservation and Coastal Lands). (2015). Personal communication between DLNR-OCCL and Adrian Tate.


Island: Maui

Issue: Wailuku-Kahului Wastewater Reclamation Facility threatened by erosion and coastal flooding (tsunami)

Figure 55. Wastewater treatment plant site in northern Maui.

Source: Google Earth

Background:

The Wailuku-Kahului Wastewater Reclamation Facility (WKWWRF) was built on the northern coastline of Maui in 1972 to serve the communities of the Central Maui region. The facility, which provides secondary treatment of sewage, was built on an oceanfront site in the most populated region of Maui, just west of Kanaha Beach Park and across the street from Kanaha Pond State Wildlife Refuge. The undeveloped dunes and beach park adjacent to the site are backed by low-lying wetlands. The beach and nearshore are used extensively by the public for such uses as kite-surfing, fishing, and diving.
In 1978, the County of Maui requested that USACE conduct a feasibility study to address erosion rates, which were as high as 10 feet per year along the facility’s shoreline. To address the erosion, the USACE planned to build a 1,500-foot revetment; however, due to funding issues, only 450 feet were constructed at the time. Lateral shoreline access is challenging along the facility fence line because the existing beach in front of the revetment has completely eroded away.

According to the University of Hawaii's Coastal Geology Group, the average annual erosion rate in the area is approximately 2.4 feet per year. However, between 2007 and 2011, the average rate increased to 3.7 feet per year with a maximum rate of 6.7 feet. Erosion of the facility shoreline is a concern due to the location of the wastewater injection wells fronting the shoreline. In addition, a tsunami from the March 2011 earthquake off the coast of Japan overtopped the revetment, causing damage to the facility further prompting measures for erosion control and tsunami-proofing. Flooding is also a concern because of the hazardous materials stored on site, increasing the potential for contamination of flood waters. To that end, the County of Maui proposed to extend the revetment to the west along 1,200 feet of shoreline and an environmental impact statement was completed. Construction of the revetment was completed in 2015.

Costs:

The original 450-foot rock revetment constructed in 1979 by USACE cost $250,000. The recent environmental impact statement exploring the proposed extension of the structure included two beach nourishment alternatives (first was for 85,000 cy for an area of 4,000 feet along with 215,000 cy to create an 80-foot berm, the other for a 2,650-ft area that would require 145,000 cy with an additional 55,000 cy every 8 years). The first option was estimated to cost between $8.1 and $13.1 million and the second between $5.5 and $10.4 million. Relocation was also considered. Although at least one contractor offered to complete the relocation project for approximately $150 million, costs were estimated to be closer to $350-475 million (2005 dollars).

Extension of the revetment was selected due to the estimated higher costs of the nourishment work. The 1,200-foot revetment extension was located as far landward as determined to be feasible. Dunes were excavated along a trench and the revetment was covered and subsequently buried. The estimated cost of the work was $4.5 million and final costs were slightly higher at $5.5 million.

As mitigation for environmental impacts of the revetment, dune restoration was included as a condition of the permit. As a result, restoration of the immediate shoreline area and coastal dune has been initiated with guidance by the University of Hawaii Sea Grant Program. Restoration activities have included removal of extensive invasive and encroaching vegetation, removal of downed tree stumps from the active beach, and revegetation of the coastal dune with native, dune-stabilizing plants.

Socio-Economic and Cultural Issues:

In the end, the County of Maui decided to extend the revetment, not without concerns expressed by the public, which include future impacts from tsunami inundation (e.g., exposure of the chlorine tanks on site and the potential to dislodge the revetment armor stones—the facility sits in a tsunami zone); increasing rates of beach loss that are associated with shoreline armoring; and the delaying of the inevitable (aging facility in a high hazard zone will have to be relocated or rebuilt eventually). Coastal erosion is a continuing and worsening problem. Further, sea level rise is a primary factor in the changing size and shape of Hawaii’s shorelines. University of Hawaii research examining 100 years of data indicates that Maui is losing beaches to erosion faster than Oahu and Kauai due to locally higher rates of sea level rise. Therefore, the County of Maui will likely continue to face challenges with this site and other infrastructure threatened by coastal hazards. While shoreline armoring (seawalls and revetments) has been the historical response to erosion in Hawaii, there are significant concerns with
the continuing practice of armoring, in particular cumulative impacts of loss of beach and shoreline access. The County of Maui has prohibited armoring except for cases where hardship, such as health and safety of the public, can be shown. The County is also seeking to promote decentralized wastewater systems for new development in central Maui so that the capacity at the Kahului facility does not increase. Further, there is intention to phase out the Kahului facility within 30 years.

References:

Comments on Kahului Wastewater Treatment Plant Shoreline Hardening. Available at http://mauisierraclub.org/comments-on-kahului-wastewater-treatment-plant-shoreline-hardening/.


**Island:** Maui

**Issue:** Kahana Bay erosion threatens residences

**Background:**

Nearly 85 percent of Maui’s shoreline is eroding and the historical response of armoring shorelines has contributed to beach narrowing and loss on the island and statewide. The sediment-starved West coast of Maui is no exception, as multiple aging condominium complexes in Kahana Bay built along the shoreline are now being threatened by erosion. Existing shoreline armoring fronting four of the area’s nine condominium complexes have contributed to beach loss and increased erosion along neighboring properties.

Built in 1959, the Hololani Resort Complex consists of two 8-story buildings with 63 units. The fronting shoreline has receded close to 40 feet since the complex was built and has lost about 5,000 square feet of property to erosion. In the winter of 2006-2007, a temporary geotextile sandbag revetment was installed with authorization from the County of Maui and DLNR-OCCL for emergency protection from severe erosion. An Environmental Assessment including proposed permanent shoreline armoring was completed in 2014. The Hololani Resort Condominium Association of Apartment Owners (AOAO) has been authorized by the State and County for armoring consisting of a hybrid sheet-pile seawall and rock revetment toe. The County approval includes conditions for mitigation of impacts, including: 1) The Hololani AOAO shall contribute to a regional beach restoration project; and 2) At the time when the regional beach restoration project is implemented, the armoring shall be dismantled and removed.

While erosion is a natural process, neighboring condominiums to the north of Hololani, with armoring installed decades ago under more lenient regulations, contribute to erosion that exacerbates the erosion problem at Hololani. Additionally, the neighboring Pohailani Resort seawall has been subject to failure and repairs in 2012-2013. There is no beach in front of the existing seawall. Given the cumulative impacts associated with continued armoring, the County of Maui has recently partnered with the condominium owners within the Kahana Bay beach cell to assess the feasibility of regional beach re-nourishment as an alternative to armoring. To this end, the County co-funded a study that investigated location, quantity, and quality of offshore sand sources; provided shoreline restoration design alternatives involving sand and erosion control structures; and developed cost estimates for such alternatives. The study was completed in September 2016 and a major finding of the sand search is the availability of an estimated volume of 400,000 cubic yards of beach quality sand in the nearshore regions. The nearly completed USACE West Maui Regional Sediment Management study has provided important numerical modeling data that has and will continue to be leveraged if regional beach nourishment is pursued (USACE, 2015).
Cost:

At the Hololani Resort Condominiums, materials and construction costs were in excess of $400,000 for the temporary geotextile sand bag and rock mattress structure constructed in December 2007. The 2010-2011 winter wave season was particularly damaging, and repairs to the temporary structures totaled $140,000. Since that year, there have been recurring repair costs following most winter swell seasons. Costs for the recently approved hybrid seawall/revetment are estimated at over $2 million. Further, large and persistent swells over the 2015-2016 winter season, likely associated with El Nino conditions, created sea level elevations that were commonly 0.5 ft. above predicted tide levels and caused extensive beach erosion in West Maui. Beach and land loss along Kahana Bay affected neighboring condominiums to the south of Hololani, Royal Kahana and Valley Isle Resort, leading to temporary emergency response including geotextile sandbags. The sandbag revetment costs for Valley Isle were around $400,000. The opportunity to study the feasibility of regional beach nourishment at Kahana Bay as an alternative to armoring was prioritized by the County of Maui through the dedication of approximately $160,000 with a matching commitment of $145,876 from the Royal Kahana Resort towards data collection and planning for a small-scale beach nourishment project. With the study completed, condominium stakeholders are attempting to coordinate to pursue an environmental impact statement (EIS) as next major step to move toward a regional beach nourishment solution. Early estimates suggest that the EIS will cost around $600,000.

Socio-Economic and Cultural Issues:

Beach nourishment is a softer alternative that conserves the beach and its associated ecosystem services while also providing protection of the existing development. However, regional beach nourishment will require cooperation and funding from many or all of the condominiums within Kahana Bay; identification of offshore sand resources; and future maintenance cycles. Seawalls and revetments could protect the buildings within Kahana Bay in the longer term but are not without impacts, including the likely complete disappearance of any remaining beach. The disappearance of a fronting beach means loss of value to the public for recreation and enjoyment as well as loss of value for condominium owners who very likely factored the beach into their decision to purchase or rent the property in the first place.

A regional approach to managing the erosion will require a tremendous amount of outreach and effort with over 1,000 condominium owners many of who are not residents of Hawaii. However, given the high costs of all the erosion-response options, a team effort may be the best approach.

These types of challenges, including the cumulative impacts of armoring, are what led Maui to adopt erosion-based shoreline setbacks in 2003—the first county in the state to do so. Maui’s setbacks are currently determined by multiplying the annual erosion rate for a given property by 50 years and adding
a 25-foot buffer. The County is currently assessing options to strengthen the setbacks by modifying the formula to include future conditions related to sea level rise. Unfortunately, the setback policies only apply to new development, not existing development built too close to eroding shorelines like Kahana.

References:


Island: Maui

Issue: Emergency protection responses for shoreline-adjacent infrastructure

Background:

The coastal Honoapiilani Highway is the only road in and out of heavily developed West Maui. This critical piece of infrastructure sits at sea level between Ukumehame and Launiupoko and regularly experiences overwash from waves and is threatened by erosion. Shoreline armoring has been the historical response to erosion by the Hawaii Department of Transportation (HDOT) in this area.

Twenty years ago, Hwang and Fletcher described the situation: “There is no development along this shoreline, only the two lane highway is threatened by the erosion. Inland of the road is a flat coastal terrace perhaps a mile wide. Rather than move the highway to the foot of the hills at the back of the terrace and make a beach park where the shoreline is receding, the beach is being sacrificed in the interest of protecting the highway.” (Rockett 2012)

There are significant concerns with the continuing practice of armoring large portions of the road with seawalls, revetments, and jersey barriers, in particular construction impacts on water quality and marine life and cumulative impacts of loss of beach and shoreline access. The nearshore reef in the area is a spawning reef for other reefs along the Maui shoreline. Given these concerns, most community members feel the road should undergo landward realignment.

There have been multiple highway armoring projects proposed and completed by the DOT over the last five years. Two armoring projects at Ukumehame (2012) and Launiupoko (2013) were completed under State of Hawaii Governor Emergency Proclamations. The proclamations waived state and county statutes that require environmental and cultural review and permitting, which led to construction impacts that caused major concern among some community members. More recently in 2016, the DOT halted a permitted armoring project on the north side of Olowalu under growing pressure from local residents concerned about impacts of seawall construction on beaches, shoreline access, and the marine environment. Activists camped out along the roadside with signs and social media

Figure 57: Aerial view of Maui. Source: Google Earth

Figure 58. This photo at Olowalu, near mile marker 14, during high tides in May 2017 demonstrates the vulnerability of the highway to coastal flooding, wave overwash, erosion and sea level rise. Credit: Branden Hazlet.
posts: #nomoreseawalls, #protectourshorelines, and #movetheroad. This proposed project would have extended an existing rock revetment by 900 ft., but the HDOT agreed instead to restripe the road allowing for a slight landward shift of the lanes while other alternatives could be explored.

Cost:

Over the past three years, the State of Hawaii spent $13 million for the two highway protection projects at Ukumehame and Launiupoko to protect the current alignment of the highway with concrete seawalls. One revetment project at Olowalu, as described above, was temporarily delayed. A separate proposed seawall at Olowalu (vicinity of mile marker 14), if pursued, would be expected to cost $20-$30 million. HDOT has estimated that realignment and widening of Honoapiilani Highway from Maalaea to the Lahaina Bypass would cost around $800 million. However, the highway needs to be maintained in the interim.

Socio-Economic and Cultural Issues:

There are tradeoffs that have to be considered by DOT when addressing coastal highway erosion. The agency has a sense of urgency when needing to repair or protect critical infrastructure like Honoapiilani Highway to maintain critical access, however the emergency measures bypass the environmental assessment and public review process when doing so. The emergency proclamations that allowed DOT to suspend county and state level permitting requirements has concerned community members who were not afforded the opportunity to comment during these projects. In the end, emergency measures and newly built seawalls are no guarantee—after $7 million was spent on a seawall at Ukumehame, public safety is still a concern as waves regularly crash into the new wall and splash onto the road, creating a potential hazard for drivers. Current and future armoring will also continue to reduce the amount of accessible natural shoreline, a big part of what makes the drive along the Honoapiilani Highway so scenic. Looking ahead, Maui County has acquired land to accommodate future realignment efforts. DOT recently let a contract for building a mauka segment between Lahaina and Olowalu. However, realignment of the rest of the endangered road is not currently included in future DOT plans or budgets.

References:


**Island:** Maui  

**Issue:** Loss of beach at Kalama Beach Park and Halama Street, Kihei  

**Background:**  
Kalama Beach Park is a 36-acre county recreational facility located in the central Kihei area on Maui's south shore. Over the years, the beach has completely disappeared from the Park’s shoreline as well as neighboring private properties along Halama Street. The loss of sand is related to several human-made alterations to the landscape during the last century.  

The USACE’s Kihei Beach Shore Protection Project began in 1971 with the installation of 2,610-foot rock revetment over existing beach. Since then, 6,500 feet of beach has been lost in the vicinity and flanking erosion at the revetments ends is an ongoing problem. Although erosion of the beach over the last century has averaged around 2 feet per year, nearly immediately after the revetment installation, the remaining beach disappeared due to impoundment of the sand that would naturally supply the beach. Further, there has been a domino effect in recent decades as the extent of beach loss has progressively increased to the north of the park along Halama Street and residential property owners began erecting seawalls in response to this sand and property loss. The 2011 USACE Regional Sediment Management Plan for the Kihei region estimated that between 50,000 and 100,000 cy of beach sand have been lost from the littoral cell since the revetment and reef alterations.  

**Cost:**  
The USACE completed the revetment in December 1971 at a cost of $308,626 (federal: $154,313; Maui County: $154,313). The Draft USACE Regional Sediment Management Plan suggested that beach nourishment using around 358,000 cy of sand along five miles of Kihei shorelines may bolster the beach at Kalama Park and along Halama Street and help reduce future storm and hurricane damage.  

**Socio-Economic and Cultural Issues:**  
The domino effect experienced at Kalama Park and at properties along Halama Street is not surprising. Property owners adjacent to hardened structures must often face the choice of hardening their shoreline or allowing it to erode away. This case highlights the potential importance of fringing reefs and their ability to reduce wave energy and protect shorelines from erosion and illustrates how the public’s perception of the environmental and economic value coral reefs has changed dramatically since World War II—reefs are now considered recreational hubs and huge economic draws for local economies, attracting snorkelers, divers, recreational fishers, and surfers. Beach loss at Halama Street has also been
a particular challenge for state and county regulatory agencies, as they work to balance preservation of the remaining beach and dunes and public access with public safety.

References:


HI DLNR (2012). USACE Kihei Beach Shore Protection Project and Ongoing Beach Loss at Kihei, Maui (Correspondence).

Gary Kubota, Weather, Seawalls Cited in Maui Beach Erosion, Star Bulletin (June 10, 2002).


**Island:** Hawaii (Big Island)

**Issue:** Restoration of Fishponds at Anaehoomalu Bay, Waikoloa

**Background:**
Waikoloa Beach is located along the northern west coast of Hawaii Island. The area contains historic fish and anchialine ponds (a landlocked body of water with a subterranean connection to the ocean), thousands of petroglyphs, and many other important historical and cultural sites, including the 175-mile Ala Kahakai National Historic trail (“trail by the sea”) which connects communities, temples, fishing areas and other important locations on the western coast of the Big Island. There are two existing fishponds along the shore and adjacent to the Waikoloa Beach Resort, Kuualii and Kahapapa, which were originally part of a large complex of fish farms. The Waikoloa Beach Association (WBA) is currently responsible for maintaining both Kuualii and Kahapapa fishponds. The Waikoloa Anchialine Pond Preservation Area (WAPPA) is a series of historic anchialine ponds, maintained by the University of Hawaii. These shallow salt or brackish water lava pools provide habitat for native fish, crustacean mollusks, and shrimp species. In addition to the unique historical and cultural sites found in the area, the beach is a popular tourist destination with snorkeling and other water sports available.

In March 2011, the Tohoku, Japan tsunami tore away a 100-foot section of beach, destroyed a 220-foot section of the wall, and displaced an estimated 9,000 cy of sand from the beach. After the tsunami, waves continued to deposit sand in the pond through the gap in the wall. An emergency repair was conducted placing three long sand-filled geotextile tubes, which over the years were covered up by sand. Construction of permanent tsunami damage repairs to the beach and Kuualii fishpond were completed in October 2016. The repairs consisted of the removal of 1,800 cubic yards of beach sand from the pond, and the construction of a new 690-foot-long rock and concrete wall to separate the beach from the pond. The sand removed from the pond was placed on the beach crest to nourish the beach.

![Figure 61. Fishponds at Anaehoomalu Bay.](image)

*Source: Google Earth*

**Cost:**
The current plan is to use insurance settlement funds to repair and replace the wall. The area is owned by the Waikoloa Development Company, but is leased to the Waikoloa Beach Association.
Socio-Economic and Cultural Issues:
The unique cultural and natural characteristics of the area have been threatened for decades. When the beach resort at Waikoloa was under development in 1985, more than 130 anchialine ponds (about 70 percent of the total) were destroyed and approximately 66 ponds with a combined water surface area of 1.4 ha were set aside to eventually become the WAPPA. Additionally, historic fishponds on the Big Island and across all the Hawaiian Islands are under threat from rising seas and coastal development pressure. Although across the islands several fishponds are being used for aquaculture purposes once again, the location of the Kuualii fishpond in the middle of a high-end destination resort area makes the development of a subsistence operation an unlikely possibility.

Only recently has the state made restoration of fishponds simpler by issuing a streamlined permitting program through the DLNR in 2015. Restoration work on the fishponds is still ongoing despite the damage that occurred over five years ago. The beach and dune repair plan consists of the replacement of approximately 690 linear feet of pond wall, the recovery of over 800 cy of beach sand remaining in the pond, and the placement of up to 4,800 cy of sand on the beach crest. Waikaloa Development Company has already secured a permit from DLNR for the sand nourishment.

Getting beach-quality sand for nourishment projects is a problem throughout the state and particularly on Hawaii Island due to its relative lack of natural carbonate beaches and dunes. For the Kuualii fishpond restoration, the association and consultants exploring using sand from a dredging project in the Haleiwa Small Boat Harbor on Oahu and used to rebuild the beach back toward its previous size.

References
Personal communication with Sea Engineering, Inc.
8 ENVIRONMENTAL IMPACTS OF COASTAL CHANGE

8.1 Section Overview

The reefs, beaches, dunes, and wetlands of Hawaii support both the economic vitality and environment of the state. The isolation of the Hawaiian Islands enabled the evolution of thousands of endemic terrestrial and marine species (Mitchell et al., 2005). Coastal changes and the impacts of climate change on the Hawaiian Islands have the potential to affect many of these unique habitats and the species that call them home.

The Hawaiian Islands are home to 47 species of shorebirds, including migratory and resident species (Engilis and Naughton, 2004). Marine species include more than 1,200 species of fish, 5,000 marine invertebrates, five species of sea turtles, and 26 species of marine mammals (Mitchell et al., 2005). Hawaii’s reef ecosystems are rich with marine life and are also valuable for cultural and economic uses (Mitchell et al., 2005; EPA, 2012). These reef systems protect beaches and coastal resources from direct wave energy, but are threatened by sedimentation, pollution, warming sea surface temperatures, and overfishing. The Islands are home to more than 100 species of corals, and more than 500 species of fish have been identified in the Islands’ reefs (Mitchell et al., 2005). The Islands are home to 30 percent of the nation’s federally-listed threatened or endangered species (Mitchell et al., 2005) and have seen the greatest number of extinctions in the United States over recent decades (Suckling, Slack, and Nowicki, 2004). Marine species of special concern include: six reptiles; 26 marine mammals; 79 plants or algae; 154 fishes; and 197 invertebrates (Mitchell et al., 2005).

The impacts of coastal change are affecting all of the Hawaiian Islands and the habitats they support. Impacts from increased sediment as a result of erosion can include smothering, blocking sunlight needed for coral growth, and promoting harmful algal blooms (Field et al., 2008). Engineered structures can alter coastal hydrology and sediment transport, both of which can drive shoreline changes. Shoreline management efforts can positively and negatively impact both the coastal habitats and the species that rely on them for foraging, breeding, or resting; however, some of the impacts of certain engineered structures (e.g., seawalls and groins) on species unique to Hawaii are largely unknown and warrant further study.

8.2 Key Coastal Habitats in the Hawaiian Islands

More than 2,000 miles away from the closest continent, the Hawaiian Islands make up the world’s most remote island chain. Varying temperatures and annual rainfall averages (less than 15 inches to over 480 inches) are caused by Hawaii’s extensive elevation range (sea level to 13,796 feet) and varying exposure to humid trade winds, and led to the emergence of all major known ecological zones on the islands. As a result, a wide variety of habitats from dry coastal grasslands to wet forests are found on the islands, though the increasing presence of humans and non-native flora and fauna species has caused deterioration in the size and health of both terrestrial and aquatic habitats (Mitchell et al., 2005).

Many of Hawaii’s coastal and estuarine areas are integral to the ecological health of the state’s coastal environment but are under threat from residential, commercial, and agricultural development. According to the Hawaii Coastal Zone Management Program’s Hawaii Coastal and Estuarine Land Conservation Plan, shorelines, coastal wetland, and adjacent upland area habitats all provide “ecological significance” by supporting endangered and threatened species and the diversity of all species present, as well as providing undisturbed areas for those species. Undisturbed shorelines—including dune, beach, and wetland habitats—are critical for natural vegetation growth and for providing long-term
protection for native coastal fauna species like the Hawaiian monk seal, green sea turtle, and numerous shorebirds (Szuster and Graceson, 2014). Coastal wetlands provide an extraordinary range of ecosystem services for the flora and fauna communities that depend on them, including the regulation of nearshore water quality and the ability to act as a buffer for coral reefs against turbidity, sedimentation, and other environmental marine threats (Szuster and Graceson, 2014). Finally, adjacent upland areas, in addition to serving as habitat for numerous species, protect their neighboring wetland and coastal habitats by helping to prevent non-point source pollution from reaching lower watershed areas (Szuster and Graceson, 2014).

This section provides an overview of several of Hawaii’s critical coastal habitats as well as threats to those habitats posed by coastal change, human development, sedimentation, and sea level rise due to global climate change.

8.2.1 Reefs

The Hawaiian Islands support multiple types of reef systems. In shallow water areas that are not close to estuaries, “fringing reefs” form near the water’s surface and close to shorelines surrounding the high islands. In addition, “barrier reefs” have developed further away from the shoreline in Kaneohe Bay on Oahu, as well as in a limited area off Kauai. Shallow water lagoons have formed inshore of both types of reefs, though to a greater extent inshore of the barrier reefs. Scattered throughout the sandy habitat of barrier reef lagoons are segments of coral called “patch reefs,” which develop at water depths of three to 65 feet. In addition, “atoll reefs,” which form in a ring around the peaks of submerged volcanoes, encircle large lagoons that sometimes contain sandy islands as well as patch reefs; many of the Northwestern Hawaiian Islands (NWHI) such as Pearl and Hermes Reef and Kure Atoll are atoll reefs (Mitchell et al., 2005).

Because of the island chain’s isolation in the Pacific Ocean, Hawaii’s coral reefs do not boast the species diversity found in corals of other Indo-Pacific reef systems. However, because of the prevalence of high energy levels along Hawaii’s coasts (e.g., extreme tides, tsunamis, large swells, tropical cyclones, and intense rainfall episodes), the coral species that do reside in Hawaii’s reef communities are readily adaptable to extreme changes in environmental conditions (Fletcher et al., 2008).

Hawaii’s reefs provide ecosystem services ranging from shoreline protection to creating habitat for the Islands’ marine life. In addition to serving as key areas for foraging and shelter for many of Hawaii’s invertebrate and fish species, coral reefs are critical for tourism in Hawaii and provide shoreline, harbor, and beach protection from storm impacts such as wave damage and erosion (Field et al., 2001). As natural ocean barriers, coral reefs play a critical role in shoreline protection by absorbing wave energy and producing sand that supports the state’s beaches (Moberg and Folke, 1999). In this fashion, Hawaii’s reefs form the critical first line of defense against coastal erosion.

In addition to the threats from sedimentation and pollutants, described below in Sections 8.2.2 and 8.3, Hawaii’s reefs are also vulnerable to other human-caused threats. These anthropogenic threats include overfishing and coral bleaching driven by warming sea surface temperatures, both of which can prevent reefs from providing the important ecosystem functions described above.

As a result of its large and economically important commercial fishing industry as well as subsistence and recreational fishing, overfishing in Hawaii has resulted in decreasing numbers of larger, adult fish who are successful breeders, leading to disruption of important trophic structures and networks in reef fisheries, a decrease in biodiversity of reef ecosystems, and lower fish biomass, all of which are damaging to reefs (Fletcher, et al., 2010). Studies comparing the NWHI (a remote area with limited fishing pressures) and the main Hawaiian Islands (which are urbanized and heavily fished) show that the
minimally-disturbed NWHI waters have maintained predatory-dominated reef ecosystems and therefore healthy, productive reefs (Friedlander and DeMartini, 2002). The stressed state of the coral reefs surrounding the main Hawaiian Islands, in comparison, correlates with that area’s lower fish biomass and decreased fish biodiversity due to high fishing pressures (Friedlander and DeMartini, 2002).

In addition to overfishing, coral bleaching has posed a major risk to the viability of Hawaii’s rich coral reef ecosystems. As of the end of 2016, coral reefs around the world are continuing to undergo the longest bleaching event ever recorded, which began in 2014 and has resulted in more than 40 percent of reefs experiencing bleaching-causing temperature stress levels that negatively affect the photosynthetic capabilities of symbiotic zooxanthellae which are consequently expelled by the coral in which they reside (Heron et al., 2016). Hawaiian reefs have been among those affected by this bleaching event, with the Hawaiian Archipelago experiencing extreme coral bleaching due to high ocean temperatures in 2014 and 2015; in particular, the coral mortality rate in the West Hawaii region, which suffered the highest sustained temperatures in the area, has been estimated at 50 percent (Hawaii Division of Aquatic Resources n.d.a). As ocean temperatures continue to trend warmer and as the annual duration of summertime ocean temperatures increases as has occurred over the past several decades, a greater number of reefs worldwide will experience bleaching events, with over 98 percent of global reefs anticipated to be exposed to bleaching-causing thermal stress annually by 2050 (Heron et al., 2016).

Figure 62. Pearl and Hermes Atoll coral reef.
Source: NOAA (http://oceanservice.noaa.gov/gallery/image.php?siteName=nosimages&cat=Fish%20on%20Deep%20Reef)

Figure 63. Sediment burying a coral reef.
8.2.2 Case Study: West Maui Watershed Study and Ridge to Reef Initiative

Issue: Coral reefs around the world, including many in Hawaii, are in decline due to terrigenous sedimentation and nutrient and pollutant runoff as a result of human activity (Richmond et al., 2007). Integrated watershed management practices are needed in addition to current reef management approaches to protect coral reefs adjacent to high islands by addressing multiple land-based stressors (Richmond et al., 2007).

Key Message: USACE and other partners are engaged in a holistic, watershed-based approach for long-term restoration and protection of West Maui’s reefs, nearshore waters, and watersheds.

Background: Accounting for more than 60 percent of coral reefs in U.S. waters, Hawaiian coral reefs encompass more than 5,000 square miles (14,000 square km), stretching from Hawaii Island to the Midway Atoll and beyond (Field et al., 2001). However, human activities leading to growing volumes of nutrient, pollutant, and sediment runoff are proving to be an increasing threat to the quality of coral reef ecosystems (International Society for Reef Studies (ISRS), 2004). For example, rapid urbanization, fertilizer runoff, and soil erosion due to agricultural development and deforestation are leading drivers of water quality degradation in coral reef ecosystems. The runoff associated with these activities harms coral reefs by triggering overall biodiversity loss, lower calcification levels, decreased coral recruitment, and changes in species composition, among other effects (ISRS, 2004).

Numerous coral reefs throughout the state have been impacted by anthropogenic drivers over the course of the past several centuries. The coral reefs off the southern shore of Molokai, for example, have been negatively affected by human activities and their alteration of the Molokai landscape since the first millennium. European settlement in the 18th and 19th centuries resulted in increased soil erosion and soil loss on the island due to commercial agriculture, sandalwood logging, sugar cane farming, and cattle ranching that led to soil deposition on the coral reef flat of the southern shore. Molokai’s coral reefs continued to be harmed into the 20th and 21st centuries as an increasing human population led to more hotel and housing construction involving dredging and increased wastewater discharge (Roberts and Field, 2008).
Other islands have experienced a decrease in coral cover over time. The Coral Reef Assessment and Monitoring Program (CRAMP) found decreasing coral cover levels across the Hawaiian Islands from 1999/2000 to 2012 (See Figure 65; Rodgers et al., 2015). The urbanization of Oahu’s watersheds in addition to seawall construction, dredging, and stream channelization degraded the Island’s coral reef ecosystems due to increased sediment trapping, polluted runoff, and eutrophication of coastal waters (Wolanski et al., 2009). Maui, in particular, has suffered from coral reef degradation, with one CRAMP study showing that the island experienced the highest proportion of significant coral cover decline in the state over the study’s 14-year period during which “stations” (or observation sites) were regularly monitored (Rodgers et al., 2015). Coral reef deterioration in Maui was noticeably steadier at open access sites where corals were exposed to anthropogenic stressors such as land-based nutrients and competition with algae for substrate due to increased fishing rates, while coral decline at marine protected areas occurred more slowly or remained stable throughout the duration of the study (Rodgers et al., 2015).
Specifically, channelized streams—which have been lined with concrete or other hard material and thereby altered physically, chemically, hydrologically, and ecologically—pose a threat to Hawaii’s reefs. Many of Hawaii’s streams have been channelized since the 1960s in order to protect property and the public from common high-runoff storm events by establishing a flood control mechanism; however, these channel modifications have significantly diminished the capability of stream ecosystems to absorb hydraulic energy and filter out pollutants, and have increased the rate and amount of nonpoint source pollution and sediments moving from upland watersheds to the ocean (Hawaii Coastal Zone Management Program, 1996).

Figure 65. Change in coral cover and statistical significance from 1999/2000 to 2012 based on the Hawaii CRAMP.

Source: Adapted from Rodgers et al., 2015

**West Maui Ridge to Reef Initiative:** The West Maui Ridge to Reef (R2R) Initiative is a local solution to anthropogenic-driven coral reef degradation. The R2R Initiative was established after the U.S. Coral Reef Task Force selected West Maui Watersheds to be a priority partnership in 2011 and the Hawaii Coral Reef Strategy determined this region to be a priority management area (R2R, n.d.).
DLNR and USACE lead the R2R Initiative, with support from other federal and state partners, and its main objective is to enhance and restore the quality of West Maui’s coastal waters and coral reefs by reducing pollution threats from Maui’s watersheds. USACE’s West Maui Watershed Study will inform the strategy for the R2R Initiative by assessing land-based drivers of coral reef decline while looking at related impacts associated with flood risk, coastal storm damage reduction, wildfires, and other issues.

Taking a multi-agency, holistic approach to address land-based pollution across five designated watersheds (Wahikuli, Honokowai, Kahana, Honokahua, and Honolua), the R2R Initiative embraces a comprehensive and integrated watershed-based strategy for coral reef protection and recovery. Early efforts by the R2R Initiative focused on watershed planning, with a Watershed Management Plan for the Wahikuli and Honokowai watersheds finalized in 2012 and the Kahana, Honokahua, and Honolua Watershed Planning-Characterization and Draft Strategies and Implementation Reports completed in September 2016. Ultimately, all of these reports will be combined into a comprehensive five watershed West Maui Watershed Plan (West Maui R2R Initiative, n.d.). Goals for the plans include reduction of soil erosion and sediment loads from urban and agricultural areas, decreased nutrient loads and fertilizer loss, reduction of treated wastewater effluent by increasing water reuse, and development of watershed and coral reef health education for both residents and visitors (West Maui R2R Initiative, n.d.).
Aquatic Habitats (Estuaries/Wetlands/Anchialine pools)

Hawaii’s aquatic habitats serve as key ecological linkages among many terrestrial habitats; the water cycle ensures that nutrients and organic matter flow from the Islands’ mountains down through mid-elevation forests and grasslands and eventually into estuaries, wetlands, and the ocean. In addition, many aquatic organisms native to Hawaii move among these various aquatic habitats as they complete their life cycles, migrating from streams to estuaries to the ocean (Mitchell et al., 2005).

**Estuaries:** Estuaries, or areas close to the coastline in which ocean saltwater mixes with freshwater, are habitats for many unique species capable of living in changing environmental conditions and can tolerate the large volumes of sand and fine grain sediments that are typical of these environments. A large variety of species inhabit estuaries because many are able to dwell in habitats where the salinity level is still relatively high. Despite coastal zone regulations, estuary habitats and their resident species are threatened by coastal development, sedimentation, boat harbors, and the introduction of non-native species (Mitchell et al., 2005).

**Wetlands:** Wetlands include marshes, bogs, and swamps and are generally defined as areas that are saturated with ground or surface water and that support species that prefer saturated soil conditions. Hawaii’s wetlands, both coastal and inland, are critical habitats for a wide variety of animal and plant species and provide numerous ecosystem services. These ecosystem services include flood conveyance.
and storage; sediment load control; protection from storm waves and erosion reduction; provision of breeding, nesting, and feeding grounds for fish, shellfish, and waterfowl; ground and surface water supply; and recreation (Hawaii Coastal Zone Management Program, 1996). Also, wetlands throughout Hawaii have been documented to support federally listed endangered waterbirds, such as the Hawaiian moorhen (Gallinula chloropus sandvicensis), the Hawaiian coot (Fulica alai), the Hawaiian stilt (Himantopus mexicanus knudseni), and the Hawaiian duck (Anas wyvilliana), in terms of habitat for breeding, rearing chicks, forage, and shelter (M.M. Abrams, personal communication, November 15, 2016). In addition, wetlands provide the vital function of improving water quality by acting as a buffer against polluted surface and subsurface runoff as well as by processing, removing, and storing nutrients, sediments, and some types of heavy metals. Threats to Hawaiian wetlands include loss as a result of agricultural and urban development activities, as well as the channelization of streams and rivers (Hawaii Coastal Zone Management Program, 1996).

Mangroves: Mangrove trees are an introduced species that has had several deleterious effects upon native species, including displacement of habitat for native and federally listed species, serving as habitat for introduced species, such as invertebrates, and altering native habitat conditions from a calcium carbonate dominated habitat to a habitat that is largely comprised of terrigenous sediment (M.M. Abrams, personal communication, November 15, 2016). Mangroves were brought to the southwest coast of Molokai in an attempt to slow coastal erosion but caused unforeseen environmental issues by aggravating land-based mud deposition and creating large mud flats. Over time, the expansion of mangroves and increased sedimentation has led to a prograding shoreline and the augmentation of interior wetland areas adjacent to the coast. Furthermore, the mangroves have spread to many of the ancient Hawaiian fishponds on the island in addition to an area of shallow shoreline east of Kaunakakai, and the coast’s shallow waters are often filled with silt and sediment (University of Hawaii, n.d.).

Anchialine Pools: Anchialine pools are exclusive to Hawaii within the United States and support rare native species that are endemic to Hawaii, including the federally listed endangered anchialine pool shrimp Vetecaris chaceorum and Procaris hawaiiana, and the non-listed species Antecaridina lauensis, Calliasmata pholidota, Metabetaeus lohena, Palemonella burnsi, Halocaridina rubra and H. palahemo (M.M. Abrams, personal communication, November 15, 2016). These localized coastal bodies of water occur in areas with porous substrates such as lava flows; the main feature of anchialine pools, also known as coastal ponds or anchialine ponds, is the presence of tidal fluctuations and salinity without the presence of a surface connection to the ocean (Tango, et al., 2012). There are over 600 anchialine pools on the islands, with the majority located on Hawaii Island (Tango, et al., 2012). Anchialine pools have historically been utilized by Hawaiians as fishponds and as sources of drinking and bathing water, and also sustain a wide variety of flora and fauna, including native succulents and shrubs, cyanobacteria and algae, several native shrimp species, and numerous crustaceans, including the species mentioned above (Tango, et al., 2012). Despite the prevalence of anchialine pools in most of Hawaii’s national parks, pools in unprotected areas are threatened by coastal development, elevated groundwater demand due to urbanization, surface water and groundwater pollution, and waste dumping (Tango, et al., 2012). In addition, anchialine pool ecosystems are threatened by non-native fish species such as tilapia and poecilid guppies, which prey on endemic species or compete with them for sustenance (Tango, et al., 2012). Finally, anchialine pool habitats are vulnerable to inundation from predicted sea level change (Marrack and O’Grady, 2014).
Figure 68. Anchialine pools on Hawaii Island and selected aquifers with pools.


Figure 69. Anchialine pool at Puuhonua o Honaunau NHP.

Source: National Park Service [http://science.nature.nps.gov/im/units/pacn/monitor/anchialine_pool.cfm]
8.2.4 Beaches and Dunes

In Hawaii, beaches, along with bluffs, terraces, and rocky shores, provide crucial habitat for terrestrial animals and birds as well as marine mammals. Fish and birds can forage for invertebrates on beaches and intertidal areas. When beaches and coastal habitats are adversely affected by erosion and accretion, the invertebrate populations that live there are likely to decrease, although they are known to be highly adaptive and mobile in the larval stage. Many invertebrates are able to cope with naturally-occurring levels of sedimentation, turbidity, and even burial (Greene 2002; Wilber et al. 2005). However, loss of beach nesting habitat from coastal development, shoreline erosion, and sea level rise is one of many environmental concerns that threaten turtle populations in the Hawaiian Islands (See Sea Turtle Case Study, below). Most Hawaiian green sea turtles (*Chelonia mydas*) nest in the NWHI, at localities including Midway Atoll, French Frigate Shoals (FFS), Pearl and Hermes Reef, and Laysan Island. Unfortunately, it is anticipated that much of today’s occupied nesting habitat will be lost or significantly degraded due to future sea level change. In an effort to ensure local populations of sea turtles are able to continue to breed successfully, U.S. Fish and Wildlife Service, the National Marine Fisheries Service, Hawaii DLNR, and partners will work to establish viable alternative breeding habitats within the main Hawaiian Islands. Therefore, future shoreline planning should integrate such resource agency plans to protect sea turtle nesting habitat within the main Hawaiian Islands (M.M. Abrams, personal communication, November 15, 2016).

Figure 70. Common features of a beach system in Hawaii with a fringing reef. (Image: University of Hawaii SOEST)


Shorebirds, in particular, depend on Hawaii’s beach habitats. Because the Hawaiian Islands encompass relatively little landmass—only 16,939 km² (6,540 mi²), 99 percent of which is contained on the Main Islands—and given that the Main Islands are largely mountainous, wetland habitats are in short supply. Despite their significantly smaller landmass, the NWHI also provide critical habitat in the form of dry grasslands and unoccupied beaches, which support large shorebird populations because of the lack of human activities, secure food supplies, and a lack of predators. Shorebirds—including migrant, resident, and winter visitors—inhabit a variety of habitats such as tidal flats and wetlands, which host the biggest density and diversity of shorebird populations; as mentioned in Section 8.2.3, wetlands are notably
important habitat for migrating shorebirds, with the Kealia Pond on Maui being one of the most prominent locations for migratory shorebirds in the Pacific Ocean (Engilis and Naughton, 2004).

In total, 47 different shorebird species have been documented in Hawaii and the state's islands are considered particularly important for four species including the Wandering Tattler, the Pacific Golden-Plover, the Hawaiian Stilt, and the Bristlethighed Curlew. The Hawaiian Stilt is a resident shorebird endemic to Hawaii and is listed as endangered, although its low population is stable and it inhabits all of the Main Islands (Engilis and Naughton, 2004). In addition, the wedge-tailed shearwater is a threatened species that creates burrows in dunes for its eggs and hatchlings. The shearwater come back to lay their eggs at the location in which they were born after approximately seven years at sea. Therefore, important breeding grounds can be affected by negative impacts to beaches and dunes (R. Pap, Personal communication, December 13, 2016). Threats to coastal shorebird habitats include the growth of invasive species including mangroves, sedimentation from upland agricultural and ranching activities, and the spread of urban development (Engilis and Naughton, 2004).

Loss of sandy beach coastline may be especially concerning for these shorebird populations. A study of sandy beaches in California demonstrated that such areas are important for shorebird breeding, foraging, and migration staging and that as other habitats (e.g., wetlands and grasslands) are degraded or lost, shorebirds increasingly rely on sandy beaches (Hubbard and Dugan, 2003). Reductions in sediment supply, from anthropogenic disturbances (e.g., dams and hardened structures), can further reduce this habitat and available food. This suggests that as Hawaiian coastline is lost to erosion, armoring, and sea level rise, the number and diversity of both resident and migratory shorebirds are likely to be negatively impacted and the habitat that remains will become increasingly critical.

Like its beaches, Hawaii’s dunes are both culturally valuable and house important ecosystems. Dunes have frequently served as sacred burial sites for at least 2,000 years, with native Hawaiians laying their ancestors (or kupuna) to rest in graves that are unintentionally disturbed by human activities or by coastal erosion or high surf (DLNR State Historic Preservation Division, n.d.). In addition, dunes offer a range of beneficial ecosystem services, such as habitat provision to a variety of invertebrates, crustaceans, and birds, and a wide-reaching nutritive structure, mostly from animals that live in the sediment (e.g., bacteria, microalgae, mollusks, and crustaceans). However, dune alteration due to human activity along the coast has resulted in major damage to sand dune habitats. For example, the primary source of dune habitat loss is the process of dune grading—flattening a section of dune to allow for construction or to provide hotels and residences with a clear ocean view. Grading weakens the dune’s buffering capacity, increases the dune’s vulnerability to erosion, and may lead to water quality degradation if soil fill is used to cap the affected area. In addition, inland sand loss from dunes can occur in areas where dunes are graded and/or access paths are situated parallel to the direction of the prevailing wind, allowing for wind funneling. To help mitigate these types of impacts on sand dunes, Maui County outlawed the grading of any shoreline area or frontal dunes in 2003 as well as the practice of soil filling in certain areas (Norcross-Nu’u et al., 2008). In fact, each county in the state maintains its own coastal development zoning and setback regulations depending on the location of the certified shoreline to protect dunes, beaches, and other coastal features. In cases where dunes have already been damaged, dune stabilization or restoration may be used as potential low-cost tools to strengthen dune systems through the planting of salt-tolerant grasses and plants that help to protect dunes from erosion (University of Hawaii and DLNR OCCL, 2007).
8.2.5 Case Study: Hawaiian Monk Seal

**Issue:** Habitat loss is one of the key factors affecting this rare and endangered seal.

**Background:** The Hawaiian monk seal is the only endangered marine mammal that is found solely in the United States. Though its primary breeding habitat is in the NWHI, monk seals can be found on all of the Hawaiian Islands (Mitchell et al. 2005). Because of the threat sea level change poses to NWHI habitat, the main Hawaiian Islands are becoming critical refugia for Hawaiian monk seals.

The Hawaiian monk seal is one of only two mammal species endemic to Hawaii that existed on the islands prior to human arrival. The species’ six main breeding subpopulations are found in the NWHI at Kure Atoll, Midway Islands, Pearl and Hermes Reef, Lisianski Island, Laysan Island, and the FFS, with smaller subpopulations found on the Main Hawaiian Islands (NMFS 2007). According to NOAA Fisheries, approximately 1,100 Hawaiian monk seals currently inhabit the Islands, with sharp and mostly steady population decline documented since the 1950s. The main source of general population decline has been low survival rates of juvenile monk seals in the NWHI, where population losses have averaged 2.8 percent annually over the past decade. Conversely, the Hawaiian monk seal population is expanding throughout the main Hawaiian Islands at a growth rate of approximately 6.5 percent per year (NMFS 2016).
The combination of ongoing shoreline erosion across the islands and increasing human recreational use of the state’s beaches and nearshore areas has increased interaction between Hawaii’s human residents and this endangered seal. Monk seals spend approximately one-third of their time out of water in “haul-out” sites. Hauling-out is necessary for seals to give birth (at “rookeries”) and is important for predator avoidance, thermal regulation, social activity, parasite reduction, and rest (Daugherty 1985). Hawaiian monk seals prefer sandy beaches for these haul-out sites and tend to avoid beaches with a high degree of human disturbance. Though the main breeding areas are in the NWHI, rapid erosion and sea level change are reducing haul-out and pupping locations vital to the seals’ survival (NOAA 2014). According to Baker, et al., monk seals may face increased competition for these critical sandy habitats as island surface areas decrease in the NWHI due to sea level change (2006). Because projected sea level change will limit the availability of Hawaiian monk seal habitat in the NWHI, the main Hawaiian Islands are becoming critical refugia for the monk seals. However, human disturbance, disease, interactions with fishing gear, and intentional killing provide an additional set of threats to the small but growing population of Hawaiian monk seals living in the main Hawaiian Islands.

8.2.6 Rocky Shores

Intertidal zones along rocky shorelines are critical and unique habitat for a wide range of flora and fauna, including many different fish larvae and many of the state’s invertebrate species, some of which have adapted to the high wave activity common to these habitats (Mitchell et al., 2005), as well as to the varying physical conditions including fresh water influxes and fluctuating temperature. The rocky beaches of intertidal zones are portions of the coastline that have a substrate made up mainly of rock and include tidepools, which occur when ocean water is left behind in coastal rocky areas after the tide subsides. Tidepools can share common characteristics with reefs, and generally provide habitat for a wide variety of fish and coral species; for example, the Waiopae Tidepools on Hawaii Island enjoy strong water circulation due to swells from the northeast trade winds, which produces favorable environmental conditions for diverse and robust coral growth as well as for juvenile fish nurseries (Hawaii Division of Aquatic Resources, n.d.b). Because of the location of this type of habitat on the coast, it is threatened both directly and indirectly by human activity, including upstream pollution and coastal construction projects (Mitchell et al., 2005).

8.2.7 Habitat Conservation Efforts: Marine Sanctuaries and Protected Areas

To preserve critical habitats, federal and state entities in Hawaii established marine sanctuaries and other protected areas. For example, in 1992, the U.S. Congress created the Hawaiian Islands Humpback Whale National Marine Sanctuary, which is jointly administered by NOAA and Hawaii’s DLNR (NOAA, n.d.). The sanctuary was founded with the purpose of protecting one of the world’s main North Pacific humpback whale (Megaptera novaeangliae) habitats and the only known U.S. coastal area in which this species reproduces (NOAA, n.d.). The sanctuary comprises the area from the shoreline to the 100-fathom isobath off of certain shorelines on Maui, Kauai, Oahu, and Hawaii Island (NOAA, n.d.).
Figure 73. North Pacific Humpback Whale, *Megaptera novaeangliae* mother and calf. (Photo: Mike Nolan)


Figure 74. Coral-rubble islet at Pearl and Hermes Atoll.

*Credit: James Watt* Source: PNMN Website (retrieved from http://www.papahanaumokuakea.gov/education/physical_coral_rubble_islets.html)

Hawaii’s DLNR regulates land use through its establishment of a Conservation District “for the purpose of conserving, protecting, and preserving the important natural and cultural resources of the state
through appropriate management and use to promote their long-term sustainability and the public health, safety, and welfare” (DLNR, 2011). These conservation districts protect designated watersheds, wilderness and wildlife areas, and all beaches and coastal areas from the state-certified shoreline out to the 3-mile limit of state waters (B. Romine, personal communication, March 31, 2016). DLNR also manages Marine Life Conservation Districts through its Division of Aquatic Resources (DAR). These areas provide spaces for conservation and replenishment of marine species (Hawaii DAR, 2016b). Beyond these protected areas, the Division of Aquatic Resources manages fishing in certain areas of the state (Hawaii DAR, 2016b). Despite these efforts at conservation, encroaching shoreline development continues to exert a detrimental effect on beaches and coastal ecosystems in the conservation district (B. Romine, personal communication, March 31, 2016).

Finally, sea level rise is a threat that cannot be avoided and is particularly a concern for the lower-lying NWHI, where many of the state’s marine sanctuaries and protected areas are located. These islands are the world’s largest tropical seabird rookery and provide breeding or foraging habitat for a number of birds, marine mammals, and other species (Reynolds, Berkowitz, Courtot, and Krause, 2012). Habitat loss is predicted to occur at varying rates in the NWHI based on differing sea level rise scenarios, with the islets of the FFS and Pearl and Hermes Reef anticipated to lose between 15 and 65 percent of their surface areas by 2100 based on a median scenario of 48 cm sea level rise (Baker et al., 2006). Although habitats on islands in the NWHI with higher elevation such as Lisianski are less likely to be impacted in the near-term, it is clear that anthropogenic drivers on the east end and the threat of sea level rise on the west end of the Hawaiian archipelago will increasingly stress both endemic and migratory species as they are forced to survive on limited habitat (Baker et al., 2006).

### 8.2.8 Case Study: Sea Turtles

**Issue:** Sandy beaches are critical nesting and foraging habitat for these threatened and endangered animals. Like the Hawaiian monk seal, as breeding habitat is lost in the NWHI from sea level rise and erosion, habitat on the Main Hawaiian Islands will become more important for sea turtles.

**Background:** The waters and shores of Hawaii are frequented by five sea turtle species (loggerhead, leatherback, olive ridley, hawksbill, and green sea turtles), all of which are listed as threatened or endangered by the federal government and the State of Hawaii (Mitchell et al., 2005), although the Hawaiian green sea turtle is under review for Endangered Species Act (ESA) delisting (NOAA Fisheries, 2014a). Common threats to all species include entanglement in or ingestion of marine debris and indirect take of sea turtles as bycatch, as well as directed take in open sea fisheries (Mitchell et al., 2005). Availability of undisturbed coastline for breeding, nesting, and foraging is essential for all five species; however, only the green sea turtle and the hawksbill sea turtle nest on Hawaiian beaches (Mitchell et al., 2005).
Background

Green sea turtles occupy waters around all of the Hawaiian Islands, with the shallow waters around the reefs and coasts of Pearl and Hermes Reef, Lisianski Island, Hawaii, Lanai, Maui, Molokai, and Oahu being principal foraging grounds. Green sea turtles nest on all of the islands, though 90 percent of breeding and nesting takes place in the NWHI on FFS (Mitchell et al., 2005). After reaching sexual maturity between 35 and 40 years of age, males often migrate to the NWHI to breed every year (Mitchell et al., 2005), while females tend to mate every two to four years during the summer on the beaches where they hatched (U.S. FWS, n.d.). In between nesting periods, both male and female green sea turtles also use the beaches in the NWHI as well as some of the main islands to haul out and bask. It is estimated that between 200 and 700 females nest annually and green sea turtle populations are thought to be growing both globally and locally in the Hawaiian Islands (Mitchell et al., 2005).

Habitat Needs and Environmental Issues

Green sea turtles depend on the availability of undisturbed nesting habitats, particularly on the sandy beaches of FFS where a high proportion of green sea turtle breeding takes place (Mitchell et al., 2005). However, the species’ breeding habitats are vulnerable to sea level rise in FFS, especially in cases where nests are situated below the spring tide level and could experience inundation and increased failure during the green sea turtle’s average incubation period of 66 days (Baker et al., 2006). East Island has become the primary nesting ground for green sea turtles on the atoll and is projected to be less impacted by sea level rise than other islands, potentially resulting in increased nest density on the island (Baker et al., 2006).

The key foraging habitat of adult green sea turtles includes the protected or semi-protected shallow waters surrounding the coastal areas and coral reefs of most of the Hawaiian Islands, which provide sources of sea grasses and algae for the herbivorous turtles and can offer protection from predators.
(Mitchell et al., 2005). While the status of green sea turtle foraging habitats differs from area to area, habitat deterioration has occurred on the south coast of Molokai; Kaneohe Bay, Oahu; Hanalei Bay, Hanamaulu Bay, and Nawiliwili Harbor, Kauai; Maalaea Bay, Kihei, Lahaina, Maui; and Hilo Bay, Hawaii (Mitchell et al., 2005). This deterioration of coastal foraging habitats poses a threat to the green sea turtle and is the result of soil erosion, sedimentation, presence of sewage, and development (Mitchell et al., 2005). Resting habitats and cleaning stations are also essential for green sea turtles but their locations in the Hawaiian Islands are not well known (Mitchell et al., 2005).

**Hawksbill Sea Turtle**

Figure 76. Hawksbill Sea Turtle.  
*Source: NOAA/Flower Garden Banks National Marine Sanctuary, retrieved from http://flowergarden.noaa.gov/about/reptilelist.html*

**Background**

Hawksbill sea turtles likely inhabited coastal areas around all of the Hawaiian Islands historically, but currently occupy waters only around the Main Hawaiian Islands, with turtles frequently seen off the West Maui coast (Mitchell et al., 2005). Sexual maturity occurs for hawksbill sea turtles between 30 and 50 years of age with females breeding approximately once every two or more years and nesting occurring on all of the Main Hawaiian Islands, although the NWHI may have provided nesting habitats for hawksbill historically (Mitchell et al., 2005). The east coast of Hawaii Island is a primary nesting area, and Kamehame Beach and a black-sand Halawa River Valley beach are known to be consistent nesting habitats for hawksbill, with several Maui beaches used periodically (Mitchell et al., 2005).

**Habitat Needs and Environmental Issues**

Adult hawksbill prefer shallow waters near bays, inlets, and reefs and most of the Main Hawaiian Islands provide foraging habitats, with the north coasts of the islands providing key foraging areas (Mitchell et al., 2005). Hawksbill turtles seem to favor nesting habitats that provide woody cover and often use sand to build nests, though it is not necessary (Mitchell et al., 2005). These nesting habitats are crucial to the species and are generally located no more than five meters above the high water line (Mitchell et al., 2005). While the hawksbill nesting areas of Halape and Apua Point are protected because they are situated in Hawaii Volcanoes National Park, other hawksbill nesting habitats are threatened by
development, general human presence (such as vehicles at Kawa and Punaluu), exotic vegetation, and beach erosion (Mitchell et al., 2005). Nesting habitat conservation efforts include the acquisition of Kamehame Beach by the Nature Conservancy in 2002 due to the beach’s role as the most critical nesting area for the hawksbill in the United States (The Nature Conservancy, 2015).

Figure 77. Map of hawksbill nesting sites on Hawaii.

Source: Adapted from Seitz et al., 2012
8.3 Environmental Impacts from Shoreline Change and Management

8.3.1 Environmental Impacts of Sediment Management

In terms of coastal management, sediment can have both beneficial and undesirable impacts. Sediment is an important resource for creating or restoring beaches and other coastal habitats. Whether sediment is abundant or in minimal supply, coastal habitats and ecosystems will be affected by the constantly changing coastal environment.

Too much sediment can damage habitats, interfere with the food chain, and cause obstructed channels, overflowing rivers, smothered reefs, and high turbidity that blocks sunlight.

Too little sediment can lead to disappearing beaches and other eroded coastal features with significant implications for aquatic and terrestrial habitat for a wide variety of species, potentially reducing the abundance and biodiversity of such animals as fish, turtles, and birds.

Before discussing the environmental impacts of sediment management, it is important to distinguish between terrestrial and marine sediments. Several studies have shown that the grain size and nutrient characteristics of sediments are important determinants in coral stress levels because of short-term sediment exposure. A study by Weber, et al. concluded that corals are less stressed by larger grain-sized and nutrient poor sediments—such as beach sand—than by silt-sized, nutrient-rich grains more typical of terrestrial sediments (Weber et al., 2006).

Terrestrial sediments in Hawaii are derived from erosion of volcanic rocks and soil and typically contain a large fraction of clay and silt, which can be particularly damaging to water quality and reef environments. Marine sediments in Hawaii are typically carbonate (limestone) and because they are derived from reef and marine organisms, they are part of the natural marine environment. However, introduced marine sediments from increased coastal erosion or beach nourishment can have a damaging effect on marine ecosystems if not managed properly (B. Romine, personal communication, March 31, 2016).

Unintended Consequences of Sediment

Beach nourishment, or replenishment, is one management tool to address coastal erosion by replacing lost sand with material from sources outside of or adjacent to the eroding beach. This activity stems erosion, enhances beach recreation opportunities, reduces hazard exposure, and improves habitat (Kalo, 1990). As presented below, there can be unintended negative environmental consequences from beach nourishment, including: short-term disturbance of the indigenous biota of the beach (e.g., by smothering with new sand or with incompatible material); impacts to the food web (e.g., potential to alter habitats or adjacent areas used by species for nesting, nursing, and breeding); environmental impacts in the subtidal area, such as increased turbidity; and impacts to the biota in the sand borrow area (NRC, 1995). According to Dr. Mary M. Abrams of the USFWS (personal communication, November 15, 2016), increased turbidity may have negative impacts to the benthic community and result in the degradation or loss of sessile species, including marine plants (e.g., native sea grass and algae), coral, and non-coral macroinvertebrates. There are three stages of coral reproduction, all of which are susceptible to altered water quality (e.g., increased sedimentation, turbidity, and nutrients) (Richmond, 1993; Richmond, 1995; Hodgson, 1990; Babcock and Davies, 1991). In particular, increased sedimentation and turbidity can reduce adult coral fecundity (Kojis and Quinn, 1984), and interfere with reproductive timing and egg-sperm interactions (Jokiel, 1985 and Richmond, 1995). Even moderate changes in turbidity can significantly alter photosynthesis/respiration ratios for corals (Telesnicki and Goldberg, 1995). USACE monitors water quality and coordinates coastal improvements and
modifications with the federal resource agencies and State of Hawaii Department of Health, Clean Water Branch, to ensure coastal resources are given appropriate consideration during project planning.

### Potential Impacts from Sediment Management Activities

#### Direct
- Equipment (e.g., anchors, pipelines, and vehicles) damage to habitats, injury of species
- Discharge burial of habitat and invertebrates
- Dredge removal of habitat and invertebrates
- Dredge entrainment of invertebrates and fish

#### Indirect
- Invertebrate forage reduction
- Disturbance or interference (e.g., noise, lights, and equipment) of wildlife movement or migration
- Turbidity effects (e.g., reduced photosynthesis, feeding, growth, or mortality)
- Sedimentation effects (e.g., reduced photosynthesis, recruitment, nutrient stimulation, or mortality)
- Enhanced sandy beach habitat and supported bioresources

*Source: SAIC 2012*

Whether natural or anthropomorphically-driven, erosion and accretion are a major concern for Hawaii’s coastal ecosystems when they are associated with elevated levels of suspended sediment in the water and an increased amount of sediment settling on the seafloor. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development (Berry et al., 2003; Germano, 2005). The most sensitive fish resources are the eggs of benthic fish that are unable to attach, grow, or hatch because of sedimentation (Berry et al., 2003; Wilber et al., 2005). Adult benthic fish can have strong attraction to certain substrate types but are also capable of relocating; however, relocation may subject fish to increased predation or loss of foraging areas (Germano, 2005). When particles settle they can smother bottom-dwelling benthic invertebrates (Berry et al., 2003). Non-burrowing substrate organisms and some submerged aquatic vegetation may be hardy enough to withstand sedimentation, but if they are impaired, the recovery time is long and populations are difficult to re-establish (Germano, 2005). Pelagic fish eggs and juvenile fish could be affected because they settle on the bottom where sedimentation would affect them. Clarke and Wilber (2000) reviewed available data on the impacts of suspended sediments to fish and shellfish and found that the duration of exposure was a critical aspect in determining mortality of eggs and juvenile fish species. Unexpected sedimentation could cause adult fish to avoid the area and fail to spawn, which could affect population numbers if an alternate site is not found.

Berry et al. (2003) describe a number of studies where birds avoided waters with increased turbidity, expressing a preference for clearer waters. Decreased water clarity might influence bird species to abandon forage or nesting areas.

In addition, placement of sand on a beach results in a temporary reduction in the invertebrate forage base for fish and shorebirds. The recovery period is generally a year or less, especially when sand is placed on sand-starved beaches with limited habitat functions. Benthic recovery rates at offshore borrow sites mostly range from one to three years (SAIC, 2012).
However, significant impacts to marine ecosystems have not been documented with beach nourishment activities in Hawaii. Benthic habitat monitoring with a 2012 Waikiki Beach Restoration project documented changes to the nearshore benthic ecosystem within the project area. However, these changes were not significant when compared to a control site outside of the project area. More research is needed in Hawaii on marine impacts and benefits related to beach nourishment (Romine, Guannel, and Eversole, 2015).

Upland Erosion

Several of Hawaii’s islands have experienced negative coastal ecosystem effects due to increased sedimentation and turbidity from upland erosion. Human activities in Oahu’s watersheds, for example, have led to the degradation of the Maunalua Bay fringing reef waters (Wolanski et al., 2009). As a result of large-scale urbanization that has taken place on the island since the 1960s, both sedimentation levels and water residence time increased in the bay, damaging the reef and thereby reducing coral coverage; in addition, high turbidity plumes in the east part of the bay eliminate a large portion of the bay’s larval supply waters (Wolanski et al., 2009). In particular, the high rate of stream channelization and hardening related to road and building construction in the Maunalua region has led to a significant expansion of impervious areas in the region’s watersheds, thereby reducing the ability of streams and land ecosystems to slow down and filter water flows (Miller et al., 2009). Water flow volume and velocity increases in streams that have been realigned and hardened with concrete, resulting in elevated sediment loads from the upper watershed—generated as the result of vegetative loss—reaching Maunalua Bay and binding with pollutants that harm corals and the species that depend on coral ecosystems (Miller et al., 2009). These non-point source pollutants from commercial and residential zones enter channelized streams by way of surface runoff and include nutrients (i.e., phosphorus and nitrogen), motor oil and gasoline, and antifreeze, among other toxic substances (Miller et al., 2009).

An excellent example of using a watershed approach to address not only upland erosion but control of pollution and other impacts upon coastal waters is the Maunalua Regional Watershed Strategy. This community-based action understands the integration of watersheds and nearshore waters involve large, complex, and interdependent ecological systems. Also understood is that management across multiple sectors of society and government is complex and the approach should be community-driven and collaborative. Collaboration among community, NGOs, businesses, decision-makers, and the government agencies, especially those associated with land development and with stormwater systems and land based pollution, are key to success (Miller et al., 2009).

### Maunalua Regional Watershed Strategy: Main Components (Miller et al, 2009)

- Information-gathering: collecting baseline data in order to understand the composition and extent of pollutant loads that will need to be addressed in each apana, and the type and number of sources from which they derive;
- Identification of alternative solutions tailored to each SMU, via individual apana management plans;
- Identification of outcomes;
- An evaluative monitoring framework to measure success; and
- Targeted outreach activities to key stakeholder groups.

*Apana. 1. Piece, slice, portion, fragment, section, segment, installment, part, land parcel, lot, district, sector, ward, precinct. Hawaiian Dictionary, Pukui & Elbert.*
Molokai also has experienced reef deterioration related to human development on the island as vegetation loss and soil erosion from activities such as upland cattle ranching, sandalwood farming, and coastal hotel and road construction caused damaging sedimentation in waters off the island’s southern coast (Roberts and Field, 2008). However, this type of impact on marine ecosystems cannot be addressed by coastal management alone, due to the upland origin of the erosion; instead, mitigation of these impacts requires a watershed (ahupuaa or mauka-to-makai) approach.

**Improving Sediment Management through Best Management Practices**

Lessons learned from past and ongoing shoreline management efforts can guide future decisions. For example, efforts have been made by Hawai‘i’s decision-makers and their partners, including USACE, to implement such integrated watershed management practices through programs such as the West Maui R2R Initiative (See R2R Case Study, above), which aims to take a holistic approach to address land-based pollution across five designated watersheds to enhance coral reef recovery and protection. In addition, Hawaii’s DLNR-OCCL has established the SSBN (small scale beach nourishment) permitting program and guidelines, which encourage landowners to consider beach nourishment projects instead of hard shoreline armoring and through its permitting process requires the development of a Site-Specific Best Management Practices (BMP) Plan and a Monitoring and Assessment Plan for each beach nourishment project (DLNR, 2005).

Beach nourishment also offers several potential environmental benefits. As described above, resident and migratory shorebirds are more diverse and abundant at wider, sandy beaches (Hubbard and Dugan, 2003). Threatened and endangered species of turtles and marine mammals use sandy shores for nesting, pupping, or haul-out sites. As wetland and other habitats in Hawaii’s narrow coastal plain are increasingly developed and protected areas in the NWHI are lost to erosion and sea level rise, sandy beach habitats on the main Hawaiian Islands will become increasingly important to birds, turtles, marine mammals, and other species that depend upon them.

**8.3.2 Environmental Impacts of Engineered Structures**

Hard structures, such as breakwaters, seawalls, and groins, can have both positive and negative impacts on the environment. As described in earlier sections, seawalls and other structures built to protect roads and buildings along the coast prevent landward beach movement from occurring, leading to the potential permanent loss of coastal environments (Fletcher, et al., 2010). These changes to physical coastal processes can lead to impoundment of sediments that would otherwise replenish beaches. Reduced supplies of sand, coupled with sea level rise and the potential impacts of refraction from shoreline protection structures, can cause passive erosion of the sandy beach (O’Connell, 2010). Other impacts to the physical environment include loss of beach access and the potential for impacts on adjacent properties.

Negative environmental impacts from shoreline armoring center on losses of habitat, organisms, and the ecological functions performed by them. Placement loss describes the habitat permanently covered by the footprint of an engineered structure. There is debate about the relative impacts of vertical versus sloping structures—though vertical seawalls cover less shoreline habitat than sloping revetments, sloping structures can attenuate some of the physical impacts in front of or adjacent to them, as compared to vertical seawalls (O’Connell, 2010).

In Hawaii, the impacts to marine habitats, organisms, and ecological functions from hard shoreline protection measures are largely unknown. A study of armored and unarmored beaches in southern California found that armored beaches had narrower dry and mid-beach zones, reducing the amount of habitat available to macroinvertebrates and birds (Dugan, Hubbard, Rodil, Revell, and Schroeter, 2008).
The same study found reduced abundance, biomass, and size among macroinvertebrates in the intertidal zones of armored shorelines. These impacts extended to birds, which were less likely to use armored shorelines for foraging or roosting (Dugan et al., 2008). Similar narrowing or passive erosion of beaches in Hawaii has the potential to reduce habitat for birds, sea turtles, monk seals, and other species of concern. Another study from Puget Sound, Washington, found reduced numbers of invertebrates and differences in species assemblages at armored beaches (Heerhartz, Toft, Cordell, Dethier, and Ogston, 2015). These impacts have the potential to disrupt existing food webs on beach and nearshore habitats.

Conversely, hard structures also may provide benefits to the ecosystems they inhabit. USACE’s Engineering with Nature Program seeks to enhance habitat in infrastructure projects. For example, the Iroquois Point beach nourishment and stabilization project was initiated in 2012 on Oahu’s south shore to curb turbidity plumes, sand migration into Pearl Harbor’s entrance channel, and significant shoreline erosion. The project included a marine monitoring program that involved both pre-project and post-project monitoring, with monitoring scheduled to be conducted for 10 years after the construction of nine T-head boulder groins. The results documented in the 2015 report indicate that the project appeared to provide some benefits to the local marine ecosystem, which supported a small fish and coral population with low species diversity before the project’s initiation. Two years after completion, fish biomass and species diversity in the project area greatly increased due to the provision of shelter and enhanced topographical complexity; in addition, coral coverage has increased, with colony recruitment occurring on groin surfaces (Kilarski, 2014).

8.4 Conclusions

Coastal habitats are critical to the natural environment, society, and economy of Hawaii. Hawaiian coastal habitats support a rich variety of terrestrial and marine species, including: dozens of migratory and resident birds; thousands of fish and marine species; and threatened or endangered turtles and marine mammals. Coastal erosion directly threatens these habitats.

Hawaii’s reefs provide the critical first line of defense against wave-driven coastal erosion, and their protection requires an integrated watershed approach. Protecting Hawaii’s reefs is a key to coastal protection and should be approached in a holistic fashion.

As described in the previous sections, Hawaii’s beaches and reefs drive the state’s tourism economy. Coastal planning should consider future habitat needs in the face of chronic erosion and sea level rise.

Key species like endangered sea turtles, monk seals, and bird species rely on beach habitats. As beaches erode, these habitats are lost.

As habitats in the low-lying NWHI are lost to erosion and sea level rise, suitable habitat on the main Hawaiian Islands will become more important to species’ survival.

Sufficient coastal water quality is a key component to maintaining high quality ecosystems and recreational environments.

The current suite of shoreline management efforts can have both positive and negative impacts. Positive and negative impacts are site-specific based on local environmental conditions and shoreline management options.

Beach nourishment can create or improve habitat for some marine organisms (e.g., birds, sea turtles, monk seals). It also can degrade water quality, smother, and disrupt behaviors for others.
Incompatible material can have negative impacts on aquatic habitats.

Hawaii’s DLNR-OCCL Small Scale Beach Nourishment Guidelines provide BMPs for protecting water quality and aquatic habitats in small beach nourishment efforts.

Benthic habitat monitoring after the 2012 Waikiki Beach Restoration did not find significant negative impacts associated with the 2012 beach nourishment activities.

Not all environmental impacts of shoreline armoring structures are well understood.

Breakwaters, seawalls, and groins are designed to protect coastal development (e.g., infrastructure, cultural sites).

Despite the intended outcome of shoreline armoring, Romine 2013 and Fletcher et al. (2012) concluded that armoring results in beach narrowing and beach loss fronting the armored shorelines, as well as unarmored shorelines located downdrift of the structures.

USACE’s Engineering with Nature initiative seeks to maximize the potential habitat benefits of hard structures. In Hawaii, some shoreline protection structures have been shown to create habitat for marine species (e.g., Iroquois Point).

However, the effects on species assemblages and biomass need more study. Limited research suggests that certain structures (e.g., seawalls) exacerbate the loss of certain habitats (e.g., beaches) and forage sites, especially on chronically eroding shorelines, and their impacts on reefs are largely unknown.

### 8.5 References for Environmental Impacts of Shoreline Change


Fletcher, C.H., Boyd, R., Neal, W.J., and Tice, V. (2010). Living on the Shores of Hawaii: Natural Hazards, the Environment, and our Communities. Beach Erosion and Loss (Chapter 9) and Reefs and Overfishing (Chapter 10). UH Press.


## Appendix A (Section 8): All Federally Listed Species in Coastal Areas in the Hawaiian Archipelago as of 2016

<table>
<thead>
<tr>
<th>PLANTS</th>
<th>NCN = No Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achyranthes splendens var rotundata</td>
<td>NCN</td>
</tr>
<tr>
<td>Bidens amplexans</td>
<td>kookoolau</td>
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<tr>
<td>Brighamia rockii</td>
<td>pua ala</td>
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<tr>
<td>Canavalia pubescens</td>
<td>awikiwiki</td>
</tr>
<tr>
<td>Cenchrus agrimonioides var agrimonioides</td>
<td>kamanomano</td>
</tr>
<tr>
<td>Chamaesyce cealastroides var kaenana</td>
<td>akoko</td>
</tr>
<tr>
<td>Chamaesyce kuwaleana</td>
<td>akoko</td>
</tr>
<tr>
<td>Cyperus pennatiformis var bryani and var pennatiformis (was Mariscus pennatiformis)</td>
<td>NCN</td>
</tr>
<tr>
<td>Cyperus trachysanthos</td>
<td>puukaa</td>
</tr>
<tr>
<td>Hedyotis st.-johnii (now Kadua st.-johnii)</td>
<td>NCN</td>
</tr>
<tr>
<td>Ischaemum byrone</td>
<td>Hilo ischaemum</td>
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<tr>
<td>Lipochaeta lobata var leptophylla</td>
<td>nehe</td>
</tr>
<tr>
<td>Lobelia niihauensis</td>
<td>NCN</td>
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<tr>
<td>Marsilea villosa</td>
<td>ihi ihi</td>
</tr>
<tr>
<td>Munroidendron racemosum (now Polyscias racemosa)</td>
<td>NCN</td>
</tr>
<tr>
<td>Panicum niihauense</td>
<td>NCN</td>
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<tr>
<td>Peucedanum sandwicense</td>
<td>makou</td>
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<tr>
<td>Pittosporum halophilum</td>
<td>hoawa</td>
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<tr>
<td>Portulaca sclerocarpa</td>
<td>poe</td>
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<tr>
<td>Portulaca villosa</td>
<td>ihi</td>
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<tr>
<td>Pritchardia aylmer-robinsonii (now Pritchardai remota)</td>
<td>loulu</td>
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<tr>
<td>Pritchardia remota</td>
<td>loulu</td>
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<tr>
<td>Pseudognaphalium sandwicensium var molokaiense</td>
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<td>Schenkia sebaeoides (was Centaurium sebaeoides)</td>
<td>awiwi</td>
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<td>Schiedea kealiae</td>
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<td>Schiedea verticillata</td>
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<td>Spermolepis hawaiensis</td>
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<tr>
<td>Solanum nelsonii</td>
<td>Popolo</td>
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<tr>
<td>Tetramolopium rockii var calcisabulorum and var rockii</td>
<td>NCN</td>
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<tr>
<td>Vigna o-wahuensis</td>
<td>NCN</td>
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<tr>
<td>Wilkesia hobdyi</td>
<td>iliau</td>
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<tr>
<td>ANIMALS</td>
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<tr>
<td><strong>Mammals</strong></td>
<td></td>
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<tr>
<td>Humpback whale</td>
<td><em>Megaptera novaeangliae</em></td>
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<tr>
<td>Hawaiian monk seal</td>
<td><em>Monachus schauinslandi</em></td>
</tr>
<tr>
<td><strong>Birds</strong></td>
<td></td>
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<tr>
<td>Nihoa millerbird</td>
<td><em>Acrocephalus familiaris kingi</em></td>
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<tr>
<td>Laysan duck</td>
<td><em>Anas laysanensis</em></td>
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<tr>
<td>Hawaiian duck</td>
<td><em>Anas wyvilliana</em></td>
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<tr>
<td>Hawaiian goose</td>
<td><em>Branta sanvicensis</em></td>
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<tr>
<td>Hawaiian coot</td>
<td><em>Fulica alai</em></td>
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<tr>
<td>Common moorhen</td>
<td><em>Gallinula chloropus sanvicensis</em></td>
</tr>
<tr>
<td>Black-necked stilt; Hawaiian stilt</td>
<td><em>Himantopus mexicanus knudseni</em></td>
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<tr>
<td>Newell's shearwater</td>
<td><em>Puffinus auricularis</em></td>
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<tr>
<td>Laysan finch</td>
<td><em>Telespyza cantans</em></td>
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<tr>
<td>Nihoa finch</td>
<td><em>Telespyza ultima</em></td>
</tr>
<tr>
<td>Band-rumped storm-petrel</td>
<td><em>Oceanodroma castro</em></td>
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<tr>
<td><strong>Reptiles</strong></td>
<td></td>
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<tr>
<td>Green sea turtle</td>
<td><em>Chelonia mydas</em></td>
</tr>
<tr>
<td>Hawksbill turtle</td>
<td><em>Eretmochelys imbricata</em></td>
</tr>
<tr>
<td>Leatherback sea turtle (incidental in Hawaii)</td>
<td><em>Dermochelys coriacea</em></td>
</tr>
<tr>
<td>Loggerhead sea turtle (incidental in Hawaii)</td>
<td><em>Caretta caretta</em></td>
</tr>
<tr>
<td><strong>Snails</strong></td>
<td></td>
</tr>
<tr>
<td>Newcomb's snail (in streams, not sure if in &quot;coastal&quot;)</td>
<td><em>Erinna newcombi</em></td>
</tr>
<tr>
<td><strong>Arthropods</strong></td>
<td></td>
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<tr>
<td>Orangeblack Hawaiian damselfly (in coastal if fresh water site available)</td>
<td><em>Megalagrion xanthomelas</em></td>
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<tr>
<td><strong>Shrimp</strong></td>
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<tr>
<td>Anchialine pool shrimp</td>
<td><em>Procaris hawaiana</em></td>
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<tr>
<td>Anchialine pool shrimp</td>
<td><em>Vetericaris chaceorum</em></td>
</tr>
<tr>
<td><strong>Hymenoptera</strong></td>
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<tr>
<td>Yellow-faced bee</td>
<td><em>Hylaenus anthracinus</em></td>
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<tr>
<td>Yellow-faced bee</td>
<td><em>Hylaenus assimulans</em></td>
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<tr>
<td>Yellow-faced bee</td>
<td><em>Hylaenus facilis</em></td>
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<tr>
<td>Yellow-faced bee</td>
<td><em>Hylaenus hilaris</em></td>
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<tr>
<td>Yellow-faced bee</td>
<td><em>Hylaenus longiceps</em></td>
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<tr>
<td><strong>Moths</strong></td>
<td></td>
</tr>
<tr>
<td>Blackburn's sphinx moth</td>
<td><em>Manduca blackburni</em></td>
</tr>
</tbody>
</table>

*Source: Foster, 2017*
9 SHORELINE MANAGEMENT: EROSION AND ACCRETION

This report assesses and evaluates the shorelines of the Hawaiian Islands and the extent, effects, and management of erosion and accretion of shorelines and sediments. The shorelines of the Hawaiian Islands consist of materials of either volcanic origin, emergent fossil reefs, sedimentary rock (beachrock) or from the breakdown of the fringing reefs and marine biological organisms associated with pelagic forma that drift into shore. Rates of erosion and coastal recession range from virtually nothing to tens of feet per year, depending upon the location, water levels, including relative rates of sea level rise, types of shorelines, exposure to wave energy, and human made modifications to shorelines. Figure 78 is a residence yielding to the effects of sudden, event-based erosion on the shoreline.

Figure 78. The forces of erosion at work; note failure of the seawall on the seaward side of the house, North Shore, Oahu along the Kamehameha Highway. 2016.

Credit: KHON

Historically, an often-used method to address shoreline erosion and protect property has been to construct engineered hard structures (note all are engineered, especially the older ones). The structures are intended to be resistant to erosion and to reflect or absorb the wave energy reaching the shore and prevent the loss of land. Coastal armoring has been widely used to combat shoreline erosion in developed areas of Hawaii, and is somewhat controversial in that it can also lead to shoreline erosion, if used improperly. Armoring the shoreline, where appropriate, is an important and useful alternative for
some coastal erosion problems. However, in some locations, landowners and developers have installed armoring without adequate consideration of or knowledge of localized littoral processes and this has resulted in a damaging and lasting effects on adjacent beaches and public access.

In general, seawalls and revetments are “shoreline armoring protection,” whereas beach and dune restoration and managed retreat are associated with conservation and preservation. However, many of these strategies can be used, often in combination, to achieve multiple goals. Both “hard” and “soft” solutions to coastal erosion must be evaluated on a site-specific basis, taking into consideration all the relevant factors—coastal processes, backshore composition, backshore value, and the potential loss as a result of erosion and shoreline recession.

9.1 Protecting Shorelines from Erosion–Coastal Structures: Seawalls, Revetments, and Breakwaters

Hardened Shoreline Approaches: Revetments

Revetments are sloped, engineered structures placed to stabilize the shoreline against wave action and forces of erosion. Usually constructed of stone, if properly designed and constructed, revetments resist scour and protect the shoreline. Other materials used for revetments include concrete, filled geotextile fabric bags, and stone-filled gabions. Rocks that have been dumped haphazardly are generally termed riprap. Figure 79 shows a typical engineered revetment placed for shoreline protection, including the design of a typical rock revetment, composed of three basic elements: the toe reinforcement that protects against foundation scour; the filter layer consisting of graded stone providing a stable layer for armor stone and resistance to piping on underlying material; and the armor stones designed to absorb and dissipate wave energy. Proper design, placement, and tiebacks for a revetment are important considerations to provide protection to backshore lands and structures. Beaches, and shorelines located around the revetment may become subject to increased erosion due to the effects of waves breaking against the structure, accelerated currents, and reduced sediment availability within the littoral cell. Figure 80 is a typical revetment for shoreline protection.
Figure 79. Typical revetment designs. Top: hybrid seawall/revetment. Bottom: revetment showing toe scour apron.  
USACE Honolulu District. Permit application from County of Kauai. 2012.

Credit: Sea Engineering Inc. 2011.

Figure 80. Revetment protecting the shoreline (location, Kauai). Notice the beach and dune sand trapped behind the structure and beach loss fronting the structure. Source: NOAA. Image courtesy of University of Hawaii Sea Grant Program. http://oceanservice.noaa.gov/facts/shoreline-armoring.html
Hardened Shoreline Approaches: Seawalls

Seawalls, vertical structures generally made of concrete and stone, protect the land behind the structure, but can also result in beach narrowing and loss fronting the structure, particularly where chronic erosion is present prior to seawall construction. One process that may occur is scouring of the beach in front of the seawall, especially on chronically eroding shorelines. The extent of this effect is dependent upon the width of the beach, the wave energy reaching the beach and seawall, and the sediment supply. Similar to revetments, seawalls must be sited and designed carefully, in consideration of the potential for increased erosion of neighboring shorelines. Figure 82 shows a typical seawall designed for erosion control to protect a residential property.

Figure 81. Typical seawall protecting residential property (Lanikai, Oahu) with a narrow beach in front of the structure.

Credit: University of Hawaii Sea Grant College Program.

A significant number of seawalls fail due to exposure of the seawall toe, leading to wave exposure of the sand impounded behind the wall, which liquefies and creates a void/sinkhole. Figure 82 shows an example of a sinkhole fronting a condominium on Maui in 2014. An 8-ft ladder is propped in the cavity. This example illustrates the importance of proper design of coastal structures with consideration of local characteristics, as opposed to a “one size fits all” approach.
Figure 82. Failure of a seawall, starting with undermining of the toe of the seawall creating a sinkhole, which, unless repaired, will lead to seawall collapse.

_Credit: Tara Owens._

Temporary seawalls or revetments are used in cases where damage to shoreline structures is imminent. These temporary structures are commonly made of geotextile sand containers or sandbags as shown in Figure 83 and Figure 84, a geotextile and sandbag revetment. This material is relatively easy to install and remove when necessary. Temporary revetments can help in emergencies, and are intended to provide protection until a more permanent solution can be evaluated, designed and constructed. They are not intended to withstand long-term wave forces, and may have impacts on the beach fronting the revetment and downdrift beaches of a receding shoreline.

Figure 83. Armoring to protect a residence with geotextile bags (Lanikai, Oahu).

_Credit: University of Hawaii Sea Grant College Program._
Figure 84. Armoring to protect a resort hotel with sandbags (Valley Isle Resort on Maui).
Credit: Tara Owens.

Hardened Shoreline Approaches: Breakwaters

Breakwaters are commonly used to protect harbors and navigation channels, and are typically placed parallel to the shoreline, which can also shelter shorelines from wave-induced erosion. Constructed of stone, concrete, wood, or steel, breakwaters offer protection to harbors and targeted beaches or shorelines, but may result in increased erosion of downdrift shorelines if sediment is trapped on an updrift shoreline. The placement of dredged material or impounded beach sand by sand-bypassing projects using pumps or machinery can help to mitigate the effects of the harbor structures. Figure 85 is an example of a breakwater protecting a harbor and navigation channel. Figure 86 and Figure 87 show breakwaters protecting beaches.

Figure 85. Breakwater constructed to protect Hilo Harbor navigation channel and berthings (Hilo, Hawaii).
Potential Benefits and Impacts of Shoreline Hardening

Hawaii’s coastal processes are typically quite complicated and dynamic. Wave climate, wave exposure, reef presence and composition, offshore bathymetry, coastline geology, sand volume, sand source, and backshore development and infrastructure can vary dramatically in a distance of a few kilometers. There are numerous locations in Hawaii where sand loss and accretion are dramatic and seasonal, where armoring the shoreline to provide a backstop during periods of sand loss does not impede the accretion of sand fronting the structure during times when sand returns. The use of coastal structures described above (e.g., revetments, seawalls, breakwaters) can provide temporary, seasonal, or continuous protection for eroding shorelines where valuable and/or critical infrastructure and public/private property lies in a vulnerable area. That said, much of Hawaii’s historical development has been sited without proper consideration of erosion and flooding hazards, and continued efforts in public outreach and county ordinances regarding proper shoreline setback should be undertaken in order to reduce the placement of structures on chronically eroding shorelines.
However, “hard” structures also have the potential to disrupt natural sediment transport, resulting in unintended consequences. Undesirable impacts of armoring may include the following (Griggs 2005):

- Negative visual and aesthetic impacts
- Beach access is sometimes impaired
- Loss of beach width and public beach on which the armoring is placed
- Loss of sand supply from the eroding shorelines
- Public safety issues if the area is a heavily used recreational area
- Gradual loss of beach in front of the armoring, if the shoreface fronting the armoring continues to migrate landward
- Active erosion fronting the structure and adjacent beaches and properties (flanking erosion) due to impacts of waves and currents around the structure

As noted in the list above, coastal armoring can have a number of potential impacts including—but not limited to—sand impoundment, passive erosion, and active erosion (e.g., flanking erosion). Passive erosion results when the beach face migrates landward toward a seawall or revetment. The result is a narrowing, and in many locations, complete loss of the beach as waves begin to impact directly against the structure. Active erosion can occur fronting the structure and downdrift (i.e., flanking erosion) of a seawall or revetment, as a result of reduced sediment availability and the normal forces of erosion (Fletcher et al. 2010). The extent of erosion downdrift of a seawall appears to be a function of the wall orientation, the angle of wave approach, and wave height and period (Griggs and Tait 1988; Griggs 2005). A drawing of the potential effects of armoring a shoreline experiencing long-term retreat is shown in Figure 88.

Unless properly designed, engineered, and installed, hard structures can fail, causing the shoreline situation to worsen (Pope et al. 1993).

Visual impacts are sometimes an inevitable byproduct of coastal armoring, a process which began in Hawaii decades before the adoption of the Coastal Zone Management Act and the associated shoreline management policies. Seawalls and other types of armoring, such as rock revetments or riprap, can affect the public’s beach-going experience by interfering with the natural landscape, and in some cases, reducing access to the beaches.

Many beaches in Hawaii are backed by sand-rich coastal plains and dunes. In these locations, an eroding beach can remain sandy if the shoreline is allowed to recede, releasing eroded sand to the littoral system. If there is a chronic trend of beach erosion, armoring to protect upland property or infrastructure may impound any backshore sand supply, leading to beach narrowing and, in some locations, eventual loss of that beach, a loss of sand in the littoral cell, and increased erosion on adjacent downdrift beaches and shorelines. Actual coastal dunes in Hawaii that can naturally release sand to beaches to maintain their widths are nearly extinct. Over the years, development and building homes on the dunes, or trapping the dune sand behind armoring has greatly limited that source of sand for the beaches. Fletcher et al. (2010) stated that: “The sand dunes that formerly lined our shores were nature’s guarantee that beaches would have a savings account of sand during times of high waves, high sea levels, and storms.”
Figure 88. Beach loss eventually occurs in front of a seawall for a beach experiencing net long-term retreat.

*Source: Beach Management Plan for Maui, 2008.*
Examples of Shoreline Hardening in Hawaii with Varying Results

Erosion of beaches and shorelines is a longstanding issue in the Hawaiian Islands. Many of the existing shore protection structures in Hawaii were constructed in response to episodic erosion caused by hurricanes, tsunamis, and extreme high surf events. Romine (2013) found that 27 percent (29 km) of shorelines on Oahu are armored. Romine 2013 and Fletcher et al. 2012 concluded that armoring contributes to additional beach narrowing and beach loss fronting the armored shorelines, as well as unarmored shorelines located downdrift of the structures. However, the study also notes significant beach narrowing in areas unaffected by shoreline armoring, suggesting that some of the beach narrowing occurring may be attributed to natural processes as well. Table 14 provides a summary of the studies conducted and reported in Romine 2013 and Fletcher et al. 2012, which examined the change in beaches on Oahu since the early 1900s. For more details on the methodologies, work conducted, results, and range of uncertainties in the values measured, the aforementioned studies should be reviewed.

Table 12. Results of beach erosion/accretion and beach changes since the early 1900s for Oahu beaches.

(Romine and Fletcher 2012, part of Romine 2013).

<table>
<thead>
<tr>
<th>Type of Beach</th>
<th>Beaches Lost</th>
<th>Narrowed</th>
<th>Widened</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kilometers</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Armored Beaches</td>
<td>8.6</td>
<td>29</td>
<td>43</td>
</tr>
<tr>
<td>Unarmored Beaches</td>
<td>0.5</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>All Beaches</td>
<td>9.1</td>
<td>8</td>
<td>49</td>
</tr>
</tbody>
</table>

As shown in the above table, of the armored beaches on Oahu, 72 percent were either lost or narrowed. Of unarmored coasts on Oahu, beach widths were stable: 53 percent were undergoing some narrowing and 47 percent were undergoing some widening. For unarmored beaches, the average beach width remained roughly the same since the early 1900s (i.e., 25–26 m). Where accretion was observed (42 percent of all beaches studied), 82 percent of the beaches accreting were unarmored.

Erosion of beaches and shorelines can be an ongoing action, or as a result of storms delivering high energy waves to the shoreline. One extreme example is Hurricane Iniki, which had a direct hit on the Kauai in 1992, causing major damage on the southern, western, and northern shorelines. Iniki was accompanied by storm tides ranging from 4.5 to 6.3 feet above normal, with 20- to 35-foot storm waves superimposed. Heavy waves battered the coastal areas of southern Kauai. Highest values occurred at Port Allen and Poipu. The highest water levels and inundation of up to 22 feet above mean lower low water (MLLW) were reported by the U.S. Army Corps of Engineers near the Poipu area of Kauai. The overall monetary value of the damage caused by Iniki in the Hawaiian Islands was two to three billion dollars. As a result of major erosion of the beaches and shoreline, numerous seawalls and revetments were constructed (Pararas-Carayannis website).

An example of the effects of armoring on beach widths and downdrift shorelines is the case of Makalii Point at Punaluu, Oahu. Armoring was installed in the 1960s. Prior to that time, the beach was accreting at about 0.5 meters per year, but following the installation of the hardened structure, the beach retreated at a rate of about 1.0 meter per year. The effect of the armored shoreline is obvious in Figure 89 and Figure 90 on the downdrift or flanking shoreline. A variety of soft and hardened shoreline structures have been installed fronting most of the properties on the north side of Makalii Point as a
last-ditch effort to protect homes now within several feet of the shoreline (Romine 2013). Another dramatic example of lost beaches and downdrift beach and shoreline erosion is included in Romine 2013 for the shoreline at Lanikai on Oahu.

Figure 89. Lost shoreline in downdrift beaches due to armoring of the shoreline at Makalii Point in windward Oahu in the mid-1960s. Where the arrow shows “Fig. 6 photo,” see below (Romine 2013).

Figure 90. The shoreline is receding, in part, due to the armored updrift shoreline. The once existent beach fronting the armored shoreline has been lost. Photo: Bradley Romine.

In most cases, shoreline hardening is not the original "cause" of erosion; rather, it is a response and solution to ongoing existing erosion where the erosion and shoreline recession threatens valuable shoreline or backshore infrastructure or features. On a historically receding shoreline, use of coastal armoring to “hold the line” will likely result in narrowing or loss of the fronting beach. As noted in the above examples, shoreline hardening can have varying results on the shoreline, depending on the existing conditions, siting and longshore extent of the structure, and the condition of the backshore area. In these cases where armoring has recently been permitted by local government agencies, the need to protect critical infrastructure or public safety has outweighed the desire to conserve the natural shoreline environment. An example is the Wailuku-Kahului Wastewater Reclamation Facility, which was
threatened by erosion and potential coastal flooding from tsunamis (see case study in Section 7). After a complete assessment of available and feasible alternatives, the revetment was extended by 1,200 feet.

In summary, for sensible and balanced shoreline management, it is important to have proactive and forward looking development regulations, in addition to having access to all the alternative solutions available. If shoreline protection is needed, shoreline managers and stakeholders must select the recommended plan based on detailed site-specific investigations and consideration of all pertinent factors. The condition of the existing beach and marine environment, public access, and local coastal geology and processes are also important considerations in weighing the need for shoreline armoring. Proper design in combination with an array of shoreline protection tools can provide both protection and be environmentally sustainable.

9.2 Managing Shoreline Erosion: Beach Nourishment and Restoration Approaches

Beach nourishment and restoration approaches for shoreline management include:

- Stabilizing structures (groins, breakwaters)
- Beach nourishment
- Nearshore placement of dredged material
- Sand bypassing and backpassing
- Beach grooming and sand pushing
- Dune protection and restoration
- Wetlands/Marsh restoration

Groins and Breakwaters

Groins are structures oriented perpendicular to the shoreline and placed as a single groin or as a series of groins with the intention of capturing littoral drift sand or containing nourished sand and stabilizing the beach. They are constructed of a wide variety of materials, such as rock, concrete, geotextile sandbags, and wood. Provided that sufficient sediment is available within the littoral cell, groins can be effective in building up or protecting existing beaches. Multiple groins are usually installed to increase the effectiveness of this type of shore protection structure.

Groins can cause localized erosion and accretion by impounding sand on the updrift side and blocking sand from the downdrift side. Permeable and “stub” groins maintain some natural sediment transport by allowing a limited amount of sediment to pass through or around the structure. Permeability can be created by shortening or notching the groin, increasing material porosity, and reducing offshore crest elevations (Rankin et al. 2003). Similar to breakwaters, sand by-passing can be used to address downdrift erosion. Shown in Figure 91, the T-groins at Iroquois Point are intended to mimic a natural embayment or pocket beach. T-heads are designed and constructed to direct and dissipate (i.e., block, refract, and deflect) wave energy to create a curved beach between the groins. In addition, groin fields can be strategically deployed within an entire beach cell, such as between headlands, to eliminate the downdrift erosion impacts.
Figure 91. Groin field with breakwaters (Kuhio and Queens Beaches, Waikiki, Oahu). Note the sand accumulation on the downdrift side of the space between the groins. T-head groin field installed in 2013 at Iroquois Point, Oahu.

Other applications of groins for sediment management are along river or creek mouths where littoral transport clogs the entrance to the ocean waters. Figure 92 and Figure 93 illustrate this point.

Figure 92. Aerial image of Ulehawa Stream showing sediment clogging the stream mouth (Nanakuli, Oahu).

Credit: Google Earth
Figure 93. Aerial image of Mailiili Stream illustrating the effective use of a rubble-mound groin to keep sediment from clogging a stream mouth (Mailiili, Oahu).

Credit: Google Earth

Breakwaters in Hawaii are usually made of stone or concrete, providing protection to beaches and recreation, as well as to safe moorage in harbors. See Figure 96.

Figure 94. Breakwater at Waikiki Beach, protecting the shoreline.

Credit: GM Today
Beach Nourishment

Beach nourishment—the placement of beach quality material in a sediment-deficient coastal environment (i.e., a beach)—controls erosion by providing more sediment available to the active system resulting in wider beaches to increase recreation, restore habitats for wildlife, and reduce damage from coastal storms. Sand can be obtained from offshore sources by dredging operations or from navigation projects (i.e., beneficial use of dredged material—see box on beneficial use and Figure 95). Upland (e.g., dune) sources may be utilized for the purpose of nourishment in some cases.

This approach is often preferred over (or used in combination with) hard structures because the fill adds material to a deficient coastal sediment budget, provides a wider beach for storm protection and recreation, is aesthetically pleasing, and does not create structural impediments to beach access. Other advantages are a reduction in downdrift impacts from armoring, restoration of natural habitat, and increased public access to the beach. Common disadvantages and challenges with beach nourishment in Hawaii include engineering and logistical challenges of working on the shoreline and shallow nearshore, difficulty finding a compatible sand sources, permitting challenges due water quality and environmental concerns, and need to conduct repeat nourishment in most cases to keep up with ongoing erosion.

Beach Nourishment using Dredged Material

Dredged material is a resource and using dredged material for beach nourishment can be a cost-effective strategy in certain locations, given the continual sediment accretion in many ports and harbors and eroding beaches in nearby areas.

Major challenges include (1) locating sand of sufficient quality (grain size, color, material qualities) to match an existing beach, (2) the location of the dredging and the distance to the beaches or littoral zones where sediment is needed (hauling dredged material appreciable distances can be very expensive), (3) the availability of dredges capable of delivering sand to the beach needing the sand, and (4) funding the additional costs of placing sand on a beach over and above disposal in the ocean.

The solution is to match, as much as possible, navigation dredging projects with proximal locations that need sediment, pre-identify sources of good quality sand, and seek sponsors and additional funding for offloading and placing and/or storing sand. The Honolulu District’s Regional Sediment Management Program is working with local government to meet those challenges and to match dredging projects with beaches needing sand.

Figure 95. Beach nourishment (Waikiki Beach, Oahu). Before and after at Waikiki Beach, Oahu, Hawaii. Nine months later, the concrete (thought to be the foundation of a tavern in mid-1900s) was again exposed. The sand comes and goes in this area. The foundation was later completely covered again due to natural variability.

Nearshore Placement of Dredged Material

Dredging is the primary response to shoaling (sediment accretion) in Hawaii’s harbors and ports. USACE dredges, on average, less than 50,000 cy of sediment per year from one or two navigation projects. Coupling dredging operations (for bypass or navigational projects) with beach nourishment (beneficial use) can be a potential cost-effective strategy to simultaneously address accretion and erosion. However, this coupling has several barriers to success, including locating compatible sediment and funding.

One of the barriers to using dredged material for beach nourishment is the Federal Standard (33 CFR 335 - 338) (USEPA and USACE 2007), which is a USACE regulation requiring federally authorized navigation projects to select the least-cost environmentally acceptable dredged material disposal alternative. USACE is a champion of beneficial use of dredged material including beach nourishment, but the Federal Standard requires that a non-federal sponsor provide the additional cost of an alternative disposal option over the least cost alternative. In many cases, the Federal Standard has resulted in disposal of beach quality dredged material in deep offshore waters (i.e., lost to the littoral zone) because funding for the costs of beach nourishment are not available. In many Hawaii projects, more study is needed to locate beach-quality sand resources within harbors and develop methods, logistics, and funding for landing and stockpiling sand.

The USACE, Environmental Protection Agency (EPA), and other federal and state agencies generally recognize that placing dredged material from navigation projects into the littoral zone (also known as nearshore placement) can be an important contribution to restoring and maintaining the environmental health of coastal shorelines. Since 1990, the concept of “systems approaches” to regional sediment management have influenced acceptable disposal alternatives for dredged material, which now include nearshore placement into the littoral zone. To this end, appropriate conditions have to be met (e.g., grain size, chemical and toxicological quality of the dredged material, depth of closure (seaward extent of the beach profile where if sand is placed may contribute to beach nourishment), and an acceptable receiving environment) such that sediments contribute to beaches and shorelines. Many of Hawaii’s shorelines have fringing reefs, and thus, nearshore placement of dredged material is not an option if the fringing reef is fronting the beach needing sand.

Sand By-passing

Sand by-passing is a response to accretion of sand updrift of navigation projects, particularly due to the impact of breakwaters. The response of adjacent shorelines to channel construction and maintenance depends upon the localized littoral processes, navigation project design, presence of breakwaters, and the mitigation used to minimize project impacts. Where a breakwater is present, substantial quantities of sand can be trapped against the updrift side of the breakwater, as the longshore drift of sand can be interrupted by the breakwater. Downdrift shorelines are deprived of the sand accumulated on the updrift side, and the implied erosion rate of the downdrift shoreline is typically similar to the accretion rate at the updrift breakwater and within the ebb and flood shoals. The management practice is to by-pass sand, that is, sand is pumped to the downdrift side from the updrift side of the structure, where sand has accumulated.
Proper design, siting, and maintenance of breakwaters and channels can reduce the impacts from navigation projects. Evaluation of dredging and shoreline erosion history is useful in determining the entrance channel configuration and alignment that will result in the least maintenance. As reported by Price (1952), it may be possible to reduce accretion and erosion by realigning navigation channels such that they are more akin to, instead of in opposition to, the dominant natural forces.

**Sand Backpassing**

Sand backpassing is a process to restore (nourish) eroding section of beaches by re-circulating sand from an accreting downdrift shoreline to the updrift beach where the sand originated. For example, the sand backpassing project at Kailua Beach Park has been done repeatedly over the past several years. Another example under discussion is the beach on the west side of the Ft. DeRussy shoreline. The beach is extensively wide and is accreting, with about 12,000 cubic yards available. Sand would be taken from this area and placed back on the updrift shoreline. This process maximizes the use of existing sand resources and eliminates the need to inject costly new sand into the system (Tom Smith USACE).

**Sand Pushing**

Sand pushing (or beach scraping) commonly consists of excavating sand from the berm, beach face, or nearshore areas and depositing the sand farther landward on the beach or in the dune system. A relatively thin layer of sand (1 foot or less) is removed from the lower beach and spread over the upper beach, typically to rebuild a backshore berm or dune. Sand is typically moved with a bulldozer, front-end loader or pan excavator, often in a landward direction across the beach. Sand pushing in Hawaii can also be utilized to cover exposed temporary erosion control structures, protect roadways, and shore up public beach access ways. In general, beach pushing can be one of the least expensive erosion mitigation techniques and allows the natural character of the beach to maintained, but typically requires repeat (e.g., annual) maintenance (Eversole 2009).

Beach pushing is often carried out as a temporary erosion control measure before the onset of seasonal high wave activity. Beach pushing should not be considered a long-term alternative for erosion management as it is generally a temporary means to protect property from seasonal storms and high waves. Sand pushing is often much more than a cosmetic fix. In some Hawaii cases, it can be the buffer...
for high swell season and a way to avoid impacts and emergency measures. The amount of sand moved and frequency of projects should be minimized to limit impacts to the existing beach system.

Successful examples of sand pushing include heavily used public beach areas, such as Pupukea-Paumalu (Sunset Beach Park) in 2009, Makaha Beach in 2011 with about 3,800 cy moved, and Ehukai Beach (Pipeline), Oahu.

**Dune Restoration**

The second edition of the Maui Beach Management Plan summarizes the value of dunes, the need to protect and preserve dunes, and approaches to dune management.

Dune restoration is critically important components of the littoral sediment budget that have been largely overlooked in the Hawaii conservation system. Dunes trap sand pushed inland by wind and waves, store excess beach sand, and serve as natural erosion buffers, protecting beach-front property and coastal infrastructure during storms, high-wave events and even tsunami. During such events, the presence of dunes may prevent waves from washing inland and damaging property and structures. Dunes also act as a sacrificial sand source during storms by eroding or releasing sand to the beach and nearshore waters. This causes waves to break further offshore, which reduces the strength of the waves attacking the beach. When gentler winds and waves return, the sand is gradually pushed back onto the beach and the dunes are naturally rebuilt.

For shoreline and beach stabilization, the use of sand fencing and planting of native salt tolerant species of plants and grasses can provide effective protection and restoration strategies for dune systems. The low-lying plants shown in Figure 97 are resistant to wind and wave erosion. In many cases, these types of vegetation can stabilize and encourage dune growth to protect against erosion. As an example, Aki Aki, a dune grass native to Hawaii shown in Figure 97, can grow directly on the sand with little or no soil, is salt tolerant, and herbicides are not needed as salt water kills the weeds. Further, these low-growing grasses and vines capture wind-blown sand to increase sand reserves. Dune vegetation is generally only effective for stabilizing shorelines impacted by intermittent erosion or wave run-up events. It should be noted that even salt tolerant species cannot withstand chronic erosion or repeated inundation by ocean waters.

![Figure 97. On the left, a restored coastal dune fronting the County of Maui Wailuku-Kahului Wastewater Reclamation Facility in 2015 (left), showing Aki Aki grass on the foredune Pohuehue vines on upper dune and crest. On the right, a restored dune at Kamaole I Beach Park in south Maui, showing nearly buried sand fencing, used for restoration, and Pohuehue vines on the foredune and naupaka on the upper dune.](image)

*Credit: Tara Owens.*

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Maintaining dunes by plants is only part of the approach, as foot traffic can impede plant growth and encourage erosion by wind, waves, and rain runoff from trampled areas. Foot traffic can be managed by designating access paths through the dunes with adequate signage (Figure 99) to direct foot traffic to the beach. In some cases where beach use is intense, such as public beach parks, dune walkovers may be needed to provide access while protecting the dune. However, the University of Hawaii Sea Grant College Grant Program cautions that footpaths should be oriented diagonally to the prevailing wind direction to avoid the depressed path becoming a wind-blown funnel for sand.

Figure 98. Wooden dune walkovers installed in 2013 and 2014 at Kamaole III Beach Park (top) and Kamaole I Beach Park (bottom) in Maui County. These dune walkovers are both ADA-compatible and provide access to the popular beach parks, while conserving the coastal habitat.

Credit: Tara Owens.

Proactively protecting coastal dunes for hazard mitigation (and other ecosystem services) is an important element in beach and shoreline management. A long-standing program of dune restoration on Maui has been very successful. Some examples of ongoing dune restoration sites include: Kamaole I, Kamaole II, Kamaole III Park, Mai Poina Oe Iao Beach Park, the Hawaiian Islands Humpback Whale National Marine Sanctuary, Kanaha Beach, and the Wailuku-Kahului Wastewater Reclamation Facility, as well as many private properties. One element of the dune maintenance and restoration activities is the placement of signs to provide an understanding of dunes importance and how to protect them, as shown in Figure 99. Many of these projects have been or are continuing to be carried out by volunteers with guidance from the University of Hawaii Sea Grant College Grant Program.
In 2003, Maui County amended the County Code to improve protection for coastal dunes. The amendment prohibits any grading of the primary frontal dune. The amendments also prohibit the grading of any dunes located in the shoreline setback area, require a dune delineation for grading permits for coastal properties, and specify that any fill used in the setback area must be beach quality sand.

Bioengineering approaches for restoration of dunes and shorelines use native plants in combination with biodegradable erosion control materials, such as fabrics, biologs, twine, wood, and rock to simulate natural shorelines. The goals are to protect the shoreline from erosion and improve the ecological functioning of the shoreline.

Bioengineering does not work for every shoreline, but the costs for appropriate locations are much more affordable than engineered hard structures, around an order of magnitude different between natural shorelines and armored shorelines.
Wetlands/Marsh Restoration

Restoration or enhancement of wetlands and salt marshes provide a multitude of ecosystem benefits, including habitat for fish and wildlife and flood control. While these projects have limited applicability in Hawaii, it is worth mentioning that these projects generally add compatible sediments to maintain sufficient elevations in the marshes, along with other project elements, e.g., planting of wetland plants.

9.3 Managing Shoreline Erosion: Managed Retreat—Setbacks and Relocation of Structures.

Managed retreat of shorelines involves mid- and long-term planning, policies, regulations, and other methods to site or realign development landward of erosion and flooding hazard zones, and may include incentives to avoid shoreline hardening. These solutions can include removal and relocation of development away from the shoreline, landward realignment of existing development back from the shoreline, elevation of structures, and the implementation of zoning restrictions and shoreline setback for new development. Relocation of structures and infrastructure, such as water and electric utilities, may be less expensive than repeated hardening of the shoreline, especially in areas with high rates of erosion, and has the benefit of preserving natural coastal environments. The limitations to moving structures are the type of structure and construction, cost-benefit of adaptation over protection, public and private funding and financial incentives for relocations, and availability of land to move structures out of the erosion zone.

The use of increased shoreline setbacks is generally more effective for areas that are not yet developed but can be implemented when a property is redeveloped. The counties of Maui and Kauai have established erosion-based setback policies based on historical erosion rates. Maui’s program has a setback requirement with the intention of protecting coastal structures from erosion for 50 years, and Kauai’s and the conservation lands setback rules are targeted to 70 years. On Kauai, the setback is 60 feet plus 70 times the average annual coastal erosion rate, adding an additional 20 feet to account for future sea level rise. For state conservation lands along the shorelines, setback lines are required to be 40 feet from the shoreline plus 70 times the average annual coastal erosion rate (DNLR 2011).

Shoreline retreat for existing development threatened by erosion has been implemented on a limited basis in Hawaii due to perceived impacts to property development rights, lack of funding and policy support, and lack of political will for enforcement.

As part of an overall strategy of managed retreat and preservation of coastal lands, land acquisition has been successful in a number of the islands. Two examples include the undeveloped shoreline at Paukukalo, Wailuku on Maui and five miles of beaches and land stretching from Kawela Bay to Kahuku Point on Oahu. The Hawaii Trust for Public Land was the driver of the public private partnerships acquisitions in both instances, along with a number of partners.

- On Maui, the property is a total of 64 acres, fronts Kaehu Bay, and includes over 4,500 feet of shoreline. It is one of the last undeveloped shoreline parcels of a once famous and vast network of wetlands and fishponds, located between the mouths of Waiehu and Iao Streams. The coastal wetlands are potential future habitat for endangered Hawaiian waterbirds such as the Hawaiian stilt, Hawaiian coot, and Hawaiian duck (The Trust for Public Land).
- The Trust for Public Land, in partnership with the North Shore Community Land Trust, negotiated a conservation agreement with the State of Hawaii, the City and County of Honolulu, and the landowner to acquire the lands fronting Turtle Bay, stretching five miles from Kawela Bay to Kahuku Point, a total of 630 acres. The Trust for Public Land secured $2.5 million from the U.S. Army to complete the $45 million effort. This coastline is home to endangered monk seals,
green sea turtles, and whales that breach just off shore. In 1986, development rights were granted to Turtle Bay for five new hotels, thousands of residences, and shopping and commercial centers. With this acquisition, these coastal lands and beaches will remain undeveloped (The Trust for Public Land).

The current policies and regulations for managed retreat are evolving as awareness of erosion and flooding hazards and understanding of risks associated with sea level rise and climate change increases among decision-makers. The ongoing development of a Hawaii Sea Level Rise Vulnerability and Adaptation Report (due December 2017) for the Hawaii Climate Adaptation Initiative Act (State Act 83, 2014) will provide additional information on threats to coastal environments and development from coastal erosion and inundation with sea level rise.

9.4 References for Shoreline Management: Erosion and Sedimentation

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The USACE missions related to shoreline management include navigation dredging and flood risk management. Navigation is the USACE’s earliest civil works mission, dating to federal laws in 1824, providing safe, reliable, efficient, and environmentally sustainable waterborne transportation systems (channels, harbors, and waterways) for movement of commerce, national security needs, and recreation. The USACE established the Flood Risk Management Program in May of 2006, the mission of which is to provide safe and reliable projects that reduce economic and environmental damages, and prevent loss of life from both inland flooding and coastal storms.

Three USACE initiatives are enhancing implementation of these missions and contributing to effective shoreline management, including: (1) regional sediment management, (2) engineering with nature, and (3) green infrastructure.

Influencing the approaches and management of these USACE programs along Hawaii shorelines are the unique qualities of littoral cells and sediments in Hawaii compared to mainland settings:

- Most sand is carbonate, biogenic in nature, originally derived from the nearshore reef.
- Sand storage on land is in beach accretion ridges and dunes.
- Erosion of volcanic rocks is not a major contributor of sand to most beaches. Most of this material is lost offshore as clay and silt.
- Erosion of carbonate sand deposits from dunes and coastal strand plain is a major contributor to the littoral sediment budget on eroding coasts.
- Sand storage in the nearshore is in channels and depressions in the reefs.
- Sand may be lost offshore through channels or off the edge of the fringing reef.

Provided in this section is first a description of USACE Operations and Maintenance (O&M) and new work/deepening dredging actions in Hawaii, followed by brief descriptions of USACE flood risk management projects. The three USACE initiatives noted above are then described in relation to beach, shoreline, and sediment management in Hawaii.

### 10.1 Navigation Dredging

The USACE Navigation mission includes two elements related to dredging, one being maintenance dredging to ensure that channel depths are at authorized depths (i.e., O&M), and the other is new work or deepening dredging to dredge existing or new channels to authorized depths. USACE funds 100 percent of O&M dredging at federal harbors, whereas new work or deepening projects are cost-shared with local sponsors.

In 2016, USACE completed O&M dredging at five federal deep draft harbors in Hawaii. The harbors and quantities dredged are shown in Table 13. Dredging was accomplished using the USACE hopper dredge Essayons. Ideally, the Honolulu District could use as much as feasible of the 170,304 cy of dredged material for beach nourishment or shore protection, or other beneficial uses. However, this will not happen until Hawaii overcomes the barriers to using dredged material beneficially in the state. Section 11 of this report identifies those barriers and primary actions the state could take before the next dredging cycle.

One of the factors that influenced whether Hawaii could use dredged material from the 2016 O&M dredging cycle beneficially for beach nourishment is the Federal Standard (USEPA 2007b). The Federal
Standard directs USACE to select the least-cost environmentally acceptable plan (i.e., the base plan) for disposal of dredged material. In many cases, the cost of beneficial uses such as beach nourishment is more than open water disposal, and thus, local sponsors need to pay the increased cost. More on the Federal Standard is included in Section 11.6. In general, the Federal Standard helps the USACE to distribute limited funding to federal navigation projects that need to be dredged.

In addition to funding limiting the extent of beneficial use, other factors include the availability of compatible sediments in O&M dredging projects, and that the USACE dredged Essayons is a hopper dredge not capable of placing sand on beaches—the shallowest disposal depth is 36 feet. Section 11 includes more on these concerns.

There are 19 federal harbors in Hawaii, four of which are shown in Figure 100. Deep draft is 14 feet or greater in depth, where small boat harbors are less than 14 feet in depth. These include:

- Hilo Deep Draft Harbor, Hawaii Island
- Kawaihae Deep Draft Harbor, Hawaii Island
- Kawaihae Small Boat Harbor, Hawaii Island
- Honokohau Small Boat Harbor, Hawaii Island
- Laupahoehoe Small Boat Harbor, Hawaii Island
- Pohoiki Bay Small Boat Harbor, Hawaii Island

- Nawiliwili Deep Draft Harbor, Kauai
- Nawiliwili Small Boat Harbor, Kauai
- Port Allen Deep Draft Harbor, Kauai
- Kikiaola Light Draft Harbor, Kauai

- Manele Small Boat Harbor, Lanai
- Kaumalapau Deep Draft Harbor, Lanai

- Kahului Deep Draft Harbor, Maui
- Kahului Small Boat Harbor, Maui

- Kaunakakai Barge Harbor, Molokai

- Kalaeloa Barbers Point Deep Draft Harbor, Oahu
- Haleiwa Small Boat Harbor, Oahu
- Honolulu Deep Draft Harbor, Oahu
- Waianae Deep Draft Harbor, Oahu
Table 13. Dredging conducted by USACE Honolulu District during FY2016 by the Hopper Dredge Essayons.

<table>
<thead>
<tr>
<th>Harbor</th>
<th>Volume (cy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalaeloa Barbers Point Deep Draft Harbor</td>
<td>45,111</td>
</tr>
<tr>
<td>Kahului Deep Draft Harbor</td>
<td>57,202</td>
</tr>
<tr>
<td>Hilo Deep Draft Harbor</td>
<td>118,275</td>
</tr>
<tr>
<td>Honolulu Deep Draft Harbor</td>
<td>8,939</td>
</tr>
<tr>
<td>Nawiliwili Deep Draft Harbor</td>
<td>64,731</td>
</tr>
<tr>
<td><strong>Total Volume</strong></td>
<td><strong>294,258</strong></td>
</tr>
</tbody>
</table>
As shown in Figure 101, EPA designated five ocean disposal sites for dredged material for the State of Hawaii. EPA established these sites in 1981 (EPA 1981).

- South Oahu
- Hilo
- Kahului
- Nawiliwili
- Port Allen

The South Oahu site off Honolulu is the most heavily used of the five disposal sites, receiving at least some dredged material in most years from navigation projects in Pearl Harbor, Honolulu Harbor, and nearby harbors and marinas. The site offshore of Hilo is the next most heavily used. Volumes disposed are much less at the Kahului (Maui), Nawiliwili, and Port Allen sites, and disposal is much less frequent as well.

To date, all five sites have been managed under the Site Management and Monitoring Plan (SMMP) first published in 1997 and updated in 2015 by EPA and USACE (EPA 2015). In support of this update, in 2013 EPA extensively surveyed the two most heavily used Hawaii disposal sites (South Oahu and Hilo). The surveys confirmed that there have been no significant adverse effects at these ocean disposal sites.

As with all of EPA’s other dredged material disposal sites, only projects having clean (non-toxic) dredged material are eligible for ocean disposal, and only when project-specific alternatives (including beneficial reuse) are not practicable (USEPA Disposal Sites Website).

Figure 101. Ocean disposal sites for dredged material in Hawaii.

Source: USEPA Disposal Sites website.
The USACE hopper dredge *Essayons* was built in Bath, Maine, and delivered to the Portland District in 1983. Because of its size and dredging depth, the *Essayons* is particularly well suited for dredging the larger coastal entrances, and is used by the Honolulu District for maintenance dredging of the federal navigation projects in Hawaii. The Essayons completed O&M dredging of five harbors in Hawaii in the Spring 2016.

Hopper dredges are seagoing vessels designed to dredge and transport dredged material to open-water relocation areas. The working of a hopper dredge is similar to that of a vacuum cleaner.

Dragheads with dragarms extend from each side of the ship’s hull. The dragheads are lowered to the channel bottom and slowly pulled over the area to be dredged. The submerged pumps create suction in the dragarm and the silt or sand is drawn up through the arms and deposited in hopper bins in the vessel’s midsection. When the bins are full, the dredge sails to an EPA designated disposal site and empties the dredged material through large hopper doors in the bottom of the hull.

The Essayons is 350 feet long with a draft of 22 feet light and 32 feet loaded with sediment. The dredging depth can be at depths of 35 feet to 80 feet. The minimum depth for disposal (i.e., by opening the hopper bins) is 35 feet.
10.1.1 Dredging History—Hawaii Island

Federal navigation dredging on Hawaii Island has been limited to initial construction for all harbors except Hilo Deep Draft Harbor and Kawaihae Harbor (Table 14). Hilo Harbor was dredged in 1977 and 1990 with volumes dredged of 54,118 cy and 80,000 cy, respectively. Unit costs of material dredged ranged from $1.92/cy in 1997 to $3.59/cy in 1990. Kawaihae Harbor has been dredged once since initial construction. Approximately 25,000 cy of material were dredged from the harbor in 1973 at a unit cost of $2.47/cy. There is no evidence that any of the dredged material was used beneficially.

Table 14. Summary of federally authorized navigation project dredging on Hawaii Island.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ISLAND</th>
<th>PROJECT</th>
<th>VOLUME (CY)</th>
<th>COST ($)</th>
<th>UNIT COST ($/CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>HAWAII</td>
<td>HILO HBR</td>
<td>80,000</td>
<td>$286,855</td>
<td>$3.59</td>
</tr>
<tr>
<td>1977</td>
<td>HAWAII</td>
<td>HILO HBR</td>
<td>54,118</td>
<td>$104,130</td>
<td>$1.92</td>
</tr>
<tr>
<td>1973</td>
<td>HAWAII</td>
<td>KAWAIHAE DDH</td>
<td>25,000</td>
<td>$61,800</td>
<td>$2.47</td>
</tr>
</tbody>
</table>

10.1.2 Dredging History—Kauai

Nawiliwili Deep Draft Harbor has been dredged six times over the last 50 years, and Port Allen Deep Draft Harbor has been dredged four times over the same period (Table 15). Approximately 1,300,000 cy has been dredged from Nawiliwili Deep Draft Harbor at an annual rate of 30,000 cy per year. At Port Allen Deep Draft Harbor, approximately 1,800,000 cubic yards have been dredged at an annual rate of 40,000 cy per year. The quality of this material is unknown, but the majority has either been disposed of offshore or placed in upland sites. Kikiaola Small Boat Harbor was dredged as part of federal modifications to the project in 2009. The material was not beach quality and was placed as landfill cover. Nawiliwili Small Boat Harbor has not needed any maintenance dredging in recent history. The largest and smallest unit costs for federal navigation project dredging on Kauai both occurred at Nawiliwili Deep Draft Harbor and were $0.31 per cubic yard in 1968 and $7.78 per cubic yard in 1991, respectively.

Table 15. Summary of federally authorized navigation project dredging on Kauai.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ISLAND</th>
<th>PROJECT</th>
<th>VOLUME (CY)</th>
<th>COST ($)</th>
<th>UNIT COST ($/CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>KAUAI</td>
<td>NAWILIWILI DDH</td>
<td>115,000</td>
<td>$894,960</td>
<td>$7.78</td>
</tr>
<tr>
<td>1990</td>
<td>KAUAI</td>
<td>NAWILIWILI DDH</td>
<td>343,500</td>
<td>$692,160</td>
<td>$2.02</td>
</tr>
<tr>
<td>1983</td>
<td>KAUAI</td>
<td>NAWILIWILI DDH</td>
<td>183,977</td>
<td>$1,314,426</td>
<td>$7.14</td>
</tr>
<tr>
<td>1977</td>
<td>KAUAI</td>
<td>NAWILIWILI DDH</td>
<td>120,917</td>
<td>$95,355</td>
<td>$0.79</td>
</tr>
<tr>
<td>1973</td>
<td>KAUAI</td>
<td>NAWILIWILI DDH</td>
<td>146,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>KAUAI</td>
<td>NAWILIWILI DDH</td>
<td>242,201</td>
<td>$75,710</td>
<td>$0.31</td>
</tr>
<tr>
<td>1999</td>
<td>KAUAI</td>
<td>PORT ALLEN DDH</td>
<td>21,000</td>
<td>$252,000</td>
<td>$12.00</td>
</tr>
<tr>
<td>1977</td>
<td>KAUAI</td>
<td>PORT ALLEN DDH</td>
<td>141,891</td>
<td>$189,540</td>
<td>$1.34</td>
</tr>
<tr>
<td>1973</td>
<td>KAUAI</td>
<td>PORT ALLEN DDH</td>
<td>107,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>KAUAI</td>
<td>PORT ALLEN DDH</td>
<td>165,978</td>
<td>$84,931</td>
<td>$0.51</td>
</tr>
</tbody>
</table>

10.1.3 Dredging History—Maui, Lanai, and Molokai

Kahului Deep Draft Harbor has been dredged three times since 1977. Volumes dredged from the harbor have increased over the years: 24,000 cy (1977), 74,000 cy (1990), and 91,000 cy (1999), 29,000 (2016) with corresponding increases in unit cost of $1.72/cy (1977), $5.78/cy (1990), and $9.07/cy (1999), and $31.88 (2016).
Table 16. Federally authorized navigation project dredging in Maui County.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ISLAND</th>
<th>PROJECT</th>
<th>VOLUME (CY)</th>
<th>COST ($)</th>
<th>UNIT COST ($/CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>LANAI</td>
<td>MANELE SBH</td>
<td>9,000</td>
<td>$570,250</td>
<td>$63.36</td>
</tr>
<tr>
<td>1985</td>
<td>LANAI</td>
<td>MANELE SBH</td>
<td>2,000</td>
<td>$435,357</td>
<td>$217.68</td>
</tr>
<tr>
<td>1999</td>
<td>MAUI</td>
<td>KAHLULUI DDH</td>
<td>91,000</td>
<td>$825,120</td>
<td>$9.07</td>
</tr>
<tr>
<td>1990</td>
<td>MAUI</td>
<td>KAHLULUI DDH</td>
<td>73,700</td>
<td>$425,876</td>
<td>$5.78</td>
</tr>
<tr>
<td>1977</td>
<td>MAUI</td>
<td>KAHLULUI DDH</td>
<td>24,329</td>
<td>$41,925</td>
<td>$1.72</td>
</tr>
<tr>
<td>1973</td>
<td>MOLOKAI</td>
<td>KAUNAKAKAI HBR</td>
<td>51,000</td>
<td>$240,649</td>
<td>$4.72</td>
</tr>
</tbody>
</table>

Approximately 51,000 cy of material were dredged from Kaunakakai Harbor (Molokai) in 1973. The unit cost of dredging was $4.72/cy. The 1985 unit cost for dredging at Manele Small Boat Harbor (Lanai) was one of the highest on record for USACE Honolulu District (POH) at $217.68/cy. The high unit cost was due in part to the small amount of material dredged (2,000 cy) relative to the mobilization/demobilization cost. Subsequent maintenance of the harbor in 2004 consisted of the dredging of approximately 9,000 cy at a unit cost of $63.36/cy.

10.1.4 Dredging History—Oahu

Honolulu Harbor has been dredged seven times since 1968 (Table 17). The most recent dredging project prior to 2016 at Honolulu Harbor was in 1999, at which time 154,000 cy of material were removed at a cost of $1,316,800 (resulting in a unit cost of $8.55 per cubic yard). The greatest and least volumes of material dredged from Honolulu Harbor were 1,000,000 cy and 122,693 cy in 1981 and 1968, respectively. The 1968 dredging event resulted in the lowest unit cost on record for that project ($0.54/cy). Maintenance dredging of 91,000 cy at a cost of $1,212,480 took place at Barbers Point Harbor in 1999 (with a unit cost of $13.32/cy). Only minor amounts of dredging have been required to maintain authorized depths at the Haleiwa and Waianae Small Boat Harbors. Haleiwa Harbor was dredged in 1999 and again in 2009 with volume removed of 4,500 cy and 6,500 cy, respectively. Waianae Small Boat Harbor was also dredged in 2009, at which time approximately 2,000 cy of sediment were removed from the federal channel. The unit cost for these dredging events ranged from $153.85/cy to $247.00/cy. The high unit costs of these maintenance dredging projects was due to the high cost of contractor mobilization and demobilization relative to the small volume of sediment required to be dredged.

Table 17. Summary of federally authorized navigation project dredging on Oahu.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ISLAND</th>
<th>PROJECT</th>
<th>VOLUME (CY)</th>
<th>COST ($)</th>
<th>UNIT COST ($/CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>OAHU</td>
<td>BARBERS PT HBR</td>
<td>91,000</td>
<td>$1,212,480</td>
<td>$13.32</td>
</tr>
<tr>
<td>2009</td>
<td>OAHU</td>
<td>HALEIWA SBH</td>
<td>6,500</td>
<td>$1,000,000</td>
<td>$153.85</td>
</tr>
<tr>
<td>1999</td>
<td>OAHU</td>
<td>HALEIWA SBH</td>
<td>4,500</td>
<td>$1,000,000</td>
<td>$222.22</td>
</tr>
<tr>
<td>1999</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>154,000</td>
<td>$1,316,800</td>
<td>$8.55</td>
</tr>
<tr>
<td>1990</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>135,000</td>
<td>$498,520</td>
<td>$3.69</td>
</tr>
<tr>
<td>1983</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>212,000</td>
<td>$445,672</td>
<td>$2.10</td>
</tr>
<tr>
<td>1981</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>1,000,000</td>
<td>$445,672</td>
<td>$0.45</td>
</tr>
<tr>
<td>1977</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>456,923</td>
<td>$445,672</td>
<td>$0.98</td>
</tr>
<tr>
<td>1972</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>188,000</td>
<td>$66,004</td>
<td>$0.35</td>
</tr>
<tr>
<td>1968</td>
<td>OAHU</td>
<td>HONOLULU HBR</td>
<td>122,693</td>
<td>$66,004</td>
<td>$0.54</td>
</tr>
<tr>
<td>2009</td>
<td>OAHU</td>
<td>WAIANAE SBH</td>
<td>2,000</td>
<td>$494,000</td>
<td>$247.00</td>
</tr>
</tbody>
</table>
10.2 Flood Risk Management

The Flood Risk Management Program has two primary purposes:

- To work across within the USACE Districts, Divisions, and research facilities to focus the policies, programs, and expertise toward reducing overall flood risk, including reducing the risk of loss of life, reducing long-term economic damages to the public and private sector, and improving the natural environment.
- To convene and facilitate dialogue at all levels of government and with other key interests (e.g., national organizations, the private sector) to develop a national vision for flood risk management.

The USACE divides the Flood Risk Management Program into two separate but related actions, coastal flood risk management and inland flood risk management. This document focuses upon the USACE actions for coastal flood risk management. The USACE cost shares the initial construction of flood risk reduction projects with local sponsors. Local sponsors are responsible for maintenance of those projects.

The federally authorized flood risk management projects that have been constructed in Hawaii are briefly described below: first, the “hard” projects (e.g., armoring, groins, breakwaters), followed by those projects that include beach nourishment (USACE Honolulu District website).

**Hard Shore Protection Projects:**

**Kekaha Beach Shore Protection Revetment project** is located on the southwest coast of Kauai near the town of Kekaha. The project was authorized for construction in July 1978 under Section 103 of the River and Harbor Act of 1962, as amended. The project was completed in May 1980 at a cost of $3,047,520 (Federal $1,374,996; non-Federal $1,672,524).

It consists of a 6,250-foot-long rubble mound revetment with a crest elevation of 12 feet mean lower low water, 1–4 ton armor stone (two layers thick), revetment toe (three stones wide), and a bedding layer (1–500 pound stones). The local sponsor is DOT. The beach has been lost fronting much of the length of the revetment.

Repair of Hurricane Iwa damages to the revetment in November 1982 were completed in October 1983 at a cost of $229,600 (Federal) under the authority of Public Law 84-99. The local sponsor is Hawaii DOT, Highways Division.

**The Kihei Beach Shore Protection Project** is located at Kalama Beach Park on the southern shoreline of Maui. The project was authorized under Section 103 of the River and Harbor Act of 1962, as amended. It was completed in December 1971 at a cost of $308,626 (Federal: $154,313; Maui County: $154,313).

The existing project consists of a protective stone revetment 2,610 feet long with crest elevation of 8.0 feet mean lower low water. The revetment on the seaward side is armored with 1,000-pound stone placed on a slope of three horizontal to one vertical. The revetment toe is placed on the underlying coral strata excavated to a depth of 4.5 feet below mean lower low water. The local sponsor is the Maui County. The beach has been lost along the 2,600-foot length of the Kalama Beach Park revetment and along an additional 2,600 feet of seawalls and revetments fronting private properties to the north.

**The Kahului Wastewater Treatment Plant Protection Project** is located on the north shore of Maui, along the shoreline between Kahului Harbor and Kaa Point. The project was constructed under the authority of Section 14, Emergency Bank Protection. In February 1979, construction of 450 linear feet of rock
revetment was completed at a total cost $306,469 (Federal: $250,000; non-Federal: $56,469). The local sponsor is the County of Maui, Department of Public Works.

The Sand Island Channel Shore Protection Project consists of 2,382 feet of revetment with a crest elevation +6 to +8 and a varying slope of 1:1 to 1:1.5. The armor stone is 400 to 3,000 pounds and is keyed and fitted. The project was completed in 1981 at a cost of $511,456 and the project sponsor is DOT, Harbors Division.

The Sand Island Park Shore Protection Project consists of 1,580 feet of revetment and a segmented offshore breakwater. The revetment has a crest elevation of +8 and a slope of 1:1.5, and the armor stone is 3,000 to 5,000 pounds and is keyed and fitted. The segmented offshore breakwater is 360 feet long fronting 600 feet of shoreline. The offshore breakwater has a crest elevation of +8 and a slope of 1:1.5, and the armor stone is 10,000 to 16,000 pounds and is keyed and fitted. The project was completed in 1990 at a cost of $3,179,504 and the project sponsor is DLNR, Parks Division. See Figure 102.

The Alii Drive Shore Protection Project is located along Alii Drive in the town of Kailua-Kona on the western coast of Hawaii Island. This project was authorized under Section 14 of the Flood Control Act of 1946, as amended. The project construction was completed in January 2000. The total project cost was $360,000 (Federal: $234,000; non-Federal: $126,000). See Figure 102.

The project provides protection and stabilization to the existing County-constructed 700-foot-long seawall along Alii Drive. The seawall structure was repaired by placing geotextile bags into the voids and then pumping the bags full of concrete. The local sponsor is the County of Hawaii, Department of Public Works.

The Haleiwa Beach shore protection project was a beach nourishment project completed in 1999 with 10,000 cubic yards of sand, along with construction of a groin and an offshore breakwater. As shown in Figure 104, sand was placed along 1,600 feet of Haleiwa Beach. The project was cost shared with the State of Hawaii, with Hawaii paying for 2/3 of the cost. Annual maintenance of the project is the responsibility of the State of Hawaii. The project had not been maintained after construction (e.g., beach loss fronting the comfort station and the pavilion seawall behind the breakwater, and seawalls failing in some location due to undermining and overtopping). In 2013, the City and County of Honolulu funded an investigation of erosion problems at Oahu beach parks, including Haleiwa and Kaawa, providing recommendations for localized erosion management (Romaine 2017).
The Kaaawa Beach Shore Protection Project is located on the windward coast of Oahu and was completed in 1975. The project was authorized under Section 103 of the River and Harbor Act of 1962, as amended. The total cost of the project was $195,150 (Federal: $97,075; non-Federal: $97,075).

The project placed 9,300 cy of sand on the beach as a means to provide recreational opportunities. The local sponsor is the City and County of Honolulu. Periodic nourishment by the sponsor is necessary to realize benefits claimed for the project, as well as to mitigate both the continuing loss of the park’s shoreline and undermining of the adjacent highway. The highway serves as the only link to the rest of Oahu.

The Kapaa Beach Shoreline Protection Project is located on the east coast of Kauai on the section of beach located north of Moikeha Canal. The project was authorized in June 1975 under Section 103 of the River and Harbor Act of 1962, as amended. The project was completed in September 1976 at a cost of $189,700 (Federal $132,800; non-Federal $56,900). The project consisted of the restoration of a 400-foot section of beach by placement of 6,000 cy of sand, rehabilitation of a 150-foot section of the Moikeha Groin, and construction of 70 feet of revetment along the north bank of Moikeha Canal. The local sponsor was the County of Kauai, Department of Public Works.

The above referenced area as well as other areas of Kapaa Beach Park continue to experience chronic erosion at a rate of approximately 1 foot per year (Figure 101). The 2,000-foot-long reach between Moikeha Canal to the north and Waikae Canal to the south was the subject of the 2012 Kapaa Beach Sand Movement Study conducted for the County of Kauai by Sea Engineering, Inc. This study outlined several restoration and mitigation options, including beach restoration of 74,000 cubic yards of sand, and identified compatible sand deposits off shore (Sea Engineering, 2012). The study also recommended the construction of jetty spurs at the end of the Moikeha and Waiakea groins to cut off and reflect the boundary currents that carry significant volumes of suspended sediment off shore. The significant challenge to implementing these projects is funding, as the project would cost upwards of 7 million dollars.

Figure 103. Kapaa Beach Shoreline. Image of north end of Pono Kai seawall at Kapa’a Beach Park. This area is experiencing significant flanking erosion, and the County has responded with several small maintenance sand renourishment events. These events are considered a stop gap measure, and a long term solution is needed.

Credit: Ruby Pap.
The Kahului Bay Mitigation Project is located in Kahului on Maui and was completed in 1976 at a cost of $751,900 (Figure 104). The project was authorized under the authority of Section 111 of the River and Harbor Act of 1968. The project consists of an 890-foot-long revetment (which included the rehabilitation of an existing 380-foot-long revetment, built by the state in 1964); a 280-foot-long west groin; a 100-foot-long offshore breakwater; a 100-foot-long seaward extension to an existing 200-foot-long east groin (also built by the state in 1964); and the beach replenishment of 6,550 cy of sand. The local sponsors are the State of Hawaii and the County of Maui.
10.3 USACE’s Regional Sediment Management-Managing Erosion and Accretion of Sediments and Shorelines

The USACE RSM Program was initiated in the late 1990s, but the baseline of recognizing the regional influence of USACE navigation projects was certainly understood as early as the 1930s. The first sand bypassing project was conducted in the mid-1930s in Santa Barbara, California, to address the net longshore sand transport to downdrift beaches. Today’s RSM approach goes beyond project-by-project management to address sediments over regions encompassing multiple projects, and by collaborating with state and local governments.

RSM refers to the effective use of littoral, estuarine, and riverine sediment resources in an environmentally sensitive and economically efficient manner. RSM changes the focus of engineering activities from the local or project-specific scale to a broader scale that is defined by natural sediment processes. A prime motivator for the implementation of RSM principles and practices is the potential for reducing construction, maintenance, and operation costs of federally authorized projects. Implementing RSM principles also has the potential to positively affect multiple projects by using sediment as a resource in a systematic approach.

The principles of RSM when they were created in the mid-late 1990s took a very large step forward to address complicated sediment management issues (USACE Regional Sediment Management website). The principles are now generally accepted and are being widely implemented.

A systems approach seeks to deliberately manage sediments in a manner that maximizes natural and economic efficiencies to contribute to sustainable water resource projects, environments, and communities. The RSM approach:

- Recognizes sediment as a valuable resource for healthy systems;
- Implements regional strategies across multiple projects and business lines to guide investments to achieve long-term economic, environmental, and social value and benefits;
- Enhances relationships with stakeholders and partners to manage sediments across a region (local actions with regional benefits); and
- Shares lessons learned, data, tools, and technology.

Figure 105 shows the USACE locations nationally, for which RSM is being implemented.

One key element as noted above is that dredged material is considered a resource and beneficial uses of that resource are encouraged. There has been a major evolution of law and policy concerning the beneficial use of dredged material since the passage of WRDA 1986. Environmental restoration joins flood risk management reduction and coastal/inland navigation as primary missions of USACE. Laws have established the authority of USACE to use dredged material for environmentally beneficial purposes, and programs have been initiated to implement these laws. Section 204 of WRDA 1995 as amended in 2007 is the key program authority for the USACE to implement beneficial use of dredged material.

In connection with dredging for constructing, operating, or maintaining USACE navigation projects, Section 204 authorizes USACE to carry out projects for creating, protecting, and restoring aquatic and ecologically related habitats, including wetlands. USACE may conduct projects to accomplish these types of beneficial uses if it finds that the environmental, economic, and social benefits—both monetary and non-monetary—justify the cost and that the projects would not result in environmental degradation. Section 207 of WRDA 1996, which modified Section 204 of WRDA 1992, allows selection of a disposal or placement method other than the least-cost Federal Standard option in order to achieve environmental benefits. It is primarily used for new navigation projects or for maintenance projects with large incremental costs. This section requires a specific Congressional appropriation for each project and is more applicable for larger projects.

Section 204 requires that local, non-federal entities participate in these projects along with USACE. Project implementation is contingent upon various conditions. The non-federal sponsor must enter into a cooperative agreement according to the requirements of Section 221 of the Flood Control Act of 1970 and must provide 25 percent of the construction costs of the project (in excess of dredging and dredged material placement costs), including provision of all land, easements, rights-of-way, and necessary relocations. The non-federal sponsor also must agree to pay 100 percent of the operation, maintenance, replacement, and rehabilitation costs associated with the project. For purposes of determining the 25 percent non-federal share of construction costs, those costs are limited to incremental construction costs exceeding the least-cost alternative means of placement consistent with economic, engineering, and federal environmental criteria (i.e., the Federal Standard). Section 204 establishes an annual appropriation limit of $15 million.


Figure 105. Map of RSM activities from the RSM USACE website. The map on the website is interactive with direct links to descriptions of RSM activities in each of the USACE District offices. Source: http://rsm.usace.army.mil.
Key aspects of RSM include (1) preparing sediment budgets for a given littoral cell for which projects are proposed, (2) striving to keep navigation channel maintenance material in the natural system, and (3) coordinating channel maintenance with beach nourishment (USACE, Primer 2004).

Sediment movement in coastal waters is a complex process that affects the physical environment, marine life, and human interests along the Hawaii coastline. Coastal sediment refers to organic and inorganic particles created through erosion, fluvial drainage, human activities, and other processes (Hapke et al. 2006). Modes of sediment transport include wind, river, or stream transport from upland areas to the coast, or processes occurring in the nearshore environment such as longshore transport. Coastal sediment is in a constant state of flux because of natural forces from wind and waves—these forces continually erode and accrete coastal land features, such as beaches, dunes, inlets, bluffs, and coastal marshes.

**Sediment Budgets.** To quantify the amount of sediment lost or added to beaches within a region, the development of a sediment budget is the baseline for understanding sediment transport processes within that region. A sediment budget computes the various inputs and outputs of sediment to determine the net quantity of sand along a shoreline. Areas where sand is added to the beach are called “sources” and where it is lost offshore or onshore (e.g., dunes) are called “sinks.” The coastline of Hawaii can be segmented into littoral cells, which are geographically distinct compartments that consist of sources and sinks of sand.

Littoral cells are more or less self-contained beach compartments that are geographically limited. Figure 106 shows how longshore and cross-shore transport moves sand along and perpendicular to the shoreline within a littoral cell. The most common natural sediment sources are rivers, beaches, dunes, and offshore sources, including sandy deposits around fringing reefs. Sediment sinks include coastal dunes and submarine canyons (Patsch and Griggs 2006). Navigation channels created by dredging also create sediment sinks, but those sediments are not necessarily lost to the system if maintenance dredging results in placing the material on beaches or in the littoral zone along the shoreline.

With knowledge of the sediment budget, proposals for shoreline modifications (such as beach nourishment or engineered structures) can be better evaluated in terms of their potential effects upon adjacent shorelines, and sediment management can be conducted on a regional basis.

**Navigation Dredging for O&M or Deepening and Beneficial Use.** As noted earlier, acquiring beach-compatible sediments is important to beach nourishment. One possible source is the dredged material from O&M dredging projects or new work/deepening dredging projects. Sediments for beach nourishment need to be compatible with grain size and appearance, and placement upon the beaches should follow BMPs. Placement in the littoral zone is now an accepted practice, if the compatibility issue is addressed, placement is within the depth of closure, and placement does not cause issues with existing marine resources.

In addition, the haul distance from the dredging site to the beach needing material is an important consideration. Placement on the beach often increases costs more than mere disposal in open waters. Per the Federal Standard, local sponsors must pay this additional cost (USEPA 2007b).
The USACE Honolulu District began implementation of RSM in 2004, conducting a comprehensive assessment of Hawaii’s sediment management needs and where it could conduct regional sediment actions. The District initiated an RSM Product Delivery Team that consisted of District staff, DLNR-OCCL, county staff, and various stakeholders. The RSM Team also worked with USGS and the University of Hawaii at Manoa Coastal Geology Group. The result is an island-by-island prioritization of RSM initiatives and a strategy to maximize beneficial use of dredged material (Smith and Lillycrop 2014).

To date, Hawaii RSM has been instrumental in quantifying coastal processes and identifying sediment-related issues in various regions on Oahu (Mokapu Point to Makapuu Point and Diamond Head to Pearl Harbor), Kauai (Poipu and Kekaha), and western and northern Maui (west Maui, Kahului and Kihei). In addition to the identification and prioritization of future RSM efforts on these Islands, the Honolulu District will also investigate opportunities to conduct RSM activities on Hawaii Island.

As an example of one element of RSM, Figure 107 shows the location of offshore sand sources at Poipu, Kauai.

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21 Much of the discussion on RSM in each of the islands was extracted directly, except for a few minor edits, from Smith, Thomas D. and Lillycrop, Linda S.; Hawaii Regional Sediment Management Needs Assessment, July 2014.
The USACE documented and prioritized opportunities to implement RSM activities by island based on input from the Hawaii RSM Project Delivery Team (PDT). The Hawaii Department of Natural Resources, Office of Conservation and Coastal Lands is a local sponsor of RSM in Hawaii. The following sections present RSM on each of the islands along with priorities for action.

10.5 Kauai—Regional Sediment Management

An RSM Plan has been developed for Kauai (Smith and Lillycrop 2014) that addresses sediment management related opportunities in the Kekaha and Poipu regions. The plan compiles available information and documents investigations conducted to identify sediment transport pathways in the regions. The information is to be used in the future as a basis for identifying potential RSM projects that could reduce federal project costs in the regions while improving environmental outcomes and increasing the public benefit.

The Kauai RSM Plan includes the following information for the Kekaha and Poipu regions: a) objectives of the overall RSM program; b) descriptions of the existing federal projects; c) geomorphologic processes such as beach sediment production; d) coastal processes including wave climate and sea level change; e) coastal ecosystems; f) characterization of the region’s shorelines including shoreline erosion maps, identification of shoreline structures, chronologies of historical events affecting the shorelines, beach profiles, and beach volume change rates (final regional sediment budgets for the Kekaha and Poipu RSM regions have yet to be developed); g) identification of potential sand sources for beach nourishment; h) identification of potential future RSM projects; and i) a bibliography summarizing each of the reference sources used in the document (USACE POH RSM website).

In the Kekaha region:

Kikiaola Harbor Sand Bypassing is a potential RSM project. The Kikiaola Harbor breakwaters and an offshore sand sink appear to prevent longshore sand transport from Waimea Beach to the downcoast beaches, based on accretion upcoast of the harbor and erosion downcoast of it. The potential project
would be to remove sand from Waimea Beach and place it on the downcoast Kikiaola Beach. It is recommended that the State of Hawaii implement the sand bypass plan for Kikiaola Harbor as cited in the fully executed project cooperation agreement, and as part of that agreement, 60,000 cubic yards were bypassed in 2014.

Another potential RSM project is rerouting of the Kikiaola Harbor Gulch. The gulch discharges directly into Kikiaola Harbor. Rerouting of the gulch to downcoast of the harbor would minimize the amount of maintenance dredging of the harbor and should be considered for future RSM studies.

The sand sources search resulted in the identification of 189.4 acres (766,461 m\(^2\)) of stable reef-top sand stored off the coast of the Kekaha region. The majority of this sand is located in two large sand fields off Kekaha Beach Park.

In the Poipu region:

Poipu Beach Park Restoration is a potential RSM project. The County of Kauai and Poipu Beach Resort Association desires restoration of the popular Poipu Beach Park. The potential project is to place 6,600 cy of sand. The recent erosion rate is 800 cy per year so the proposed beach fill quantity would be expected to remain in the reach for six to eight years.

The sand sources search identified 72.2 acres (292,104 m\(^2\)) of stable reef-top sand stored off the coast of Poipu, Kauai. The majority of this sand is located in a large sand field off Brennecke Beach.

USACE identified federally authorized projects on Kauai that could potentially benefit from implementation of RSM principles and practices, along with potential sediment sources and shorelines that are experiencing shoreline recession. A portion of the Kauai shoreline consists of steep sea cliffs with little to no sediment resources. Other areas of the island are virtually undeveloped or do not offer any RSM opportunities.

### 10.6 Oahu—Regional Sediment Management

Oahu is the third largest and most populated of all the Hawaiian islands. There are two federally authorized deep-draft harbors, Honolulu Harbor and Barbers Point Harbor, on Oahu. Hawaii DOT is the non-federal sponsor of the deep-draft harbor projects. Honolulu Harbor handles over 11 million tons of cargo annually and is a critical piece of infrastructure as Hawaii imports over 80 percent of its required goods. Not only does Honolulu Harbor serve Oahu’s waterborne commerce needs, but also those of the neighbor islands as a vast percentage of the goods and commodities that enter the harbor are ultimately barged to the outer islands. Barbers Point Harbor is a relatively new facility constructed in 1985 by excavating and dredging out of fast land (land located above the high water line) at the southwest point of the island. The facility specializes in receipt and shipment of conventional and containerized general cargo and petroleum products, receipt of miscellaneous dry bulk commodities and grain, shipment of cement, and bunkering of vessels. There are two federally authorized small boat harbors, Haleiwa Harbor and Waianae Harbor, on Oahu. Both of these harbors provide opportunities for commercial and recreational boating. The non-federal sponsor of the small boat harbor projects is the State of Hawaii, Department of Land and Natural Resources, Division of Boating and Ocean Recreation (DOBOR).

The River and Harbor Act of 1965 authorized the Waikiki Area Erosion project. The goal of the project is to provide for a stable protective beach that is both publicly and environmentally acceptable. The authorized plan includes restoring and protecting approximately 10,800 feet of shoreline along Waikiki Beach from Duke Kahanamoku Beach to the Elks Club. Two of the eight project reaches authorized for construction in 1965 have been implemented to date. The Fort DeRussy reach was completed in 1971 with non-appropriated military funds. Construction of the Kuhio Beach sector was completed by the
State of Hawaii in 1972. Construction of the uncompleted portions of the authorized project is currently estimated at $24,000,000.

The Federally authorized Waikiki Area Erosion project is currently in the Preconstruction and Engineering (PED) phase. However, because of a lack of funds the project has been suspended. The project sponsor, DLNR, has solicited assistance from the Hawaii delegation in the project implementation process. A study recommending federal participation in the PED phase was submitted to Headquarters USACE in November 2002. The study concluded that the project, as authorized, fulfills the current day needs at Waikiki Beach and is economically justified based on estimated National Economic Development (NED) benefits exceeding project costs. However, the economic justification was based on recreation benefits, considered a low administration budget priority; and visitor expenditures, which are not recognized as NED benefits. Subsequently, the state has decided to pursue design and construction of a locally funded Waikiki Beach shore protection project, a special improvement district with authority to tax businesses in the Waikiki Beach area has been established for this purpose.

The federally authorized projects of interest on Oahu include the (a) Honolulu Deep Draft Harbor, (b) Barbers Point Deep Draft Harbor, (c) Waianae Small Boat Harbor, (d) Haleiwa Small Boat Harbor, (e) Haleiwa Shore Protection Project, (f) Kaaawa Shore Protection Project, (g) Waikiki Beach Shore Protection Project, and (h) Sand Island Shore Protection Project.

Honolulu District’s RSM efforts began in the Southeast Oahu region (Smith and Lillycrop 2014). The region extends from Mokapu to Makapuu points (M2M). Subsequently, RSM has been implemented in the Diamond Head to Pearl Harbor Region (D2P) and the Haleiwa Region. These are described below.

The results of the RSM study from Mokapu to Makapuu included the following:

- Documented long-term trends in wave climate for the windward side of Oahu, Hawaii;
- Developed a regional sediment budget and GIS data set for three interconnected littoral cells along the southeast Oahu coast;
- Identified suitable sand sources; and
- Developed/calibrated a sediment transport model for the region.

The final products from this study are a sand source inventory, RSM plan, and a web-enabled GIS platform for the M2M Region.

Key findings of the Diamond Head to Pearl Harbor (D2P) studies include the presence of near-shore sand sources on the reef top in the project area, and generally low sediment transport rates (a few thousand cy annually). These findings suggest that beach nourishment could be economically viable.

The Haleiwa Region includes the federally authorized Haleiwa Small Boat Harbor navigation project and Haleiwa Beach Park shore protection project. Sediment related issues in the Haleiwa Region include interception of littoral transport on the updrift harbor breakwater and erosion downdrift, which has prompted the need for an offshore breakwater, groin, and beach fill designed to maintain a nominal beach width.

Sunset Beach RSM region extends along the three miles of shoreline from Pupukea Quarry to Velzyland on Oahu’s north shore. RSM studies will engage various federal, state, and county agencies in the implementation of strategies to maximize the use of the region’s scarce sediment resources. The Sunset Beach RSM initiative will quantify shoreline changes, coastal processes, and the regional sediment budget; and identify potential RSM projects in the region.
**10.7 Maui—Regional Sediment Management**

Maui County consists of the Islands of Maui, Kahoolawe, Lanai, and Molokai. Lanai is a privately owned island, other than the state-owned airport and the federally authorized navigation projects of Kaumalapau Harbor and Manele Small Boat Harbor. Kahoolawe is held in trust for a future Native Hawaiian sovereign entity and is managed by the Kahoolawe Island Reserve Commission. Since there are no federally authorized projects on Kahoolawe, the entire island is excluded from RSM activities. Federally authorized projects in Maui County that could potentially benefit from implementation of RSM principles and practices have been identified along with areas that could potentially be used as sediment sources and areas of chronic erosion.

The federally authorized studies and projects of interest in Maui County include (a) West Maui Watershed Study, (b) Kahului Deep Draft Harbor, (c) Kahului Light Draft Harbor, (d) Kihei Shore Protection Project, (e) Manele Small Boat Harbor, (f) Kaumalapau Harbor, and (g) Kaunakakai Harbor.

Three actions relating to RSM in Maui are helping to scope the implementation of RSM projects.

- An RSM Plan has been developed for Maui (Smith and Lillycrop 2014), which addresses sediment management related opportunities in the Kahului and Kihei regions, including information from a 2011 workshop in Maui. The plan compiles available information and documents investigations conducted to identify sediment transport pathways in the regions. The information is to be used in the future as a basis for identifying potential RSM projects that could reduce federal project costs in the regions while improving environmental outcomes and increasing the public benefit.

- USACE held a workshop 17 August 2014 in Kihei, Maui, where stakeholders discussed RSM projects that might be implemented in the West Maui Region. The results of the workshop are detailed in *Potential RSM Projects: West Maui Region* (USACE 2016) and include conclusions and recommendations on: (1) engineering considerations, (2) environmental considerations, and (3) potential RSM projects.

- Erosion is an issue along many shorelines in West Maui including Kaanapali, Kahana, and Honokowai. The West Maui Watershed Project (Ridge to Reef) has recently been initiated under USACE and State leadership with federal, state, and local partners. The Ridge to Reef project provides opportunities to implement a number of different types of projects, some of which may address sediment-related issues along the shoreline (Ridge to Reef website).

Based partially on the findings of the 2014 workshop, the County of Maui identified Kahana Bay as Maui’s first priority.

- Kahana Bay: The shoreline within this reach of the West Maui Region is chronically eroding and various types of *hard* shore protection alternatives have been recommended to reduce future economic and environmental impacts. A draft environmental assessment was presented to the County in 2012. Because of concerns related to impacts to neighboring shorelines, technical design of the revetment, and questions on longshore transport, the County recommended looking further into other alternatives including groins, offshore breakwaters, and beach nourishment. As of early 2017, it now appears that this project will be carried out through private firms. See the case study in Section 7. As stated in Section 7, the Hololani Resort Condominium Association of Apartment Owners (AOAO) has been authorized by the State and County for armoring, consisting of a hybrid sheet-pile seawall and rock revetment toe. The County approval includes conditions for mitigation of impacts, including: 1) The Hololani AOAO shall contribute to a regional beach restoration project; and 2) at the time when the regional beach restoration project is implemented, the armoring shall be dismantled and removed.
A potential RSM project is to place Kahului Harbor dredge material along the Kahului Harbor shoreline, which has a current beach erosion rate of approximately 800 cy per year. The dredge material may also be appropriate and have higher potential benefit for other beach nourishment sites in the region, depending upon the grain size compatibility with the other sites. The RSM sand sources search identified 7.8 acres (31,656 m²) of stable sand stored on the reef flat off the north shore of Maui, serving as a potential resource for beach replenishment. A sand search done as part of a separate project also indicated a very large (~3,500 acres) potential source of beach-quality sand seaward of the Kahului Harbor breakwater. The recently dredged material at Kahului Harbor was disposed of offshore, but there may still be opportunities to use dredge material in phases two and three of the dredging project.

The Kihei Beach Hurricane and Storm Damage Reduction Project is a potential RSM project. Kalama Park is widely used by the public for recreation. Shoreline erosion north of the park in recent years led to initiation of a Section 103 study, which has been on hold for an extended time due to lack of non-federal funds. The project would include an initial beach nourishment (approximately 358,000 cy), as well as future renourishment. The sand sources search identified 13.8 acres (55,821 m²) of stable sand stored on the reef flat off the coast of Kihei, Maui, serving as a potential resource for beach replenishment (USACE and State of Hawaii 2016).

RSM can address brown water issues caused by agriculture and construction site runoff. Runoff from construction sites is often sediment laden and ultimately results in increased turbidity in nearshore coastal waters. Sediment BMPs at construction sites should be employed to reduce point-source runoff.

Alternate solutions must be available when it becomes apparent that existing BMPs do not apply to a specific area. RSM could help with site design and enhanced BMPs for these areas. Examples include Honokahua Bay, Mahana Ridge (originally part of Kapalua Mauka permits in 2007 that promised no negative downstream effects), and Honolua Bay.

Outreach and guidance should be offered to stakeholders in the West Maui Region regarding RSM concepts, modeling, research, and coordination. This will aid in better understanding the sediment/reef relationships through RSM principles. Knowledge gaps, current tools, and anticipated future needs should be identified to aid in planning. A series of workshops to provide RSM guidance to the West Maui Region stakeholders should be conducted.

Detailed offshore sand investigations in support of beach nourishment should be conducted. Viable sand resources through reconnaissance sampling and geophysics should be ascertained. When viable sand resources are identified, workshops with communities to discuss beach nourishment logistics should be conducted. The primary candidate area includes Napili Bay, as a sand study was already carried out for Kahana Bay.

One additional RSM opportunity in Maui County that should be investigated is at Manele Small Boat Harbor (Lanai), where a stream settling basin located upstream of the harbor is not effectively maintained. Once the settling basin has filled with stream sediments, additional sediments are allowed to discharge directly into the harbor basin. Routine maintenance of the settling basin would reduce harbor shoaling and navigation operation and maintenance costs. Records for Maui County do not indicate that any of the dredged material has been used beneficially.

### 10.8 Hawaii Island—Regional Sediment Management

Due to limited sediment supply, as well as a lack of shoreline change analysis on Hawaii Island, no RSM investigations have been conducted to date.
10.9 Hawaii RSM Priorities and Observations

The Hawaii RSM Project Delivery Team has identified opportunities to manage coastal sediments on a regional scale throughout the main Hawaiian Islands (Kauai, Oahu, Maui, and Hawaii Island). The Project Delivery Team consists of POH staff, DLNR-OCCL staff, County staff, and various stakeholders. The Project Delivery Team has a comprehensive understanding of RSM needs throughout each county, and the state as a whole. The Team conducted an island-by-island prioritization of RSM initiatives resulting in directions on development of future Hawaii RSM studies and evaluations.

The following is an island-by-island listing of USACE RSM priorities in the State of Hawaii with objectives to maximize beneficial use opportunities.

- **Kauai (Kauai County)**
  - Kekaha Region
  - Poipu Region—The Poipu region has previously been studied by the Hawaii RSM initiative. Kauai County has completed a small beach nourishment project for a portion of the Poipu shoreline, has investigated larger scale nourishment, and considers it a priority RSM region.
  - Kapaa Region—Like Poipu, Kauai County has conducted a small-scale beach nourishment project and investigated larger-scale beach nourishment at Kapaa.
  - Implementation of RSM Principles—Kauai County seeks to shorten permitting timelines for state water quality certification and wants to investigate the logistics of stockpiling beach quality sand for future renourishment activities.

- **Oahu (City and County of Honolulu)**
  - The DLNR-OCCL seeks to investigate recovery and stockpiling of beach quality sand from offshore sources.
  - Haleiwa Region
  - Ala Moana Region
  - The City and County of Honolulu seek to improve stream mouth clearing operations and attain programmatic permitting of beach placement of stream sediment.

- **Maui (Maui County)**
  - West Maui Region (Kaanapali through Honolua Bay)
  - Kihei Region
  - Kahului Region
  - Maui County and DLNR seek to investigate logistics of stockpiling beach quality sand for future renourishment actions and to develop ways of implementing soft solutions to beach erosion rather than hard solutions that remove coastal shorelines from the public domain.

- **Hawaii Island (Hawaii County)**
  - Waipio Valley Region
  - Hilo Bay Region
  - Kawaihae Region
General observations by the RSM Project Delivery Team on Kauai, Maui, and Oahu are noted below that focus upon opportunities for improvement and enhancement of shoreline management in terms of timing and effectiveness. The observations are directly extracted from *Hawaii Regional Sediment Management Needs Assessment* (Smith 2014) quoting from each of the three Project Delivery Teams:

- The State of Hawaii, Department of Health (DOH), Clean Water Branch (CWB), issues water quality certifications for beach fill projects. Programmatic coordination with CWB regarding the goals of RSM, and regarding the importance of utilizing the state’s valuable sediment resources, should be conducted to streamline the water quality certification process for RSM actions.
- Stockpiling beach quality sand for future use as beach fill would be a worthwhile initiative.
- Sediment management at stream mouths is a major RSM issue on Oahu.
- Water quality certification is one of the major roadblocks to effectively managing littoral sediments on Oahu. Routine maintenance of infrastructure at and near the shoreline is hampered by the lack of urgency provided by the DOH Clean Water Branch.
- Sand is not recognized as a mineral by the State of Hawaii, and therefore, neither its sale, use, nor transport is regulated by state or County policy.
- Maui County needs to stockpile sand until such time that it can be used for beach nourishment.
- Maui County staff recommended that lessons learned from the recent Waikiki Beach be documented and reviewed so they can be incorporated into future beach renourishment activities.
- Maui County is processing an ever-increasing number of permits to harden shorelines. It feels that there is a need to develop alternatives to hardening since those types of alternatives remove beaches from the public domain.

For the first time, RSM was expanded beyond the State of Hawaii and into the U.S. Pacific territories in Fiscal Year 2016. RSM introduced the systems approach concept to civil works projects in the U.S. Territory of American Samoa (AS) at Utulei Beach. USACE has a rich history of providing civil works assistance to the territory for enhancements of navigation, shore protection, flood control, emergency management capabilities and life safety measures. USACE has constructed and maintains small boat harbors on the territory’s main islands (Tutuila, Aunuu, Tau, Ofu and Olosega). Shore protection projects have been constructed by USACE along many miles of the shoreline within the territory to reduce the impacts of storms on critical infrastructure and upland development. Utulei Beach RSM focused on identifying the changes that have occurred within the region, causing loss of beach area and upland erosion. The study quantified coastal processes and sediment related issues in the region, and used this information (along with consideration of the challenges of construction in such an isolated and relatively undeveloped location) to implement projects for more efficient use of available sediment.

Expansion of RSM concepts and practices into additional U.S. territories, such as Guam and the Commonwealth of the Northern Marianas, is a possibility in the future.
10.10 Engineering with Nature

Building upon a number of operating policies, USACE is moving to ensure that projects are engineered with nature as a key element of the overall design process. Engineering with Nature is defined as:

The intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes (Corps Engineering with Nature website).

The key Ingredients in Engineering with Nature include:

- Strategic placement of sediments, in combination with hydrodynamics and natural transport processes, to build near-shore habitats;
- Engineering features to focus natural processes to minimize navigation channel infilling and to transport and focus sediments for positive benefits;
- Cost-efficient engineering practices for enhancing the habitat value of infrastructure;
- Natural systems, such as wetlands and other features, to reduce the effects of storm processes and sea level change on shorelines and coasts; and
- Science-based communications processes to improve stakeholder engagement and collaboration (Bridges et al. 2013).

A number of Engineering with Nature projects have been completed by USACE Districts with local partners around the United States. The Honolulu District is evaluating opportunities in concert with their upcoming maintenance dredging activities to incorporate the Engineering with Nature principles.

10.11 Green Infrastructure

USACE has constructed and operates many navigation and shore protection structures in the Hawaiian Islands, such as breakwaters, groins, and revetments. These structures provide habitat for fisheries and waterfowl, but as a side benefit to the navigation and/or shore protection missions. One of the USACE’s new initiatives being championed out of USACE’s Engineer Research and Development Center in Vicksburg, Mississippi, is to explicitly design habitat-enhancing features into future projects and into maintenance of existing projects. While the primary objective of the projects will remain the priority, adding green aspects to projects is limited to appropriate and feasible applications, but projects can provide expanded habitat for such ecological benefits as aquatic insects, fish spawning, bird nesting, or critical habitat for endangered species in Hawaii such as sea turtles and Monk Seal.

Examples of green enhancements include:

- Fish habitat shelves, as shown in Figure 108;
- Adding pea gravel around the base of breakwaters to enhance fish spawning habitat;
- Scratching hard surfaces of breakwaters to enhance settlement of aquatic insects; and
- Dune restoration for critical habitat for sea turtles and Monk Seals.
In addition to funding, challenges to implementing green infrastructure include apprehension about ensuring the structural integrity and functional performance of the projects. Another serious concern regards future maintenance of projects, and in particular about environmental restrictions on “disturbing” the habitat and fishery or rookery created by the green features of the project. Suggestions to address these challenges include creating interagency state and federal partnerships, including stakeholders in project planning, conducting pilot studies, and assessing existing green projects (USACE Spring 2012).

10.12 References for USACE Missions Related to Shoreline management

Garvey, Kim; Sloop, Robert; Smith, Thomas; and Podoski, Jessica; Regional Management—Hawaii Style Studies on Maui and Kauai, H2O Conference, Co-Sponsored by State of Hawaii Department of Land and Natural Resources and USACE Honolulu District. May 2012.


Romaine, Bradley, Personal Communication, Jan 2017.


USACE, Making Great Lakes Coastal Structures Greener, Spring 2012.


Many beaches and shorelines in Hawaii are eroding. Many residential and commercial properties and infrastructure, such as roads, have been built too close to eroding shorelines. Section 9 presented the array of approaches available to address beach and shoreline erosion, including construction of seawalls and other engineered structures, beach restoration and nourishment, and nature-based management approaches. The forces of erosion are not easily tamed, especially in view of rising sea levels. Management efforts to save beaches and shorelines, and to address related development and infrastructure, are essential to Hawaii’s culture, economics, and environmental resources.

Types of beach nourishment projects in Hawaii generally fall into two categories:

1. Beach maintenance (discussed in Section 9)
   a. Sand backpassing from an area of seasonal beach accretion to an area of seasonal beach erosion
   b. Sand pushing or beach scraping to rebuild back-beach volume or dunes using seasonally-accreted sand from lower on the beach profile
   c. Dune restoration using borrowed sediment and other measures such as re-vegetation with native species and dune fencing

2. Beach restoration (discussed in Section 9)
   a. Using land-based sand resources (e.g., dune sand)
   b. Using sand dredged from offshore deposits
   c. Beneficial reuse of sediment, such as from a harbor dredging or stream mouth clearing
   d. Using sand imported from outside Hawaii (generally not permitted on state submerged lands)

This section focuses on the challenges in maintaining and restoring Hawaii beaches.

11.1 The Elements of Beach Restoration and Nourishment Projects

Generally, the terms beach restoration and beach nourishment are used interchangeably, and for this report, they are, but the subtle differences are that restoration of a beach restores the beach to its prior width and volume. Nourishment can do the same but it is sometimes considered in the maintenance category of adding sand to a beach on a regular basis. Another term is beach maintenance, which generally implies redistribution of beach sand using heavy equipment in response to erosion by storms, seasonal variability, or other needs such as maintaining access pathways eroded by foot traffic.

Nourishment of eroding beaches is not a new activity in Hawaii. There have been numbers of successful beach nourishment projects, such as Waikiki Beach and Iroquois Point. Planning for Kaanapali is underway, as it has not been nourished before. Beach nourishment at Waikiki Beach in the 1940s and 1950s used sand from other Oahu and other island beaches. Privately funded projects have restored smaller pocket beaches on the north shore and southwest shore of Maui. Small publicly funded projects have also been implemented at beaches in south and east Kauai.

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22 Unless otherwise noted, the information in this section is from Romine, Bradley; Conger, Chris; Eversole, Dolan; and Guannel, Greg; Beach Restoration in Hawaii, Outcomes from the Hawaii Beach Preservation Association 2014 Hawaii Beach Restoration Workshop; April 17, 2015.
To implement a beach nourishment project, there are a number of upfront steps that must be achieved. These include (but are not limited to):

- **Scoping** – including identification, prioritization, and justification for beach restoration as a potentially viable management/improvement option for a specific site.
- **Funding** – including identification of funding sources and acquisition of funds. There may be competition for limited available funding from federal, state, county, or private sources, and prioritization and justification of the needs for beach restoration is the first action.
- **Design** – including identification of sand sources, alternatives analysis, and environmental impact assessment. Project designs should address how best to maximize the residence time of the sand on the beach and include BMPs to limit impacts to the coastal and marine environment.
- **Permitting** – including all relevant federal, state, and local permits and authorizations, including public review\(^\text{23}\).
- **Construction** – including mobilization, dredging, sand placement, and demobilization.
- **Monitoring** – short-term and long-term monitoring and impact assessments (e.g., beach profiles, water quality, benthic habitat).

### 11.2 The Challenges to Achieve Successful Beach Restoration and Nourishment Projects in Hawaii

Beach nourishment is a key element in Hawaii’s management efforts to restore beaches and to combat erosion and accretion. However, there are a number of barriers, which can be overcome, to implement a beach nourishment project. The following subsections discuss these, and include:

- Availability of sand supplies compatible with existing beaches
- Evaluation of the potential risk upon coral reefs and nearshore ecosystems of beach nourishment
- Technical logistics of placing sand on a beach
- Funding
- Environmental permitting, especially CWA 401 certification

### 11.3 Challenges: Sand Availability—Sources and Characteristics of Sand for Beach Nourishment

Beaches in Hawaii are generally narrow and contained within pockets between rocky headlands. As a result, beach nourishment projects in Hawaii typically require orders of magnitude less sand volume than with mainland projects (thousands to tens of thousands of cy of sand compared to hundreds of thousands to millions of cy of sand). Hawaii’s famous “white” sand beaches are composed largely of skeletal carbonate (limestone) sediment originally derived from the nearshore reef.

Natural carbonate beach sand is available in limited quantities, generally in thin deposits overlying a narrow coastal plain, in dune systems, on narrow beaches, and on depressions and channels of nearshore reefs (see Figure 109).

\(^{23}\) For the DLNR’s SSBN program, public review is only required for projects over 500 cubic yards.
Supplies of beach quality sand on land have been largely exhausted or are protected from mining and using the sand for beach nourishment. Compatibility of the sand is also an issue, as land-based sand supplies sometimes contain too many fine-grained materials. It is illegal to take sand from beaches or nearshore dunes for any purpose (HRS 205a). Maui’s commercial sand businesses mine inland sand dunes, but that supply is diminishing, and is of questionable quality for beach nourishment. Although the dune sand is primarily marine (carbonate) in origin, some dune sands have a relatively high fraction of fine and organic material if not washed/processed thoroughly (expensive). Dune sands available for extraction on Kauai and Oahu are more limited than on Maui, and there are essentially no inland marine sand deposits on Hawaii Island. As a result, recent beach nourishment projects on Maui and Oahu have gone offshore to recover beach-quality sand.

The other alternatives for sand for beach nourishment are (1) dredged material from a USACE dredging project, which needs to be within a reasonable haul distance from the dredging site; (2) inland sources, while limited may be viable in some cases, or (3) sand from offshore either from USACE dredges or private dredges. Not all nearshore sand deposits contain material that is compatible with existing beach sand. Offshore sand beds may be poorly sorted, containing beds or lenses of coarse (e.g., gravel) material and fine sediment (e.g., silt) (Romine et al 2015).

USACE has identified sand deposits along the shorelines of Oahu, Kauai, and Maui. Figure 110 is one example of the results of the USACE efforts. Moving that sand to the beach to be nourished is not without issues (Figure 111), one being the expense (especially for small projects) and the other being concerns over potential environmental impacts to benthic and shoreline ecosystems. Water quality regulations require the sand to be dewatered prior to placement on beaches, rather than pumping the slurry directly onto the beach, as done on the mainland. Volume requirements for beach nourishment restoration in Hawaii are far below those on the mainland.

Figure 109. Beach sand in Hawaii is typically composed of carbonate skeletal material from nearshore reefs.

Source: Romine et al 2015.
Another alternative could be importing sand from out-of-state sources, as done by the concrete industry. However, state regulations do not allow use of imported sand on beaches.

Figure 110. Potential sources of sand identified in RSM assessments by USACE offshore of Oahu.

Credit: Thomas Smith, USACE, and University of Hawaii.

Figure 111. Dredging offshore sources of sand is not without issues, including waves, “not in my backyard,” and environmental concerns.

Credit: Scott Sullivan, Sea Engineering Inc.
11.4 Challenges: Evaluation of the Potential Environmental Impacts of Beach Nourishment Sand

Hawaii beaches are a critical component of the coastal ecosystem. Beaches front sensitive reef and marine environments, so understanding and mitigating potential impacts from restoration projects is needed. Concerns have been raised over some beach restoration projects related to perceived impacts to water quality and reef sedimentation, in spite of the required environmental monitoring and use of BMPs. Science and engineering with beach restoration and sediment management continues to evolve and better techniques for monitoring impacts have been developed.

While potential environmental impacts of beach restoration deserve careful attention, the environmental permitting process for beach restoration has become unnecessarily burdensome and time-consuming, making many beach restoration projects impractical and cost-prohibitive.

The 2012 Waikiki beach restoration project is a recent example of a successful/completed beach nourishment project that got a Section 404 permit from the Corps and 401 Water Quality Certification from the State Department of Health, Clean Water Branch. The project was required to discharge and “de-water” dredged sand slurry in a retention basin at the shoreline as a water quality BMP. On the U.S. mainland, the slurry is typically pumped right onto the beach placement area with the dewatering occurring on the beach. While a successful project, issuance of the 401 Certification by the Hawaii’s Department of Health was well beyond what project sponsors considered timely and effective for project initiation.

One element of the environmental review process that apparently impedes progress for certain beach projects is that the Hawaii state regulations include sand as a pollutant, as noted in the box.

Sand is a Pollutant—Hawaii Water Quality Regulations

"Water pollutant" means dredged spoil, solid refuse, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical waste, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, soil, sediment, cellar dirt, and industrial, municipal, and agricultural waste. 2011 Hawaii Code, DIVISION 1. GOVERNMENT, TITLE 19. HEALTH, 342D. Water Pollution, §342D-1 Definitions.

Section 11-54-1.1 General policy of water quality antidegradation. (a) Existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

Section 11-54-4 Basic water quality criteria applicable to all waters. (a) All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including:

(1) Materials that will settle to form objectionable sludge or bottom deposits; ...

The DLNR requires that sand used for nourishment closely match existing beach sand in composition and grain size and be free from pollutants, which is a protective statement. However, because sand is listed in the state regulations as a pollutant, evaluation of compatibility and the potential for unacceptable environmental impacts is more complicated. See text box.
Continued research and scientific information are needed in assessing the potential impacts on near
shore waters and fringing reefs of beach nourishment projects (i.e., might placing sand on beaches have
unacceptable impacts to offshore resources?). In the interim, state policies prohibit placing sand upon
the beach in slurry form, such that turbid waters are released back into marine waters. This is
protective, but causes logistic issues, increases costs for placement, and has been questioned as being
over-protective and unnecessary. There were encouraging environmental assessments completed
during the recent Waikiki and Iroquois Point nourishment projects that did not demonstrate
unacceptable impacts.

11.5 Challenges: Logistics and Costs of Placing Sand on Beaches

The USACE Regional Sediment Management Program aims to match available dredged material from
navigation dredging projects to beaches that are in need of sand. One limitation is the distance from the
source to the beach, and the other very practical issue is the type of dredge being used for the
navigation dredging. The USACE usually uses the Dredge Essayons (Figure 112), which is a hopper
dredge. It essentially excavates harbors by suction, places the material in the vessel’s hopper, and then
bottom dumps the material at designated ocean disposal sites. The vessel cannot dump in less than 35
feet of water and cannot pump to shore. One preliminary estimate was that it would cost more than $20
million to modify the Essayons to enable it to pump dredged material to shore (Jessica Podoski, personal
communication, 2016).

The department of land and natural resources is responsible for the management of coastal resources,
including beaches and dunes. The department has promoted adaptive sediment management techniques to
mitigate erosion and beach loss in some areas, including beach scraping, stream mouth clearing, and sand
bypassing and backpassing. To be effective, some of these maintenance activities must be conducted on a
recurring basis.

Unfortunately, efforts by government and private entities to mitigate beach loss have been hampered by
state water quality regulations that severely inhibit the use of sediment management as an erosion
management tool. The reason is that Hawaiian beach sand has been interpreted to be a "water pollutant"
under state water quality regulations. As a result, sand that is cleared from stream mouths or channels is
often removed from the beach system because it is considered a "water pollutant." In addition, it has
become extremely arduous to obtain the permits necessary for sediment management projects because,
based on the state’s interpretation of the federal Clean Water Act, clean locally-sourced beach sand is
considered to be a "water pollutant."

Note: Bill did not pass in 2016.

*https://legiscan.com/HI/text/HB1457/id/1284235

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Hawaii House Bill 1457: Introduction on “Sand as a Pollutant”*

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considered to be a "water pollutant."

Note: Bill did not pass in 2016.

*https://legiscan.com/HI/text/HB1457/id/1284235
Alternate private dredges could be used that are able to pump to the beach, but the state’s policy that sand must not be placed on the beach in slurry form impedes that option. Use of mechanical dredges is possible, but the logistics of getting barges with the dredged sand to the beach for placement may not be possible given the depths of any fringing reefs at the specific location.

Beach restoration is costly. A recent example is the 2012 Waikiki Beach Restoration Project, which restored 1,700 feet of shoreline with 27,000 cy of sand recovered from offshore at a total cost of $2.4 million, or about $90 per cubic yard of sand. This includes project planning, permitting, construction, and monitoring. The project was funded through a public-private partnership between the DLNR, the Hawaii Tourism Authority, and Kyoya Resorts. Tens of thousands of cy of sand have been placed in smaller private beach restoration projects on Kauai, Oahu, and Maui using both land-based and offshore sand sources with a wide range of costs. “Beach-quality” sand purchased from private suppliers can cost $100 or more per cubic yard (Romine et al 2015).

As mentioned, beach-quality sand is in short supply for restoration projects in Hawaii. Large-scale sand recovery and stockpiling projects could take advantage of economies of scale, which smaller projects cannot afford. Funding is needed for sand recovery, material storage and processing, and to subsidize transport and placement of sand in cost-shared beach restoration projects.

Mined inland sand can be of similar cost, especially if the sand needs to processed/washed. Sand in mainland projects can be an order of magnitude less expensive. Sand costs could be reduced by economies of scale, i.e., by recovering larger amounts of sand with each mobilization. Much of the cost of offshore sand comes from mobilizing boats and dredge equipment. There is a lot of discussion among local federal, state, and county beach management agents about recovering a large volume of sand ($100K cubic yards +) for stockpiling for future projects.
### 11.6 Challenges: Funding

There are numerous potential sources of funding for beach nourishment, but the key to this statement is “potential,” because funding is quite limited especially from government sources.

The Federal Standard is the key federal regulation that affects the ability of the USACE to contribute to local beach nourishment programs with dredged material from channels in ports and harbors. The Federal Standard directs the USACE to select the least-cost environmentally acceptable plan (i.e., the base plan) for disposal of dredged material. In most cases, disposal of dredged material at an approved ocean disposal site is less expensive than transporting to a beach nourishment project. The Federal Standard is a budget management tool, the result being that the incremental cost above the base plan to use the dredged material in a beneficial manner (e.g., beach nourishment) has to be paid by local sponsors (USEPA 2007b).

If the least cost environmentally acceptable disposal alternative for dredged material from a federal dredging project is beach nourishment, the federal government will cost share with local sponsors, which could be the state, the county, or private funds, or a combination (USEPA 2007a). A federal cost-share project like this has not yet been implemented in Hawaii. Beach nourishment projects and the cost-sharing that comes with them are governed by a number of WRDA provisions (USEPA 2007b).

As an example of the costs of beach nourishment, using sand from offshore and not from a federal navigation project, Waikiki 2012 restoration cost was $2.4 million for about 27,000 cubic yards. This is $89 per cubic yard, including environmental assessment, planning, permitting, design and construction.

There is not enough local, state, or federal funding to support beach management and restoration in Hawaii. State and local funding sources are quite limited; they include:

- DLNR Beach Fund
- Special Tax Districts: e.g., Waikiki Beach Special Improvement District
- Legislative Capital Improvement Project allocations
- County allocations

The State of Hawaii manages a Beach Restoration Fund (Hawaii Statutes 2015) via the DLNR. The beach restoration fund may be used for planning, designing, development, or implementation of beach restoration projects.

The Fund provided $1.5 million to the 2012 Waikiki Beach Restoration Project, but the Fund does not receive sufficient funds to meet statewide needs for beach restoration. Revenue into the Fund is from a number of sources, including coastal land use applications, proceeds from leases of public lands, fines, easements, appropriations from the legislature, and a portion of a state Transient Accommodation Tax.

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24 Emphasis upon alternate and innovative sources of funding is presented in this section because traditional sources of funding for beneficial use are diminishing, in particular federal funding.

25 Hawaii HB 444, passed June 16, 2015, authorizes the use of transient accommodations tax revenues for a beach restoration and conservation special fund. The bill was enacted to effectively develop and implement plans to slow the degradation of Hawaii’s beaches; as well as to restore beaches through the coordination of activities involving the counties and the formation of public-private partnerships. The legislation expands the uses of the beach restoration fund to allow the Department of Land and Natural Resources to include studies about the effect of sea level rise when developing beach conservation plans.
Special tax districts are likely to be the most effective approach to shoreline management and beach erosion given that insufficient federal and state funds exist for these needed actions, especially in view of sea level change and climate change. In May 2015, Honolulu Mayor Kirk Caldwell signed two bills that establish a new Waikiki Improvement District to focus exclusively and help pay for the maintenance and restoration of Waikiki Beach. Property and business owners in Waikiki will be required to pay into the District under Bills 81 (2014) and 82 (2014) (Star Advertiser website). The Waikiki Beach Special Improvement District could serve as an example for other communities to develop funding for beach restoration projects.

- A Special Improvement District is a defined area in which specified property owners pay assessments to fund projects within the area that are supplemental to government services. Special Improvement Districts are among the most effective ways of forming and funding public-private partnerships to muster resources to tackle especially complicated challenges. A Special Improvement District focused only on saving Waikiki Beach harnesses the resources of the private sector to partner with government in this effort.

- All of Waikiki from the Ala Wai Harbor to Kaimana Beach and from the Ala Wai Canal to the submerged lands and coastal water 150 feet makai of the shoreline are included in the Waikiki Special Improvement District. There is no one isolated part of Waikiki Beach that acts on its own; it is all one marine coastal system and must be addressed comprehensively and over the long term. Additionally, all property owners in Waikiki benefit from a world-class Waikiki Beach and the more property owners within the Special Improvement District, the more the overall private sector contribution to saving Waikiki Beach is distributed around and the lower the assessment for each owner.

- The Special Improvement District covers all Waikiki properties zoned or utilized commercial (not residential) as those properties have the most direct economic benefit from a world-class Waikiki Beach. There are over 6,500 such parcels and they would be assessed a portion of the total Special Improvement District budget every year based on tax assessed value so that the more valuable parcels pay a higher proportion of the overall assessments. With a proposed annual budget of $600,000, parcel assessments (at 7.63 cents for every $1,000 of assessed value) would range from tens of thousands of dollars per year for the large beachfront parcels to under a hundred dollars for the smaller off-beach parcels.

- The only specified projects in the ordinance are to develop a comprehensive Waikiki Beach Management Plan, retain a project manager to oversee development and implementation of the plan, and provide a required private sector match to an already approved and publicly funded Royal Hawaiian groin replacement project. That particular groin is in imminent danger of collapsing, in which case the entire beach on the Diamond Head side of the groin is in danger of disappearing. (Waikiki Improvement Association website).

Another example of a public-private partnership is the Kaanapali Beach Restoration Project. In October 2014, Governor Neil Abercrombie released $400,000, which will be matched by the same amount by the Kaanapali Operations Associations, to plan and design a beach renourishment project for Kaanapali Beach. The project calls for replacing about 50,000 cy of sand from near offshore locations to enhance about 3,200 feet of Kaanapali Beach. The tentative beach nourishment plan, which is subject to an environmental impact statement, is to dredge sand offshore of the beach, to put it on a barge, and to bring it ashore. When completed, the cost of nourishment is estimated to be $7.5 million (Mauitime website).
The state does not currently have a funding source to support SSBN projects. Larger state projects have been funded through Legislative capital improvement project (CIP) requests and/or through the DLNR-OCCL “Beach Fund.”

Potential local sources of funding are numerous, but in reality are quite limited as many require legislation (e.g., a Capital Improvement Project allocation), prioritized expenditure from limited government “special funds,” such as the DLNR Beach Fund, or funds from special tax districts (e.g., Waikiki Beach Special Improvement District). SSBN projects have typically been funded through private means or through local government agencies (e.g., county parks departments). There are notable successes such as the sand pushing project at Sunset Beach-Rocky Point (North Shore, Oahu), which is authorized by DLNR but funded by private landowners; county agencies frequently pay for beach maintenance (e.g., Kailua, Makaha, Ehukai) and beach nourishment (e.g., Poipu and Kapaa). Maui County has a recent proposal for a beach nourishment feasibility study for Kahana, Maui.

The list of potential county and local sources of funding are summarized in Table 18, presented by Andrew Wycklendt of CB&I during the 2014 Hawaii Shore and Beach Preservation Workshop (Wycklendt 2014).

**Table 18. Potential local sources of funding for beach nourishment projects. Credit: Wycklendt 2014.**

<table>
<thead>
<tr>
<th>ALTERNATIVE</th>
<th>DESCRIPTION</th>
<th>ESTABLISHMENT</th>
<th>PROS</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ad Valorem Tax</td>
<td>Uniform Property Tax</td>
<td>Budgetary Process</td>
<td>Existing authority</td>
<td>No continuous source; poor management; competition</td>
</tr>
<tr>
<td>3. Independent Special Taxing</td>
<td>Independent Gov’t established by Legislation to</td>
<td>By act of Legislature</td>
<td>Continuous source of funds</td>
<td>New government added - not favored by Legislature; voter dependent</td>
</tr>
<tr>
<td>4. Dependent Special Taxing</td>
<td>Ad Valorem tax collected and administered by the</td>
<td>By act of Legislature</td>
<td>Ability to fund projects</td>
<td>Limited by total County capital subject to political climate</td>
</tr>
<tr>
<td>5. Erosion Prevention Taxing</td>
<td>A dependent taxing district collecting property</td>
<td>Established by County</td>
<td>Existing authorization; benefit zones can</td>
<td>Included in total County millage cap; politically affected</td>
</tr>
<tr>
<td>6. Municipal Service Taxing</td>
<td>Taxing Unit (MSTU)</td>
<td>Taxing Unit</td>
<td>Existing authorization; not project limited</td>
<td>Project limited; difficult to establish</td>
</tr>
<tr>
<td>7. Municipal Service</td>
<td>Special assessments of benefitted properties</td>
<td>Petitions of majority of</td>
<td>Existing authority; no competition with</td>
<td>Non-continuous source; time delays; confined to projects; poor tool for management/ planning</td>
</tr>
<tr>
<td>8. Bonding</td>
<td>Selling bonds to create revenue - bond retired by</td>
<td>Referendum</td>
<td>New revenue covers large initial costs</td>
<td>Non-continuous source; time delays; confined to specific projects; poor tool for management/planning</td>
</tr>
<tr>
<td>9. Private Funding</td>
<td>Donations</td>
<td>By mutual agreement</td>
<td>Addresses needs of private property</td>
<td>Not practical for countywide funding</td>
</tr>
<tr>
<td>10. Parking Meters and Park Feed</td>
<td>User Fees</td>
<td>Locally initiated</td>
<td>User benefits = pay</td>
<td>Private benefit is not assessed; limited funding</td>
</tr>
<tr>
<td>11. Beach Management</td>
<td>Larger government spanning a number of Counties</td>
<td>State Legislature</td>
<td>Stable funding source; larger tax base;</td>
<td>Funds may be disproportionately used</td>
</tr>
<tr>
<td>12. Districts (Regional)</td>
<td>with property taxing authority</td>
<td></td>
<td>politically motivated</td>
<td></td>
</tr>
</tbody>
</table>
11.7 Challenges: Environmental Permitting for Beach Nourishment Projects

The report from the 2014 Hawaii Shore and Beach Preservation Workshop (Hawaii 2014) indicates that as many as seven different permits are presently required for a beach restoration project. These include:

1. A Conservation District Use Permit (CDUP) or SSBN Permit from DLNR;
2. A county SMA permit / Shoreline Setback Variance;
3. Right-of-Entry from DLNR and/or county;
4. A Federal Coastal Zone Management Act (CZMA) Consistency Assessment administered by the State Office of Planning, Coastal Zone Management Program;
5. A CWA Section 404 Permit from USACE;
6. A CWA Section 401 Water Quality Certification (WQC) from CWB; and
7. A National Pollutant Discharge Elimination System (NPDES) permit from the Hawaii Department of Health, Clean Water Branch.

The two permits required under the CWA to restore a beach in Hawaii are:

1. A CWA Section 404 permit for any work, including construction and dredging, in the Nation’s navigable waters – administered by USACE’s, Regulatory Branch, Honolulu (USACE Honolulu District website).
2. A CWA Section 401 WQC is a requirement under USACE’s Section 404 Permit Program and is administered by CWB. The WQC is a “statement of reasonable assurance that the construction activity will comply with the applicable provisions of the state’s water quality standards. Construction activities include dredge- and-fill work in our nearshore waters and inland waters.”[Hawaii Department of Health website].

As discussed earlier in this section, the 401 certification that water quality standards will not be violated by a beach nourishment project is not a simple issue; it is complicated by the Hawaii regulations that specify sand as a pollutant and the questions regarding whether placing sand on a beach will cause unacceptable impacts on nearby coral reefs.

While beach restoration is a positive outcome creating habitat for a wide range of species, including recreation opportunities for humans, environmental concerns regarding potential impacts to offshore reefs, benthic organisms, and water quality need to be addressed. Larger projects need to follow National Environmental Policy Act (NEPA) procedures, including preparation of an Environmental Assessment or an Environmental Impact Assessment (regulations for environmental assessments are State HRS 343) (Hawaii HRS 343). For small-scale projects, a Programmatic Environmental Assessment has been used and is in the process of being updated.

The State of Hawaii Coastal Lands Program supports restoration of beach and dune ecosystems through the SSBN application program. The SSBN program provides a viable alternative to shoreline hardening through development and enhancement of beach restoration programs—encouraging landowners to consider beach restoration over hard shoreline armoring.

- The SSBN program provides a streamlined application process for beach restoration projects within the DLNR under a programmatic Conservation District Use Permit and Environmental Assessment.
- SSBN authorizations allow placement of compatible beach sand within the State Conservation District and may be submitted under one of two Categories: SSBN Category I – (up to 500 cy of sand), or SSBN Category II – (up to 10,000 cy).
The Department will be exploring the possibility of an agreement with USACE, Department of Health, and Coastal Zone Management Program to reestablish a streamlined inter-agency programmatic permit for SSBN projects following the expiration of a similar programmatic agreement in 2010. This is anticipated to take place over the next few years, beginning with the development of a statewide programmatic environmental assessment in 2017.

11.8 Findings and Next Steps: Conclusions from the Beach Restoration Workshop

To improve the viability of beach restoration of Hawaii's beaches, the 2014 Workshop on Beach Restoration in Hawaii, Challenges and Opportunities, provided the following suggestions:

- The permitting process is time-consuming and too expensive for many projects. The Workshop suggested that improvements to the State 401 Certification Process and updating the State Programmatic Agreement for small projects should be a priority.
- Funding sources should be identified for support of beach conservation, restoration, and coastal land use planning.
- A proactive regional approach to beach management and restoration should be led by DLNR-OCCL and funded through partnership between government and local stakeholders. Innovative public-private partnerships have proven successful in recent state-led beach restoration projects and should serve as models for future projects.
- Large-scale sand recovery and stockpiling projects can take advantage of economies of scale, which smaller projects cannot afford. Additional studies are needed to assess availability and quality of onshore and offshore deposits of sand supporting large-scale recovery efforts.
- Further research is needed to better understand the potential impacts of beach restoration projects upon corals and nearby coastal waters to inform BMPs and monitoring guidelines.

11.9 References for Beach Restoration and Nourishment: Lessons Learned, Challenges, and Next Steps


Hawaii Revised Statues, Title 12, Conservation and Resources 171. Public Lands, Management and Disposition of 171-156 Beach Restoration Special Fund. 2015.


Podoski, Jessica, Personal communication, October 13, 2016.

Romine, Bradley; Conger, Chris; Eversole, Dolan; and Guannel, Greg; Beach Restoration in Hawaii, Outcomes from the Hawaii Beach Preservation Association 2014 Hawaii Beach Restoration Workshop; April 17, 2015.


Wycklendt, Andrew, CB&I, Local and Federal Funding for Mainland Beach Restoration Projects, Presented during the 2014 Beach Restoration Workshop; Sponsored by the Hawaii Shore and Beach Preservation Association; November 24, 2014.
Beaches are the economic lifeline, a major driver of the economy in Hawaii, significant to the people of Hawaii’s way of life, and a key attraction for tourism. Ensuring that beaches are available is important not only to Hawaii residents but to the 7 million tourists visiting Hawaii each year. Also important to Hawaii residents is where they live, work, and play. Many homes, commercial properties, industrial facilities, and infrastructure, such as roads, have been built too close to eroding beaches and shorelines.

In comparison to other hazards, such as flooding, coastal erosion is particularly challenging for governments and communities to manage and recover from because it results in permanent land loss. Attempts to control shoreline erosion can accelerate erosion on adjacent beaches and impact coastal environments. All levels of government (i.e., federal, state, county, and local), academia, interest groups, and stakeholders are involved depending upon the specific issues related to erosion, loss of beaches, and shoreline recession. Research by Anderson et al. (2015) finds that rates of historical erosion are likely to double by mid-century. The State, through the DLNR, Interagency Climate Adaptation Committee and University of Hawaii, is looking beyond existing hazards and assessing how sea level rise will increase the extent and severity of coastal erosion in Hawaii for a statewide Sea Level Rise Vulnerability and Adaptation Report (State Act 83, 2014; due December 2017). The answers to these growing challenges are extremely complex, including managing and mitigating the:

- Loss of public beaches and shoreline access;
- Loss of natural coastal environments;
- Loss of public and private coastal property;
- Cultural impacts;
- Socio-economic impacts; and
- Impacts to critical infrastructure.

Appropriate responses to address coastal erosion vary from one shoreline area to the next. Appropriate measures can also vary substantially among agencies and communities.

There have been state and county laws and regulations since the 1970s that aim to protect beaches and beachfront properties from the effects of erosion, including state Coastal Zone Management policy (Hawaii DLNR 205A), state Conservation District rules, and county policies. In spite of these rules and policies, Hawaii has a legacy of dense development built too close to eroding shorelines in many coastal communities.

Some laws, regulations, and their implementing guidance have been updated recently to reduce erosion hazard exposure. Examples include adoption of erosion-rate-based shoreline construction setback policies on Kauai, Maui, and for state conservation district areas. Setback rules work best for undeveloped or re-developed properties; addressing issues of existing developed properties built too close to the shoreline is a major challenge, without sufficient options. For the most part, government officials at the state and county level understand that eroding beaches and shorelines threaten the financial health of those property owners. However, agencies are required to balance concerns about public health and safety with requirements to conserve beach and marine resources in the public trust. Local government agencies approved those locations for structures to be built, without proper consideration or understanding of the risks from shoreline erosion. Historically, the typically response by
government agencies has been approval to install seawalls, revetments and other coastal armoring
structures. In recent decades, science and understanding of negative impacts of coastal armoring has
increased and agencies have generally only approved coastal armoring as an option of last resort.

The government management system in Hawaii addressing coastal erosion includes all levels of
government. However, the lack of an integrated coastal management program adds to the challenges of
shoreline management in Hawaii with multiple overlapping state, federal, and county jurisdictions at the
shoreline.

There are no easy answers to these issues, and challenges for agencies charged with coastal
management in Hawaii will only increase with increasing erosion and flooding from sea level rise.

Integrated coastal planning and management is an important step in this direction, preparing long-term
plans for shoreline management. Actively involved are stakeholders and academia; in particular, the
University of Hawaii’s Coastal Geology Group and the University of Hawaii Sea Grant College Program
are integral to understanding the science of erosion and looking to the short and long-term effects of
sea level rise. Other active groups include the Hawaii Shore and Beach Preservation Association,
Surfrider Foundation, Sierra Club, and various homeowner groups.

12.1 Federal Government

The primary federal agency in Hawaii addressing erosion and related shoreline management issues is
USACE. USACE maintains the depth of navigation channels in Hawaii in 15 ports and harbors.
Maintenance of those channels includes construction and maintenance of breakwaters and similar
structures, as well as dredging accumulated sediments. USACE also has a mission for coastal storm
damage risk reduction.

The primary federal laws providing USACE authority and direction for these activities include the Rivers
and Harbors Act of 1899, the CWA, and the Marine Protection, Research, and Sanctuaries Act (MPRSA).
These laws and the implementing regulations include permit conditions for construction of structures in
or adjoining navigable waters, and permit conditions for dredging and disposal of dredged material. A
number of federal laws also apply to these activities, such as NEPA, CZMA, and the ESA.

EPA is integrally involved with USACE in permitting of dredged material and managing the disposal
locations; EPA has a concurrence role in permits for disposal of dredged material in ocean waters under
the MPRSA, and for disposal in inland waters or placement along the shoreline for beneficial use, EPA
has a veto role in permits. EPA can add conditions to permits. The State of Hawaii Department of Health
can also add conditions to the permit through the CWA water quality certification (i.e., CWA section
401) requirements. The state has responsibility to assess proposed projects to ensure that the dredged
material disposal or the placement of dredged material on a beach for nourishment will not result in
violations of state water quality standards. Issuance of the CWA 404 permit for disposal or beach
nourishment cannot be issued without the State-administered CWA 401 certification.

The federal CZMA was passed in 1972. The objectives provide for management of the nation’s coastal
resources, and the Act is administered by NOAA, through the states. The goal is to “preserve, protect,
develop, and where possible, to restore or enhance the resources of the nation’s coastal zone.” (NOAA
CZMA website) One of the state roles in beach federal dredged material disposal or placement is to
ensure that the proposed activities are consistent with the state’s CZM program. Thus, a consistency
determination by the state Office of Planning – Coastal Zone Management Program is needed for major
projects to go forward.
The ability of USACE to contribute to local beach nourishment programs with dredged sediments from channels in ports and harbors is directly related to the “Federal Standard.”

- The Federal Standard is defined in USACE regulations as the least costly dredged material disposal or placement alternative (or alternatives) identified by USACE that is consistent with sound engineering practices and meets all federal environmental requirements, including those established under the CWA and the MPRSA (see 33 CFR 335.7, 53 FR 14902).
- The term “base plan” is a more accurate operational description of the Federal Standard, because it defines the disposal or placement costs that are assigned to the “navigational purpose” of the project. The costs assigned to the navigational purpose of the project are shared with the non-federal sponsor of the project, with the ratio of federal to non-federal costs depending on the nature and depth of the project.
- In many or likely most cases, disposal of dredged material at, for example, an EPA-approved ocean disposal site, is less expensive than transporting to a beach nourishment project for placement directly on the beach or in the littoral zone near the beach. The Federal Standard requires that the incremental cost above the base plan must be paid by local sponsors (EPA 2014b).

As discussed in Section 10, the USACE’s regional sediment management program is intended to integrate coastal sediment management across federal, state, and local jurisdictions, to evaluate projects in a systems approach, and to incorporate the principles of engineering with nature.

Other federal agencies having shoreline management roles include NOAA, FEMA, USGS, and U.S. Fish and Wildlife Service (FWS). NOAA has a mandate to establish the official shoreline boundary for the nation with an emphasis on safe navigation generating nautical charts, and assisting agencies in delineating shorelines for a variety of purposes. Congress authorized and funded FEMA to report on the economic impact of erosion hazards on coastal communities, and on claims to the National Flood Insurance Fund. To accomplish this goal, FEMA contracted with state agencies and academic researchers to conduct a pilot study of erosion hazards that included shoreline change data for limited geographic areas. USGS conducts research pertaining to coastal change hazards, understanding the processes that cause coastal change, and developing models to predict future change (Fletcher et al 2012). FWS and NOAA ensure that shoreline management, including beach nourishment, are conducted in a manner that does not affect threatened or endangered species or essential fish habitat.

### 12.2 State Government

The DLNR Office of Conservation and Coastal Lands (OCCL) is responsible for regulation and management of beaches and shoreline and submerged areas from the edge of the county jurisdiction (certified shoreline, see below) out to the three-mile limit of the State’s jurisdiction. This area is called the Conservation District, and also includes other protected coastal property, such as watersheds, forested areas, and parklands. Significant land uses within the Conservation District require a Conservation District Use Permit and approval by the Department of Land and Natural Resources.

Erosion and related shoreline management is coordinated through the Coastal Lands Program at the OCCL with ongoing partnerships with the University of Hawaii Sea Grant Program and School of Ocean and Earth Science and Technology. The CZM Program in the Office of Planning is responsible for oversight and funding of the county-administered CZM program for regulation and management of the Special Management Area landward of the DLNR’s jurisdiction. In practice, DLNR handles all the day-to-day shoreline and erosion management in the state. State CZM is more involved in long-range coastal and ocean resource management planning and inter-agency coordination through county-administered
CZM policy. However, the DLNR is presently leading the development of a statewide Sea Level Rise Vulnerability and Adaptation Report, in partnership with the Office Planning, for the Hawaii Climate Adaptation Initiative. In addition, the Department of Health, Clean Water Branch is responsible for issuing or denying CWA Section 401 water quality certification.

The DNLR, Department of Accounting and General Services, Land Division manages state-owned lands to promote the social, environmental, and economic well-being of Hawaii’s people and for ensuring that these lands are used in accordance with the goals, policies and plans of the state. Lands that are not set aside for use by other government agencies come within the direct purview of the division. These lands are made available to the public through leases, licenses, grants of easement, rights-of-entry, month-to-month tenancies, or kept as open space area (Hawaii Land Division website).

Certified Shorelines. The DLNR Land Division, in partnership with the Department of Accounting and General Services (DAGS) Land Survey Division, manages the Shoreline Certification Program. The purpose of the certified shoreline is to provide the baseline for measuring shoreline setbacks. The certified shoreline also establishes the jurisdictional boundary between the State Conservation District and the County SMA. The shoreline certification plays an important part in ensuring that new development is not located in a coastal hazard area. The certified shoreline is also important in preserving access to Hawaii’s shorelines. In Hawaii, the right of transit (i.e., access) exists seaward of the shoreline and that area is defined as a beach transit corridor (Hawaii Revised Statutes §115-5). The shoreline certification process also assists state and county regulatory agencies in resolving shoreline issues such as encroachments, violations, unauthorized land uses, and unauthorized shoreline structures.

As defined in regulations and shown in Figure 113 and Figure 114, “Shoreline means the upper reaches of the wash of the waves, other than storm or seismic waves, at high tide during the season of the year in which the highest wash of the waves occur, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves.” (Randall and deBoer 2012) (DNLR Regulations).

![What is the Certified Shoreline?](image)

"Shoreline" means the upper reaches of the wash of the waves, other than storm or seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves.

Figure 113. Identification of the certified shoreline for a particular beachfront is done by the Hawaii DNLR Lands Division.

Credit: Andy Bohlander, University of Hawaii Sea Grant College Program DLNR Office of Conservation and Coastal Lands, Coastal Data Exchange workshop 2014.
In October 2006, the Hawaii Supreme Court issued a ruling strongly reaffirming that the shoreline in Hawaii, which marks the boundary between public beach and private land (i.e., county jurisdiction), extends to the highest wash of the waves, and rejecting the use of artificially planted vegetation to determine the shoreline.

The court ruled that the vegetation line trumps the debris line only when the vegetation line lies "more mauka" (inland) than the debris line and furthers the public policy of extending to public ownership and use "as much of Hawaii's shoreline as is reasonably possible." (Hawaii CZM Program website) (Beachapedia website)

Figure 114. The blue line represents the certified shoreline, which is the boundary between the state and county jurisdictions for beach and shoreline management.


Coastal Erosion Management Plan. In partnership with the University of Hawaii, the Coastal Lands Program produced the Coastal Erosion Management Plan (COEMAP) in 1999, providing guidelines and planning approaches for beach and dune protection, management, and restoration. Encouraging science-based decision-making, the Coastal Lands Program uses the COEMAP as guidance in assessing erosion issues including BMPs, erosion control, and construction practices (Hawaii Coastal Lands Program website).
Small Scale Beach Nourishment Program (SSBN). The Coastal Lands Program at the DLNR-OCCL also administers the SSBN Program for restoration of beach and dune ecosystems, which provides an alternative to shoreline hardening. Two categories are included: Category I is up to 500 cy of sand and Category II is up to 10,000 cy of sand. Currently, SSBN applicants are required to get addition permits and certifications from the USACE and State Department of Health if they wish to place sand below the high water line. Beach nourishment projects generally need to place sand across the beach profile, including submerged areas, to be the most effective at restoring a beach.

The DLNR-OCCL Coastal Lands Program is initiating a project in 2017 to update a programmatic environmental assessment for SSBN projects statewide, with the eventual goal of streamlining the permitting process for beach restoration in Hawaii. This may include reestablishing a Programmatic Inter-agency Agreement for small-scale restoration projects between the Department of Health and USACE, similar to an agreement that expired in 2010. The objective is to streamline the permit process by consolidating permitting and environmental review oversight under the Coastal Lands Program (State of Hawaii 2014) and provide a general set of guidelines and pre-approved best management practices for SSBN projects.

Coastal Zone Management Program. The Office of Planning implements the CZM Program (Hawaii DLNR 205A) with the goal to “preserve, protect, develop, and where possible, to restore or enhance the resources of the nation’s coastal zone.” The Program was initiated with the 1975 Coastal Protection Act, and is supported by the national Coastal Zone Management Act of 1972, administered by NOAA. The State CZM program is not a regulatory agency in Hawaii. They administer the CZM program (and funding) through the county planning departments, which also provide Special Area Permits.

State CZM provides CZMA consistency determinations for certain types of projects. CZMA, Section 307, requires federal agency activities and development projects affecting any coastal use or resource to be undertaken in a manner consistent to the maximum extent practicable with the state’s CZM program. Also, activities requiring a federal permit or license, and activities conducted with federal financial assistance, that affect coastal uses and resources must be conducted in a manner consistent with the state’s CZM program. The CZMA federal consistency provision ensures that federal agencies cannot act without regard for, or in conflict with, state policies that have been officially incorporated into a state’s COEMAP

Goals for Improvement of the Erosion Management System in Hawaii

1. Promote consistent and uniform policy of erosion management at the state level.
2. Consider erosional trends and process and other coastal hazards, at the zoning and subdivision stages of land development.
3. Implement beach and dune restoration with sand nourishment as a viable management option.
4. Implement a continuous source of scientific data and research to assist in addressing management decisions on erosion hazards.
5. Create and maintain a continuous public education and awareness campaign.
6. Establish coastal land acquisition programs.
7. Develop a technical guidance manual for development, restoration, and redevelopment of the coastline.

COEMAP also includes 20 detailed recommendations to improve erosion control and 21 specific implementation steps. See http://dlnr.hawaii.gov/occl/files/2013/08/COEMAP1.pdf.
CZM program. Federal actions affecting any coastal use or resource must be reviewed by the state CZM program to ensure that proposed activities are consistent with state enforceable policies. The federal consistency procedures and requirements are established in the Code of Federal Regulations, 15 CFR 930 (Hawaii Office of Planning CZM website).

One of the key elements of the Coastal Zone Management Program is the issuance of Special Management Area Management Permits through the county planning departments. SMAs include the shorelines generally extending inland to the nearest highway. The objectives of SMA permits are summarized as follows:

“....special conditions on developments within an area along the shoreline are necessary to avoid permanent losses of valuable resources and the foreclosure of management options, and to ensure that adequate access, by dedication or other means, to public owned or used beaches, recreation areas, and natural reserves is provided.”

The SMA permit regulates permissible land uses that are already allowed by land use policies including zoning designations, county general plans, and community development plans; permits are issued by counties. One example is that the SMA permits implement the state’s required minimum setback distance of 40 feet for community development districts from the certified shoreline (Hawaii DBEDT 2012). Counties have the authority to increase that setback distance and set zoning restrictions to account for local conditions.

Hawaii’s Coastal Zone Management program, enacted in 1977, discourages and in some cases prohibits shoreline armoring. Hawaii Revised Statutes Chapter 205A, Part I, Section 205A-2(9), states:

(9) Beach protection

   (A) Locate new structures inland from the shoreline setback to conserve open space, minimize interference with natural shoreline processes, and minimize loss of improvements due to erosion;

   (B) Prohibit construction of private erosion-protection structures seaward of the shoreline, except when they result in improved aesthetic and engineering solutions to erosion at the sites and do not interfere with existing recreational and waterline activities; and

   (C) Minimize the construction of public erosion-protection structures seaward of the shoreline.

Although federal lands are administratively excluded from the CZM area, federal activities on these lands are subject to federal consistency requirements, i.e., Hawaii COEMAP.

CWA State Water Quality Certification. The Department of Health, Clean Water Branch issues or denies CWA Section 401 water quality certification for any project/activity that requires a federal license or permit and may result in a water pollutant discharge to state surface waters. The 401 certification is a requirement under CWA Section 404 that must be received by any dredging or beach nourishment project. More information is included in Section 11 on barriers to beach nourishment.

Potential Tools and Approaches to Address Loss of Beaches in View of Sea Level Rise. To address the on-going issues of erosion and shoreline management, the governance actions summarized in this section are critical. Those may not be enough to address the challenges of climate change and sea level rise along the shorelines of Hawaii and the resulting erosion and loss of beaches. Creative solutions will likely be needed to manage the shorelines, finding ways to preserve existing beaches or to purchase developed land such that the sand dunes are once again available to naturally nourish beaches. It is important that coastal lands are sand-rich so that continued shoreline retreat will release these sands to the beach. Rock or clay uplands are less likely to be successful beach locations.
under higher sea level. A list of possible approaches for state and local governments (Fletcher et al. 2010) is shown in the text box.

**Future Beaches: Purchasing sandy land where beaches are wanted. Alternative approaches (Fletcher et al. 2010):**

- Reverse mortgages offered by the State and funded by general obligation bond issues. Owners would turn over their homes at the end of a fixed period of payments or upon their passing, the property becomes state property.
- Authorities implement a series of increasingly restrictive code or rule updates (e.g., upgrades to building codes, paving codes, electrical or plumbing codes) that reflect the growing liability of the location given sea level rise, and which ultimately drives the owner to seek new locations – perhaps aided by a government assistance program.
- Homeowner donation program.
- Tax relief for businesses or families in exchange for later transfer of coastal property to a local government.
- Transferable development rights for businesses.
- Country, state, and federal land conservations funds.
- Land swaps of upland lands for prime coastal lands.
- Conservation easements that pay owners to manage their land for the environment.
- Set asides of fees generated by coastal properties to fund purchase of prime coastal lands, e.g., real estate transfer tax, coastal property tax, local business proceeds, land lease fees.
- Agreements for unpermitted vacation rentals, or other nonconforming uses, to operate for some period of time after which the property is turned over to the state or county, or sold to the state or county at some reduced percentage of market value.
- A buyout program for properties that are in imminent danger of erosion. Eroded properties are not worth full market value – the program would provide some reduced percentage of market value.
- A new revenue stream for property buyouts – could be tied to coastal activities or carbon footprint.

### 12.3 County Government

In Hawaii, each county defines unique zoning and setback regulations for coastal development based on the position of the certified shoreline. Most (not all) counties apply a minimum 40-foot setback zone from the certified shoreline where development is prohibited. Generally, the state is responsible for regulation of the area from the certified shoreline seaward to the 3-mile offshore limit of the state’s jurisdiction, often referred to as the Conservation District. Likewise, each county regulates the area from the shoreline landward in a SMA. Both the Conservation District and the SMA have restrictions on the type of activities that are allowed within this area based on HRS 205A (Coastal Zone Management Act) and other state and county rules and policies.

Under state legislation, Chapter HRS 205A, the four counties are required to establish a “shoreline area” with setbacks no less than 20 feet and no more than 40 feet inland from the shoreline wherein no development is allowed. The law also allows counties to establish ordinances creating setbacks greater than 40 feet, and to extend jurisdiction over the shoreline area seaward to the mean sea level (COEMAP 1997).
Unique to Hawaii, HRS 205A grants individual counties with regulatory authority over designated areas of concern, SMAs. The SMA theoretically represents the most sensitive area of the coastal zone. From a spatial context, the SMA generally extends from the shoreline inland to the nearest highway. Within the SMA, the counties have established rules that govern the immediate shoreline area, such as shoreline setbacks and procedures for variances (Owens et al. 2012). The county authorities that administer SMA permits and shoreline setback provisions are as follows:

- City and County of Honolulu: Honolulu City Council
- County of Hawaii: Windward or Leeward Planning Commissions
- County of Maui: Maui, Molokai, or Lanai Planning Commissions
- County of Kauai: Kauai Planning Commission

Relevant County permitting requirements for erosion and shoreline management projects include:

1. SMA permits (minor and major)
2. Shoreline Setback Determinations
3. Shoreline Setback Variances
4. Repair and Maintenance Permits
5. Right-of-Entry permits

### 12.4 County Government—County of Kauai

Erosion and shoreline management are not new issues in Kauai. The 1990 Kauai Shoreline Erosion Study findings and recommendations are similar to those being recommended today (DHM et al. 1990).

- In general, non-structural remedies (zoning, setbacks, development regulations, etc.) are preferable to structural remedies (seawalls, revetments, offshore structures, etc.). Not only can the non-structural approaches be adjusted should new information regarding patterns or rates of erosion come available, but the “hardening of coastlines” is a problem which has been long recognized.
- Where structural remedies are absolutely necessary, buried revetments and beach nourishment are preferred methods of shore protection. Actions which are “proactive” rather than “reactive” are also preferable and any new actions need to take account of both the long term, possibly cyclical aspects of erosion as well as the economic life of any building, dwelling, or facility built on the shoreline.
- Finally, this report brings attention to the importance of beach preservation, recognizing that dynamic beach systems are not only a basic aspect of the island’s morphology, but also, an important, unique, and valuable resource, which must be preserved.

The County of Kauai made headlines in 2008 when it adopted some of the most, if not the most, stringent setback rules in the United States. The rules did not come easy, as many studies and hard discussions preceded the adopted rules. The 1990 Kauai Shoreline Erosion Management Study provided an in-depth look at the Kauai shorelines with numbers of recommendations for beach and shoreline management. Setback standards were one of those recommendations (DHM et al. 1990).

The County of Kauai adopted setback standards in 2008, and amended them in 2009 and 2014. The objective of the Shoreline and Setback Coastal Protection Ordinance is to reduce the impact of coastal erosion and hazards to property, life, and coastal resources, and to avoid shoreline armoring.
Figure 115. Ordinance No. 863.

Ordinance Number 863 established two standards for a setback determination based on average lot depths, building footprints, and annual erosion rates (NOAA OCRM website). Ordinance 863 was amended in December 2014 by Ordinance 979. In passing Ordinance 979, the County Council stated that (Kauai 2014):

> The Council finds that the shoreline environment is one of Kauai’s most important economic and natural resources. Beaches, dunes, and offshore topographic features also help to minimize risks from coastal hazards by dissipating wave energy, which could otherwise cause significant damage to coastal property. Beaches provide important habitat for seabirds, turtles, monk seals, and other animals and plants. In all of the above-mentioned ways, beaches and coastal areas are part of the public trust, and it is government’s fiduciary responsibility to protect beaches and coastal areas.

The June 2014 setback requirements:

1. As shown in Table 19, if a lot's average depth is less than 160 feet, the setback is based on average lot depth. If the average lot depth is 100 feet or less, the minimum setback of 40 feet applies. As the lot depth increases, so does the setback. For every 20-foot increase in average lot depth, the setback increases by 10 feet. Therefore, a lot that is an average of 100 feet deep must be set back 40 feet, a lot that averages between 101 and 120 feet deep must be setback 50 feet, and so on. At the option of the applicant, the setback for lots greater than 160 feet can be determined based upon a coastal erosion study as provided in Table 20.

Table 19. The distance in feet of the shoreline setback as measured from the certified shoreline.

<table>
<thead>
<tr>
<th>If the average lot depth is:</th>
<th>100 feet or less</th>
<th>101 to 120 feet</th>
<th>121 to 140 feet</th>
<th>141 feet to 160 feet</th>
<th>161 feet to 180 feet</th>
<th>181 to 200 feet</th>
<th>More than 200 feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Then the minimum setback is:</td>
<td>40 feet</td>
<td>50 feet</td>
<td>60 feet</td>
<td>70 feet</td>
<td>80 feet</td>
<td>90 feet</td>
<td>100 feet</td>
</tr>
</tbody>
</table>

2. As shown in Table 20, if a lot's average depth is greater than 160 feet, the setback is based on the building’s footprint, which includes decks, pools, and other out buildings, and a coastal erosion study. If the building footprint is less than or equal to 5,000 square feet, the setback distance is 40 feet plus 70 times the annual erosion rate. If the building footprint is greater than 5,000 square feet, the setback distance is 40 feet plus 100 times the annual erosion rate. In no case will the setback distance be less than those in Table 19.
Table 20. Setback determination for lots greater than 160 feet.

<table>
<thead>
<tr>
<th>For structures with a building footprint that is</th>
<th>Less than or equal to 5000 square feet</th>
<th>Greater than 5000 square feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Then the setback distance is</td>
<td>40 feet plus 70 times the annual coastal erosion rate</td>
<td>40 feet plus 100 times the annual coastal erosion rate</td>
</tr>
</tbody>
</table>

Variances to the required setback are allowed. Stringent requirements are set that must be met for a variance to be issued; an administrative process is set including a public hearing and possibly preparation of an Environmental Assessment or Environmental Impact Statement.

12.5 County Government—City and County of Honolulu and County of Hawaii

Both of these counties use the State of Hawaii minimum setback distances for building along the shoreline. The City and County of Honolulu has not adopted erosion-rate based setbacks beyond the 40 state minimum, in part, because much of the shoreline is already developed. Hawaii County has a “minimum” setback of 40 feet. The term minimum is important because it allows them to require greater setbacks. Both the City and County of Honolulu and Hawaii County have negotiable 55-foot setbacks. If a landowner accepts the increased setback above the minimum 40 feet, the county will waive the requirement for a certified shoreline. This practice has been ongoing for the past several years but is not formally stated in their setback policies.

There have been recent state legislative attempts to make erosion-rate based setback policy statewide. However, erosion based setbacks are more complicated for Oahu (Honolulu) due to dense, existing development in many areas. A zone-based approach or construction control line might be other options.

The regulatory regime governing Hawaii’s coastal environment is a complex blend of county, state, and federal jurisdictions set forth in ordinances, statutes, and administrative rules and regulations. The City and County of Honolulu implements the CZM Program, one area of which includes SMAs and managing setback distances for actions along the shoreline. The City and County of Honolulu Department of Parks and Recreation and DLNR-OCCL share management authority for some beaches on Oahu, such as Sunset Beach and Ala Moana Beach Parks, through executive order from the Governor of Hawaii.

The natural forces of erosion, development, and other actions are threatening Hawaii’s beaches and shorelines. What is needed to manage the short term and long-term threats from coastal erosion are holistic (i.e., regional, littoral cell based) management policies and practices. To meet these needs, the Department of Land and Natural Resources, in cooperation with the University of Hawaii Sea Grant Program, has prepared a beach management plan for Kailua. The focus is now more on developing feasibility studies and environmental assessments for beach restoration and improvement projects (e.g., Kaanapali Beach and West Maui and Waikiki).

Kailua Beach, located on the windward coast of Oahu, was selected as a prototype for development of a beach management plan. There are insufficient shoreline construction setbacks to ensure conservation and hazard mitigation over the long term, especially considering projected sea level rise.

Following are highlights of the recommendations of the Kailua Beach Management Plan, including comments on the relevance of these recommendations to future beach management and climate change adaptation plans.
1. **Anticipate the effects of sea level rise** by providing more accurate information on the projected rate and extent of the rising sea level, developing contingency plans for the relocation of infrastructure in low-lying coastal areas of Kailua, and incorporating projected future shoreline locations into the planning and design of new developments within the coastal zone.

2. **Preserve and restore primary coastal dunes** by installing signs and walkovers to provide appropriate pedestrian access, identifying and marking the private and state-owned land boundaries, prohibiting inappropriate grading and fill in the shoreline setback area, and encouraging dune restoration efforts.

3. **Develop more proactive standards for new construction** in the coastal zone by adopting into law the concept of a Coastal Construction Control Line.

4. **Increase public awareness and education** by developing educational materials on beach systems and disseminating this information.

5. **Provide reliable funding and support mechanisms** for management and adaptation planning.

Another ongoing initiative, applicable to the other islands, is the establishment of the Waikiki Special Improvement District. In May 2015, Honolulu Mayor Kirk Caldwell signed two bills that established a new Waikiki Improvement District to focus exclusively and help pay for the maintenance and restoration of Waikiki Beach. Property and business owners in Waikiki will be required to pay into the Special Improvement District. This was discussed in Section 11 of this report.

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**Hawaii’s Eroding Coastline Puts Homeowners and Government at Odds Responding to Eroding Beaches**

Setback ordinances and laws are very contentious, and not without potential legal challenges. For example, beaches are defined going up to the certified shoreline. As erosion continues and the beach moves further inland and the state re-certifies the property line, homeowners might consider that a “taking” and pursue legal remedies (Codiga 2011).

Another conundrum for county governments is where homes have been damaged by erosion and the county allows rebuilding, but does not allow a seawall to be built. The legal question is whether that leaves the county vulnerable to the liability of future damage due to erosion.

*Cocke, Sophie; November 12, 2014.*

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**12.6 County Government—County of Maui**

The Hawaii CZM Program provides Maui County with regulatory control and authority over all development within SMAs and Shoreline Setback Areas (SSA) on each of the islands of Maui, Molokai, and Lanai.

**Special Management Areas.** The purpose of designating and managing SMAs is to regulate any use, activity or operation that qualifies as a "Development," and that may have a significant adverse environmental or ecological effect within the SMA. This provides a means to preserve, protect, and where possible, restore the natural resources of the coastal zone of Hawaii by establishing special controls on development within the area along the shoreline.

Once a determination is made as to whether a proposed activity and/or structure is a development or not a development, the Maui Planning Department evaluates the proposed action to determine if it is exempt from SMA rules (Maui SMA Rules) or requires a Major, Minor, or Emergency SMA Permit. Typically, the SMA evaluation considers impacts to the environment, historic and cultural resources,
drainage and impervious surface cover, public views of the ocean, public access to beaches and shoreline, and the cumulative impacts of development (Maui SMA Permits).

Major SMA permits are issued for those structures or activities costing more than $500,000 or that may have coastal or environmental impacts. Major permits are required to go through a public hearing process and approval rests with the Maui Planning Commission rather than with the Director of the Planning Department. An SMA exemption is issued when the proposed activity and/or structure is not a development and will have no negative impacts.

Embedded in the SMA assessment process is the application of setbacks for development activities that fall within close proximity to the shoreline. Additional restrictions apply to developments and/or activities within the SSA. The additional restrictions seek to maximize a property owner's protection from coastal hazards while preserving coastal amenities and shoreline access for the public.

**Shoreline Setback Areas.** Shoreline properties include those abutting, adjacent, across from, and/or in proximity to the shoreline. The Maui Planning Department issues a Shoreline Setback Approvals for those activities and/or structures that are explicitly allowed in the SSA. The Department also issues a Shoreline Setback Determination indicating that calculating the shoreline setback area was done properly and correctly (Maui Informational Sheet).

For structures or activities proposed to be within the shoreline setback area, applicants may request that the Director determine whether the proposed action qualifies as a “permitted structure or activity” by obtaining using this application. The Director may issue an SSA when a proposed action does not hinder sand transport, does not harden the shoreline, does not adversely beach processes, and does not interfere with public views or access to and along the shoreline. The Approval (SSA) may include specific conditions or requirements before the activity may proceed. Typical SSA conditions are the implementation of Best Management Practices or having an approved Archaeological Monitoring Plan in culturally sensitive areas.

A Shoreline Setback Variance is required for those activities and/or structures not permitted within the SSA. For example, most hardening structures such as seawalls, geotextile sea bags, groins, and revetments may require a variance from regulatory prohibition that is approved by the Maui County Planning Commission. Shoreline permits, like SMA permits, may include certain conditions or requirements before the proposed structure and/or activity is allowed to proceed (Maui Informational Sheet).

Maui’s setback rules were strengthened in 2003. The setbacks are the greater of two approaches, either based upon lot size or are variable based upon local shoreline erosion rates, as shown in Figure 116. To assist in the determination of erosion rates, Maui’s beaches have been divided into 30 sections and erosion rates were measured for transects placed every 20 meters.
Figure 116: Shoreline setback determinations on Maui are determined by lot size and erosion rates.

Source: Tara Owens.

- The setbacks are determined by multiplying the erosion rate for the property shoreline under consideration by 50 years and adding a 25-foot minimum setback. This current formula essentially ensures that a structure will be safe from erosion for 50 years. The erosion rates were based upon University of Hawaii studies of historical shoreline change from the early 1900s to 1997. The Maui Shoreline Setback Rules require that the erosion rates are updated every 10 years. The Maui Beach Management Plan (see below) suggests that setbacks should be increased for sandy shorelines to 70 times the erosion rate plus a 40-foot minimum setback. The County of Maui is currently considering these and other revisions to the formula, possibly including a factor for sea level rise.

Beach Management Plan for Maui. The County of Maui, in partnership with Hawaii’s Coastal Zone Management Program, initially prepared the “Beach Management Plan for Maui” in 1997 (Mullane and Suzuki 1997). It was updated in 2008 (Norcross-Nu’u 2008). The objective of the plan is to provide comprehensive guidance and a set of concepts and tools to move away from ad-hoc decision-making on beach and shoreline erosion. The Plan promotes beach preservation and sustainable development within the coastal zone. The Plan includes recommendations in 13 areas, which are noted in the text box below. The partnership that the state and county regulatory agencies have with Sea Grant (on-site support) that strives to ensure science based coastal management decisions and permitting was a key to development of the Beach Management Plan.
Figure 117 presents the Maui Beach Management Plan’s basic decision-making process to address threatened structures from eroding shorelines. The Plan states that ideally, interference with natural processes should be minimized. If the structure cannot be moved and if beach nourishment is not feasible, installation of hardened structures should be considered as a last resort. Knowing that an armored shoreline leads to beach loss, the Plan requires an evaluation of those losses, and, if approved, the decision is to be clearly stated that the development was favored over protection of the beach.

Coastal Dunes, Beaches, and Sand Mining. In 2003, the Maui County Code was amended to better protect coastal dunes. The amendment specifies that any grading of the primary frontal dune—the first dune encountered mauka of the beach—is prohibited. The amendments also prohibit the grading of any dunes...
located in the shoreline setback area, require a dune delineation for grading permits for coastal properties, and specify that any fill used in the setback area must be beach quality sand (Maui County Code).

Sand mining of Maui’s interior dunes has long been a source of sand for commercial purposes, but that resource is being depleted. See the text box.

**Sand Mining, Beaches, Construction, and County Action**

In 2006, in a report commissioned by the County of Maui, it was reported that Maui’s sand supplies could run out within 5 years (Hanzawa 2006). About 5.5 million tons of sand had been mined from Maui since the 1980s. Sand is used for beach nourishment and for construction. At that time, about 318,000 tons of sand was mined annually, 70 percent of which was shipped to Oahu for use in the construction industry, primarily in concrete for commercial and residential development. A total of about 3 million tons had been mined to date.

In the 1970s and 1980s, concrete companies in Honolulu were using “mansand,” which was sand made from crushing basaltic rock. Mansand required more cement than natural sand, and because of the angularities of the individual particles, the concrete made with mansand was not as fluid or workable. Natural sand is rounded in shape and provides for fluid workability of concrete into forms and construction needs.

The first barge load of sand to Honolulu was in 1985.

The sand deposits were built up over thousands of years, primarily wind-blown accumulation. Most of the inland sand dune areas are no longer available for excavation. Some are depleted and others have been developed for housing projects. The computed inventory of sand remaining was 984,000 cy, or about a supply of five years or less from the date of the report (2006).

While use of the sand has been primarily to meet the needs of the construction industry in Maui and Oahu, sand has been used for beach nourishment, although in much less quantities. In 2006, Zoe Norcross-Nu’u, University of Hawaii Sea Grant College Program, estimated that a total of 43,000 cy of inland sand had been used for beach replenishment projects to date. In the near future, there may be an annual demand of 10,000 cy, or 12,500 tons of sand for beach replenishment. This need will also increase over time.

In 2007, the Maui Planning Commission said Hawaiian Cement could only continue mining Maui sand provided it did not export any to Oahu. Hawaiian Cement began sand shipments from Canada. "I think we’re looking at the sunset of local sand sources," said Chip Fletcher, a geology and geophysics professor at the University of Hawaii-Manoa. "These are islands, and sand is limited. Much of it is under buildings and roads, so it was only a matter of time before we ran out of easily available supplies." (Gomes 2007)

Sand is still being actively mined and exported by Ameron cement, though supplies are limited and sales of sand to outside sources, such as beaches, are accordingly limited. However, the County of Maui is currently (in 2016) working on a draft ordinance focused on the beneficial use of sand for beaches in association with grading projects around the island. For example, if a homeowner is excavating beach quality sand for the construction of a pool, the County would have a mechanism for purchasing that sand for beach use.
Partnerships. Twenty years ago, at the request of the County of Maui, the University of Hawaii Sea Grant College Program (Hawaii Sea Grant) established a partnership with the County of Maui Office of Economic Development, Maui Community College (currently University of Hawaii Maui College), the County of Maui Planning Department, and the U.S. Department of Interior Office of Insular Affairs by creating the Pacific Island Regional Coastal Processes Extension Project. Since its inception, the objectives of the program have become more localized, now focusing primarily on coastal management and shoreline issues in the County of Maui. Through the partnership, an on-site Extension Agent provides specialized expertise on a daily basis to the county on coastal processes, beach preservation and restoration, coastal hazard mitigation options, coastal erosion response, climate change adaptation including potential sea level rise impacts, and other coastal processes-related issues. This technical support is intended to assist the County of Maui in making informed land-use and policy decisions based on the latest scientific information to increase community resilience. Similar programs have since been adopted through UH Sea Grant partnerships with DLNR-OCCL and the County of Kauai.

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13 FINDINGS AND CONCLUSIONS

This section provides the findings and conclusions of the NSMS assessment of Hawaii regarding the effects of erosion and accretion and how Hawaiian jurisdictions are managing their shorelines.

Erosion of Beaches and Shorelines in the Hawaiian Islands

The Hawaiian Islands stretch across approximately 1,700 miles of the Northern Pacific Basin. The State of Hawaii consists of eight main islands: Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, Niihau, and 124 small volcanic and carbonate islets offshore of the main islands. Hawaii has over 750 miles of coastline comprising a diverse mixture of environments, including sandy carbonate beaches, steep bluffs, densely developed lowlands, lava benches, marshes, and fishponds.

The Hawaiian Islands are mostly surrounded by fringing coral reefs, consisting of primarily stony or hard coral. The reefs break down by either mechanical erosion (i.e., waves and currents) or by bioerosion, which is the breaking down of the reef by marine organisms. One of the marine organisms that breaks down reef material into carbonate sand is the Parrotfish. This sand, along with the mechanically-eroded reef sediments, provides an important source of sand for Hawaii beaches. Much of the sand on Hawaii’s beaches and dunes is old and was likely deposited during a late Holocene sea level high stand 500 to 4,000 years ago.

A comprehensive 2012 study found that 70 percent of the beaches were eroding on Kauai, Oahu, and Maui, and over 13 miles of beach have been completely lost to erosion. Shoreline retreat (averaging 1 foot per year (0.3 m/year) statewide), wetland migration, and cliff collapse due to erosion are occurring now on many of Hawaii’s coastlines.

Coastal erosion and sea level rise threaten beaches, buildings, roadways, public services, community infrastructure, and cultural and environmental resources. Chronic erosion in front of developed lands (e.g., residential homes, hotels, roads) has historically led to seawall construction resulting in beach loss; approximately 9 percent of beaches on Oahu have been lost to seawall construction (Fletcher et al. 2012). Losses are similar on Kauai and Maui.

Scientists and state personnel expect shoreline erosion to worsen and likely accelerate as sea levels continue to rise. Research by Anderson, et al. (2015) finds that historical trends of erosion are likely to double by mid-century. Sea level has been rising in Hawaii for the past century or more. Rates of rise vary amongst the islands due to differing rates of subsidence based on distance from the actively growing Hawaii Island. Rates of sea level rise in Hawaii ranged from 1.5 cm (0.6 Inches) on Oahu and Kauai, to 3.3 cm (1.3 inches) on Hawaii Island per decade over the last century. Current rates are 1.41 mm per year for Kauai and Oahu, 2.04 mm per year for Maui, and 2.95 mm per year for the Island Hawaii. The DLNR is investigating the future impacts of sea level rise and coastal erosion with University of Hawaii researchers for a statewide Sea Level Rise Vulnerability and Adaptation Report (due December 2017) for the Hawaii Climate Adaptation Initiative (State Act 83, 2014).

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26 This section is a summary of the information in Sections 1-13 and except for a limited few citations in this section, references are included in those sections.
Socio-Economic Impacts of the Loss of Beaches and Shoreline Erosion

The beaches and shorelines of Hawaii are the backbone of the state economy and the centerpiece of the Hawaiian way of life. Beaches provide access to historic shrines, are visited for spiritual ceremonies, contain historic burial sites, and allow access to nearshore reefs for fishing. The coast is where ports, highways, and other critical infrastructure are located, and the shoreline provides valuable recreational opportunities and a uniquely beautiful setting that people travel thousands of miles to visit; the Hawaiian shore is where people want to live and tourists want to visit. The ocean-based economy and shoreline resources of Hawaii are worth upwards of $9 billion annually,\(^\text{27}\) and shoreline erosion and associated beach loss would have substantial negative impacts to the economy, the high quality of life residents and visitors enjoy, cultural resources, and coastal ecosystems.

The information on federal and state expenditures for nourishing beaches and dredging harbors reveals a comparatively small cost in addressing erosion and beach loss given the value of the shore to the state economy. Approximately $20 million has been spent on dredging Hawaiian federal harbors since 1999, on average $1.8 million annually. To nourish beaches, the state has been responsible for the majority of projects at a cost of roughly $3.5 million annually ($35.1 million total since 2007). Only a handful of “Civil Works” USACE projects have occurred in the last 30 years in Hawaii, which involved shoreline armoring. Two of the largest projects—Kaumalapau Deep Draft Harbor (Lanai) in 2007 and Kalaeloa Barbers Point Deep Draft Harbor (Oahu) in 1985—totaled $87 million. Even without consideration of all the market and nonmarket values the beaches and shore provide, the annual tourism and recreation revenue associated with the shore ($6.2 billion) is a good incentive to continue relatively small investments that address erosion and accretion.

Other expenditures to address erosion impacts (e.g., to roadways) may also appear relatively minor in comparison to the value of the shoreline-based tourism and recreation economy. For example, emergency proclamations were issued in 2012-2013 to repair and protect two stretches of the Honoapilani Highway in Maui after damage from erosion. The cost totaled $13 million. Tourists alone spent $1.3 billion on transportation in 2014 (e.g., interisland travel, car rentals, ground transportation, and gas), with the majority of that amount, nearly 70 percent ($860 million), spent on vehicle rentals that use the many coastal highways and roads of the all the islands. Given these facts, the cost of repair, protection, and even relocation projects that address longer-term concerns, like the re-alignment of Honoapilani Highway (estimated cost of $80 million), appear justifiable (HTA, 2015b, HTA, 2013).

However, the costs of armoring shorelines to protect infrastructure and property from erosion go beyond the construction and maintenance costs of hardened structures such as seawalls and revetments. While constructing a seawall along a stretch of shoreline to protect a resort from erosion may cost between $2,000 and $5,000 per linear foot, this amount does not include the indirect costs such as the potential narrowing or loss of beach in front of the structure leading to lost public access and recreational opportunities. The State of Hawaii is exploring potential future erosion impacts and beach loss through the development of the statewide Sea Level Rise Vulnerability and Adaptation Report, described previously. Beach nourishment and dredging also have indirect costs associated with them, such as habitat disturbance and noise pollution.

Very few studies or reports exist exploring the nonmarket value of the shoreline in Hawaii, which means the economic picture of the impacts of erosion and accretion is incomplete. The lack of studies is surprising given the importance of the shoreline’s market value across the islands. Even considering

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dated beach attendance numbers for Oahu, it can be estimated using nonmarket values from Penn et al. (2012) that if the beaches of Oahu are clean, with clean water, no overcrowding, and ideal safety conditions, they are worth minimally $1.6 billion annually. Additional information gaps, if filled, could allow for a more robust evaluation of the economic impacts of erosion. These gaps include complete inventories of projects costs, both state and federal, for beach nourishment, shoreline protection, and dredging; tourism and recreation studies for beaches across all the islands (beyond just Waikiki Beach); information on historic infrastructure expenditures to address erosion damage; and reports that examine the value of the shoreline to cultural practices.

Although in some parts of the coastal U.S., sand is available to replace eroding beaches thereby presenting a viable alternative to shoreline hardening, Hawaii presents a different case due to the limited availability of beach-compatible material.

The economy of Hawaii heavily relies on tourism and recreation, which in turn rely on the state of the beaches and shorelines. Diversification of the ocean economy would add stability to a state that depends on an eroding shoreline experiencing accelerating rates of sea level rise.

**Environmental Impacts from the Loss of Beaches and Shoreline Erosion**

Coastal habitats are critical to the natural environment, society, and economy of Hawaii. Hawaiian coastal habitats support a rich variety of terrestrial and marine species, including: dozens of migratory and resident birds; thousands of fish and marine species; and threatened or endangered turtles and marine mammals. Coastal erosion directly threatens these habitats. Hawaii’s reefs provide the critical first line of defense against wave-driven coastal erosion, and their protection requires a watershed approach. Protecting Hawaii’s reefs is a key to coastal protection and should be approached in a holistic fashion.

Coastal planning should consider future habitat needs in the face of chronic erosion and sea level rise. Key species like endangered sea turtles, monk seals, or bird species rely on beach habitats. As beaches erode, these habitats are lost. As habitats in the low-lying NWHI are lost to erosion and sea level rise, suitable habitat on the main Hawaiian Islands will become more important to species’ survival.

The current suite of shoreline management efforts can have both positive and negative impacts. Positive and negative impacts are site-specific based on local environmental conditions and shoreline management options. Beach nourishment can create or improve habitat for some marine organisms (e.g., birds, sea turtles, monk seals) and improve access to shoreline recreation. It can also can degrade water quality, smother, and disrupt behaviors for others if not conducted with appropriate mitigation and best management practices (BMPs). Incompatible material can have negative impacts on aquatic habitats. Hawaii’s DLNR-OCCL Small Scale Beach Nourishment Guidelines provide BMPs for protecting water quality and aquatic habitats in small beach nourishment efforts. Benthic habitat monitoring after the 2012 Waikiki Beach Restoration did not find significant negative impacts associated with beach nourishment activities.

Beach loss from shore-parallel armoring has been widely documented in Hawaii. Breakwaters, seawalls, and groins are generally effective at protecting coastal development (e.g., infrastructure, cultural sites) but can accelerate erosion and beach loss. The habitat impacts of hard shoreline structures are not as well understood. The USACE’s Engineering with Nature initiative seeks to maximize the potential habitat benefits of hard structures. In Hawaii, some shoreline protection structures have been shown to create habitat for marine species (e.g., Iroquois Point). However, the effects on species assemblages and biomass need more study. Limited research suggests that certain structures (e.g., seawalls) exacerbate the loss of certain habitats (e.g., beaches) and forage sites.
Protecting the Beaches and Shorelines from the Forces of Erosion

A great deal of development happened in the 1950s and 1960s before state and county laws and regulations for shoreline protection were put in place in the 1970s; those rules and policies had the intention of protecting beaches and beachfront properties from the effects of erosion, including state Coastal Zone Management policy (Hawaii DLNR 205A), state Conservation District rules and policy, and county policies. In spite of these rules and policies, development pressures have resulted in dense development built too close to eroding shorelines in many coastal communities.

A primary source of sand on many chronically eroding shorelines in Hawaii is the dune system and sand-rich coastal plain at landward edge of the beach. A beach may be maintained in many of these chronically eroding areas if the beach system is allowed to migrate landward, releasing sand from upland deposits. Historically, management authorities have not explicitly recognized the role of these backshore deposits in natural maintenance of healthy beaches, and allowed development to proceed within this critical backshore area of the beach system.

The common solution to prevent shoreline erosion and protect property over the last 50 years has been to construct engineered hard structures that were resistant to erosion, to reflect or absorb the wave energy reaching the shore. In many locations, armoring was installed without adequate consideration of or knowledge of localized littoral processes and in many cases, had a damaging effect on beaches and public access. Negative effects are included in the text box below. Armoring and engineered structures include breakwaters, revetments, and seawalls. Groins are engineered structures as well, but have been used effectively to retain sand with beach restoration projects. However, groins can have negative impacts on neighboring shorelines if not designed and sited carefully.

Over the last two decades, the science and understanding of negative impacts of coastal armoring has increased and in recent times, government agencies have generally only approved coastal armoring as an option of last resort. When structural remedies are necessary, buried revetments with beach nourishment are the preferred approach depending on the specific characteristics of the location needing armoring.

Negative impacts of armoring may include the following:

- Negative visual and aesthetic impacts.
- Potential impairment of beach access.
- Loss of beach width on which the armoring is placed.
- Loss of sand supply from the eroding shorelines.
- Gradual loss of beach in front of the armoring, if the shoreface fronting the armoring continues to migrate landward.
- Active erosion fronting the structure and adjacent beach (flanking erosion) due to impacts of waves and currents around the structure.
- Loss of habitat and foraging areas.

Soft approaches to beach maintenance and restoration include:

- Beach nourishment
- Sand bypassing
- Sand backpassing and sand pushing
- Placement of dredged material from navigation projects onto beaches and into the littoral zone
- Dune protection and restoration
Challenges to Beach Nourishment

In Hawaii, nourishment has played a limited role in the management of beach resources around the state other than at Waikiki. Nourishment has largely been restricted to locations where erosion poses an immediate threat to development. Sites of beach nourishment include Sugar Cove on Maui, Waikiki, and Lanikai on Oahu, as well as other isolated locations. A beach restoration project for Kaanapali, Maui, is currently in the planning and permitting phase.

However, beach nourishment is a key element in Hawaii’s management efforts to restore beaches and to combat erosion and accretion. Barriers to timely and effective beach nourishment include:

1. **Availability of Sand Supplies**
   Supplies of beach quality sand on land have been largely exhausted, and jurisdictions are prevented from using mined sand for beach nourishment. Compatibility of the sand is also an issue because land-based sand supplies sometimes contain too many fine-grained materials.

   Other sand alternatives for beach nourishment are: (1) dredged material from a USACE dredging project, which needs to be within a reasonable haul distance from the dredging site; and (2) sand from offshore—either from USACE dredges or private dredges.

   Large-scale sand recovery and stockpiling projects can take advantage of economies of scale, which smaller projects cannot afford. Additional studies are needed to identify available offshore deposits of sand that can be used for current projects and stockpiled for later use.

   Another alternative could be importing sand from out-of-state sources, as done by the concrete industry. However, state regulations do not allow use of imported sand on beaches.

2. **Evaluating the Potential Risk upon Fringing Coral Reefs of Beach Nourishment**
   Continued research and scientific information are needed in assessing the potential impacts on fringing reefs of beach nourishment projects (i.e., might placing sand on beaches have unacceptable impacts to offshore resources? What are BMPs to limit those potential impacts?). In the interim, state policies mandate that sand cannot be placed upon the beach in slurry form, such that turbid waters are released back into marine waters. This is protective policy, but causes logistical issues, increases costs for placement, and has been questioned as being overprotective and unnecessary. Studies during the Waikiki Beach nourishment project showed no significant impacts to the marine environment.

   The DLNR requires that sand used for nourishment closely match existing beach sand in composition and grain size and be free from pollutants, which is a protective measure. However, because state regulations list sand as a pollutant, evaluation of projects under the state-administered CWA 401 certification is more complicated, and frequently not conducted in what many private and government applicants consider a timely manner.

3. **Technical Logistics of Placing Sand on a Beach**
   The USACE Honolulu District uses the Portland District based USACE Dredge Essayons, which is a hopper dredge, for O&M dredging of deep draft harbors. The dredge essentially excavates harbors by suction, places the material in the vessel’s hopper, and then bottom dumps the material at EPA designated ocean disposal sites. The vessel cannot dump in less than 35 feet of water and cannot pump to shore. Thus, unless a different USACE dredge is used that can place dredged material on the beach, beneficial use of dredged material from navigation projects is technically infeasible.
Alternatively, private dredges could be used in place of the Essayons that are able to pump to
the beach, but this is a USACE budget and logistics issue. In addition, the state’s policy that sand
must not be placed on the beach in slurry form impedes this option.

Large-scale sand recovery and stockpiling projects could take advantage of economies of scale,
which smaller projects cannot afford. Funding is needed for investigations of sand quality, sand
recovery, material storage and processing, and to subsidize transport and placement of sand in
cost-shared beach restoration projects.

4. **Funding**

There is currently not enough federal, state, or county government funding to support beach
management and restoration in Hawaii. State and local funding sources are limited and include:

- DLNR Beach Fund
- Special Tax Districts (e.g., Waikiki Beach Special Improvement District)
- Legislative Capital Improvement Project allocations
- County allocations

The Waikiki Beach Special Improvement District could be a model for the future, establishing a
special tax district for dedicated funds for use in nourishment or protection of a specific beach
or shoreline.

The *Federal Standard* (USEPA 2007b) is the key federal regulation that impacts the ability of
USACE to contribute to local beach nourishment programs with dredged material from channels
in ports and harbors, which means that the incremental cost above the base plan to use the
dredged material in a beneficial manner (e.g., beach nourishment) has to be paid by local
sponsors. Planning is essential for upcoming federal dredging projects, such that local sponsors
are identified that can share in the funding the costs of beach nourishment.

5. **Timely environmental permitting**

To nourish or restore a beach in Hawaii, the CWA requires a USACE-issued permit under CWA
Section 404; that 404 permit cannot be issued without a State of Hawaii-issued CWA Section 401
certification. Issuance of the 401 Certification is the conclusion of the environmental assessment
that state water quality standards will not be violated by a beach nourishment project. Issuance
of the 401 Certification is complicated by the Hawaii regulations that specify sand as a pollutant
and the questions regarding whether placing sand on a beach will cause unacceptable impacts
to marine waters.

The State of Hawaii DLNR Office of Conservation and Coastal Lands supports restoration of
beach and dune ecosystems through the SSBN application program. The Department has
initiated the development of an updated programmatic environment assessment for SSBN
projects statewide and will be exploring the possibility of an agreement with other agencies for
a streamlined permitting process. This should be a priority.
Governance: Managing the Shorelines

**Federal Actions.** USACE in Hawaii has responsibility for 19 deep and shallow draft harbors and ten shore protection projects. Through the RSM Program, USACE is facilitating the use of a systems approach to deliberately manage sediments on a regional or littoral cell basis instead of project-by-project, working with state, county, city governments, the academic community, the private sector, and other stakeholders.

One important action that USACE is facilitating is the development of comprehensive assessments of Hawaii’s sediment management needs and where regional sediment actions could be conducted. Regional and local sediment and shoreline management plans are critical to systematically approach the issues of eroding beaches and the loss of natural habitats (e.g., for animals like turtles and monk seals). While USACE is helping to facilitate these efforts, federal funds are limited or non-existent to carry out the projects.

**State Actions.** The DLNR-OCCL Coastal Lands Program manages coastal resources seaward of county jurisdiction (the certified shoreline), including dunes, beaches, rocky shorelines, and submerged lands seaward to a three-mile limit of state waters from the shoreline. Landward of the certified shoreline, one of the key elements of the CZM Program is the issuance of SMA Permits through the county planning departments. This is one area that reflects a need for careful integration between state and county policies and regulations, given that it is state jurisdiction on the ocean side of the certified shoreline and county jurisdiction on the landside of the line.

The Office of Planning implements the CZM Program. It administers the CZM program (and funding) through the county planning departments. The State CZM Program also provides CZMA consistency determinations for shoreline armoring or beach management projects (e.g., projects requiring a CWA 404 permit).

Stakeholders and academia are actively involved in support of state and county actions; in particular, the University of Hawaii’s Coastal Geology Group and the University of Hawaii Sea Grant College Program are integral to understanding the science of erosion and looking to the short- and long-term effects of sea level rise.

One emerging concern, researched by the University of Hawaii Sea Grant College, is the legal issue of takings of private property by government in the name of beach and shoreline management. State and county government regulatory action, such as shoreline setbacks and hardening policies, will form an integral part of Hawaii’s response to the threats posed by erosion and sea level rise.

This theoretical issue has become a reality as a number of owners of coastal properties are seeking to harden shorelines with permanent structures to protect their properties from natural hazards. This challenge will continue to grow with increasing erosion with sea level rise. Owners may resist or oppose government regulation of armoring and development activities on the grounds that enforcement violates the Constitutional takings prohibition. Threatened or actual takings claims may negatively influence the application and enforcement of beach and shoreline protection regulations.

**Progress at the County Level.** Both the County of Kauai and the County of Maui have established erosion based setback rules, as has the state for conservation districts.

The City and County of Honolulu has not adopted erosion-rate based setbacks beyond the 40 feet state minimum, in part, because much of the shoreline is already developed. Hawaii County has a “minimum” setback of 40 feet. The term “minimum” is important because it allows them to require greater setbacks. Both the City and County of Honolulu and Hawaii County have negotiable 55-foot setbacks. If a landowner accepts the increased setback above the minimum 40 feet, the County waives the requirement for a certified shoreline.
Future Challenges to Create Resilient Hawaii Shorelines

Seventy percent of Hawaii’s beaches are eroding, which has enormous implications for Hawaii’s economy and way of life. Overcoming the barriers to beach nourishment and shoreline protection is essential, but overall, there are insufficient funds to protect every shoreline and nourish every beach.

Climate change and sea level change significantly compound the regional and local issues regarding the management steps needed to establish resilient shorelines. The DLNR is investigating projected impacts of coastal erosion and inundation with sea level rise through a statewide Sea Level Rise Vulnerability and Adaptation Report (due December 2017) for the Hawaii Climate Adaptation Initiative.

Federal support is integral in helping regional and local efforts to identify shoreline management issues, develop shoreline management plans, and provide the basis and funding for action. Improved Federal, State and county coordination is vital to overcome the scientific, technical, and regulatory challenges to beach nourishment and shoreline management in Hawaii.

Federal, state, and local governments should collaboratively establish priorities for protecting and maintaining beaches and shorelines and finding innovative financing approaches using public-private partnerships and alternative financing options. Short- and long-term planning is essential and should include a wide range of stakeholders, particularly considering increasing challenges for coastal management in an uncertain future with changing climate and sea level rise.