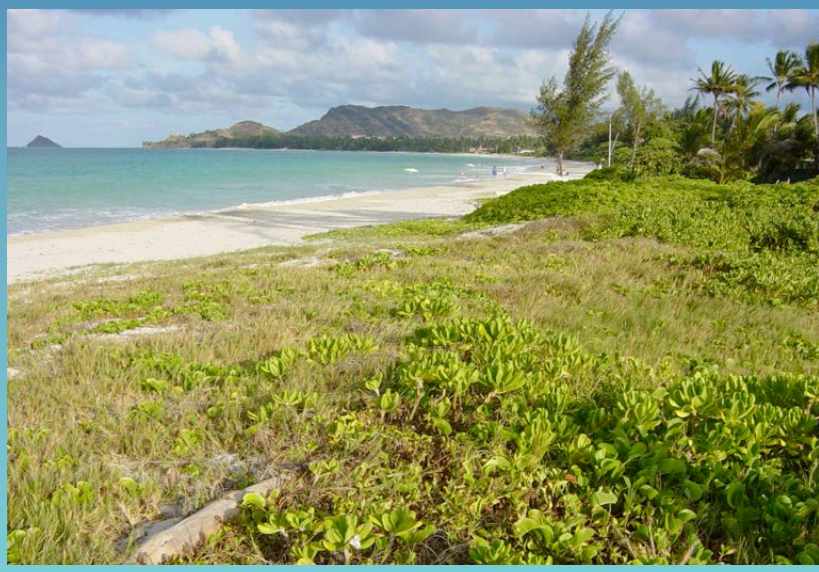
University of Hawai‘i Sea Grant College Program

Hawai‘i Dune Restoration Manual

2022



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PREFACE

The *Hawai‘i Dune Restoration Manual* was written and created by the University of Hawai‘i Sea Grant College Program (Hawai‘i Sea Grant). Hawai‘i Sea Grant supports and conducts innovative research, education, and extension services toward the improved understanding and stewardship of coastal and marine resources nationwide.

The *Hawai‘i Dune Restoration Manual* is written in response to increasing awareness of the importance of preserving, restoring, and maintaining coastal dunes. There are clear ongoing impacts associated with climate change, including sea-level rise, coastal flooding, and more frequent and severe storm events, all causing beach and dune erosion. However, there are also direct human impacts on coastal dunes from coastal development and recreation, and a demonstrated need to address foot traffic erosion in high impact areas, like public beach parks. Proactive coastal dune restoration, coupled with responsible coastal development, will be crucial to protecting Hawai‘i’s iconic beaches and dunes, shorefront infrastructure, and nearshore cultural and natural resources. Healthy coastal dunes are essential components that enable shorelines to adapt naturally to changing climate and ocean conditions, and contribute to the resiliency of coastal communities.

This manual is intended for use by community groups, nonprofits, county and state agencies and departments, coastal resorts and condominiums, coastal landowners and managers, and anyone interested in conducting proactive dune restoration projects in partnership with Hawai‘i Sea Grant community extension agents. It is important to note, however, that dune restoration may not be appropriate at all locations and is closely regulated by state and county resource agencies (Appendix B). Before initiating a project, it is advisable to consult with a professional or contact your local Hawai‘i Sea Grant extension agent for advice and guidance (Appendix A).

The beaches and coastal ecosystems of the Main Hawaiian Islands are incredibly diverse and represent a striking number of climates, geologic conditions, and local coastal processes. This diversity presents an inherent challenge when attempting to provide broadly applicable guidance and best management practices for dune restoration statewide. We hope that this guide will be used in collaboration with local practitioners and experts, and will provide a starting point for conducting restoration activities. However, it is not intended to replace place-based knowledge or the practical, on-the-ground experience of local restoration practitioners and land managers. While dune restoration is a powerful tool in the nature-based, coastal ecosystem restoration toolkit, it does not apply to every situation and location.

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I. THE HAWAIIAN COASTAL ENVIRONMENT

He aliʻi ka ʻāina, he kauwā ke kanaka
Land is the chief, man is the servant

Beloved by locals and visitors alike, the beaches of Hawaiʻi evoke a romantic sense of "paradise found." Beyond images in promotional materials, Hawaiʻi's beaches and dunes represent treasured natural and cultural resources, collections of diverse coastal ecosystems, and areas of traditional fishing, gathering, and cultural practice for all. Behind each incredibly picturesque beach scene is a local story, tradition, and complex coastal ecosystem, and while there are no strictly private beaches in Hawaiʻi, many of Hawaiʻi's coastal dunes are at least partially located on private property. Thus, the protection, preservation, and restoration of these ecosystems is a shared responsibility, or kuleana, of us all, as residents and members of Hawaiian coastal communities.

Restoration, monitoring, and maintenance are critical activities for proper management of coastal dune systems. In developing a dune project site plan, it is important to acquire a basic working knowledge of the dominant dune plant species, appropriate planting locations on the dune, and plant maintenance needs. This working knowledge and a detailed understanding of the project site conditions, uses, and geographic constraints are all essential components of proper dune management.

Beaches represent the leading edge of an active and often eroding sandy coastal plain or dune field. Dunes and inland sand deposits are an important source of sediments that nourish the beach during high waves and storms. Historically in Hawaiʻi, many of the beachfront homes, hotels, and resorts have been constructed on top of frontal dunes, locking up vital sand beneath shorefront buildings and landscaping so that it can no longer replenish the active beach.

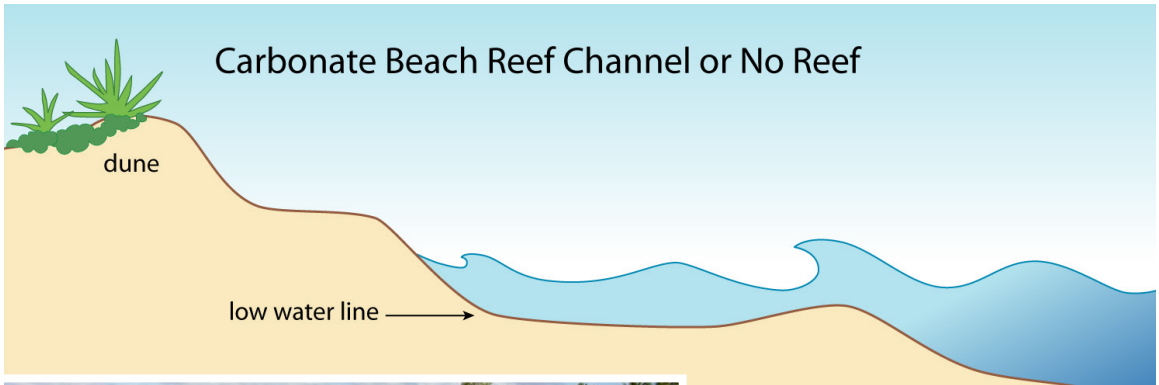


FIGURE 1. (Top) A typical beach profile shows platforms at low and high tide levels and has a healthy, vegetated dune. (Graphic courtesy of UH Coastal Geology Group) (Left) This beach at Kailua, Oʻahu, illustrates a typical healthy beach profile.

In cases where inland sand is not naturally present, pocket beaches form between rocky headlands, and sand is exchanged freely between coastal dunes, the beach, and offshore sand deposits. This type of beach has an inherently small 'sand budget' so that a loss of dunes in these areas make the beaches extremely vulnerable to seasonal erosion, when entire beaches can disappear during certain seasons, ideally returning again in the next one. Without a source of sand for replenishment, these beaches and dunes can be lost permanently. Maintaining the connection between the active beach and dune system is an important component of a holistic coastal management strategy.

Beaches in Hawai'i are highly variable and dynamic environments with waves, currents, and winds constantly shifting sand and reshaping the shoreline on both seasonal and long-term timescales. Large seasonal swells and storm waves can erode most or all of a beach within a matter of hours, only to have the beach fully or partially recover after waves subside.

FIGURE 2a. Kapukaulua (Baldwin Beach), Maui, provides an example of a dynamic beach area that erodes and recovers seasonally. The tree roots in the foreground are typically buried each winter and become exposed again during the summer months. (Photos: Heidi Sherman)

Some areas of Hawai'i have a history of sand mining from the beach. While this practice was outlawed in the 1970s, we continue to see its negative impacts as current beach erosion accelerates due to prior sediment deficiencies and modern sea-level rise. Erosion trends are also highly variable from one section of beach to the next, depending on localized wave energy, sand transport and supply, and the presence of human-made structures or introduced vegetation, which can interfere with natural sand movement and beach processes.

Nearly all Hawaiian beaches are exposed to seasonal high waves at some time in the year. In winter months, large waves from North Pacific storms impact the offshore reefs and beaches on north- and west-facing shores, while waves from South Pacific storms affect south- and west-facing shorelines in summer months. Persistent trade winds

and winter storms in the eastern Pacific can send large waves to east-facing windward shores, while hurricanes and locally-generated Kona (southerly) storms can cause rapid coastal erosion and flooding on south- and west-facing coasts.[1]

FIGURE 2b. 'Ehukai Beach, on the North Shore of O'ahu, also experiences seasonal erosion, replenishing in the winter (left), and eroding in the summer (right).

With its central location in the Pacific, Hawai'i is also vulnerable to inundation, wave damage, and erosion from tsunamis. These long-travelling waves are generated by earthquakes associated with the "ring of fire," a band of volcanically active tectonic plate boundaries ringing the Pacific Ocean basin. Earthquakes over the last 60 years have caused several damaging tsunamis that affected Hawaiian coasts: from the Eastern Aleutian Islands in 1946, from the Central Aleutian Islands in 1957, from Chile in 1960, from the Gulf of Alaska in 1964, and from Japan in 2011.

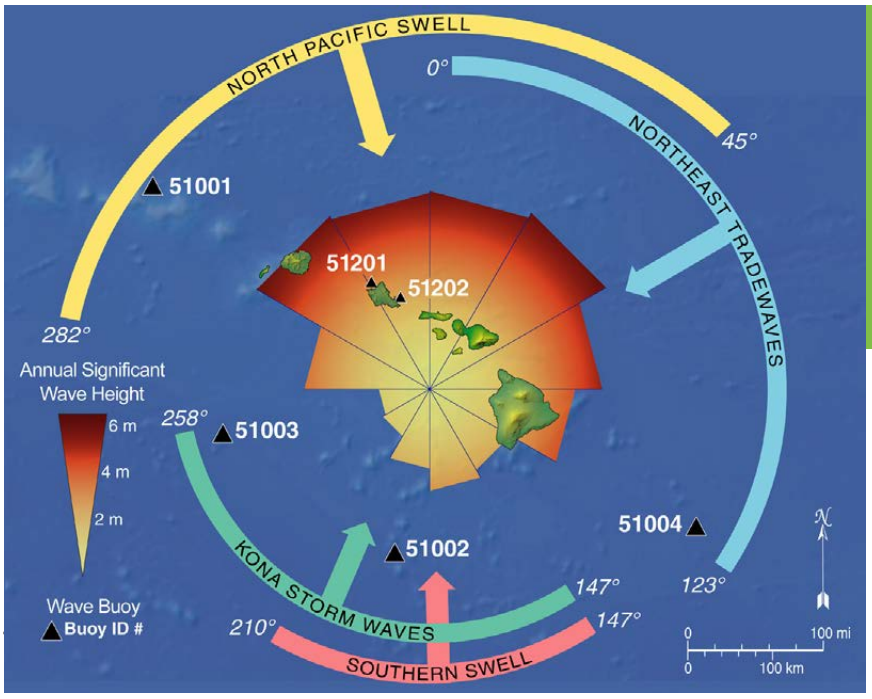


FIGURE 3. Dominant swell regimes and wave-monitoring buoy locations in Hawai'i. (Modified from Moberly and Chamberlain, 1964, and Vitousek and Fletcher, 2008[2]).

1 Fletcher et al. (2002) Atlas of Natural Hazards in the Hawaiian Coastal Zone. USGS, Geologic Investigations Series I-2761, http://pubs.usgs.gov/imap/i2761/

2 Vitousek, S. CH Fletcher, Barbee, M. - Maximum Annually Recurring Wave Heights in Hawai'i. Pacific Science, 2008

Climate Change and Sea-level Rise

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (August, 2021) states: "It is unequivocal that human influence has warmed the atmosphere, ocean, and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred."

We are experiencing the effects of climate change in Hawai'i today in the form of increasing air and sea-surface temperatures, sea-level rise, and changing rainfall patterns. Hawai'i's coastal environment is uniquely vulnerable to impacts associated with climate change and sea-level rise due to our dense coastal infrastructure. An intermediate sea-level scenario from NOAA projects a local sea-level rise of 1.31 m (4.3 ft) by the end of the century, with continued rise likely for years beyond that. Under some scenarios, six feet or more of rise by 2100 is plausible. But even decades before global mean sea level reaches these benchmarks, high-tide flooding will affect low-lying coastal areas. With this in mind, there is strong evidence that sea-level rise will continue to accelerate in the near future and inevitably result in increased coastal erosion and impacts to our coastal ecosystems, including dunes.

In June of 2018, the Honolulu Climate Change Commission provided a Climate Change Brief on local, regional, and global impacts of climate change based on peer-reviewed scientific literature and Sea Level Rise Guidance, building on the findings of the 2017 State Sea Level Rise Report and other recent governmental reports and scientific literature. The Commission recommends all future planning include contingencies for at least 3.2 feet of local sea-level rise.

Proactive coastal planning and adaptation measures, including dune restoration projects, will make coastlines more resilient to present-day hazards including coastal erosion, extreme high wave and tsunami events, and rainfall flooding. However, a realistic, site-specific evaluation of the exposure and risk of a location should be considered when defining the design lifetime and performance expectations of coastal dunes in the face of anticipated sea-level rise.

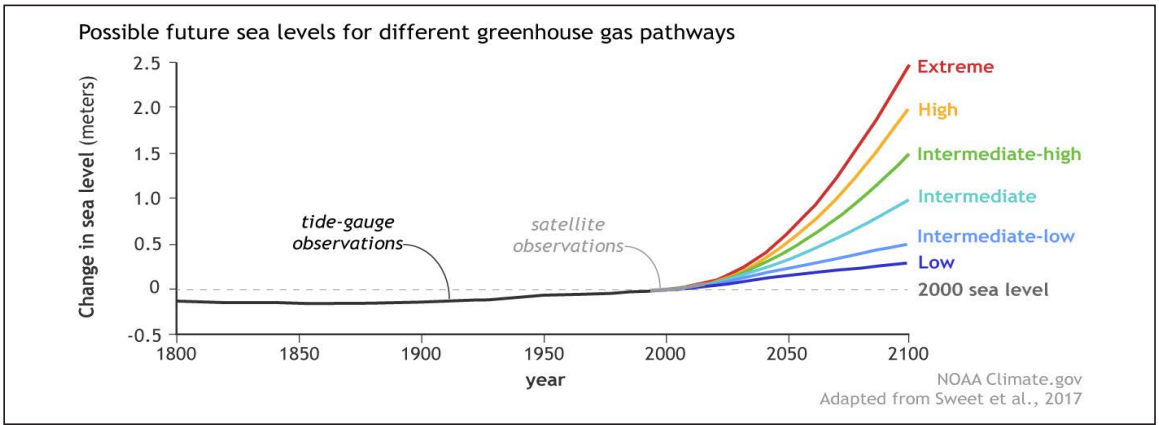


FIGURE 4. Global sea-level rise projections based on greenhouse gas emission scenarios. (Source: NOAA/ Sweet, 2017[3])

3 Sweet, W.V., Kopp, R.E., Weaver, C.P., Obeysekera, J., Horton, R.M., Thieler, R.E., Zervas, C., (2017) NOAA technical report NOS CO -OPS 083. Global and Regional Sea Level Rise Scenarios for the United States, Silver Spring, Maryland

Hawai'i's Sand: A Precious and Limited Resource

Hawai'i's beach sand consists primarily of calcium carbonate ($CaCO_3$) grains made of eroded remnants of shells, exoskeletons, and coral fragments from various organisms such as mollusks, echinoderms, bryozoans, sponges, calcareous algae, and pelagic foraminifera. Hawaiian sand also contains a small component (on average about 5 percent) of eroded volcanic minerals and rock fragments. These volcanic components give color to the famous red, black, and green sand beaches of the state.

FIGURE 5. Beach sand types originate from different sources. (Top, left to right) Green sands with the mineral olivine and black sand of basalt lava fragments both occur on Hawai'i Island. (Bottom, left to right) Golden tan carbonate sand and white carbonate relic dune-beach sands are both found at Kailua Beach, O'ahu.

The process of coral reef building and erosion is ongoing today, and healthy coral reefs provide an important renewable source of carbonate beach sand, while also acting as protective barriers to wave energy. However, reef building and erosion is not a uniform process through time. It is important to note that the majority of Hawai'i's beach sand formed during an ancient period of intensive reef building and erosion that peaked during the late Holocene geologic epoch about 4,000 years ago, when sea levels were higher; radiocarbon dating of some of Hawai'i's older relict dune sand gives an average age of approximately 4000 years before present.[4,5]

4 Harney, J.N., Grossman, E.E., Richmond, B.M., and Fletcher, C.H. (2000) Age and composition of carbonate shoreface sediments, Kailua Bay, Oahu, Hawaii: Coral Reefs, v. 19, pg. 141-154.

5 Fletcher, C.H., Jones, A.T. (1996) Sea-level highstand recorded in Holocene shoreline deposits on Oahu, Hawaii. Journal of Sedimentary Research. 66.3, p. 632-641.

FIGURE 6. (Left) Sources of beach sand in Hawai'i. (Image: UH Coastal Geology Group) (Right) A magnified image of typical Hawaiian beach sand.

With an inherently limited sand supply based almost entirely on the biological process of reef building and erosion, Hawai'i's beaches are typically narrow when compared to North American beaches, which are naturally replenished with silicate mineral sand derived from upland watersheds, erosion of coastal bluffs and cliffs, and continental shelf deposits. Thus, for the continued existence of Hawaiian beaches, careful and deliberate management of beach sand, treating it as a finite resource, is essential.

Beach Erosion

Beach erosion trends in Hawai'i are highly variable with areas of extreme erosion often found in close proximity to areas of sand accretion or accumulation. In Hawai'i, sand movement is generally described in the context of a littoral cell, a mostly self-contained area found between two rocky headlands. The headland boundaries keep most of the sand contained between them, and while sand moves about within a littoral cell, it does not move significantly between littoral cells, for purposes of beach and dune restoration.

Indications of erosion on a beach are varied and may include: a steep erosion scarp, or vertical drop-off, in the upper beach or dune; overhanging roots and vegetation; remnants of fallen trees on the beach; exposed rocky or clay outcrops near the water line; or an overall steep and narrow beach profile without a dry upper beach area. Excess erosion in developed areas is visible in other ways, including: structures located very close to the shoreline or erosion scarp; exposed irrigation pipes or other underground infrastructure; coastal armoring structures, which may be failing; high-wave impacts, such as undermining or over-washing of roads and other infrastructure; and sometimes even ocean waves washing through a shorefront development.

We strongly encourage coastal community members to familiarize themselves with the long- and short-term shoreline trends for their neighborhood beaches. Beach erosion

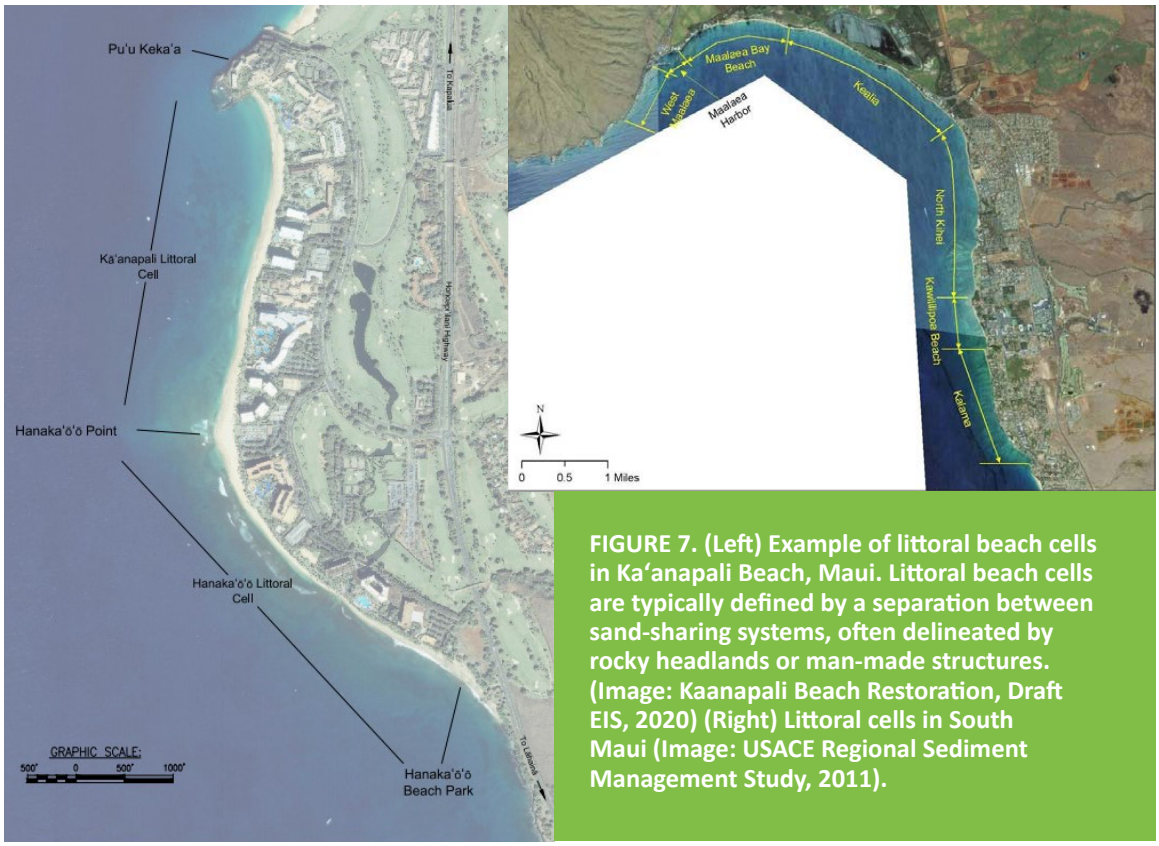


FIGURE 7. (Left) Example of littoral beach cells in Ka'anapali Beach, Maui. Littoral beach cells are typically defined by a separation between sand-sharing systems, often delineated by rocky headlands or man-made structures. (Image: Kaanapali Beach Restoration, Draft EIS, 2020) (Right) Littoral cells in South Maui (Image: USACE Regional Sediment Management Study, 2011).

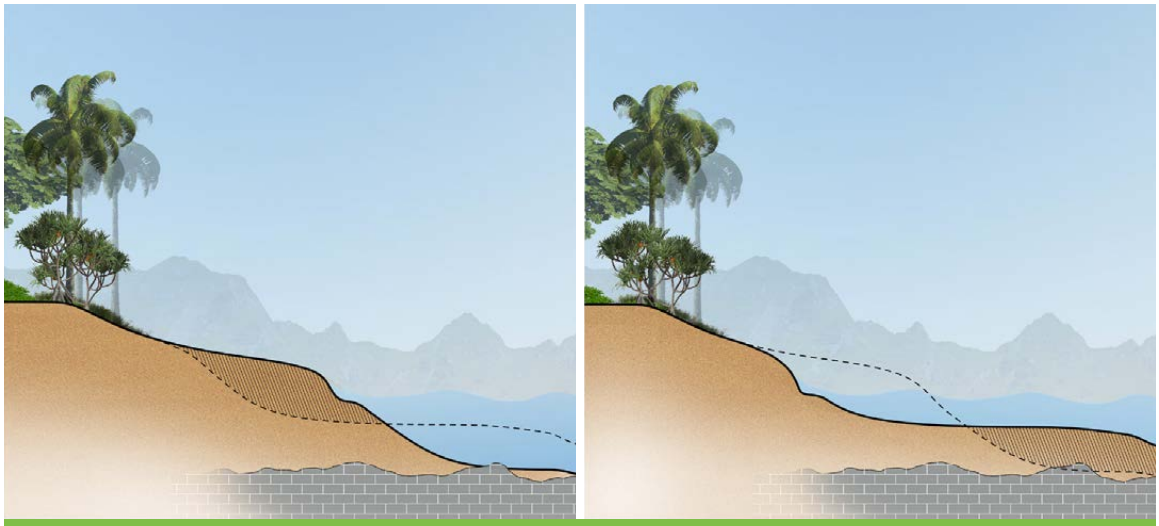


FIGURE 8. Depiction of a typical seasonal beach profile adjustment. Sand is eroded offshore during periods of high surf or erosion (left to right) and re-distributed back to shore during periods of favorable conditions (right to left). These do not always coincide with large or small wave conditions but rather a complex and unique set of site conditions including swell, period, height, direction, and tide stage.

maps for Kaua'i, O'ahu, and Maui are available at the University of Hawai'i Coastal Erosion Website.[6] Additional helpful information can be found in the Hawai'i Sea Grant guide *Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawai'i*.

6 https://www.soest.hawaii.edu/coasts/index.php/resources/hawaii-shoreline-study-web-map/

FIGURE 9 (top). Homes along Sunset Beach, O'ahu, are threatened by seasonal beach erosion along this dynamic coastline.

FIGURE 10 (left). Kualoa Beach Park illustrates the lateral, alongshore transport of sand (from the top to the bottom of the image), indicated by the updrift collection of sand, now developed upon, and downdrift erosion due to the lack of sediment being transported downdrift of the groins. (Photo: USGS)

The Importance of Coastal Dunes to Beaches and Coastal Communities

Shorefront dunes are an important resource that store excess sand reserves and provide an emergency supply of sand back to the beach when erosion occurs. Healthy dunes also protect development and infrastructure from inundation and erosion damage and provide habitat for unique coastal flora and fauna. Dunes are naturally resilient and able to adapt to storm waves, high winds, and high tides. In conjunction with offshore reef systems, coastal sand dunes are one of the first lines of defense against high wave impacts, and are an important component of a healthy, sandy beach.

FIGURE 11. Typical Hawaiian sand dune with beach sand reservoir at Kamaole III Beach Park in Kihei, Maui.

The Importance of Coastal Dune Vegetation

Coastal dunes are dynamic environments that support species that often occur nowhere else in the islands. They are unique among lowland areas in Hawai‘i in still containing a number of native plant species, which provide critical habitat to associated native animals, such as breeding seabirds and the endemic yellow-faced *Hylaeus* bees, which are important pollinators of native plants.

Due to their close proximity to the ocean, dune plants must withstand strong winds, an accumulation of windblown sand grains, salt spray, and occasional inundation by waves during high-surf events. The plants function as sand-catching systems that trap windblown sand and allow it to accumulate over time. During episodic high wind and

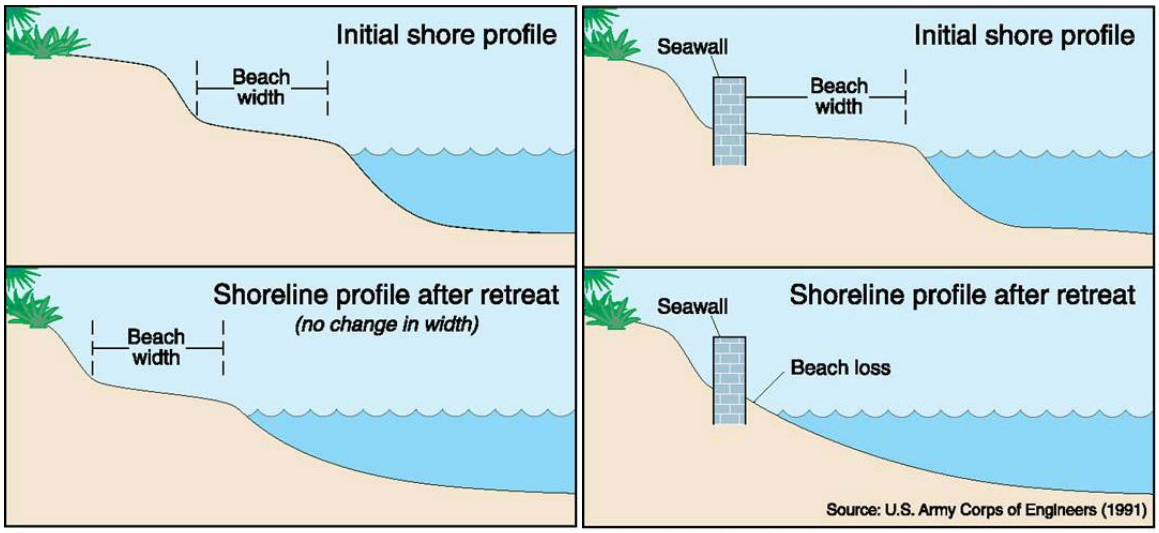
wave events, dune plants help keep sand in place and enable dunes to recover efficiently after the storm or waves have passed. Ensuring the presence of low-lying native dune plants is especially important due to their ability to capture sand but not overtake the dune habitat and ecosystem, or restrict lateral beach access.

However, coastal habitats are also stressful to plants due to high levels of solar radiation, hot temperatures, and limited freshwater availability. Although coastal dune plants are thought to have adapted to these harsh environments, thus enabling them to withstand these stressors, these plant communities are increasingly threatened by more frequent and severe storms events, decreased rainfall, disturbance by people, and added pressure from invasive species. Careful restoration of the dune environment and monitoring of the area are needed to ensure dune plants' healthy persistence into the future.

FIGURE 12. Pohuehue and ʻaki ʻaki grass growing on a dune at Kanahā Beach on the north shore of Maui (Photo: Forest and Kim Starr, Starr Environmental).

The Hazards of Shore Hardening

Coastal armoring, including the use of seawalls and revetments, has contributed to beach narrowing and loss along many miles of Hawai'i's beaches. Coastal armoring is typically deployed as a reaction to a severe erosion event or a long-term trend of beach erosion. Armoring, or other methods of 'holding the line,' attempt to keep the shoreline at its current position in opposition to natural forces, which can contrarily lead to beach loss in a number of ways.



A beach undergoing net longterm retreat will maintain its natural width.

Beach loss eventually occurs in front of a seawall on a beach experiencing net longterm retreat.

FIGURE 13. Illustration of natural coastal erosion and retreat with no loss of beach width (left), compared with (right) the nearly complete loss of beach when retreat combines with the presence of a seawall. (Image: UH Coastal Geology Group.)

Hardening the backshore on a chronically eroding beach often leads to narrowing and loss of sand as the water line moves further and further mauka (towards the mountains), approaching the fixed armoring on the backshore. Additionally, coastal armoring acts as a retaining wall, trapping sand behind it that would otherwise be available to resupply the depleted beach. Reflected wave energy that bounces off a hardened beach structure inhibits sand deposition, which could counter increasing beach loss. Lastly, currents and wave energy can wrap around the end of a hardened structure, increasing erosion to neighboring unarmored shorelines. This phenomenon, known as flanking, has historically led to a domino effect of armoring one adjoining property after another.

FIGURE 14. Sunset Beach, along O'ahu's North Shore, demonstrates substantial erosion of the dune and the destruction of a walkway following a strong swell event in 2018.

In an unarmored natural beach system undergoing erosion, assuming there is sufficient sand supply in the backshore, the whole beach system will migrate mauka while maintaining a uniform beach width and profile shape. Prohibitions against shoreline armoring have been strengthened in recent years in Hawai'i, recognizing the negative impacts that these structures have had on beaches here and worldwide. A wide stable beach coupled with a robust dune ecosystem can provide an effective long-term buffer to chronic coastal erosion and beach loss.

Beach Nourishment

Several beaches in Hawai'i have been rebuilt through beach restoration projects which use sand brought from local or offshore sources. Beach nourishment projects generally require extensive environmental impact studies, major engineering design, and sand compatibility based on composition, color, grain size distribution, and other characteristics. These projects are multi-year endeavors and typically very expensive, costing millions of dollars, well beyond the scope of this guide.

In many cases, dune restoration and management is a proactive and standalone activity that is not associated with beach nourishment. However, in cases where beach nourishment is planned, a dune restoration component should also be considered, since dunes can provide extra benefits, such as additional sand supply and wave run-up protection, which may enhance the overall project outcomes. Beach nourishment information and permitting requirements can be found in the State Department of Land and Natural Resources (DLNR) Small Scale Beach Nourishment (SSBN) Guide.[7]

FIGURE 15. Restored dunes are complementary to beach nourishment projects such as in this location at Stable Road on Maui's north shore.

7 http://dlnr.hawaii.gov/occl/forms-2/

II. DUNE MANAGEMENT PRACTICES

Dune preservation and restoration is one of the most proactive ecosystem-based strategies in the coastal management toolbox. Sometimes referred to as a mix of art and science, dune restoration is the process of working with the natural processes of sand accumulation and vegetation growth to encourage buildup of healthy dunes over time. While a successful dune restoration project must effectively balance the needs of the community and the project budget with the desired ecological outcomes, the technical methods of restoration are fairly simple. It is important to consider that coastal restoration sites require varying degrees of ongoing maintenance and stewardship over time, and dune restoration is as much about managing the interface of humans with the beach as it is about ecological restoration.

The dune management methods and best practices listed below vary in complexity and scope, from passive to active restoration, and may be used independently or in combination. These methods, discussed in detail in this section, range from relatively minor interventions (e.g., beach access changes) to complete reconstruction of dunes (e.g., sand pushing, or skimming of sand from the active beach):

- **Manage foot traffic** with delineated beach access pathways.
- **Designate dune restoration areas** with rope or other barriers to protect vegetation from foot traffic.
- **Remove obstructions and invasive species** in the restoration areas.
- **Plant native vegetation** to encourage sand build up over time and to stabilize dunes.
- **Install sand fencing** to accelerate accumulation of wind-blown sand.
- **Rebuild dunes** with sand from the same littoral/beach cell, if needed.
- **Construct elevated boardwalks** or dune walkovers, for special circumstances.

Manage Foot Traffic with Pathways

Foot traffic and trampling of vegetation are often the primary threats to the maintenance or re-establishment of coastal dunes. Thus, a significant part of any successful dune restoration project is developing a clear understanding of how people access the beach. Is there a parking area associated with a beach park? Are there beach showers in the vicinity of the shore? Are pathways clearly delineated? Are there ad hoc or opportunistic walkways to the beach?

It is important to balance the needs of beach access with the ecological objectives of dune restoration. For example, signs pointing the way to showers, parking, bathrooms, and other amenities will steer people around sensitive dune plants and restoration areas, and prevent trampling of vegetation. Restoration done correctly, and with identification of various user groups and their unique needs, will improve beach goers' understanding of the importance and value of a healthy dune ecosystem, which may encourage them to abide by the designated walkways.

Ignoring the human element during dune restoration can cause a project to be viewed as an impediment to beach access, a nuisance, and a self-serving attempt to close down

beach areas or keep people out. It is essential for the success of any restoration project to engage beach users and community stakeholders in the restoration process and educate the public about the need for, and benefits of, coastal dunes.

FIGURE 16. (Top, left) The Ka ʻIwi Scenic Shoreline on Oʻahu illustrates the chaotic outcome of an unmanaged coastal trail system. (Top, right) A constructed public beach access ramp to Kamaʻole Beach I in Kihei, Maui, helps guide foot traffic and protect the dune system from foot-traffic erosion. (Photo: Lis Richardson) (Bottom) More simply, dune access pathways may be delineated with ropes or barriers, as illustrated in this conceptual plan.

Local topography and usage will heavily influence the types of access paths needed. Path types may range from simple sandy paths delineated by signs, posts, or ropes, to more substantial paths designated by fencing, to even more extensive stairs, ramps, or walkovers. (See Figure 31 for reference).

An understanding of the area's unique coastal processes is also important when laying out beach access pathways. For example, in areas where wind transport of sand is a predominant force, pathways should be aligned perpendicular to the prevailing winds, or as close to perpendicular as is practical. This alignment prevents a blowout,[8] which can cause sand to be blown off the active beach along the pathway. Sand blown inland can create a nuisance if it accumulates on roadways or nearby buildings, and once removed from the active beach area, it is essentially lost to the beach system. This process of sand loss from blowout can contribute further to chronic erosion since the sand is no longer available to replenish the beach when storms or heavy waves occur. Therefore, it is critical for beach and dune system preservation to mitigate and minimize blowouts.

FIGURE 17. Dune blowouts at Waipuilani Beach Park, Kihei, Maui.

8 Blowout: an area on a dune where an absence of vegetative ground cover allows wind activity to funnel sand over and out of the dune system, causing scouring of the dune and accelerating beach loss; these frequently occur along shoreline access paths and at drainage outlets that are aligned parallel with the prevailing wind direction.

FIGURE 18. Sand blowing into parking areas or roadways presents a major management problem in Kihei, Maui.

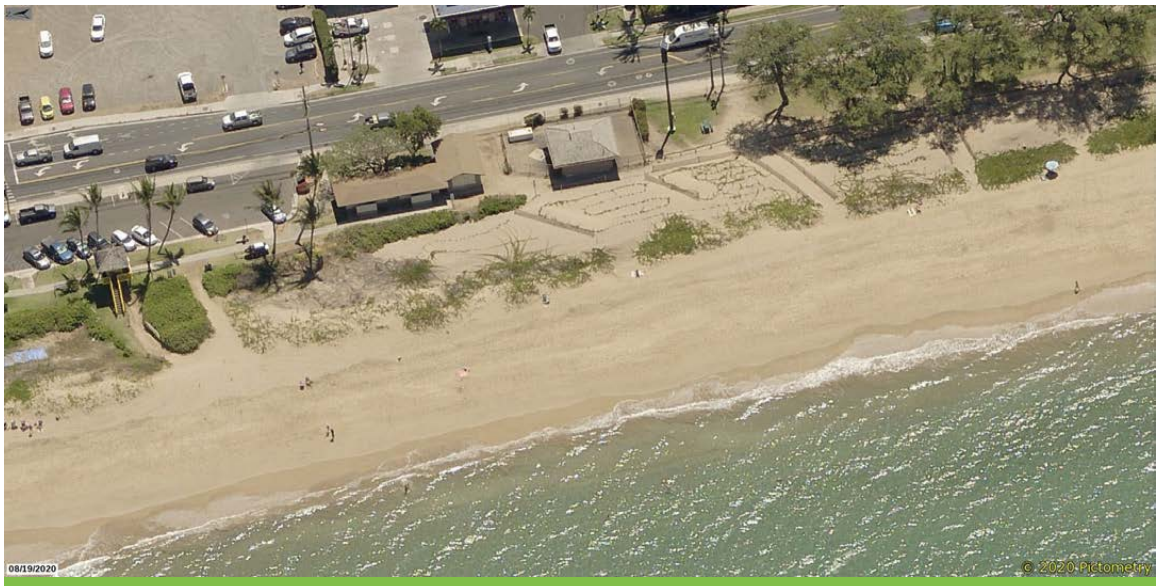


FIGURE 19. Properly aligned dune pathways can greatly improve dune stability and sand management in windy coastal environments. In this image from Kamaole I Beach Park, Kihei, Maui, paths are oriented perpendicular to the prevailing wind direction to avoid dune blowouts. (Photo: Eagleview Connect Explorer/County of Maui)

Blowouts can also be a concern in areas of high foot traffic and beach use, where up-and-over pathways may wear down through a dune and quickly become a valley or breach susceptible to prevailing winds. These openings in the dune ridge are also vulnerable to high wave runup, allowing ocean waves to flow through the dune and flood backshore areas.

Preventing these dune gaps from forming is a significant challenge, with methods ranging from temporary rubber mats and boards that can be set up and removed each

day, to steps, ramps, and bridges that keep foot traffic elevated above the dunes (see: *Construct Elevated Boardwalks*). However, before undertaking an expensive and involved option, always consider or test out a simple practical solution, such as adding more or better-placed pathways, or closing off and relocating an existing path to allow the dune to recover.

Designate Dune Restoration Areas

Once beach access or dune walkover pathways are effectively delineated, the areas for dune and plant establishment can be identified. Restoration areas can be roped off with simple wooden posts and rope, wooden fences, or other natural material structures that match the local or desired aesthetic. Once the potential dune areas have been identified and roped off to prevent human foot traffic and trampling, passive or active restoration activities can begin.

FIGURE 20. Fencing to delineate restoration areas and manage access can be as simple as wooden posts and rope, like these examples from Sunset Beach, Oʻahu (left) and Lower Pāʻia Park on the north shore of Maui (right). In some cases, available wood sources can be repurposed for the job, as was done for the Sunset Beach fence project, which used invasive Ironwood trees that were cut down nearby.

In many cases, simply eliminating the constant pressure from foot traffic will allow plant growth to improve greatly; long dormant seeds will sprout, and opportunistic native plants will reestablish in the area with little additional intervention. Native plants that are adapted for dunes will naturally capture, accumulate, and stabilize sand over time, although some light hand-weeding may be necessary if invasive plants are present and spreading. This type of passive restoration may require little to no further intercession, although there are several strategies to speed up dune recovery by working with the site's natural coastal processes, including planting native vegetation, installing sand fencing, or actively pushing sand to establish dunes.

Remove Obstructions and Invasive Species

Depending on a site's history and current surroundings, there may be obstructions such as buildings, concrete rubble, asphalt debris, old irrigation lines, or invasive plants that are negatively impacting the natural processes of sand movement and dune formation. While removal of these obstructions may be warranted as an important step towards

restoring the ecological integrity of a site, it is important to check with the county planning department and a Hawai'i Sea Grant extension agent to ensure that removal will not cause further damage or pose any harm to beach users.

When buildings, roads, or other infrastructure are obstructions to planned restoration, removal is likely to be impractical or cost-prohibitive, in the short run. In such cases, compromises have to be made to accommodate these obstacles. Other possible complications may involve invasive trees such as ironwoods, kiawe, or hau that may have encroached onto the site and are causing disruption to coastal processes. Removal should not be undertaken without full consideration of the impacts, and a deliberate and phased approach is most likely necessary.

Plant Native Vegetation

What to plant

One major goal of restoring dune vegetation is to ensure a diversity of native species. Appendix C provides a list of commonly utilized native and Polynesian-introduced plant species that are recommended for use in dune restoration projects. While native plants are the preferred components of a dune restoration planting palette, plant selection for specific dune restoration projects must consider a number of objectives, and it is essential to use the right plant in the right place or situation, with attention to weather, climate, and environmental conditions.

Consideration of future climates will improve species selection for restoration projects. For example, climate change is likely to increase salinity in coastal dune habitats, which may lead to declines in, and possible extinctions of, salt-sensitive dune plant species. To ensure the persistence of a diversity of plant species in coastal dunes, prioritize salt-tolerant species for restoration of foredunes and salt-sensitive species in mauka dunes that receive less salinity exposure.

In addition, note that human-centric desires for unobstructed ocean views, manicured lawns, or plants that match a certain Hawaiian-resort landscape aesthetic may lead to selecting species that interfere with the ecological purpose of a healthy dune system. However, dunes systems provide both beauty and function, and restoration projects can often support varied objectives.

Some plant species that thrive in the coastal environment can be a problem if they become overgrown through excessive irrigation and fertilization, or are planted in the wrong location. For example, many coastal plants have dense root systems that displace sand or have woody, above-ground stems and leaves that can create a physical barrier that acts functionally similar to coastal armoring or a seawall. This may inhibit natural sand accumulation and result in narrowing of the un-vegetated, active beach, which will interfere with coastal processes and inhibit longshore and lateral public access.[9]

As an example, naupaka (*Scaevola taccada*) is a fast-growing native plant that can be appropriate on the crest or mauka side of a dune. However, when planted in the foredune and overwatered through excessive irrigation, it can spread uncontrollably,

9 Public access along the *beach transit corridor,* defined as the areas extending makai of the shoreline is under the jurisdiction of the State of Hawai'i Department of Land and Natural Resources (DLNR) pursuant to Hawai'i Revised Statutes (HRS) Chapter 115, Public Access to Coastal and Inland Recreation Areas. §115-4 Right of transit along shorelines. See Figure 33.

become dense and woody, encroach onto the active beach to impede public access, and choke out other native foredune plants. Selecting a diversity of species to plant will help ensure that the dune vegetation is not dominated by a single species.

FIGURE 21. Encroaching dune vegetation can create an overhang and unsafe conditions during erosion events and severely restrict lateral public access. Images show before (left) and after (right) encroaching vegetation was managed and trimmed back to reopen the beach. (Photos: Lucinda Pyles)

Where to plant

In general, dunes plants can be classified (Appendix C) according to where they belong in relation to the active beach (zone 1). Nothing should be planted or encouraged to grow on the active beach. If dune plants are cultivated too densely and too far makai (seaward) on an eroding dune, a steep erosion scarp with overhanging vegetation is likely to develop.

Low-lying, loosely bound grasses and vines, such as ʻaki‘aki grass and pohuehue vines, are naturally found and can be planted in the foredune (zone 2), providing many benefits. These plants capture sand that is transported by wind or waves, developing or restoring dunes after a high-wave event. Their root systems help to stabilize dune sand, and they tolerate the natural disturbances that occur close to the constantly changing ocean and beach conditions.

Sometimes low-lying grasses and vines transition to, or combine with, low-growing shrubs in the middle dune (zone 3). In a natural setting that is not irrigated or manicured, these shrubs may provide natural erosion control during high-wave events. They also tend to provide other ecosystem benefits, such as shelter to burrowing seabirds.

Larger woody shrubs or trees, such as naupaka, milo, or beach heliotrope, are not as well suited for high wave inundation, and are generally found in the back shore (zone 4), mauka of the dune. Applying this plant selection guidance will ensure that looser and less obtrusive vines and grasses provide a light and flexible protective cover to the dune face. This will aid the capacity to capture sand while still allowing the dune to fluctuate naturally and supply sand to the beach system during periods of high waves and erosion (see Appendix C).

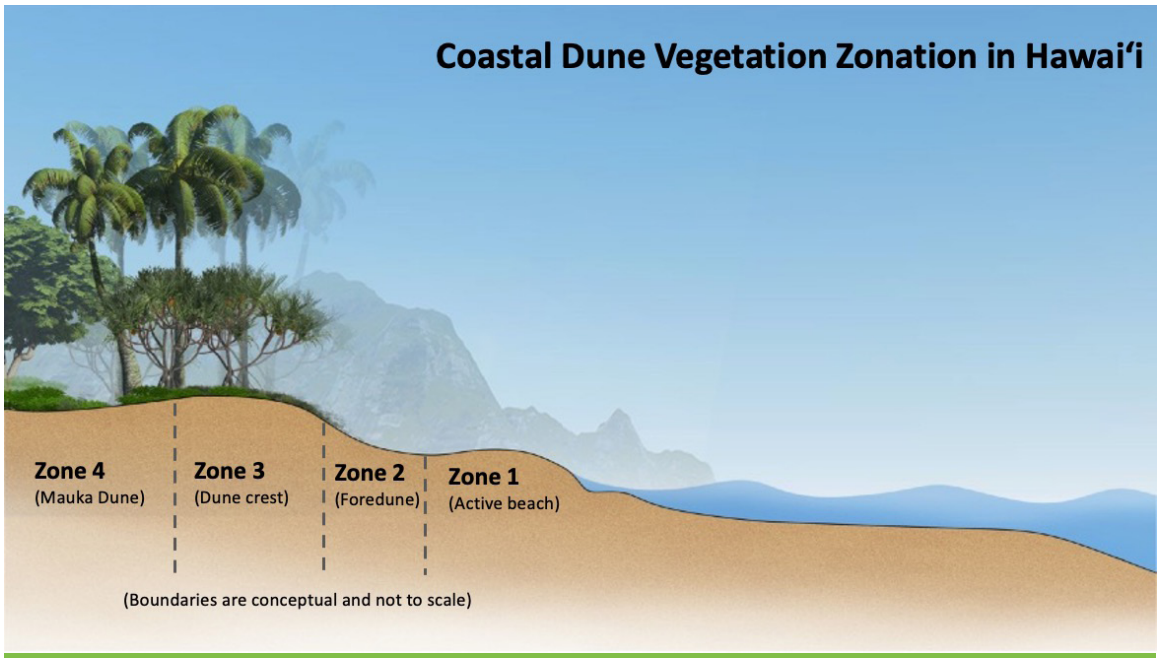


FIGURE 22. Conceptual drawing of plant typology and locations across the zones of a typical Hawaiian dune.

FIGURE 23. Typical Hawaiian dune vegetation at Kailua Beach, O'ahu, with low vines (pohuehue) and grasses ('aki'aki) makai of the foredune, and shrubs and bushes in the middle dune. Trees and large vegetation should be located mauka of the dune crest.

Irrigation

Even along the rainiest coasts of the state, newly introduced dune plants will generally require some irrigation for the first few months in order to get established. However, be aware that state policy prohibits irrigation, or any landscaping, makai of the certified shoreline[10] (often marked by the naturally occurring line of vegetation) because this would encourage encroaching vegetation, which inhibits public access and interferes with coastal processes.

Landscaped areas like beach parks usually have irrigation present, and a temporary line can be set up for simple drip irrigation of a newly-planted dune restoration area. (Areas without fresh water may require a temporary water tank that can act as a rain catchment or be filled periodically with brought-in water.) It is important to limit watering to the plants' establishment period and avoid overwatering to prevent unnatural conditions and weed-management challenges. Monitor for unintentional irrigation that may occur around beach showers, from sprinkler overspray, or from runoff or passive watering from parks or heavily watered landscapes. Also consider the time of year when planting new vegetation. Generally the wetter winter months are more suitable for new planting and will require less frequent initial watering.

In the past, coastal dunes have not needed ongoing supplemental irrigation to thrive. However, note that rainfall distribution is changing and becoming more extreme across many of the Hawaiian Islands due to climate change, with potentially negative consequences for coastal dune plant performance. In particular, germination and seedling establishment are threatened by reduced rainfall, so supplemental irrigation may be needed to promote natural regeneration and persistence of chosen plant populations for a healthy dune landscape. Once dune plants are established and flourishing, irrigation can be shut off and removed, or possibly left in place for rare use during periods of intense drought, with careful management to prevent excessive growth and encroachment onto the active beach.

FIGURE 24. Newly installed drip irrigation with newly planted pohuehue (beach morning glory). (Photo: Lis Richardson)

10 Hawai'i Administrative Rules §13-222-2 Definitions: "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. See Figure 33. https://dlnr.hawaii.gov/ld/files/2013/07/Ch13-222-Amend-Compil-Stand-Rev1.pdf

FIGURE 25. Tote tank used for temporary irrigation where a dedicated water line is not available.

Install Sand Fencing

Sand fencing consists of a low-lying, temporary fence, typically made of wood slats, that captures and accumulates windblown sand grains rapidly along its base. At a wind-dominated site, sand fencing can encourage sand accumulation when installed at a 45 - 90 degree angle to the predominant wind direction. Sand fencing can also serve a secondary purpose of creating a visible barrier to foot traffic and directing pedestrian flow to safe pathways to prevent trampling of vegetation and disruption of dune formation. While sand fencing can be a quick and effective way to encourage dune building, the fence must be maintained, removed, or replaced as it gets buried, torn by the wind, or degraded by the sun. In addition, the most effective sand fencing products are generally not biodegradable and eventually must be removed and discarded.

FIGURE 26. Sand fencing was installed at Kanahā Beach Park on the north shore of Maui to capture wind-blown sand and stabilize restored dunes. Sand fence panels eventually require maintenance or removal.

Rebuild Dunes

Sand pushing

Sand pushing, or beach skimming, involves moving sand by mechanical means from an area of sand accumulation to one of erosion restoration. A typical approach for sand pushing is to skim a thin layer of sand (i.e., less than one foot) from the dry beach surface and pile it elsewhere to create or add to a dune. This practice can jump start a dune restoration effort by quickly creating the beginnings of a dune, which otherwise could take many months by natural accretion.

FIGURE 27. Sand pushing has been used at ʻEhukai Beach, Oʻahu, and while not always necessary for a successful dune project, it is an option to quickly restore a dune.

Sand pushing should be done during a time of year when the beach is at its widest, prior to the onset of any seasonal erosion events. It is important to understand the beach system in a holistic context, and recognize that taking sand from one location may cause erosion or sand-starve another area, if not planned carefully.

While sand pushing is a relatively simple method to kickstart dune restoration, it is only appropriate in beach settings with abundant sand, and to do it effectively requires a careful analysis of coastal processes. Otherwise, the efforts could simply transfer erosion problems from one section of the beach to another. Sand pushing is most applicable at locations that are heavily impacted by foot traffic, such as public rights-of-way and beach parks. The technique is not the recommended solution for all locations, though, and is closely regulated by state and county resource agencies (Appendix B). It is advisable to consult with a professional or contact a local Hawaiʻi Sea Grant extension agent for advice and guidance on this technique (Appendix A).

Alternative sand sources and sand transport

When considering alternative potential sand sources for dune replenishment, it is important to find a high-quality, compatible source. In other words, the source should have sand grains similar in size to those on the existing dune, and should not have a disproportionate amount of fine material (dirt) relative to the existing coastal environment. Minimal dirt is important if the sand is likely to be eroded by waves or during storm events, so that it will not negatively impact the marine environment. Check with your local planning department of the DLNR for more information on sand quality requirements.

In urban or developed areas, wind-blown sand sometimes travels off the active beach and outside of dune systems to collect on walkways, roads, and parking lots, becoming a nuisance or liability and representing a loss of sand from the natural system. Restoration practitioners can often recommend strategies to minimize these losses and re-incorporate wayward sand back into parent dune areas. Beach shower areas often accumulate sand deposits that need periodic removal; this sand can be returned to the beach or used to augment dune restoration areas.

Where intermittent streams enter the ocean, a sand plug can form in the stream mouth when flow is diminished. Local municipalities often clear this plug to prevent flooding, but state law requires the sand to be placed in close proximity or adjacent to where it was removed. While the geography of each site is unique and stream mouth clearing practices vary considerably throughout the state, such cleared sand can potentially be used to create or augment dunes nearby and within the same littoral cell, provided the excavated sand meets quality criteria.

FIGURE 28. Sand plugs, as illustrated in this overhead view of Ka‘elepulu Stream on Kailua Beach, O‘ahu, are a common occurrence at Hawai‘i stream mouths, especially those with limited flow volumes.

FIGURE 29. Sand can be a maintenance problem for areas where walkways (left, Waikīkī Beach) or other infrastructure (right, Kualoa Park) get covered by wind- or wave-driven sand migration.

Construct Elevated Boardwalks

Whether a dune restoration project is passive or active, dune walkovers and boardwalks can greatly assist with minimizing foot traffic erosion and can be important tools for maintaining a resilient dune system. If a site requires construction of stairs, ramps, walkovers, or boardwalks, it is important to consult with the county's planning department to understand whether there are code requirements and American Disabilities Act (ADA) compliance. Construction of an ADA-compliant beach access ramp requires a knowledgeable contractor and unique carpentry skills. In general, structural elements like post foundations and boardwalks should be kept as small as possible to accommodate safe foot traffic while causing minimal interference and impact to the dune ecosystem.

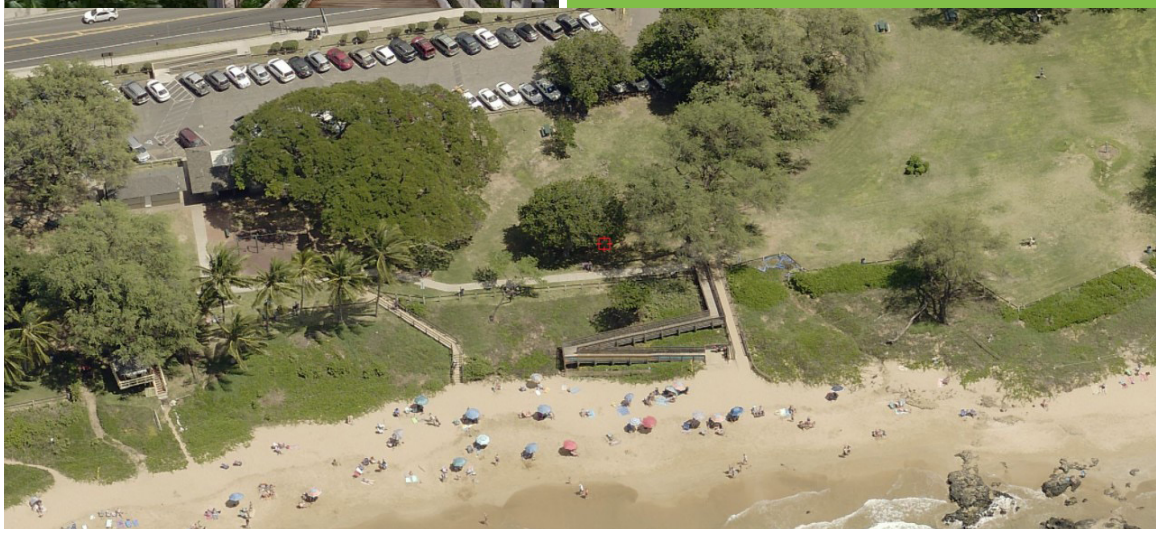


FIGURE 30. (Left) Dune ramp constructed to provide shoreline access and protect the restored dunes at Kamaole Beach Park I in Kihei, Maui. (Photo: Wes Crile, Hawai'i Sea Grant) (Bottom) Dune Walkovers at Kamaole Beach Park III in Kihei, Maui. (Photo: Eagleview Connect Explorer/County of Maui)

Dune walkovers and boardwalks are not appropriate at all locations and are closely regulated by state and county resource agencies (Appendix B). It is advisable to consult with a professional or contact your local Hawai'i Sea Grant extension agent for advice and guidance on this endeavor (Appendix A).

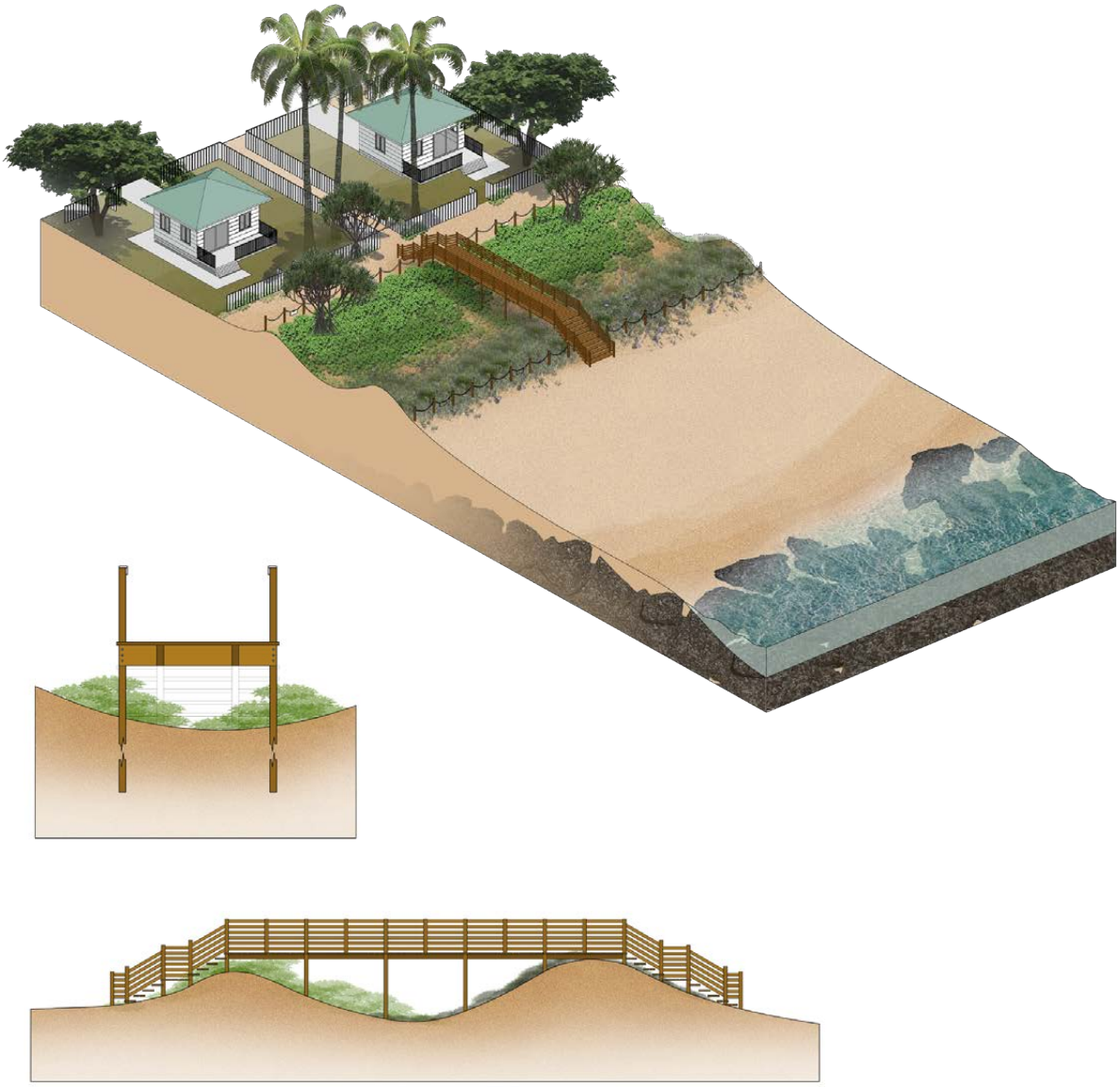


FIGURE 31. Conceptual plans from above (top), the end (middle), and the side (bottom) for a dune walkover

III. PLANNING AND IMPLEMENTING A DUNE RESTORATION PROJECT

Restoration of a coastal dune requires a robust understanding of the site's current coastal, ecological, and beach user conditions, details of its historical context, and any logistics and regulatory requirements of future restoration activities. While restoration of dunes and vegetative buffers can be one of the most proactive and low-cost shoreline management options available, there are complexities for any project located at the shoreline that warrant careful forethought and consideration.

Planning considerations include not just physical coastal processes, such as wind and waves, but also social factors like historic or cultural significance and traditional uses. For example, dunes in Hawai'i were commonly used as burial sites, so great care should be taken when working with them. If historic remains such as artifacts, burials, or concentration of charcoal are encountered, work should cease immediately, and the State Historic Preservation Division of the DLNR[11] should be contacted.

To illustrate our recommended, best-practices procedures for planning and implementing a dune restoration project, we will present elements from a case study at Kapukaulua (Baldwin Beach) where they apply to the following planning steps. In 2020, Hawai'i Sea Grant was awarded a grant from the National Fish and Wildlife Foundation (NFWF) Coastal Resilience Fund to develop site-specific plans for dune restoration at Kapukaulua (Baldwin Beach), Maui, in the area from Lower Pā'ia Park to Wawau Point (Baby Beach). In the face of sea-level rise and chronic shoreline erosion, the long-term goal of the project is to implement community driven restoration activities that have the complementary benefits of habitat restoration, infrastructure protection, and community resilience.

FIGURE 32. A portion of the proposed Kapukaulua dune restoration area, where dunes have been degraded by heavy use, erosion, and high waves. (Photo: Eagleview Connect Explorer/County of Maui)

11 DLNR State Historic Preservation Division (808) 692-8015

Recommended steps, described in more detail below, include:

1. Kilo (observe) the site to gain an understanding of its history and define the problem.
2. Engage stakeholders and identify a community champion.
3. Develop a detailed site plan, considering phases of effort over time.
4. Implement the site plan.
5. Monitor and manage the site.

1. Kilo (observe) the Site to Define the Restoration Problem

Dune restoration projects often begin with a problem: the dunes have been destroyed or degraded by intense or unmanaged human uses; invasive or encroaching vegetation dominates the landscape; there is a loss of native biodiversity (plants and associated animals); excessive dune erosion is observed in the form of scarps or gaps; or sand is accumulating where it is not wanted. Such concerns invariably lead to the question of how to remedy the problem. Any project should begin by identifying the particular challenges at the site and determining whether dune restoration is an appropriate solution. Keep in mind that dunes are often, but not always, a suitable solution for a particular coastal problem.

Build a team

This investigative period is the time to establish a working relationship among interested parties, including the land owner or land steward, a Hawai‘i Sea Grant extension agent, a County Planning Department coastal zone management planner, and a representative from the County Parks & Recreation Department, if a public park is involved. Hawai‘i Sea Grant personnel will have extensive knowledge and technical resources to offer about the site, coastal issues, the planning process, and community engagement (See Appendix A).

Understand the rules: Permits and jurisdictional boundaries

The coastlines of Hawai‘i are jointly managed by county, state, and federal agencies whose jurisdictional boundaries are not immediately apparent on a beach. In general, county jurisdiction is mauka of the highest wash of waves; state jurisdiction is makai of the highest wash of waves; and federal jurisdiction (overlapping the state’s) is makai of the high tide line.

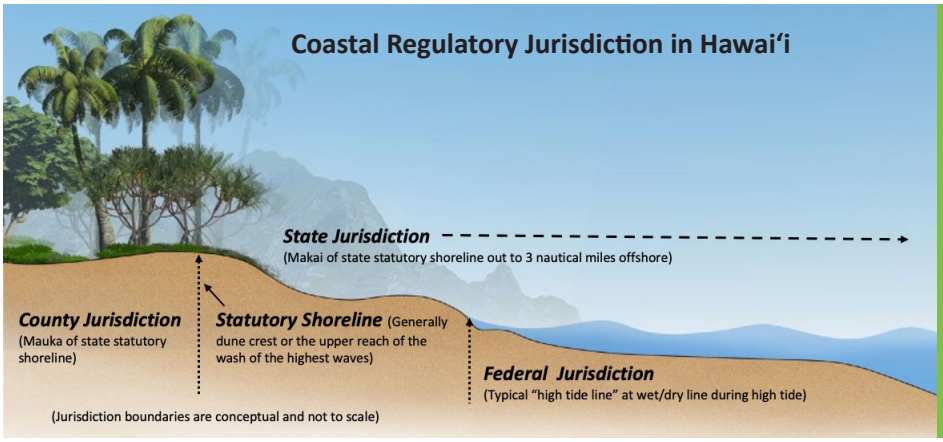


FIGURE 33. Conceptual drawing illustrating the coastal regulatory jurisdiction definitions of Hawai‘i shorelines.

For many dune restoration projects, only county permits will be needed. A complete explanation of the shoreline permitting process is beyond the scope of this manual, but a Hawai'i Sea Grant extension agent can be a useful resource for understanding the permitting process for dune restoration projects. Depending on the location and nature of the dune restoration activity, county, state, and/or federal permits may be required, including one or more of the following:

- County (often):
  - Special Management Area (SMA) Assessment
  - Shoreline Setback Assessment
  - Grading Permit
  - Flood Development Permit
  - Right of Entry (if a county beach park)
- State (sometimes):
  - DLNR Site Plan Approval[12]
  - DLNR Small-Scale Beach Restoration (SSBR)
  - DLNR Right of Entry
  - Dept of Health NPDES[13]
- Federal (rarely):
  - Clean Water Act Section 401
  - Clean Water Act Section 404

Understand the site

An understanding of the unique coastal processes of the site is important since its natural processes will guide and shape restoration plans. It will be key to visit the site a number of times because conditions may be dynamic, and each view could highlight different and significant characteristics that are not always present.

Plan to visit the site at both high and low tide, when waves are both calm and large, and on windy and calm days. Changes from seasonal erosion can be dramatic with large volumes of sand moving around within a littoral cell. Observing a site a number of times will ultimately enable a fuller understanding of the situation. Talking with local residents, beach users, surfers, and lifeguards also provides an excellent source of historical information. It is also important to consider projected future changes to the weather and temperature in order to select appropriate plant species and actions (e.g. to irrigate or not). Useful observations to note include:

- dominant directions of both wind and waves;
- potential causes of erosion and seasonal changes to beach and shoreline;
- major geologic features in the immediate and surrounding areas;
- significant cultural and historical features in the area;
- drainage structures, stream mouths, wetlands, or other watershed features that might affect dune formation;
- types and states of existing vegetation, and whether some need removal;
- availability of water for irrigation of newly planted dune vegetation;
- and endangered coastal species in the area and their habitats or resting places. (Protecting these species should be considered when selecting plant species and actions.)

12 The DLNR may require additional permits depending on the scope of the project. More detailed information can be obtained from the DLNR Office of Conservation and Coastal Lands. https://dlnr.hawaii.gov/occl/coastal-lands-program/

13 https://health.hawaii.gov/cwb/permitting/general-permits/

Case Study: Understanding Kapukaulua

Located on the north shore of Maui and exposed to strong trade winds and ocean waves, the project site has one of the highest rates of coastal erosion in the state. It experiences significant seasonal shifts of sand throughout the year: in summer, trade winds move sand from east to west; in winter, ocean swells dominate as the transport mechanism, reversing the sand's motion. The beach pavilion at Baldwin Beach Park is often undermined during peak summer erosion, only to be filled with sand and then recover a wide, fronting beach during winter. Dynamic coastal processes like these are not readily apparent from a single visit, illustrating the value of evaluating a site through time to fully grasp its complexities.

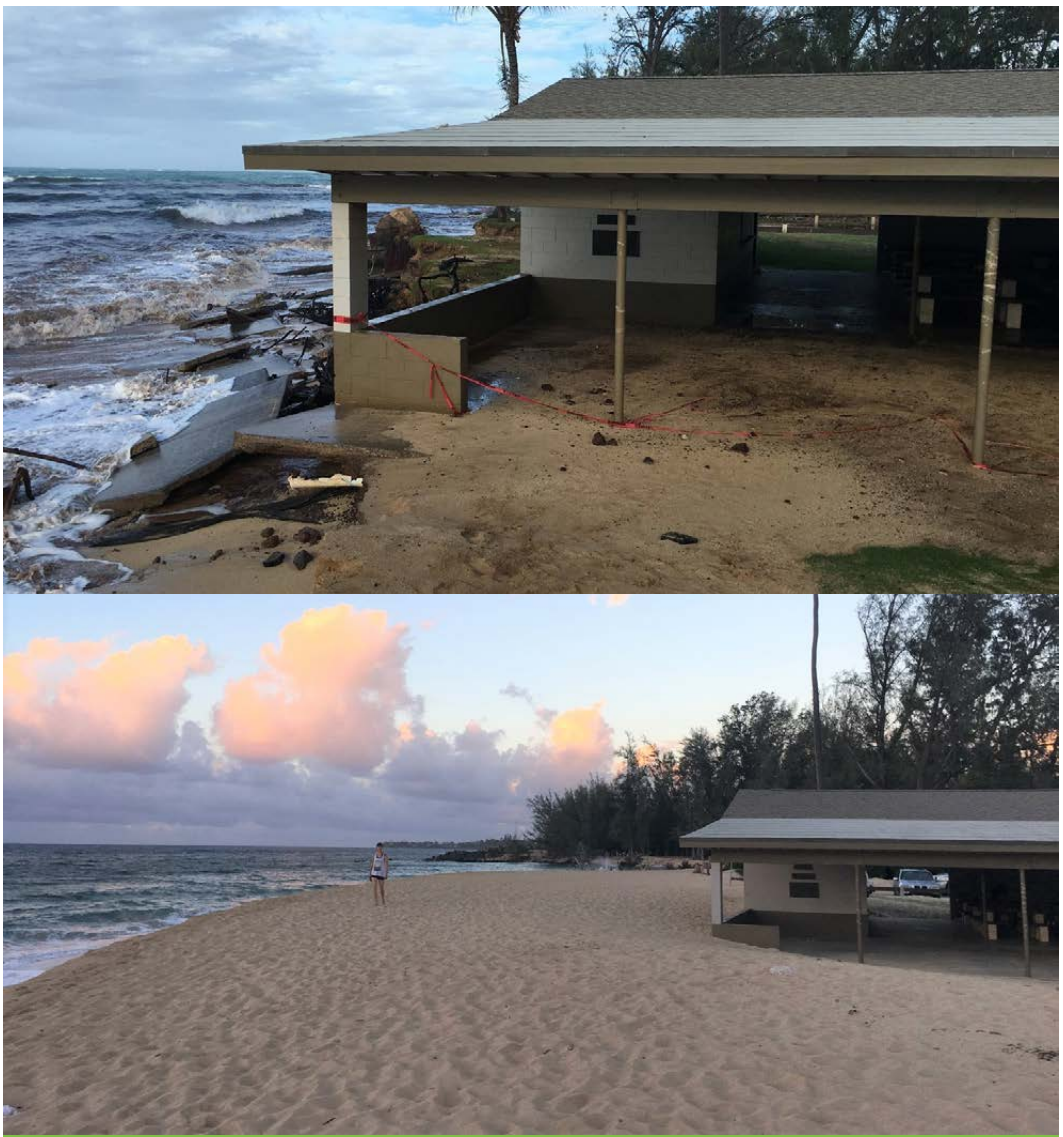


FIGURE 34. (Top) The Kapukaulua (Baldwin Beach) Pavilion is impacted by high waves during the peak seasonal beach erosion in the summer. (Bottom) The beach in front of the pavilion recovers as a result of winter season swells that push sand back toward the pavilion.

Historical context

Hawai‘i’s beaches have a long history of use, dating back hundreds of years from human’s first arrival to the present. An understanding of historical activities and how they relate to current uses of a site can help guide restoration activities while protecting important cultural and historic resources. Social and cultural characteristics include the site’s historical context, different uses and cultural importance, cultural resources such as ‘iwi kupuna (burials) and archaeological sites, and human-caused impacts to beach processes. Some coastal plants are also culturally important, such as the vining parasitic kauna‘oa (*Cuscuta sandwichiana*), the official lei plant of Lāna‘i.

Case Study: Historical context of Kapukaulua

Kapukaulua is an important cultural site with a number of archaeological features, burials, and a long history. Past centuries of human interference and environmental degradation have impacted the site including a large sand mining operation that operated for nearly 70 years, sewage outfalls into the ocean, existing debris from old roads and buildings, as well as two constructed rock revetments that interrupt the natural flow of sand within the littoral cell. Understanding this legacy of sand mining and loss of the natural beach ecosystem over time was important for determining what restoration activities could reasonably be proposed, and for guiding the desired outcomes of the restoration project

FIGURE 35. Pā‘ia lime kiln was associated with the sand mining operations at Kapulaulua. (Photo: Maui 24/7; https://www.facebook.com/maui247/photos/the-old-paia-lime-kiln-in-ancient-times-kapukaulua-the-ulua-fishing-hole-was-a-f/2469937953086197/)

Current usage

Another element to establish is the way a site is currently being used by the community. Consider distributing a simple park-user survey to determine who is using the area and for what activities. Keep in mind that user groups and numbers can vary significantly by season, so create a picture of overall usage by surveying site users at different times of the year. Ideally, gather observations through at least a full year, with the knowledge that no single site visit will represent typical conditions. Useful information to gather includes current users and groups (fishers, surfers, snorkelers, etc.), both resident and visitor usage and access, and current beach access points or walkways, both formally designated and informal or opportunistic.

2. Engage and Identify Stakeholders

Successful projects will need a mechanism for engaging with the community and incorporating feedback into site plans and implementation activities. Engagement and outreach ideally should happen throughout planning and implementation. Outreach could be as simple as signage or a project information table set up onsite, or as formal as public meetings or a project website. The essential component is to provide opportunities for the community to contribute to the restoration activities and site plan development.

Case Study: Stakeholder Engagement at Kapukaulua

Stakeholder engagement at Kapukaulua (Baldwin Beach) was conducted with the assistance of a community advisory group that brought together 25 individuals with a diverse array of experiences and backgrounds, including local fishermen, long-time area residents, native plant botanists, endangered seabird and sea-turtle biologists, traditional Hawaiian cultural practitioners, and Aha Moku representatives. Feedback was gathered through virtual and in-person meetings, a project website storymap, informal talk-story sessions, and a survey. While not all dune restoration projects will necessitate a formal advisory committee as was used here, successful projects will need some mechanism for engaging with the community and incorporating feedback into planning and implementation.

Ongoing management and stewardship capacity

Before undertaking a dune restoration project, it is important to acknowledge that there is an ongoing financial, time, and maintenance commitment, although restoration projects require varying degrees of long-term stewardship. Identifying from the start the group or department that will be responsible for project maintenance, as well as understanding their overall management capacity, can help determine the proper scope for a project to ensure its long-term success. For example, a smaller project can be successfully maintained by a volunteer group, homeowner's association, or a state or county department, which may be preferable to engaging in a larger project that may ultimately fail due to a lack of capacity. All too often, restoration projects do not adequately consider ongoing maintenance needs, resulting in well-intended projects

that suffer a lack of upkeep. Determining who has the kuleana (responsibility) for initial and ongoing maintenance should be resolved early in the planning phase.

Case Study: Management at Kapukaulua

At Kapukaulua, there was an existing stewardship group included as a partner in the early phases of the project. The Pāʻia Youth and Cultural Center (PYCC), which operates an after-school program for middle and high school students, had previously worked with Hawaiʻi Sea Grant extension agents and the South Maui Volunteers to install a pilot dune restoration project near their youth center in Lower Pāʻia Park. Youth center students and staff actively participated in the project throughout the early stages of outreach and engagement, designation of pathways, and installation of irrigation, and they continue with ongoing monitoring and maintenance of the restoration sites.

FIGURE 36. Students and staff from the Pāʻia Youth and Cultural Center (PYCC) participated in the design and installation of the dune restoration project at Lower Pāʻia Park, and they continue to provide ongoing maintenance, monitoring, outreach, and education. (Photo: PYCC)

Education and signage

The beach and shoreline area are environmentally, culturally, and socially sensitive regions to work in. Beachgoers are likely to ask about project goals, and may have strong opinions about how to care for coastal areas. Engagement with the public about the goals of a dune restoration project prior to construction is essential to success. Based on these early engagements, restoration project managers should develop an in-depth understanding of potential points of opposition and be prepared to speak to expressed concerns using simple and concise educational materials including signage, FAQ webpages, and other informational materials and documents. In particular, educational signs[14] about dune restoration efforts should be designed to alert the public about the sensitive work being done in the area. Crafting a careful educational message will help gain support for a project, enhance behavioral compliance, and educate the public about the importance of dune restoration.

14 Contact your local Hawaiʻi Sea Grant extension agent for sign templates that have been used in other dune restoration projects and that can be adapted as needed.

Key dune restoration goals to incorporate into educational messaging include:

- protecting the beach and dune against the effects of erosion and beach loss;
- helping to restore native ecosystems and natural processes;
- ensuring access to a healthy and wide beach;
- and creating natural protection from erosion and other coastal hazards.

FIGURE 37. Example of dune educational signage on display at Kamaole I Beach Park, Kihei, Maui.

3. Develop a Site Plan using Dune Management Practices

Developing a site plan will put the relevant dune management practices (section II) into action. Site plans are an important tool used for project planning and public outreach as they help to convey to stakeholders the specifics of a proposed restoration project in a visual format. They will also be used when filing for permits and during implementation and construction phases of a restoration project. Plans can be as simple as a hand-drawn depiction of proposed restoration activities, or as complex as a professionally designed set of engineering or architectural prints. Generally, more detailed site plans with scaled maps, topography, and elevations are preferred or required by state and county resource agencies.

There are several important elements to remember when designing site plans.

- Place dune restoration efforts as far mauka of the active beach as possible.
- Always align beach access paths and walkways 45-90 degrees to the predominant wind direction to prevent dune blowouts.

- Provide scaled maps with property boundaries whenever possible.
- Estimate the potential restoration area(s) that will need to be roped off.
- Identify vegetation that may need to be removed, thinned, or replaced, including invasive vegetation species or plants disrupting the natural movement of sand.
- Consider the natural processes of the site and, wherever possible, work with them.

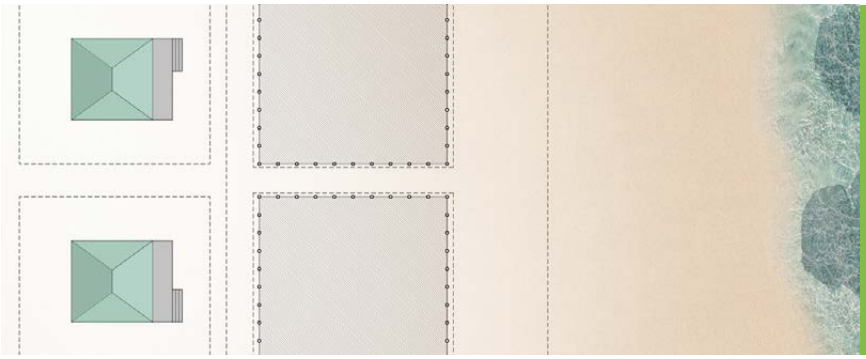


FIGURE 38. Conceptual site plan for perimeter fencing around the restoration area. Typically the shoreline location and property boundaries would be delineated on a site plan.

FIGURE 39. Kapukaulua dune restoration conceptual site plan based on expert and community input. (Image: Tetra Tech Inc. and Hawai'i Sea Grant)

Case Study: Obstructions at Kapukaulua

The proposed restoration site at Kapukaulua has invasive ironwood trees growing onto the active beach with remnant root systems that are undermined by erosion. These trees become a public hazard to swimmers and walkers when they fall across the beach and litter the nearshore area. The upright ironwoods also form thick stands, whose accumulated needles cover the ground, hindering the establishment of native dune plants below them. While removal of the ironwoods is appropriate from an ecological restoration standpoint, these trees also provide desirable shade and windbreaks for beachgoers, and in many cases are beloved by the community. As part of the site planning and community engagement process, phased removal of the ironwoods is identified as a dune restoration practice, along with establishment of native plants and trees that can provide desired functions, like shade and windbreaks.

FIGURE 40. Fallen ironwood trees and construction debris create a hazard to beachgoers.

4. Implement the Site Plan

In order to execute a site plan efficiently, it is important to form a dedicated planning and implementation team. While the number of individuals may vary, some key positions are critical, and the implementation team should be willing to help develop the project budget and schedule, and share responsibility for oversight and management of the project.

A project manager or leader is necessary to coordinate the schedule, material acquisition, and contracts for any work. Hire a licensed contractor to design and construct any built walkways or ramps, which will likely require rigorous building permits. Similarly, an architect or engineer may be important to help with the plans and permits for any constructed features. Finally, if a volunteer workforce is part of the plan, it is strongly recommended that a dedicated volunteer coordinator be on the implementation team.

When implementing the site plan, develop a construction schedule that considers seasonal factors and any possible weather delays.

5. Monitor and Manage

After a dune restoration project is planned and implemented, there will need to be some forms of monitoring and maintenance, particularly in areas that are heavily used by the public, such as beach parks. The following section provides some additional monitoring and maintenance strategies.

IV. MONITORING AND MAINTENANCE OF A DUNE RESTORATION SITE

As a dune restoration site becomes more established, the plants will grow and reproduce, natural coastal processes will continue, and ideally a restored site will mature into a healthy functioning coastal ecosystem that will provide the same or similar ecosystem services as a naturally occurring dune. Dunes are dynamic areas that can change rapidly due to human use, seasonal conditions, storms or high-wave events, climate change, and sea-level rise. Therefore, it is important to continue to monitor the structural and ecological performance of a restored site to document the changes over time and inform adaptive management decisions or adjustments for the site.

Once plants have been established, maintenance of a dune restoration project is generally minimal, consisting primarily of: preserving access paths; ensuring vegetation does not encroach too far makai; repairing and replacing fences that delineate dune restoration areas; weeding and pruning to encourage the desired vegetation; and continuing to educate the public about the importance of dunes and of keeping to the designated access pathways. Regular monitoring will identify areas of the site where adjustments, repairs, and further maintenance are needed.

It is important to remember that it is beneficial to the beach if coastal dunes are allowed to erode periodically during storm events, releasing sand onto the beach. Storm erosion into a restored dune may sometimes be viewed as a project failure by stakeholders. However, community and project stakeholders should be reminded that this is exactly how a natural dune is meant to function. The restoration project has provided a valuable service by supplying a healthy dune to replenish the beach with sand after a major storm, and the dune will most likely recover after the storm event.

Depending on the site and goals of the project, monitoring may consist of any or all of the following approaches: visual or photographic inspections, vegetation and habitat surveys, or dune profiles or topographic surveys.

Visual or Photographic Inspection and Monitoring

Generally, a simple method for site monitoring is through visual inspection, to document physical conditions, including changes in dune dimensions or elevation, changes in vegetation, seedling emergence, and evidence of human or natural impacts. At a minimum, monitoring these physical conditions can include taking time-lapse photographs, a technique that can easily be accomplished by recruited community scientists.

Taking a picture from the same position at a standard time interval will show changes in a site over the short- and long-term. Most simply, this is done by taking pictures from established fixed reference points in the landscape, such as rocks or trees, that are not likely to move over the years. In addition to taking shots at regular intervals (every month, for example), photographs should be taken before and after the restoration project is installed, and after any major, landscape-altering events, like storms or high-wave runup. This will provide a thorough, sequential record of changes in the site over time.

FIGURE 41. Comparison of Sunset Beach, O'ahu, before (top) and after (bottom) dune restoration.

Photographs should be accompanied by field notes of site observations, such as vegetation composition changes, sand accumulation or loss, presence of dune fauna, and other indicators of dune ecosystem health. Selected photos can demonstrate to stakeholders and the public how the site has changed and improved since the installation of the restoration project.

Habitat and Vegetation Monitoring

Depending on the site and goals of a project, in addition to visual and photographic monitoring, dune vegetation monitoring is also important to ensure stability and persistence of any restored plant species. For example, documentation of plant survival, growth, and assortment of native plant species is recommended to ensure a diverse community persists and to identify spreading or problematic species (especially non-native ones). Restoration areas may need to be monitored with high frequency through the plant establishment period, but after that period, monitoring frequency can more reasonably revolve around the seasons and in association with any landscape-altering events. Monitoring protocols often involve the use of transect lines or square quadrats to measure the habitat conditions.

To achieve the final goal of a naturally self-sustaining dune ecosystem, restored plant species must not only grow but also flower and produce seeds, which can then germinate and grow into the next generation of plants. Seed germination and seedling establishment are natural bottlenecks for dune population stability, because these young life stages are particularly vulnerable to stressors such as trampling by beach-goers, limited water availability, strong winds, storm surges, and flooding. Climate change will intensify many of these stressors in the future, and a lack of new seedlings will be an early indicator of coastal dune revegetation failure. Careful monitoring of seed production and seedling emergence are needed to ensure population sustainability, and in the absence of seedling emergence, additional irrigation may help by reducing salt accumulation in the sand, which imposes the strongest limitation to germination and seedling survival. Without flowering, seed production, and successful germination, regular out-planting will be required, leading to long-term investments in time and resources.

Physical Condition Monitoring

Likewise, depending on the site and goals of a project, it would be helpful to develop metrics for tracking changes in the physical conditions associated with sand dune development. These may include the dimensions of the dune (length, width, height), the volume of the dune, and any changes in its footprint or configuration. Again, the monitoring frequency should revolve around known seasonal beach changes, as well as any changes associated with landscape-altering events.

Simple and inexpensive monitoring protocols usually involve the use of basic dimension measurements and the installation of field stakes to mark and measure height increments. More resource-intensive options would involve the collection of beach profile surveys, using a survey laser transit or similar instrumentation, or full topographic surveys employing survey quality GPS equipment or airborne LiDAR (by either drone or aircraft).

Maintenance

Encouraging appropriate vegetation, and discouraging weeds or invasive species, in a restoration area will involve some maintenance. Beyond the inevitable weeding to remove invasive or native species that are becoming too dominant, nearby trees may heavily shade the site or grow too fast, smothering preferred vegetation, and will require trimming.

It is also important to replace plants that do not survive, in order to preserve dune health. Where necessary, choose alternative plant types to utilize species that appear to be more successful and better suited to their habitat, but keep in mind the goal of achieving a diversity of species. It may be tempting to plant a few species with known success, but remember that a healthy dune functions best when a diversity of species grow together. Be aware that if desired vegetation becomes buried by dune sand, it is nothing to worry about; it is a natural part of the dune rebuilding process, and the plants will often keep growing and trapping more sand.

For best maintenance, be sure to remember the following:

- Continue to weed restored areas to ensure ideal conditions for desired vegetation.
- Strictly manage or turn off irrigation.
- Prune vegetation to ensure desired heights and densities of native vegetation.
- Replace plantings that do not survive, if needed.
- Do not use pesticides and fertilizers in dune areas.

Troubleshooting Common Problems

Problem: People are not using the delineated access pathways and are making new ways to get to the beach.

Solutions:

- Maintain all of the post & fence, post & rope, sand fences, and signage so that the public sees that the area and restoration work is important.
- Work with beach users instead of against them. If a path is showing up where one is not wanted, perhaps something has changed. Is there a new beach shower at that location? A new parking area? Check whether the new path can be incorporated into the restoration site.
- Keep entry points to trails or access ways inviting to the public.
- Signage is an important way to educate people of the access points.

Problem: Plants are getting too tall or are encroaching onto the active beach or blocking access.

Solutions:

- Overgrowth is often caused by irrigation overspray or runoff from a beach shower. Try to identify the overwatering issue and reduce the source, if possible.
- Trim back encroaching vegetation, and consider replacing the offending plants with slower-growing or lower, prostrate varieties of native plants (particularly naupaka).
- Ground cover, such as pohuehue vines, that are growing onto pathways can often simply be picked up and redirected in a desired direction.

V. SUMMARY

The general concept of dune restoration practices can be summed up simply as working with a site's natural coastal processes to encourage sand accumulation over time through establishment of the native plants that form the foundation of these hotspots of local biodiversity, while managing how people access the beach and interact with the natural landscape. To achieve this outcome is not always so simple, though, since coastal ecosystems in Hawai'i consist of more than just sand and plants. Any successful restoration project requires careful and deliberate planning, with outreach to, and input and participation from, the large and diverse set of community stakeholders that live, work, and play on Hawai'i's beaches.

Best of luck with your restoration projects!

VI. APPENDICES

Appendix A: University of Hawai‘i Sea Grant College Extension agents by Island

Hawai‘i Sea Grant extension agents provide science-based technical support on coastal issues and serve as connectors to stakeholders in the community and government agencies. Inquiries about dune management or restoration can be directed to the following Hawai‘i Sea Grant extensions agents, listed by island.

Kaua‘i:

Ruby Pap
(Coastal Land Use Extension Specialist)
Advisor to the County of Kaua‘i
Planning Department
4444 Rice St., Suite A473
Līhu‘e, HI 96766
(808) 241-4183
rpap@hawaii.edu

O‘ahu:

Dolan Eversole
(Coastal Management Specialist)
2525 Correa Rd., HIG 206
Honolulu, HI 96822
(808) 956-9780
eversole@hawaii.edu

Shellie Habel
(Coastal Lands Program Manager)
Advisor to the Department of Land
and Natural Resources, OCCL Room 310,
Kalanimoku Building
1151 Punchbowl St. #131
Honolulu, HI 96813
skey@hawaii.edu

Maui:

Tara Owens
(Coastal Processes Specialist)
Advisor to the Maui County
Planning Department
2200 Main Street
One Main Plaza, Suite 630
Wailuku, HI 96793
(808) 463-3868
taram@hawaii.edu

Wesley Crile
(Dune Restoration Coordinator)
Advisor to the Maui County
Planning Department
2200 Main Street
One Main Plaza, Suite 630
Wailuku, HI 96793
wcrile@hawaii.edu

Appendix B: Coastal and Regulatory Agency Contacts

State and County Regulatory and Planning Departments

Department of Planning and Permitting
City and County of Honolulu
650 South King St.,
Honolulu, HI 96813
Fax: (808) 768-6743
Email: info@honoluludpp.org

Department of Parks and Recreation
City and County of Honolulu
650 South King St.
Honolulu, HI 96813
Phone: (808) 768-3440

Planning Department, County of Maui
2200 Main Street
One Main Plaza, Suite 315
Wailuku, HI 96793
Phone: (808) 270-7735
Fax: (808) 270-7634

Planning Department, County of Kauaʻi
4444 Rice Street., Suite A473
Lihue, Hawaiʻi 96766
Phone: (808) 241-4050
Fax: (808) 241-6699

Planning Department, County of Hawaiʻi
East Hawaiʻi:
Aupuni Center
101 Pauahi Street, Suite 3
Hilo, HI 96720
(808) 961-8288
Fax: (808) 961-8742

West Hawaiʻi:
74-5044 Ane Keohokalole Highway, Building E
Kailua-Kona, 96740
(808) 323-4770
Fax: (808) 327-3563
Email: planning@hawaiicounty.gov

Office of Conservation and Coastal Lands
State of Hawaiʻi Department of Land and Natural Resources
Kalanimoku Building
1151 Punchbowl St., Room 131
Honolulu, HI 96813
https://dlnr.hawaii.gov/occl/
Small Scale Beach Nourishment (SSBN) Guide
http://dlnr.hawaii.gov/occl/forms-2/
Phone: (808) 587-0377
Fax: (808) 587-0322

Clean Water Branch
State of Hawaiʻi Department of Health
2827 Waimano Home Rd., #225
Pearl City, HI 96782
Phone: (808) 586-4309
Email: CleanWaterBranch@doh.hawaii.gov

Pacific Ocean Division, U.S. Army Corps of Engineers
Honolulu District, Building 230
Fort Shafter, HI 96858-5440
Phone: (808) 835-4004
Email: CEPOH-PA@usace.army.mil

Hawaiʻi Coastal Zone Management Program
State of Hawaiʻi Office of Planning
PO. Box 2359
Honolulu, Hawaiʻi 96804-2359
Phone: (808) 587-2846
Fax: (808) 587-2824

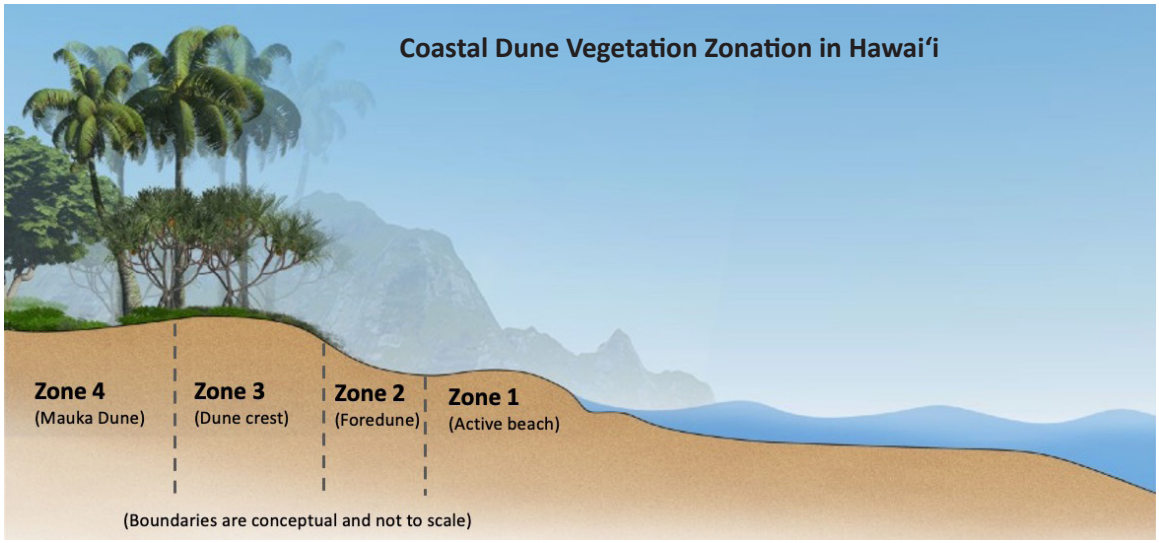
Appendix C: List of Native Plant Species and Nurseries

The following is a list of commonly utilized native and Polynesian-introduced plant species that are recommended for use in dune restoration projects. The subject of native Hawaiian plants opens a fascinating scientific and cultural world, and is beyond the scope of this guide. The list provided is by no means comprehensive, but is made up of species that have been used successfully by restoration professionals. Consult with Hawai'i Sea Grant extension agents, local botanical gardens, and horticultural experts who can provide geographically specific information about appropriate species.

Due to climate change (particularly decreasing rainfall) and sea-level rise, increasing salinity in dunes poses a serious threat to out-planting success and long-term dune plant stability. It is difficult to predict which species will perform best under increasing salinity, because most dune plants are actually salt-sensitive, relying on freshwater below the sand for growth and regular rainfall to remove accumulating sand from above-ground tissues. Coastal dune plants are not adapted to the increasing salinity they are experiencing in the dunes today and into the future. While the following list is based on recently documented success, the performance of these species in the short-term future (within the next couple decades) is likely to decrease. If out-plantings perform poorly, it may be because the species being used are particularly sensitive to salinity and should be replaced with more tolerant species or populations. Ultimately, migration inland is likely going to be necessary to conserve dune plant species, as the freshwater lens below the sand becomes too salty from seawater intrusion.

We recommend that restoration start with these species, tried-and-true under historical climates, which will ensure a higher likelihood for success, planting the appropriate species in their appropriate zones. Refer to "Plant Native Vegetation: Where to plant" (page 19) for additional information on dune profile zones, but recall these recommendations:

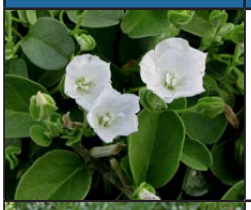
- Zone 1 (active beach): No planting allowed by state law.
- Zone 2 (foredune): Low-lying and loosely bound grasses and vines.
- Zone 3 (middle dune and dune crest): Low-lying grasses and vines transition to, or combine with, low-growing shrubs.
- Zone 4 (back beach and mauka dune): Larger woody shrubs or trees.



Two additional useful definitions are provided by the University of Hawai'i College of Tropical Agriculture & Human Resources's Salt and Wind Tolerance Landscape Plants for Hawai'i report:

> Makai plants (those in zone 2) are assumed to be adapted to tolerate strong winds, salt spray, and occasional wave inundation, and can be used in exposed locations, such as areas near the beach receiving direct winds from the ocean. However, recent research indicates that these species are quite salt-sensitive and suffer mortality and reduced growth under moderate to high salinity, highlighting the importance of monitoring their performance under climate change.
>
> Mauka plants (those in zones 3 and 4) are assumed to be less tolerant of soil salinity and salt spray, but should not be used in exposed locations since they may be sensitive to wind. These plants do best when protected by buildings, fences, or plantings of makai zone species and can be rinsed with fresh water frequently.

	Hawaiian Name	Scientific Name	Comment	Zone/ Placement	Detailed plant profile
Low Growing (grasses, vines, and groundcovers)					
	ʻAkiʻaki	*Sporobolus virginicus*	A creeping perennial, grows on sandy coasts within reach of the ocean spray making it tolerant of both salt air and hot sun.	2,3	http://nativeplants.hawaii.edu/plant/view/Sporobolus_virginicus
	Pōhuehue	*Ipomoea pes-caprae*	A perennial seashore vine, its 2-4 in leaves help trap sand with a pink or light purple flower. Also known as Beach Morning Glory.	2,3	http://nativeplants.hawaii.edu/plant/view/Ipomoea_pes-caprae_brasiliensis
	ʻĀkulikuli	*Sesuvium portulacastrum*	A succulent herb that grows along the ground, it has trailing branches, and its leaves and stems are a fleshy red or green with a white or pale violet flower.	2,3	http://nativeplants.hawaii.edu/plant/view/Sesuvium_portulacastrum
	Pōhinahina	*Vitex rotundifolia*	A low lying creeper shrub, it has light green, grayish, or silvery leaves with a blue or purplish flower. Also known as Beach Vitex.	2,3	http://nativeplants.hawaii.edu/plant/view/Vitex_rotundifolia
	Huna kai	*Ipomoea imperati*	A perennial seashore morning glory whose flowers often emerge directly from the sand.	2,3	http://nativeplants.hawaii.edu/plant/view/Ipomoea_imperati

	Hawaiian Name	Scientific Name	Comment	Zone/ Placement	Detailed plant profile
	Pāʻūohiʻiaka	*Jacquemontia sandwicensis*	Sprawling vines that forms mat up to 8 inches deep. Steps can be up to 10ft long. Small white flower.	2,3	http://nativeplants.hawaii.edu/plant/view/Jacquemontia_sandwicensis
	Hinahina	*Heliotropium anomalum*	A perennial that grows close the ground, its leaves have a greenish & grayish appearance with a white fragrant flower.	3,4	http://nativeplants.hawaii.edu/plant/view/Heliotropium_anomalum_argenteum
	ʻIlima papa	*Sida fallax*	A small low lying plant with trailing branches, its leaves are green and has a yellow-orange five petaled flower while enjoying a typically drier climate.	3,4	http://nativeplants.hawaii.edu/plant/view/Sida_fallax
	Ohelo kai	*Lycium sanwicense*	Low lying coastal groundcover with succulent leaves, small whit to pinkish flowers, and bright red berries.	3,4	http://nativeplants.hawaii.edu/plant/view/Lycium_sandwicense
	Nanea	*Vigna marina*	Sprawling vine that can grow to 1ft tall and 8ft wide. Small yellow flowers.	3,4	http://nativeplants.hawaii.edu/plant/view/Vigna_marina
Brushes/Shrubs					
	Maiapilo	*Capparis sanwichiana*	Maiapilo has very showy bright white flowers with yellow centers. The flowers open after sunset and bloom into the early morning hours fading to pink by mid-day.	3,4	http://nativeplants.hawaii.edu/plant/view/Capparis_sandwichiana
	ʻAʻaliʻi	*Dodonaea viscosa*	Tough shrub with green leaves. Species vary. Can be medium shrub to small tree up to 25ft. Most often 6ft to 12ft. May have several main trunks that are reddish-brown.	3,4	http://nativeplants.hawaii.edu/plant/view/Dodonaea_viscosa
	ʻĀweoweo	*Chenopodium oahuense*	Very tolerant of salty coralline soils. Leaf sizes vary but the small-leaved varieties are best for small hedges.	4	http://nativeplants.hawaii.edu/plant/view/Chenopodium_oahuense

	Hawaiian Name	Scientific Name	Comment	Zone/ Placement	Detailed plant profile
	Ma‘o	*Gossypium tomentosum*	Shrub that grows to about 5ft tall and up to 8ft wide. Yellow flower and also known as Hawaiian cotton.	4	http://nativeplants.hawaii.edu/plant/view/Scaevola_sericea
	*Naupaka Kahakai (**Use with caution**)	*Scaevola taccada*	A low lying and wiry shrub when not irrigated and fertilized, bright green succulent flowers with a white flower and berry. Nursery cultivars tend to grow tall and encroach onto the active beach (use with caution).	4	http://nativeplants.hawaii.edu/plant/view/Scaevola_sericea_
Trees					
	*(Beach Heliotrope)*	*Hiliotropium arboreum*	A small to medium flowering tree/bush, that is not native to Hawaii, but is generally recognized as a suitable coastal shade tree that does not have invasive tendencies.	4	https://en.wikipedia.org/wiki/Heliotropium_arboreum
	Milo	*Thespesia populnea*	A medium sized shrub to an upright tree with a thick crown, shiny green heart shaped leaves, and yellowish flowers.	4	http://nativeplants.hawaii.edu/plant/view/Thespesia_populnea
	Hala	*Pandanus tectorius*	A widely branching tree species supported by aerial roots, its leaves are long, thin, thorny, and fibrous, and has a yellowish pineapple-like fruit	4	http://nativeplants.hawaii.edu/plant/view/Pandanus_tectorius
	Kou	*Cordia subcordata*	Small to medium sized tree that can grow up to about 35ft. Broad, dense crown. Large, beautiful orange flowers. Likes coastal areas on leeward side.	4	http://nativeplants.hawaii.edu/plant/view/Cordia_subcordata
	Loulu	*Pritchardia hillebrandii*	Single-trunked palm tree with fan-shaped leaves. Medium to large tree growing 30-50 ft tall. Variety of species.	4	http://nativeplants.hawaii.edu/plant/view/Pritchardia_hillebrandii
	Kamani	*Calophyllum inophyllum*	Polynesian introduced tree not to be confused with the false kamani/beach almond (*Terminalia catappa*).	4	http://data.bishopmuseum.org/ethnobotanydb/ethnobotany.php?b=d&ID=kamani

	Hawaiian Name	Scientific Name	Comment	Zone/ Placement	Detailed plant profile
	Ohe makai	*Polyscias sandwicensis*	Large and interesting native tree that looses its leaves during the dry season therefore possibly isn't recommended for shade.	4	http://nativeplants.hawaii.edu/plant/view/polyscias_sandwicensis
	*Hau (**Use with caution**)	*Hibiscus tiliaceus*	A densely branching shrub or small tree, has wide heart shaped leaves and yellow, orange, or red flower. (not recommended due to a propensity for creeping onto the active beach).	4	https://www.canoeplants.com/hau.html
	*(Sea Grape)* (Also know as: platter leaf, Jamaican kino) (**Use with caution**)	*Coccoloba uvifera*	Thrives in tropical climates. Distribution generally limited to coastal areas and lower elevations. Naturalized on main Hawaiian Islands. *Regarded as invasive in Hawaiian Islands and elsewhere.*	4	https://plantpono.org/hpwra/coccoloba-uvifera/

* These plants should be used with caution as they have the potential to grow too vigorously and encroach onto the active beach. This commonly happens when they are planted in landscaped areas that receive excessive irrigation, either directly from spray or drip lines, or indirectly from irrigation runoff from a manicured landscape.

To find plants locally, try some of the following island nurseries that may have these native plants available.

Kaua'i:
- Kaua'i Native Plant Society
- Kaua'i Seascapes Nursery
- Kīpapa Nursery

O'ahu:
- Hui Kū Maoli Ola
- Native Plant Source

Maui:
- Ho'olawa Farms Inc: A Native Plant Nursery
- Native Nursery, Inc

Hawai'i Island:
- Aikane Nursery
- Aileen's Nursery
- Amy B.H. Greenwell Ethnobotanical Gardens
- Big Island Plants
- Future Forests Nursery

Appendix D: DLNR Hawai‘i Dune Management Fact Sheet

DAVID Y. IGE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
OFFICE OF CONSERVATION AND COASTAL LANDS
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
FIRST DEPUTY

M. KALEO MANUEL
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE

August, 2021

Hawai‘i Dune Management Fact Sheet

Laws Regarding Beach Transit Corridors in Hawai‘i

Public access along the beach transit corridor is under the jurisdiction of the State of Hawai‘i Department of Land and Natural Resources (DLNR). Access is regulated pursuant to Hawai‘i Revised Statutes (HRS) Chapter 115, Public Access to Coastal and Inland Recreation Areas. DLNR’s Office of Conservation and Coastal Lands (OCCL) is the lead agency with authority for maintaining public access along Hawai‘i’s beach transit corridors

- These rights include the rights of transit along *beach transit corridors*, defined as the areas extending seaward of the shoreline.[1]
- Beach transit corridors are public property, and obstructing access via gates, fences, walls, barriers, rubbish, guards, dogs or other animals, and human-induced, enhanced, or unmaintained vegetation access is prohibited by statute.[2]
- All vegetation must remain landward of the shoreline (Figure 1).[3] Shoreline vegetation if left unmaintained, can encroach into beach transit corridors and limit shoreline public access.
- Coastal landowners are required to maintain the vegetation along the seaward boundary of their property to ensure that it does not inhibit the ability of the public to access the shoreline. The DLNR may require abutting landowners to remove encroaching vegetation when it interferes or encroaches upon the beach transit corridor.[4]
- DLNR has the authority to issue notices to landowners who fail to maintain access within beach transit corridors.[5] Landowners who fail to remove the encroaching vegetation may be subject to fines and other enforcement actions pursuant to HRS Chapter 183C Conservation District.[5]

Figure 1. Typical Hawaiian coastal dune with low grasses and vines on the seaward dune crest, and shrubs, bushes, and trees landward of the dune crest.

Should you have any questions, contact the Office of Conservation and Coastal Lands at:
https://dlnr.hawaii.gov/occl/ or (808) 587-0377.

[1] HRS §115-4 Right of transit along shorelines
[2] HRS §115-9 Obstructing access to public property
[3] As defined in HRS 205A or indicated on a certified shoreline map
[4] HRS §115-5 Beach transit corridor defined
[5] HRS §183C-7 Penalty for violation

Appendix E: Case Study: Kailua Beach Park Dune Restoration Plan

The concept for a *Kailua Beach Park Dune Restoration Plan* was formulated in response to the request from the City and County of Honolulu for the development of such plans. This conceptual plan closely follows procedures set forth in the *Hawai'i Dune Restoration Manual* and was built off research completed for the *Kailua Beach and Dune Management Plan*. Kailua Beach Park was chosen for this particular dune restoration plan because it is a valuable asset for both residents and the visitor industry, while being heavily impacted by extensive use from both sectors.

The City and County of Honolulu's Office of Climate Change, Sustainability, and Resiliency has prioritized the protection of shorelines by expressing its intent to partner with state agencies and private property owners in supporting restoration projects like this one. The Office of Resiliency has offered to develop policy to fund shoreline preservation and beach nourishment efforts to accomplish their goals. The City and County of Honolulu's Department of Planning and Permitting also requested, in the *Koʻolau Poko Sustainable Communities Plan*, for beach restoration plans to be created, and broadly expressed a prioritization of protection shoreline areas on Oʻahu in seven other sustainable communities and development plans. Additionally, the Windward Oʻahu Tourism Assessment may offer insightful input from the public, and this plan could serve as one way to answer public demand for better beach conservation.

This *Kailua Beach Park Dune Restoration Plan* would ideally be implemented by the City and County of Honolulu's Department of Parks and Recreation in cooperation with other agencies, community volunteers, and other private stakeholders who have an interest in protecting Kailua Beach Park. There will be shared jurisdiction over the shoreline areas, but after completion, the Department of Parks and Recreation will be responsible for maintaining Kailua Beach Park.

In summary, the *Kailua Beach Park Dune Restoration Plan* is a conceptual two-phased management and protection plan that works to enable Kailua Beach Park to handle a high volume of daily visitors. This restoration plan is fundamentally different from other dune restoration plans, because Kailua Beach is less prone to degradation from seasonal waves and more prone to degradation by the number of supported users. The greater Kailua Beach dune system to the north is stable, but at Kailua Beach Park itself, consistent erosion has narrowed the beach over the past few decades.

The first portion of this plan discusses the long-term, artificial dune height accumulation trend and its cause, and recommends grading the dune at Kailua Beach Park, redistributing the sand back into the natural coastal and dune systems. The second portion of this plan addresses maintenance issues at Kailua Beach Park, including scattered debris, large residual tree stumps, invasive vegetation, and the sand-blown, wind-facing walkway. The plan recommends removal of scattered debris, large tree stumps, and invasive vegetation; suggests reorientation of the walkway direction and construction of a dune walkover; and promotes planting of native vegetation with temporary fencing around restoration areas. If the first portion of this plan is not implemented, the second portion of this plan will be a fair alternative to conserve the dune system at Kailua Beach Park.