



# **COASTAL CHANGE IN THE PACIFIC ISLANDS**

## **VOLUME ONE**

A Guide to Support Community Understanding  
of Coastal Erosion and Flooding Issues





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This guide was developed through a wide collaboration of partners in several countries and regions to support community based management or adaptation planning. In 2010 Micronesia Conservation Trust, through the Micronesia Challenge<sup>1</sup> Initiative, developed a climate change tool to foster community based adaptation. MCT convened natural-resource managers, community leaders, climate scientists, and experts from various sectors to determine what a community based tool should look like. Through this collaboration a tool—*Adapting to a Changing Climate: Guide to Local Early Action Planning (LEAP) and Management Planning*—was developed in Micronesia and further adapted for the Coral Triangle Region. The LEAP tools help communities build social and ecological resilience to climate change. These tools provide a series of outreach and planning materials to explain climate change, in the context of other local threats and from the perspective of a Pacific Island community.

During training workshops and implementation of the LEAP process in the field, several communities expressed concerns over the high degree of vulnerability of their shorelines and coastal lowlands, and associated buildings and homes, to both erosion and flooding events. They also discussed the high degree of vulnerability of coral reefs and associated fisheries to various local threats, as well as climate change. Through these LEAP efforts, communities identified the need to improve the resilience of their coastlines and marine resources and identify actions to reduce the communities' social vulnerability to potential impacts to these resources.

Although many communities expressed these concerns through the LEAP process, there were few tools available to support community level decision making on increasing resilience of coastal and marine resources and understanding and addressing negative impacts of coastal hazards such as erosion and flooding. Without further understanding of coastal processes and what can be done, management strategies for shorelines tend to focus on reactive approaches; these are typically characterized by engineering approaches such as seawalls. Additionally, while there are tools developed for professional managers in order to support the design of resilient MPAs and reefs, there have been few developed that help community members understand how to design locally managed areas so that their marine resources continue to provide them with the benefits they depend on while also building resilience. Therefore, LMAs tend to lack the permanent and/or spatial protection often needed to provide long-term benefits and resilience.

To address this gap, two new guides have been developed in the Micronesia and Coral Triangle regions to complement the LEAP process. These guides provide more in-depth outreach and planning

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<sup>1</sup>The Micronesia Challenge is a shared commitment among the five Micronesian governments: the Republic of Palau, the Federated States of Micronesia, the Republic of the Marshall Islands, the U.S. Territory of Guam, and the Commonwealth of the Northern Mariana Islands to “effectively conserve at least 30 percent of the near-shore marine resources and 20 percent of the terrestrial resources across Micronesia by 2020.” ([www.micronesiachallenge.org](http://www.micronesiachallenge.org))

processes for communities that want to strengthen resilience of their locally managed areas, including coral reefs, fisheries, and the coastal zone. The guides are:

1. *Designing Effective Locally Managed Areas in Tropical Marine Environments: Guidance to Help Sustain Community Benefits through Management for Fisheries, Ecosystems, and Climate Change* focused on helping communities understand how to design locally managed areas (LMAs) to achieve community benefits through fisheries sustainability, biodiversity conservation, and ecosystem resilience in the face of climate change. Found at: <http://weadapt.org/knowledge-base/small-islands-and-climate-change/designing-effective-locally-managed-areas-in-tropical-marine-environments>
2. *Coastal Change in the Pacific Islands Volumes One & Two* focused on helping communities understand how coastlines work and what causes coastal change, and supporting decision-making to reduce the impacts of coastal hazards such as flooding and erosion on communities.

These guides can all be used separately or in combination with one another to support outreach and planning that ultimately builds natural and social resilience to climate change and other threats.

# About This Guide

This guide responds to the emerging needs of many communities in the Pacific Islands whose members are expressing concerns about storm damage, sea-level rise, and the frequency and severity of coastal flooding events and shoreline erosion. For the purpose of the guide, the term “coastal zone” refers to the entire area from the upland forest out to the reef edge. On small low-lying islands and atolls, the entire island would be considered the coastal zone.

The term “coastal change” refers to:

1. Flooding of coastal lowlands from any, or combination, of the following: high (king) tides; typhoons/cyclones/storms; large ocean swells; and heavy rainfall leading to storm water, river, or stream flooding.
2. Gain or loss of land along the shoreline, which is the area of the coastal zone that directly interacts with the sea and is changeable (e.g. sandy beaches, mangroves, cliffs).

With existing tools, communities have been able to identify the potential impacts of threats and hazards to the coastal zone. However, understanding the complex interaction between natural coastal systems and human development in order to determine effective responses often requires further technical assistance, which is often not accessible.

Strategies to address the impacts of coastal erosion and flooding also tend to focus on reactive approaches, normally through engineering projects such as building seawalls. In many cases, these “solutions” have negatively impacted the surrounding environment and have increased conflicts with other community values. Likewise, they are typically short-term in effectiveness, ignoring the role inappropriate human development often plays as a key driver of the problem. Furthermore, these strategies often result in a false sense of security, leading to further development in hazard-prone areas. This usually results in the problem of hazards in the coastal zone becoming more significant and more complex to address over time.

## PURPOSE

This document is part of a two-volume guide that provides a foundation for communities to assess local coastal processes and the impacts humans are having on coastal areas, and identify appropriate actions required to build the resilience of coastlines and communities. It is divided into 1) Volume One: Outreach 2) Volume Two: Planning. This volume (I) provides detailed outreach materials to support an understanding of how coastlines work and what causes coastal flooding and shoreline change (natural and human-related). It also provides examples of case studies and community stories from around the Pacific region that illustrate key concepts about coastal change. This document includes illustrations and photos, with simple information that clearly explains coastal-process concepts, and key messages and recommendations from coastal experts about specific actions that have the best chance for providing long-term benefits for the community and coastline.

Both of the volumes in this guide can be used together as a step-by-step process to carry out outreach and conduct planning to select a suite of appropriate actions that, in combination, address local coastal-hazard issues. Alternately, the individual volumes can be used separately to support existing community resource-management processes such as raising awareness or completing vulnerability assessments.

## AUDIENCE

This guide is designed for use by small planning teams consisting of people from communities, agencies, and organizations that normally facilitate stakeholders through community based planning and implementation processes. Stakeholders include community leaders; community members who use or depend on coastal and marine resources; and/or agencies and organizations that have jurisdiction over, or a supporting role in, these areas.

## CONTEXT

This guide does not provide a process for developing a full community management or adaptation plan. However, there are several ways the volumes of this guide can support management planning or adaptation planning, including:

- For communities that are undergoing management planning or adaptation planning and have identified that their coastlines are vulnerable to flooding and shoreline change, this guide can help these communities understand how coastlines work and decide what actions are appropriate to help manage the short- and long-term changes to their coastline.
- Even if communities are not undergoing natural resource-management planning processes, this guide can support outreach activities to help communities understand how coastlines work and what causes them to change, and to foster planning processes.
- Communities that have already developed full management or adaptation plans can use this guide to modify existing plans and further develop actions to address specific coastal-change issues. The objectives and actions developed through the use of this guide should be integrated back into the larger plan to be implemented.

It is advised that a planning team or community facilitator review the guide and use components that best support existing planning processes. The actions identified by using this guide can be integrated into management or land-use plans that already exist or are under development. The full set of volumes and content are described here:

### **Volume One: Outreach (This Document) — How Coastlines Work and What Factors Influence Coastal Change**

- **Session One: How the Coastal Zone Works** — This session provides detailed information on the coastal zone, the active shoreline, natural processes that move sediment around in a shoreline, and natural components of the coastal zone that help to manage sediment in the system.
- **Session Two: Natural Events That Influence Coastal Change** — This session reviews the various natural factors that can cause coastal flooding or shoreline change.
- **Session Three: Human Activities That Influence Coastal Change** — This session reviews the various human activities to the coastline that can increase the negative impacts from coastal hazards such as flooding and shoreline erosion. It also explores how future climate change scenarios could worsen impacts of existing hazards.
- **Session Four: What Actions Can We Take to Reduce the Negative Impacts of Coastal Change on Our Community?** — This session reviews several approaches that can be taken by communities to plan for changes in coastal zone. These include recommendations from coastal experts on actions that most effectively address existing threats, as well as ways to plan for future hazards.

Volume One also includes the following distributed throughout the document:

- **Case Studies:** Provided from around the Pacific and developed through coastal expert assessments that demonstrate specific concepts and/or provide recommended actions for specific coastal change scenarios.
- **Example Community Coastal Stories:** Developed through workshops that involved community members, governmental and non-governmental agencies, and coastal experts. These provide a sample of what can be completed through the use of this guidance document in combination with local and expert input. While community members were present for these, a more complete planning process with a broader range of stakeholders present would be needed before any recommendations can be advanced.

## **Volume Two: Planning — Choosing Actions to Reduce the Impacts of Coastal Flooding and Shoreline Erosion**

- **Session One: Assessing the Coastline** — This session involves a series of activities for the community to explore and understand their coastal zone. It includes mapping the area, physically walking the shoreline, reviewing coastal features and processes, reviewing historical events that impacted the coastal zone, and recording observations of change over time.
- **Session Two: Developing Actions to Reduce the Impacts of Coastal Flooding and Shoreline Erosion** — This session provides communities with steps that can help them identify actions to address coastal changes and hazards (short- and long-term). This session includes a checklist based on recommendations from coastal experts. The checklist provides a quick and simple way for communities to discuss and decide on various approaches and actions that will provide them with the best chance of effectively reducing the short- and long-term negative impacts of coastal hazards on the community.
- **Session Three: Developing Your Coastal Story** — All of the information collected through the engagement activities in Session One and Session Two can be used to write a summary about the place, or a "community coastal story." This story template includes coastal zone features and conditions, coastal uses and changes over time, future impacts to the coastal zone, and actions the community will take to build a resilient coastal community.
- **Appendix A** — Provides details on each of the recommended actions including 1) description, 2) benefits and challenges, 3) technical expertise required, 4) general cost for implementation and maintenance, 5) resources available, and 6) examples from the region.

And finally, a word of caution. While this guide makes every effort to provide information to help communities to reduce the negative impacts of coastal change, it is important to recognize that shoreline and coastal processes can be highly complex. This means there are limits to any such guide. It is always advisable to seek expert advice in situations where significant infrastructure or other assets already exist, where investment is planned, or where engineering structures may be implemented.

# **VOLUME ONE: OUTREACH**

**How Coastlines Work and What  
Factors Influence Coastal Change**

# INTRODUCTION

Communities are noticing changes to their coastlines all over the Pacific Islands. This outreach session will explore the causes of these changes and summarize actions that communities can take to reduce negative impacts from coastal hazards, both now and into the future.

## SESSION ONE: HOW THE COASTLINE WORKS

### THE COASTLINE AND ACTIVE SHORELINE

HIGH ISLAND



LOW ISLAND

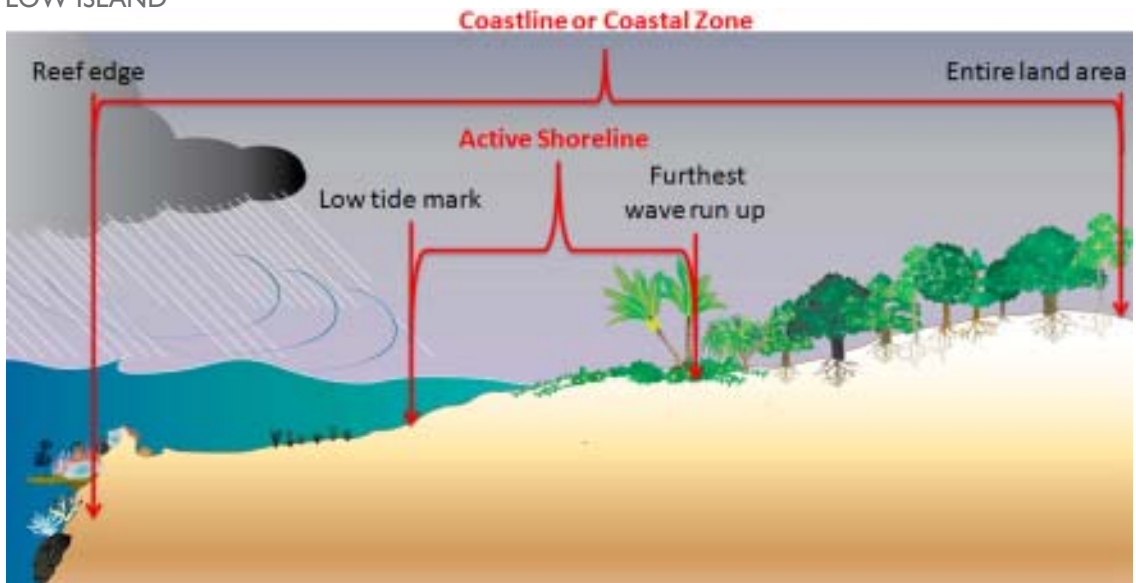


ILLUSTRATION BY DUANE LEEWAI

The coastline (or coastal zone) refers to the entire area from the upland forest out to the reef edge. For many Pacific Islands—particularly low-lying islands and atolls—the entire land area can be considered a coastal zone, because most land on these islands is closely connected to and interacts with the sea.

The coastline is typically formed from many different components (or ecosystems) and can include some or all of the following: reefs and reef flats, lagoons, beaches of different types, seagrass beds, mangroves, mudflats, and cliffs. These components all act together to provide natural functions, such as protection from waves and storms, or important habitats for other marine resources.

The active shoreline is the area of land within the coastal zone that directly interacts with the sea and is changeable. It includes the beach area, which extends from or below the low-tide mark to where the biggest waves run up, including wave overwash from periodic large storms. Generally, there are three types of common shoreline in the Pacific: beaches (made of sand, gravel or rubble), mangrove shores, and rocky shores.



Some shorelines are more active than others. Mangrove and rocky shorelines are relatively stable and do not change position or shape quickly. On the other hand, soft shorelines or beaches can be highly active, consisting of loose sediment that can be constantly shifting in response to the environmental conditions around it—specifically the combinations of wind, waves, tides, storms, and other factors such as heavy rain and river and stream flows—and the effects that humans have on the active shoreline.



The term “coastal change” refers to:

1. Flooding of coastal lowlands from any, or a combination, of the following: high (king) tides; typhoons/cyclones/storms; large ocean swells; and heavy rainfall leading to storm water, river, or stream flooding.
2. Gain or loss of land along the shoreline, which is the area of the coastal zone that directly interacts with the sea and is changeable (e.g. sandy beaches).



## **Group Activity: Preparing the Group to Discuss Coastal Change**

This activity will prepare participants to discuss coastal change. It includes sharing examples from communities around the Pacific as well as capturing some information about observed changes in the local community.

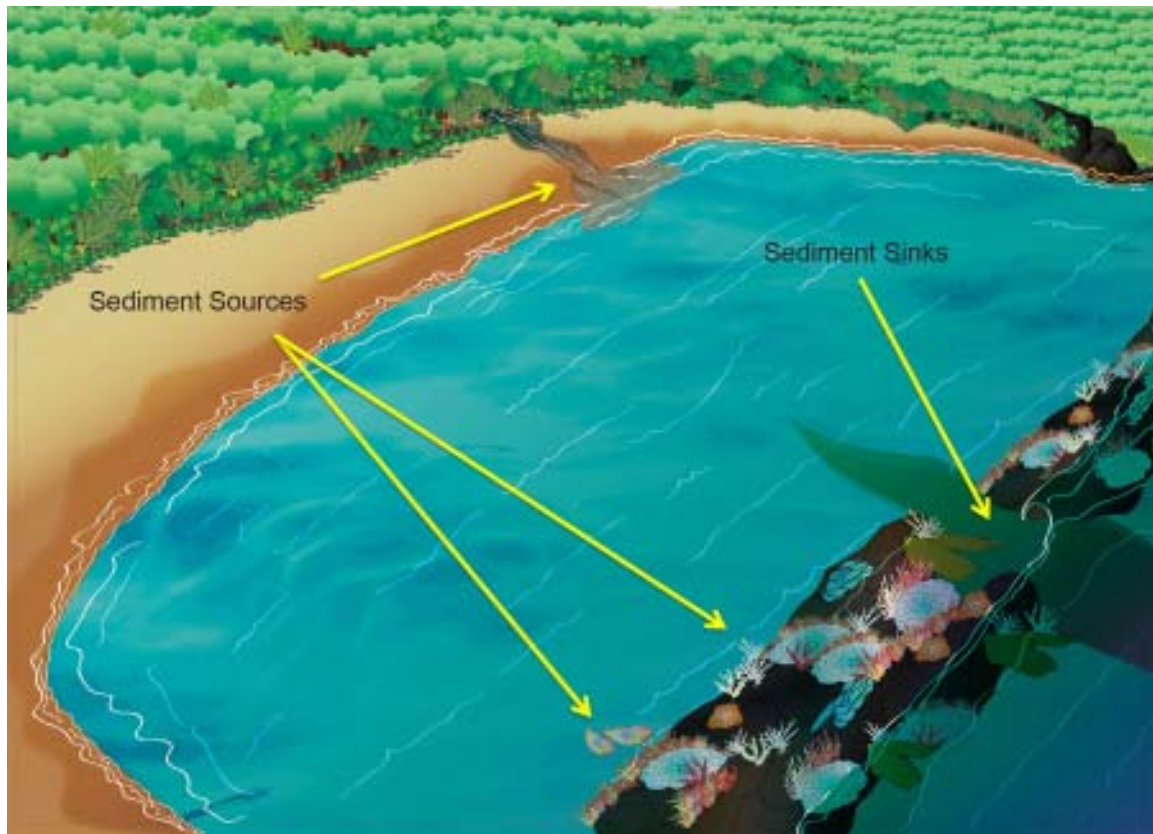
### **Facilitator Instructions**

- Review the definitions of following terms, as stated above: coastline/coastal zone, active shoreline, and coastal change.
- Explain to the group that many communities are experiencing coastal change and wondering why it is happening and what they can do about it.
- Share the following questions asked by the following communities around the region:
  - We are experiencing more frequent flooding events. Why is that and what can we do about it? (Torres Islands, Vanuatu)
  - Our beaches have been eroding over the last ten years and we don't know why. Why is that, and what can be done? (Rock Islands, Palau)
  - We have lost land in front of our homes and we are worried we will lose our homes. What we can do? (Malem, Kosrae)
- Ask the group:
  - Have you observed changes in your shoreline or coastal zone over the past couple generations (consider changes to both the natural environment and development changes)? If yes, what are they?
- List their answers on a piece of flip-chart paper labeled "local observations/questions."
- Explain that you will spend the next several sessions reviewing information that will help answer these and other questions shared by many Pacific communities. This will include reviewing how shorelines work, what causes them to change, and what can be done to manage for coastal change both now and in the future.
- Tell the group that if they decide they want to develop actions to manage the impacts of coastal change, they can also go through a planning section that will help them better understand their local coastal situation and decide what combination of actions will best address their immediate and long-term concerns about coastal change. The outcome of that section will be the development of several actions that they can add into new or existing management or adaptation plans.

In order to understand why these changes may be occurring, and to ultimately help determine what actions can be taken to manage for coastal change now and into the future, it's important to first understand:

- How the coastal zone works
- What factors influence coastal change (natural and human related)
- What actions can be taken to reduce negative impacts of coastal change
- How to monitor coastal change over time

## THE SEDIMENT CELL



The term sediment refers to all particles on the shoreline from both land and sea (e.g. sand, rocks, coral rubble). Each shoreline is made up of “sediment cells” or specific areas along the shoreline where local sediment moves around but does not leave. A sediment cell is best described by example: a pocket beach between two rocky headlands is a “sediment cell.” In this case the sediment on that beach cannot move further along the coast easily because it is trapped by the two rocky headlands, and new sediment from outside cannot easily move in to the area from other beaches. In other words, it is hard for sediment being moved along the shoreline outside of the cell to move in and hard for sediment from inside the cell to move out.

In some cases, small round-shaped islands—in the Pacific these are often atolls—can be considered to be a single sediment cell. Sediment typically comes from surrounding reefs and moves around the island depending on waves and currents. It typically moves out of the cell through channels that funnel sediment to deeper water or by storms that carry sediment offshore.

Each sediment cell has its own sources of new sediment—for example the nearby reefs, sandy areas below low-tide levels, sediment stored in the land behind the shoreline, and sediment brought down rivers and streams to the coast. There are also sediment sinks in each cell, where sediment moves to and is lost from the shoreline. However, in most cases there is generally not a lot of new sediment coming in or out of a sediment cell on a regular basis without a large event like a storm. Therefore, if sediment is permanently lost, it can take a very long time for new sediment to be made to replace the lost sediment.

## SEDIMENT SOURCES

Sediment can come from the land—usually carried by streams and rivers to the shore—or the sea—waves wash sand, rocks, and coral rubble up from the reef. The types of sediment sources determine the kind of shoreline you have.



ARTHUR WEBB



MEGHAN GOMBOBOS

On most tropical Pacific Islands, the source of this loose beach sediment is mainly from broken pieces of coral reef, coral rubble, and small particles from shells of various organisms that live on the reef such as mollusks, sea urchins, sea cucumbers, and coralline algae. In many parts of the Pacific this can also include an organism called foraminifera. Each of these organisms has a tiny shell, and there are so many of them that many beaches in the Pacific are made up of foraminifera shells. Because coral reefs (and organisms that live within them) provide an important source of sediment, healthy coral reefs and the continued growth of associated organisms are necessary to maintain healthy beaches.

Certain fish species such as parrotfish can also be very important sources of sediment. Parrotfish feed on algae found on coral reefs, actually ingesting pieces of coral as they do so by scraping away the algae with their beak. Through digesting these pieces of coral, they break



ARTHUR WEBB



them down and then excrete sand. In fact, studies have shown that an 18-inch parrotfish can produce up to 700 pounds (about 300 kg) of sand per year! These fish can also help keep coral reefs healthy by scraping away algae that would otherwise smother the reef. Therefore, healthy fish populations not only provide fisheries benefits through food and income, but they are also important for maintaining sediment sources.

On some large high islands, shoreline sediment can also be made up of land-based particles that move onto the coast from rain, rivers, streams, and wind. Notice the darker color of the sediment on the upper right picture, which indicates it is from land-based sources rather than a coral reef, which tends to provide sediments that is lighter in color or white.

## SEDIMENT SINKS

Sediment can also be lost from shoreline systems to sediment sinks. For example, sediment can be lost from shorelines and beaches:

- Off the edge of reef to deep water through channels or during storm events
- Into deeper lagoon basins
- Along the shoreline and to the next cell where it can't easily return
- By large waves picking sediment up and moving it on land (overwash)

Sediment can also be lost due to human activities, for example:

- Sand mining to provide sediment for construction
- Dredging pits on the reef flat that can trap sediment
- Construction activities, such as reclamation or sea walls, over the shoreline, which can block sediment moving along the shoreline or direct sediment seaward



### Questions to Consider

- What type of sediment do you have on your beach?
- Is it from the reef, land, or both?
- Can you identify any sediment sinks on your shoreline?

# Community Coastal Story

## NGARAARD, PALAU

Ngaraad State is in the northeast of Babeldaob Island in Palau. Historically, community members of Ngaraad lived inland on clan lands. However, after a chief had visited Japan in the 1950s and saw people living along the shoreline, he and other community members began moving down to live close to their shoreline.

Ngaraad faces east and is exposed to both the easterly tradewinds and occasional typhoons. The coast has a wide shallow fringing lagoon, with beds of seagrass, between the outer reef and the shoreline. Immediately behind the sand beach shoreline is where the community has developed, with areas of mangrove and low-lying swamp also occurring before the land levels rise into the main land mass of Babeldob.

Today, the Ngaraad coastal area is highly valued and where many families have homes. A popular girls' school is located there, as well as an old church, the community meeting house, and elementary school.



The community noted that they could remember that during their lifetimes the shoreline at the northern end of Ngaraad extended much further seaward. However, it has been eroding since the 1990s. This was a cause of concern, as land had been lost at the northern end of the village.

In 2012 the community was also severely hit by Typhoon Bopha. This caused significant coastal flooding (almost up to roof level at some properties) and damage to homes and community buildings, with the community meeting house destroyed. Many tree roots on the shoreline were exposed and some large trees fell over.





Our assessment included walking along the Ngaraard coast and talking to some of the older people we met in the community. At the northern end of the village, the erosion did indeed seem to be significant and a real problem causing loss of land.

However, we began to notice some other things as we walked south.

Here the beach was much wider, no tree roots were exposed, and Beach Morning Glory vine was established between the older trees and the beach. This suggested that this section of coast had built out (accreted) recently.

Behind the beach, some young coastal shrubs and trees were growing amongst the older coconut trees. We dug down into the sand. This showed about 1 ft of light-coloured sand on top of older, darker sediment. This suggested that the sediment on the top had recently been deposited there from the beach.



Further behind the current beach we also found a line of old ironwood and coconut trees. This is evidence of an old shoreline. Sometime in the past, during the lifetime of the trees, the shoreline would have been at this location. Since then over 50 m of land had built out.



Back at the northern end of Ngaraard an old man told us that Typhoon Mike in the 1980s had brought lots of sand to the area, which had been taken away by Typhoon Bopha. He also mentioned a seasonal cycle where sand tended to move offshore during times of westerly winds and onshore during easterly winds.



One of our group members also then remembered as a young girl swinging from the old ironwood trees that were behind the beach in to the sea. This showed that within living memory the shoreline had previously been even further landward than it was at present.

The visit to Ngaraad and talks with the elders in the community gave us a better understanding of the changes that had happened at Ngaraad due to Typhoon Bopha, and whether or not these changes were unusual in the context of a longer period of time.





## KEY CONCLUSIONS:

- The perceived erosion problem at the northern end of Ngaraad was more likely a shifting around of beach sediment, both along the shoreline to the south and onto the land behind the beach (building up land levels) during Typhoon Bopha.
- There was evidence that previous cyclones had resulted in substantial shoreline changes in the past, both building up and eroding land areas. Much of the land area on which people now live at the northern end of Ngaraad has been deposited within living memory.
- Much of the human development over the last 60 years in the coastal areas at Ngaraad has been located in areas that are:
  - exposed to cyclone flooding.
  - too close to the shoreline to accommodate the large shoreline changes that can occur here.
- Sand removed from the beach for building construction will also have contributed to the extent of shoreline change and loss of land.
- As the effects of sea-level rise and climate change increase, the Ngaraad community will be ever more exposed to the impacts of coastal flooding and shoreline change.

## RECOMMENDED ACTIONS:

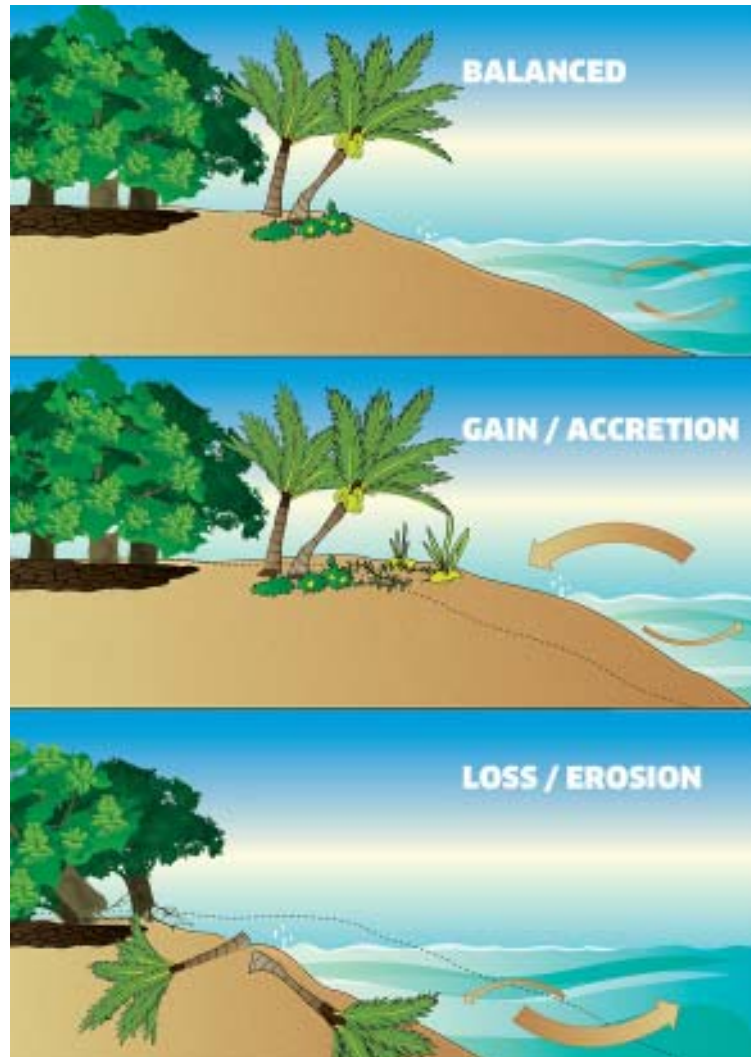
Actions that were developed for the Ngaraad community to consider included:

- Managed retreat of shoreline homes over the next few generations. This could include government incentives to help people move out of hazard-prone areas. This is particularly of interest for the girls' school, and it was discussed that over time that should be moved to safer ground. This would also include working with people who don't have land inland, and the need for discussions among clans to determine how people could possibly move back to familial lands.
- Prohibiting the building of hard structures that can cause more damage to shorelines and create more erosion problems in nearby areas.
- Prohibiting sand mining to prevent a loss of sediment out of the system and potential increases of erosion of the area.
- Fixing damaged homes from storms by putting them up on stilts that allow for the passage of water under the homes.
- Developing a locally managed marine area (LMMA) in the reef area in front of the community. This LMMA should consider prohibiting any activities that damage coral reefs or sea grass, and manage key fish populations (including parrotfish) that produce sand and other marine life that help to maintain natural and healthy reef ecosystems.

PHOTOS BY DOUG RAMSAY

Coastal Story developed through information provided at the Coastal Change tool development workshop in the Republic of Palau, hosted by the Palau Office of Environmental Response and Coordination and the Melekeok, Ngaraad, and Koror State Communities.

## THE SEDIMENT BALANCE



The **sediment balance** describes how much sediment an area is gaining from its sources and how much sediment the area is losing over the long term through its sinks. The illustration shows:

**Balance:** A healthy balanced beach will have almost the same amount of sediment moving into the sediment cell as there is moving out of it over a long term (many years). Overall, the gain and loss of sediment are about equal; however, the shoreline may change shape due to wind and waves, even as the amount of sediment stays roughly the same.

**Gain/Accretion:** If a shoreline is gaining more sediment than it is losing over many years, coastal lands will build up—this is called “accretion.” New vegetation such as coconut seedling may even begin to grow on this new land.

**Loss/Erosion:** If a shoreline is losing more sediment than it is gaining over the long term, vegetation and land behind the beach will be lost. This is called “erosion.”

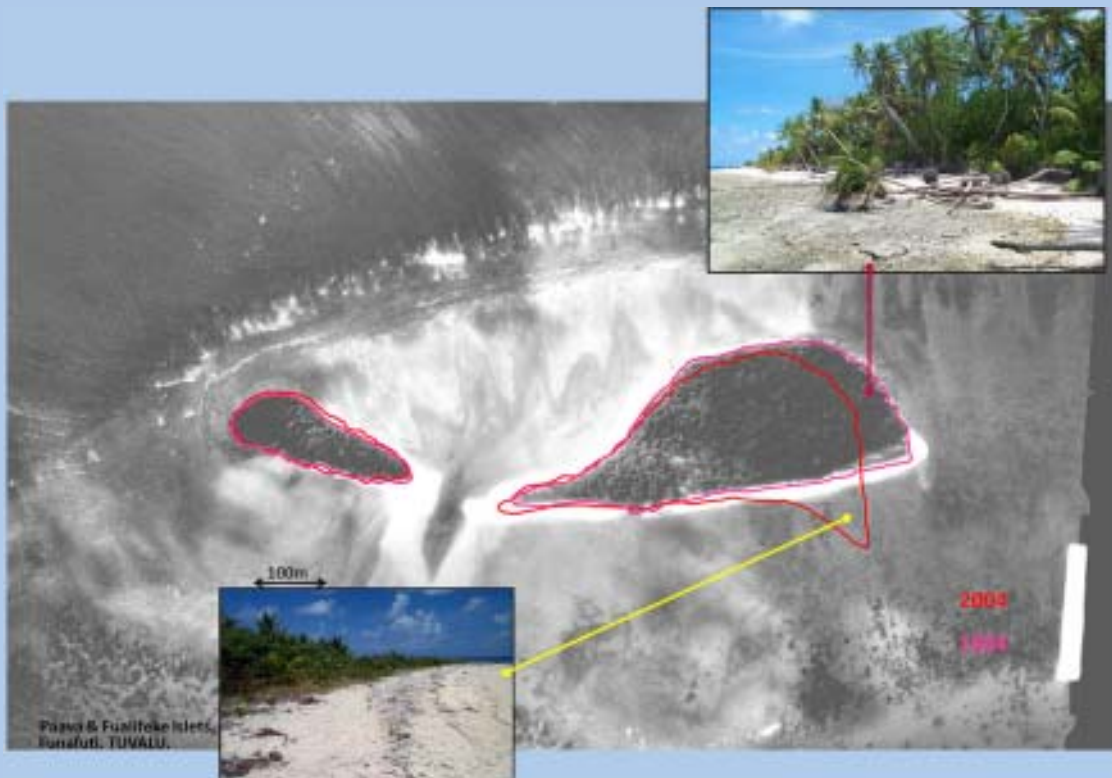
A healthy and balanced system is always gaining sediment in some areas and losing sediment in other areas—for example, after a storm event. This change is a natural process. Many island shorelines that people assume are losing sediment and eroding away may actually be shifting sediment to a different area of the sediment cell. This is still considered a healthy and balanced shoreline, as the sediment is not lost; it has only moved.

Looking at shoreline vegetation can help communities determine what areas of the shore are more stable. Young vegetation may indicate that the land is also young, built from recently deposited sediment. This indicates the shore is an actively accreting shoreline. On the other hand, old trees can mark areas of shoreline that have remained stable over time and are out of the active zone. For example, in the Pacific Islands large *Calophyllum* trees may border the active shoreline and can indicate that this is land that has been more stable over a longer period of time.

## CASE STUDY 1

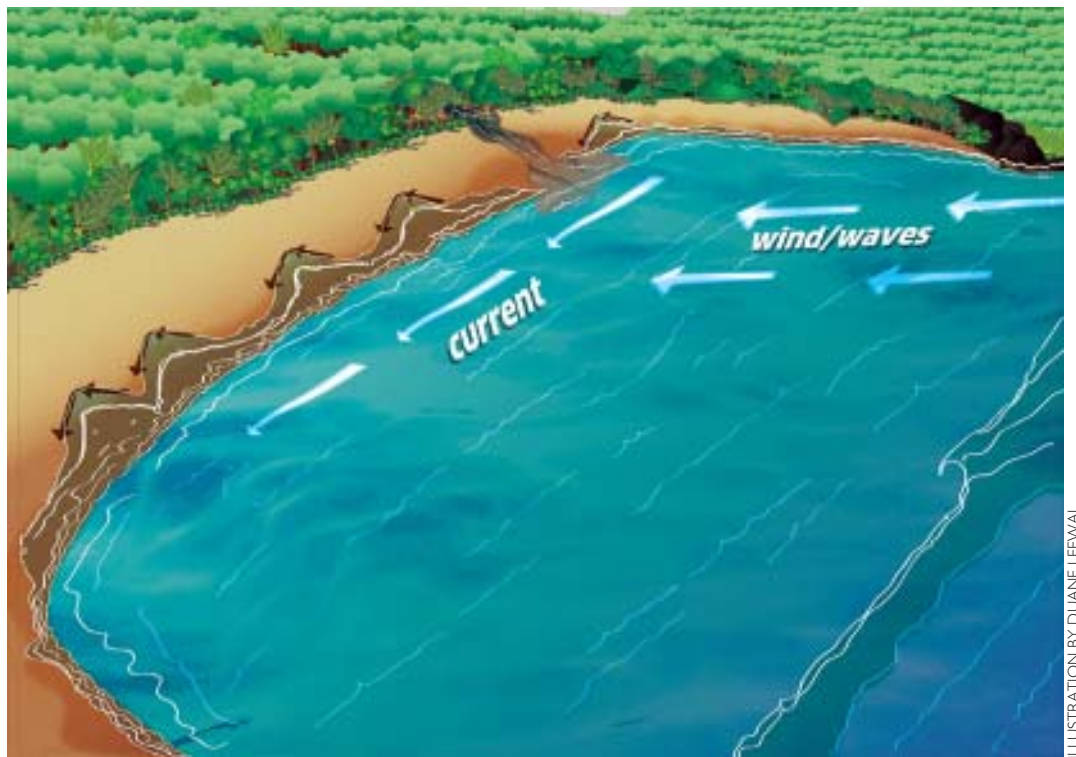
### Funafuti, Tuvalu

This image shows islets in Funafuti, Tuvalu. You can see the red outline shows the shoreline shape in 2004 and the pink outlines shows the shoreline shape in 1984, illustrating that the tip of the island moved quite a bit over 20 years. When coastal scientists reviewed the total land area over that period, there was only a .09 hectare loss of land, or one-percent change. Overall, the island neither lost nor gained land; however, for the people who are emotionally connected to those active shoreline areas, those changes were either perceived as “terrible” or “great.” The people who own land in the area where the sediment was moved away may have considered this change a big “erosion problem.” However, the people who owned land where the island gained sediment were likely happy to see their land growing.



## LONGSHORE MOVEMENT

Sediment naturally moves around a shoreline through tides, wind, waves, currents, and storms. Currents that run along the beach are generated by the predominant wind/wave patterns, which meet the shoreline. These currents move sediment in one direction. As sediment from a particular part of the beach is lost, it enters another part of the beach in the direction of the current; this is referred to as long-shore movement. Wind across the Pacific Islands frequently comes from the east (trade winds), which means that sediment on a beach would predominantly move west with currents during normal trade winds. Long-shore movement can change direction when wind patterns change because of seasonal changes or storms. This can result in dramatic changes in beach shape as sediments are redistributed.



## NATURAL DEFENSES THAT HELP MANAGE THE SEDIMENT BALANCE

Natural defenses refer to the natural-resource components of a healthy coastal ecosystem (e.g. coral reefs, seagrasses, beaches, mangroves, wetlands, and upland forests) that in combination can slow the rate of shoreline change and limit the amount of coastal flooding. Additionally, a healthy coastal ecosystem provides other benefits to communities including food and income (e.g. from fisheries); medicine; tourism; and cultural and recreational areas.

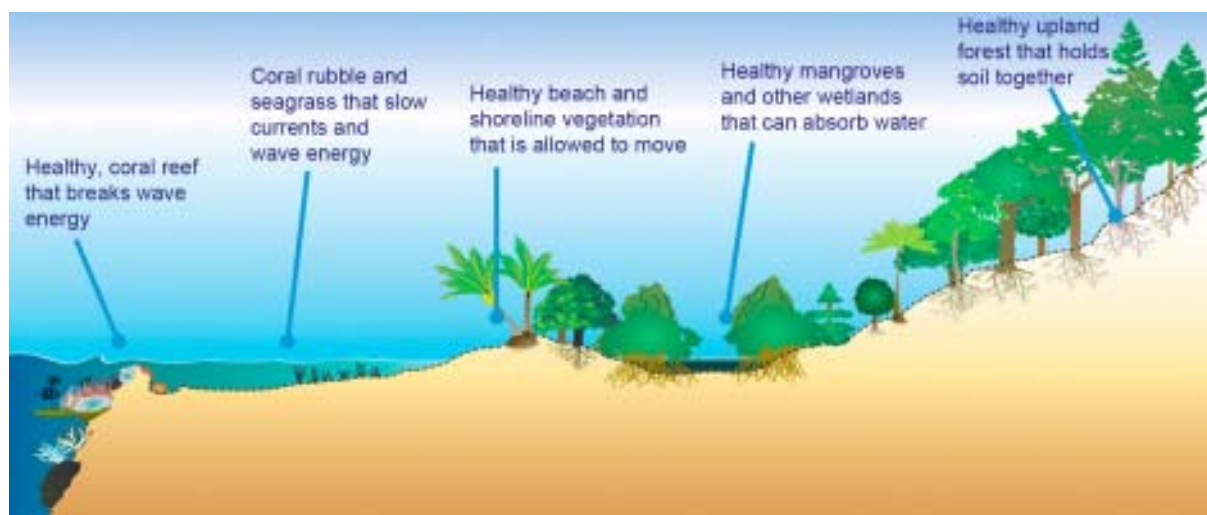


ILLUSTRATION BY DUANE LEEWAI

Natural Defense	Benefits to the Community
Coral Reefs, Reef Flat, and Coral Rubble	<ul style="list-style-type: none"> <li>• The first line of defense against large waves-waves break on the reef edge, reducing the size of waves reaching the shoreline and therefore reducing the potential to move sediment at the shoreline or cause flooding.</li> <li>• One of the main sources of sand/sediment on islands.</li> <li>• Provides habitat for important fisheries.</li> </ul>
Seagrass Beds	<ul style="list-style-type: none"> <li>• Trap and stabilize sediment through their leaves and extended root systems, helping maintain stores of sediment close to the shoreline.</li> <li>• Limit sediment being washed seaward off the reef and reduce the depth of water over the reef flat, reducing the size of waves reaching the shoreline.</li> <li>• Provide important habitat for fisheries, especially juveniles.</li> </ul>
Beaches and Beach Vegetation	<ul style="list-style-type: none"> <li>• Acts as a barrier protecting inland areas from waves and high sea levels. The beach changes shape in response to the wave conditions.</li> <li>• Vegetation helps to stabilize the top of the beach and reduce both the amount and extent of wave overwashing.</li> </ul>
Mangroves	<ul style="list-style-type: none"> <li>• Web-like roots of mangrove trees can act to trap sediment coming from inland areas from rains, rivers, and streams. This prevents sediment from moving out to sea, where it can smother and kill coral reefs and seagrass.</li> <li>• Sediment builds up in the roots and can help to stabilize the shore.</li> <li>• Have a unique ability to adapt to rising sea levels and move inland if there are no structures blocking their movement.</li> <li>• Act as a strong barrier against the energy of waves and can protect inland areas from flooding.</li> <li>• Provide important habitat for fisheries, especially juveniles.</li> </ul>
Other Wetlands	<ul style="list-style-type: none"> <li>• Absorb and hold a lot of water, especially during heavy rains, and so can protect nearby land from flooding by absorbing water and releasing it slowly.</li> <li>• Trap large amounts of sediment washed down rivers and streams during heavy rain. This prevents sediment from moving out to sea, where it can smother and kill coral reefs and seagrass.</li> </ul>
Upland Forests	<ul style="list-style-type: none"> <li>• Roots of trees in upland forest hold sediment together and keep it stable, reducing risk of landslides and soil erosion.</li> <li>• Leaf cover and litter also reduce the impact from heavy rains, preventing soil erosion.</li> <li>• Vegetation near streams and rivers also prevent sediment from entering waterways. This prevents sediment from moving out to sea, where it can smother and kill coral reefs and seagrass.</li> </ul>



### Questions to Consider

- What direction does the current flow along your shoreline and does it change seasonally?
- What natural defenses are in your coastal zone and how healthy are they?
- How does the community use the natural defenses and what benefits do they provide?

## SESSION 1 KEY MESSAGES

- Coastlines are a collection of different components that all interact and are dependent on each other. For coastlines to be healthy and reduce impacts from storms and climate events, the individual coastline components must be healthy.
- All shorelines are active and change shape over time, and so will not always look the same. However, some areas, like rocky shores, may change slowly while others, like sandy shores, may change quickly. For example, extreme events such as typhoons can cause rapid changes to the shape of a shoreline.
- Natural ecosystems provide sources of sediment and are therefore important to maintain healthy shorelines.
- When sediment is removed from a sediment cell, it is lost for good and very hard to replace; this will cause erosion.
- Natural defenses are components of a healthy coastal ecosystem (e.g. coral reefs, seagrasses, beaches, mangroves, wetlands, and upland forests) that in combination can slow the rate of shoreline change and limit the amount of coastal flooding, as well as provide other socio-economic benefits to communities (e.g. food, income).

## SESSION TWO:

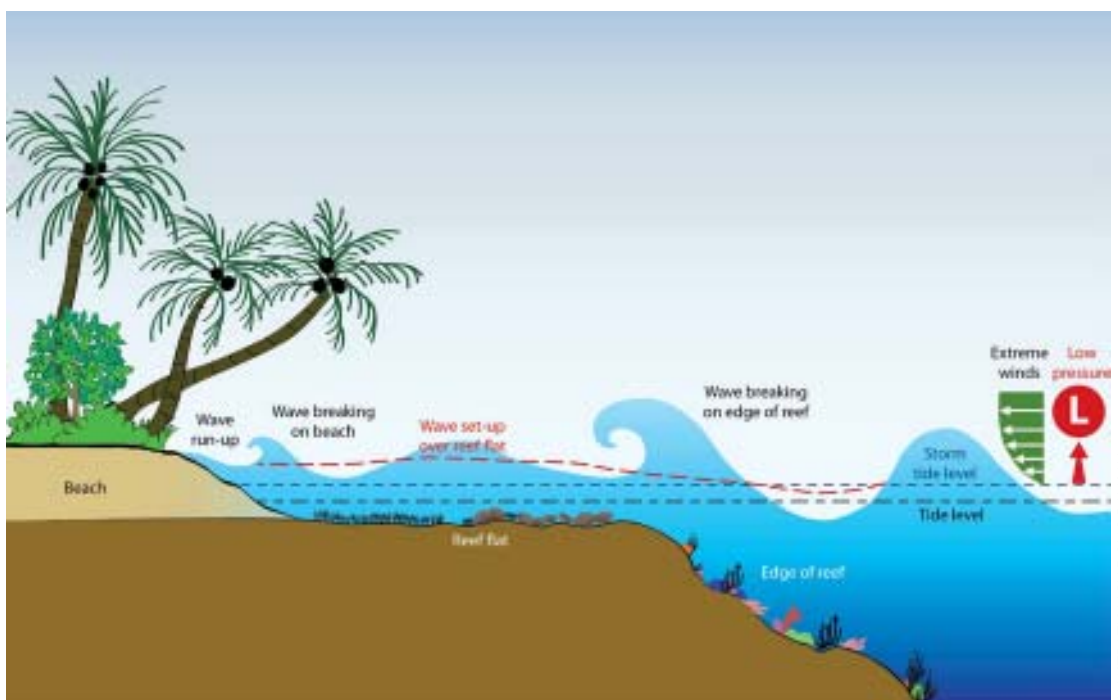
### NATURAL EVENTS THAT INFLUENCE COASTAL CHANGE

Now that we understand how coastlines work and that they are always changing naturally, we can better understand natural processes that can cause faster-than-average rates of coastal change (including shoreline erosion and coastal flooding).

The main drivers of coastal change are sea level and waves. However, there are natural events that have a big influence on sea levels and the size of the waves and can greatly influence the rate of coastal change. These natural events include:

- Storm events (e.g. typhoons, tropical storms)
- Climate variability (e.g. El Niño/La Niña)
- Movement of land masses (e.g. uplift/subsidence)

### STORM EVENTS



Large waves created by storm events (typhoons/cyclones and tropical storms) can move sediment in, around, and out of a coastal zone very quickly. During storms low pressure—and in certain cases, winds blowing on-shore—causes higher-than-normal sea levels called storm surge. With higher sea levels and larger waves from high winds, water can move further into coastal areas with higher-than-normal energy. This can cause flooding further inland and move large amounts of beach sediment alongshore, wash it over the land behind the beach, or move it offshore, where it may be permanently removed from the shoreline. Storm events coinciding with high tides often cause the worst coastal-flooding events.



DOUG RAMSAY

Additionally, heavy rain events can also flood local streams and rivers. During high tides and storms water moves inland, blocking heavy river/stream flow from moving out to sea. The river/stream water combined with ocean water can cause severe flooding to low-lying areas of the coastline.



DOUG RAMSAY

It is possible for severe storms to pick up and carry sediment from the sea and deposit it onto the land. Such severe storms can also create new sediment by breaking up coral on the edge of the reef and depositing it on to the reef flat. These piles of coral rubble and sediment can be a source of protection and sediment to local shorelines for long periods of time. Though they often cause significant short-term destruction, typhoons/cyclones and storms play a very important role in providing rubble and sediment, creating and maintaining many of the coastal land areas and shorelines in the Pacific. The images above show how a coral bank was left after Cyclone Bebe in 1972 (left), and became part of the landmass by 2003.

The photo above was taken in Anguar, Palau after Typhoon Bopha. The storm deposited a large pile of coral rubble on the reef platform, where it now acts as a natural defense against further storms. Over time these mounds of coral rubble will break down and migrate landwards, eventually joining the shoreline.



FENNO BRUNKEN

# CLIMATE VARIABILITY

## What are El Niño and La Niña?

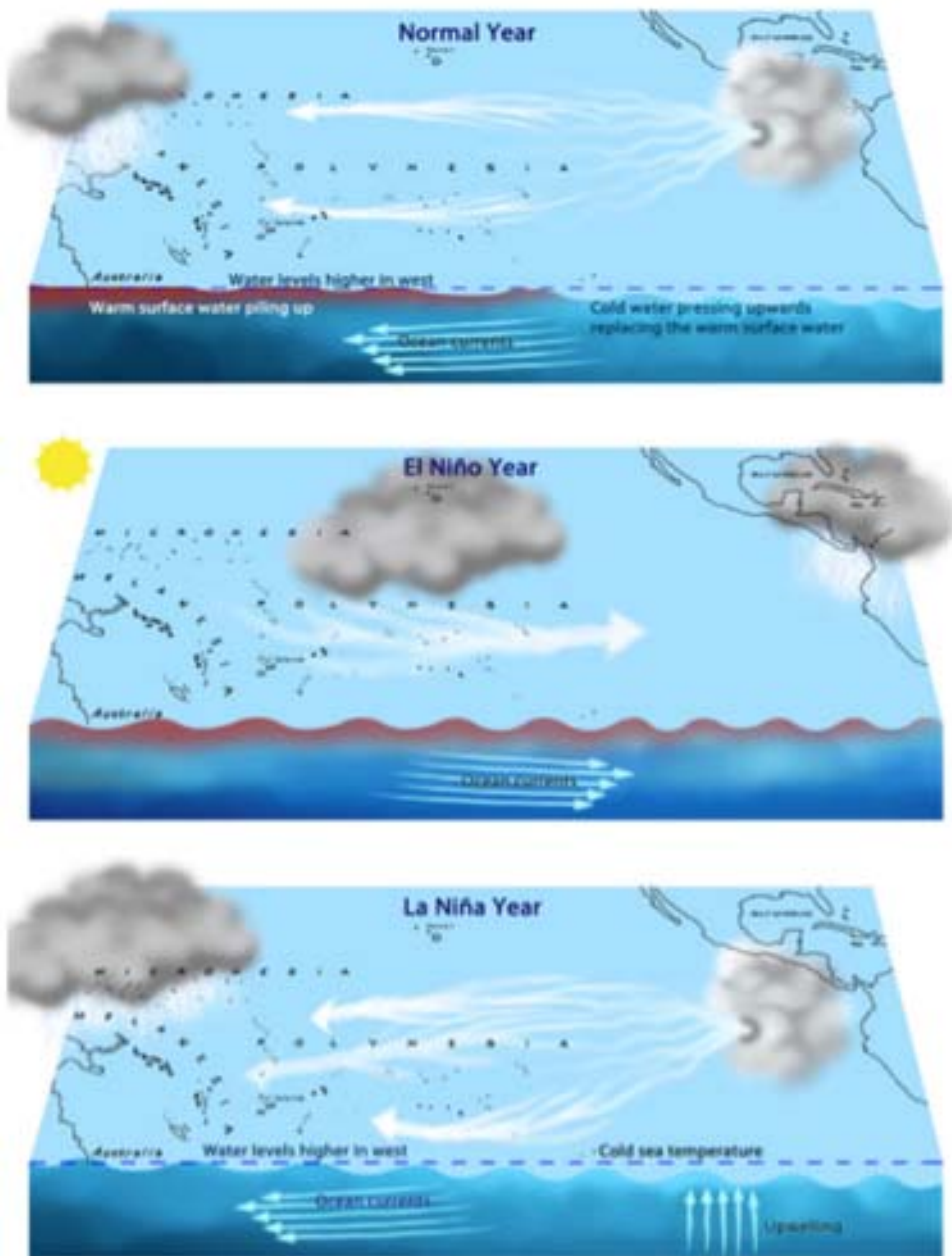


ILLUSTRATION BY SEVULONI TORA

El Niño Southern Oscillation (ENSO) seasonal events, commonly known as El Niño/La Niña events, have a strong influence on sea levels and weather and wave patterns in the Pacific Ocean. These events are natural and have been happening for thousands of years, occurring approximately every three to seven years; while they may be influenced by long-term climate change, they do not result from climate change.

### Normal Conditions (ENSO Neutral)

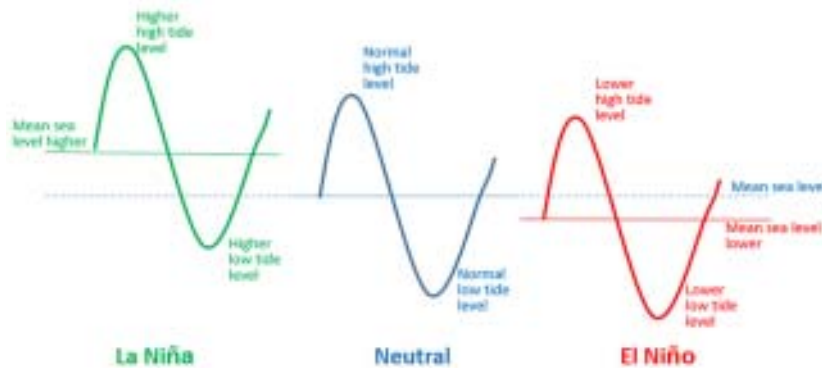
In the western Pacific, a pool of warm water causes the sea level to rise. In normal years, the ocean surface is about one foot (about 30 cm) higher in the western equatorial Pacific than in the eastern equatorial Pacific. Normal easterly trade winds blow east to west and keep the water piled up in the west.

### El Niño

During El Niño, the trade winds blowing from east to west weaken. Calm weather is more common in the western Pacific as storms move across to the east. The equatorial warm-water pool shifts toward the eastern Pacific, and sea levels in the western Pacific fall and conversely rise in the eastern Pacific, which can cause extreme-high sea levels along the Californian coast. Storms also become more common in the eastern tropical Pacific. In the western Pacific, El Niño is associated with lack of rain—and in some cases, severe drought and coral bleaching from increased sea-surface temperatures.

### La Niña

During La Niña, trade winds blow more strongly from east to west and the equatorial warm-water pool is pushed to the western Pacific. This causes the sea level to rise in the western Pacific; in an extreme event, this may cause about a one-foot (30 cm) increase over average or “normal” conditions. This is coupled with increased storms in the western Pacific, which can cause more frequent coastal flooding—and in some locations, shoreline change.

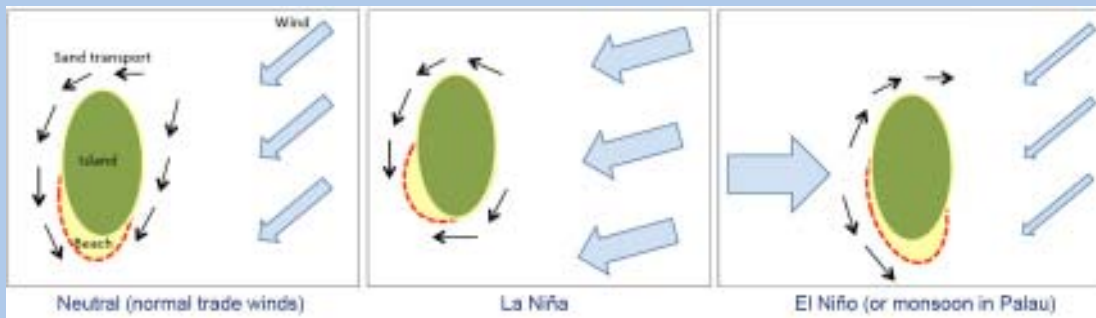


The changes to wave conditions from wind patterns during ENSO events have a strong impact on shoreline processes. The natural fluctuation between La Niña and El Niño can cause sandy shorelines to naturally shift by many feet or metres. There are also longer cycles that cause higher sea-level rise during certain periods. For example, there are 15- to 30-year cycles where there tend to be more La Niña-like or El Niño-like conditions. Therefore, there are long periods of time where the average sea levels tend to be higher or lower than normal conditions.

Many people misunderstand ENSO seasonal cycles, especially because they can last several years. The conditions caused by ENSO fluctuations (e.g. higher sea levels causing shoreline changes and increased flooding) are sometimes confused with climate change impacts. It is important to understand that ENSO seasons have always occurred; however, climate change-associated sea-level rise will make impacts from these ENSO events worse over time.

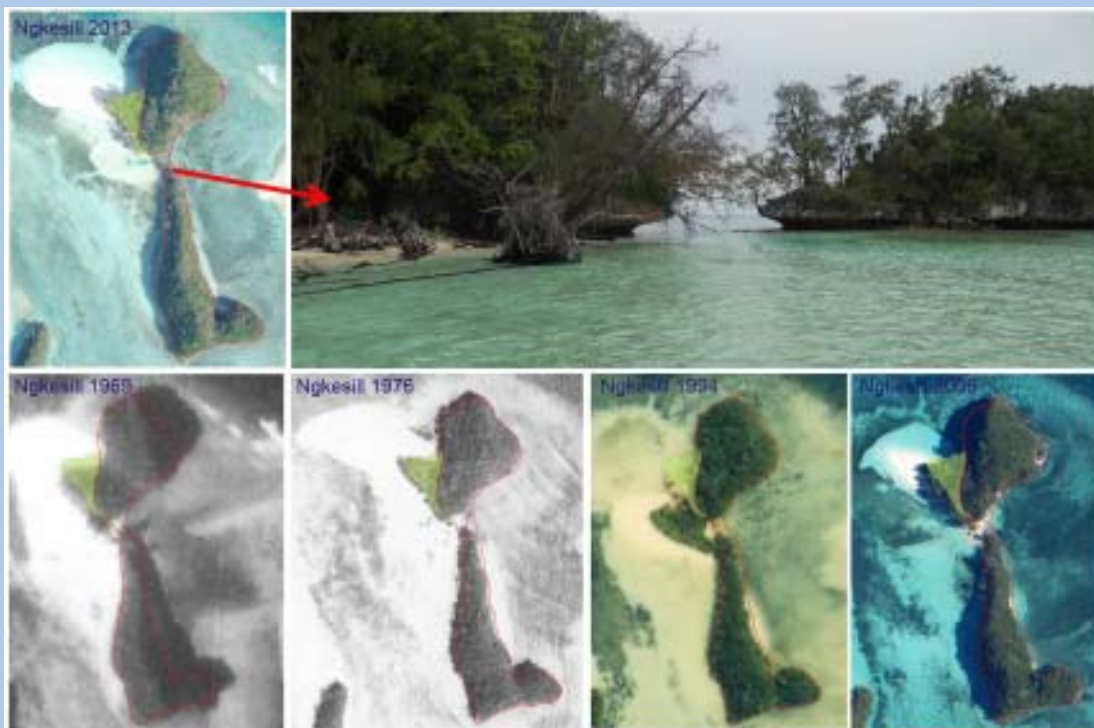
To learn more about ENSO events see the short “climate crab” video at: <https://www.youtube.com/watch?v=sIUSWEftN4w>

## Ngkesill Island in Rock Islands, Palau



ARTHUR WEBB 2013

The image above shows how in the Rock Islands of Palau, El Niño conditions will cause sandy beaches to build up on the southwestern side of the island. However, La Niña conditions will shift sands to the southeastern side of the island.

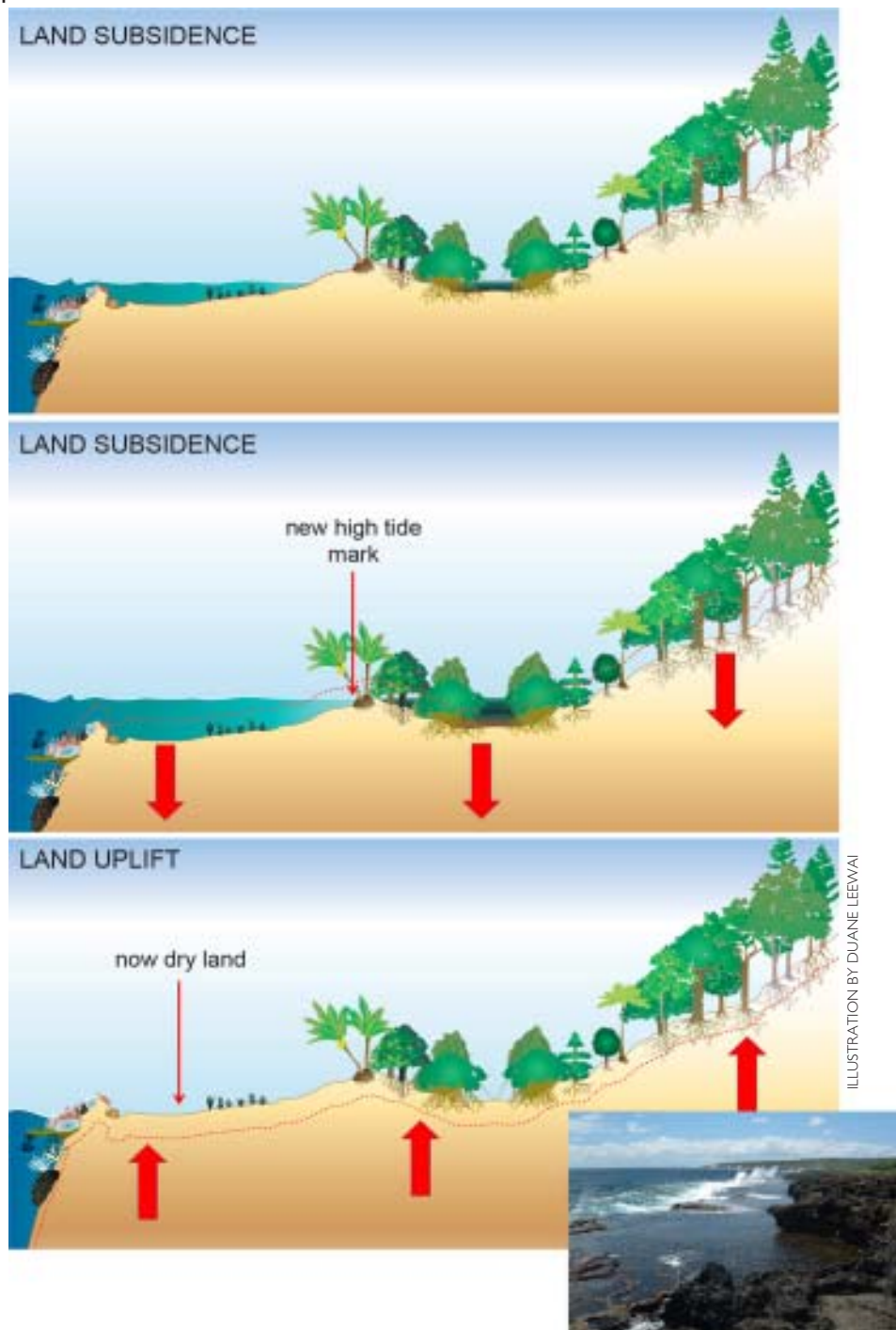


ARTHUR WEBB 2013

The images above show the Ngkesill Island in Palau over time. Looking at historical photos of this island you can see how the active shoreline (area marked in green and associated white sandy patch) moves north and south based on prevailing winds. At certain times (such as 1994) there is a large area of vegetated shoreline connecting the two parts of the islands. At other times when the shoreline moves north, this area is opened up and no longer connected (as seen in the photo taken in 2013). If you look back as far as 1969 you can see the island was a very similar shape as it is today, indicating that these are natural patterns of shoreline movement.

## MOVEMENT OF LAND MASSES

Many parts of the Pacific experience a lot of earthquake activity. Earthquakes are natural events that are not related to climate change. When these events occur, they can cause entire islands (or parts of islands) to move either up or down. If the land moves down (referred to as subsidence) the sea level can appear to have risen rapidly, and flooding of coastal lands from regular tides and waves can reach further inland. If the land moves up (referred to as uplift) the sea level can appear to have dropped suddenly; flooding may decrease in these areas and certain marine resources such as coral reefs may even be exposed to air.



## Torres Islands, Vanuatu

Torres Islands, Vanuatu are in a region of high earthquake and volcanic activity. This area has been known for the relocation of communities due to more frequent flooding events during the 1990s and early 2000s. These events were attributed to climate change, but more recently researchers began studying how earthquake activity in the region caused the “sinking” of these islands. They found that during the time when more flooding events were observed, there was



significant subsidence or “sinking” of the islands due to several earthquakes and related activity between events. The sinking of the islands made the sea level appear to have risen rapidly in a short amount of time. Data revealed that the island subsided by nearly 12cm between 1997- 2009, which is one of the highest rates of subsidence on Earth. This accounts for almost half of the total change in sea level measured during this period. As such, the researchers believe that the 1997 earthquake was a major cause of the sea level rise and flooding in the region. While communities felt the flooding gradually, researchers believe this may have been due to the loss of natural defenses over time due to the changes, which made the flooding gradually get worse.

The photo, taken in April 2009, shows a flooded coconut plantation on Loh Island, with many dead coconut trees. The flooding extends along about 400 m of land that was dry before 1997.

Additionally, in 2010 researchers conducted a survey of oral traditions, which demonstrated that there is traditional knowledge of danger from the ocean and that villages were formerly located on a 100+-meter-high coral platform where gardens are still located. Artifacts and documents from Christian mission papers confirm that villages were located in that area. It was believed during this time that natural disasters such as tsunamis along the coast were caused by black magic. Moving closer to the active shoreline coincides with the time when black magic was rejected and began to be replaced with other religious beliefs. The researchers also collected data which show that earthquakes in 2009 lifted the islands back up to about the same position they sat at in 1998. In areas subject to high rates of tectonic activity (including much of Melanesia and parts of Polynesia) it is important to understand the interaction of vertical land movement in order to better assess coastline risks and take appropriate action (Ballu V et al., 2011).



### Questions to Consider

- Have there been any big events that have caused a loss or gain of sediment?
- Has coastal flooding occurred in your community? If yes, can you remember anything about the tide, wave, and weather conditions? What do you think was the main process causing the coastal flooding? Were there periods when more- or less-frequent coastal flooding occurred?

## SESSION 2 KEY MESSAGES

- The main drivers of coastal change are sea level and waves. However, there are natural events that have a influences on sea levels and the size of the waves, and can influence the rate of coastal change. These natural events include storms, climate variability (e.g. El Niño/La Niña), and movement of land masses.
- Storms are natural events that can create higher sea levels and waves, which can cause coastal flooding and faster rates of shoreline change (erosion and accretion) than normal conditions.
- El Niño and La Niña are natural cycles that can cause temporary changes to coastal conditions and weather patterns (e.g. changes in sea levels, rainfall, and wind patterns). The conditions caused by ENSO fluctuations (e.g. higher sea levels, causing shoreline changes and increased flooding) are sometimes confused with climate change impacts. It is important to understand that ENSO seasons have always occurred; however, climate change-associated sea-level rise will make impacts from these ENSO events worse over time.
- Movement of land masses can happen quickly with natural events such as earthquakes, which can cause rapid changes in sea level and coastal flooding. These events are not related to climate change, but are natural and somewhat unpredictable events.
- It's important to remember that when natural defenses (e.g. reefs, seagrass beds, beaches, mangroves, and other wetlands) are healthy, they can limit the impacts these drivers have on coastal change and the resulting impacts on communities.

## SESSION THREE: HUMAN ACTIVITIES THAT INFLUENCE COASTAL CHANGE

This session will review various human activities that influence or disrupt how sediment moves and the sediment balance of a coastal area. These human activities can increase the rate of shoreline erosion or increase the potential impacts of coastal flooding, which can have negative safety, health, and economic impacts on communities. This session will also explore how climate change will exacerbate coastal change impacts from both natural processes and human alterations.

### PRACTICES THAT NEGATIVELY IMPACT NATURAL DEFENSES



Human practices that change natural coastal defenses can negatively impact their ability to add sediment to coastlines or manage the sediment balance. These include:

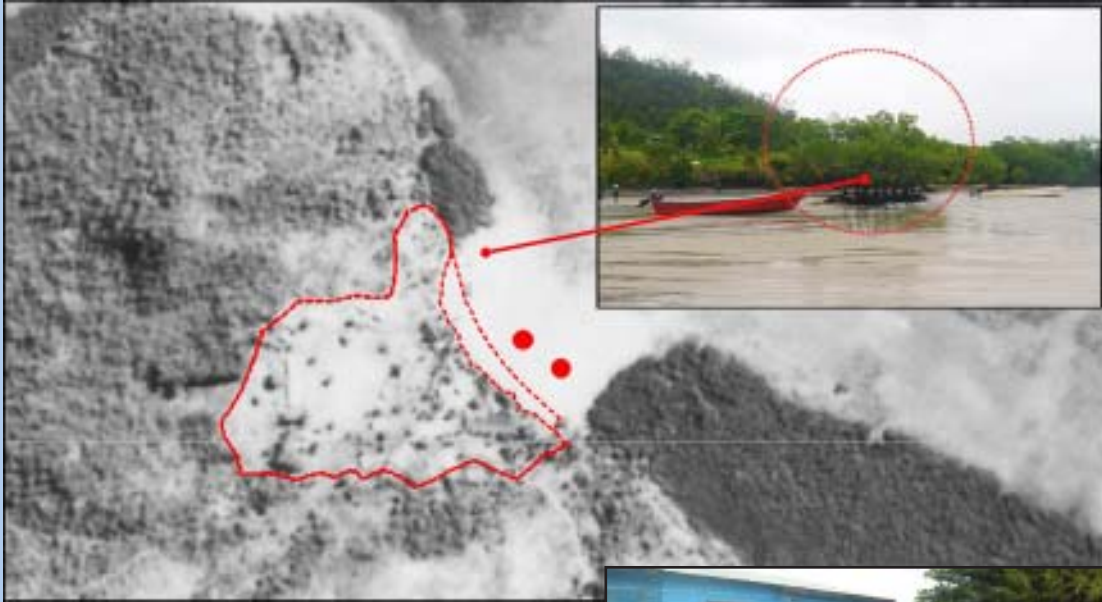
Natural Defense	Threats to Natural Defenses	Benefits Lost to the Community
Coral Reefs, Reef Flat, and Coral Rubble	<ul style="list-style-type: none"> <li>• Destructive fishing practices such as blast fishing or fishing with poison can directly damage reefs.</li> <li>• Pollution and over-harvesting reef systems also reduce the health and strength of reefs.</li> <li>• Sediment from poor land-use practices (e.g. deforestation) flowing onto reefs can smother them, weakening them or killing them.</li> <li>• Dredging reefs directly removes coral structures and rubble to be used for development. When reefs are lost, a critical source of sediment is also lost, reducing the amount of sediment entering onto the shoreline.</li> </ul>	<ul style="list-style-type: none"> <li>• The first line of defense against large waves—waves break on the reef edge, reducing the size of waves reaching the shoreline and therefore reducing the potential to move sediment at the shoreline or cause flooding.</li> <li>• One of the main sources of sand/sediment on islands.</li> <li>• Provides habitat for important fisheries.</li> </ul>
Seagrass Beds	<ul style="list-style-type: none"> <li>• Pollution and poor water quality reduce the health of seagrass beds.</li> <li>• Sediment from poor land-use practices (e.g. deforestation) flowing onto reefs can smother them, weakening them or killing them.</li> <li>• Dredging for sand directly removes seagrass beds.</li> </ul>	<ul style="list-style-type: none"> <li>• Trap and stabilize sediment through their leaves and extended root systems, helping maintain stores of sediment close to the shoreline.</li> <li>• Limit sediment being washed seaward off the reef and reduce the depth of water over the reef flat, reducing the size of waves reaching the shoreline.</li> <li>• Provide important habitat for fisheries, especially juveniles.</li> </ul>
Beaches and Beach Vegetation	<ul style="list-style-type: none"> <li>• Mining for sediment that can be used to develop channels or collect material to build houses, roads, airstrips, etc. These activities permanently remove sediment from the system and will increase erosion.</li> <li>• Development projects that change or block natural water movement along beaches. These include causeways, piers, or roads. If currents are blocked from carrying sediment downstream, it will build up on one side of the structure. However, the areas down-current will no longer be gaining sediment and begin to experience rapid erosion.</li> </ul>	<ul style="list-style-type: none"> <li>• Acts as a barrier protecting inland areas from waves and high sea levels. The beach changes shape in response to the wave conditions.</li> <li>• Vegetation helps to stabilize the top of the beach and reduce both the amount and extent of wave overwashing.</li> </ul>
Mangroves	<ul style="list-style-type: none"> <li>• Clearing of mangroves for fire wood or timber.</li> <li>• Filling of mangroves to “create land” that can be developed.</li> <li>• Structures that block water from moving into wetlands or mangroves will stop sediment and freshwater from entering those areas and can cause damage or death to those natural defenses.</li> </ul>	<ul style="list-style-type: none"> <li>• Web-like roots of mangrove trees can act to trap sediment coming from inland areas from rains, rivers, and streams. This prevents sediment from moving out to sea, where it can smother and kill coral reefs and seagrass.</li> <li>• Sediment builds up in the roots and can help to stabilize the shore.</li> </ul>

Natural Defense	Threats to Natural Defenses	Benefits Lost to the Community
		<ul style="list-style-type: none"> <li>• Have a unique ability to adapt to rising sea levels and move inland if there are no structures blocking their movement.</li> <li>• Act as a strong barrier against the energy of waves and can protect inland areas from flooding.</li> <li>• Provide important habitat for fisheries, especially juveniles.</li> </ul>
Other Wetlands	<ul style="list-style-type: none"> <li>• Filling of wetlands (including mangroves) to “create land” that can be developed.</li> </ul>	<ul style="list-style-type: none"> <li>• Absorb and hold a lot of water, especially during heavy rains, and so can protect nearby land from flooding by absorbing water and releasing it slowly.</li> <li>• Trap large amounts of sediment washed down rivers and streams during heavy rain. This prevents sediment from moving out to sea, where it can smother and kill coral reefs and seagrass.</li> </ul>
Upland Forest	<ul style="list-style-type: none"> <li>• Clearing of forest from upland systems on high islands for agriculture or development.</li> <li>• Lands cleared are often replaced with non-native or alien species. These species often take over native species or habitat and are not as effective in maintaining sediment as native species.</li> </ul>	<ul style="list-style-type: none"> <li>• Roots of trees in upland forest hold sediment together and keep it stable, reducing risk of landslides and soil erosion.</li> <li>• Leaf cover and litter also reduce the impact from heavy rains, preventing soil erosion.</li> <li>• Vegetation near streams and rivers also prevent sediment from entering waterways. This prevents sediment from moving out to sea, where it can smother and kill coral reefs and seagrass.</li> </ul>



ARTHUR WEBB

## Druadrua Island, Fiji



The aerial photo shows part of the coastal community in Fiji. The dark areas are mangrove forest, and you can see that there is a large area in the middle of the forest that has been cleared away. This area was originally cleared to let more breeze come through the homes built behind the mangroves. However, the owner of one of the coastal homes has begun to notice the shoreline in front of his house has been eroding. When coastal scientists reviewed the area, it was clear that the loss of mangroves has also removed the natural defense; waves and water are now able to move further inland and remove sediment. They proposed re-planting strands of mangroves to re-build the natural defense, while also allowing some air to move through (Webb, 2007).



PHOTOS BY ARTHUR WEBB



### Questions to Consider

- How have the natural defenses in your community changed over time?
- What caused those changes?

## MELE BEACH IN MELE, VANUATU



### COASTAL VALUE AND USES

Mele Beach is located on the southwestern shores of Efate Island, Vanuatu. Just south of Mele Bay is the capital of Port Vila, which is the most densely populated area of Vanuatu. This coastal community story is focused on the northwest subsection of Mele Bay north of Hideaway Island, which is just offshore. This beach is locally referred to as Mele Beach and has been experiencing erosion and inundation issues over roughly the past thirty years. The Mele community historically resided on Hideaway Island, but in 1950 the community moved onto the mainland opposite the island due to policies of the former colonial powers pre-independence in 1980.

Around the time of the Second World War, a road was developed to move military vehicles along the shoreline. This unpaved gravel road now extends along the shoreline of almost all Mele traditional lands, and is known as Devil's Point Road. The community began leasing the lands adjacent to the beach and road to private homeowners in the 1950s. After a long history of various uses (e.g. logging and coconut plantations), Hideaway Island is currently being leased to a resort developer and is used for tourism activities (e.g. accommodation, diving,

kayaking, and swimming). Additionally, wetlands that were present along the developed end of the beach were filled in around 2008 to create a subdivision. This subdivision is located directly opposite Hideaway Island and in recent years has become a hub of commercial leisure activity (beach bar, kayaking, diving, and sailboat-chartering vendors). The southeast end of Mele beach, as well as property landward of Devil's Point Road, is primarily valued for its commercial-leasing benefits by the community. Specifically, the funds acquired through the leasing of land have been a long-term sustainable source of funds for the community.

More recently (since the mid 1980s), funds have been obtained through mining and selling sand from the entire beach, both west and east of Hideaway Island, for development activities around Port Vila. The slightly offshore reefs to the east of Mele Beach are valued for limited reef fishing for bait, and occasional diving when conditions are rough further out. The northwest portion (the approximately 800m-long Mele Beach) retains a somewhat more natural character than the beach to the east. Mele Beach is very highly valued for swimming and picnics by both the Mele community members and residents

of Port Vila. Also of significant cultural importance to the community is a graveyard located in the center of Mele Beach, at the beginning of Devil's Point Road.



### COASTAL FEATURES AND CONDITIONS

The sand at Mele Beach is made up of both marine and terrestrial sediments. While there are only small patch reefs offshore from Mele Beach, they provide a source of sediment from fragments of corals and shells. These reefs also provide the first line of defense from storms by breaking up wave energy. The majority of beach sediment, however, comes from land-based sources brought to the coastline by local rivers. This sediment is noticeably dark, and volcanic in origin. Deeper sands are lighter, indicating more marine-derived sediment.

Wave exposure in Mele Bay creates a northwest to southeast longshore movement of sand on the beach. Wave energy along Mele Beach is moderately high and the shoreline is steep, indicating that the seafloor gets deep very quickly offshore. Large old *Calophyllum* trees (80+ years) are located right behind the beach and just in front of the road. This suggests that the shoreline has been stable over long periods of time and has not significantly changed shape. The beach, with its old growth tree cover, therefore has a history of providing natural-defense services for inland areas through a buffer against storm waves and flooding. On the inland side of the road there are low-lying swamplands where land is leased and a series of coastal homes have been built.



### COASTAL CHANGES OVER TIME

Since the late 1980s, community members and local stakeholders have been aware of high levels of erosion on Mele Beach. The west end of the beach has no more large trees, only bushes and second growth pandanus trees. The beach itself has lost a lot of sediment and vegetation, and roots from old trees adjacent to the shoreline and road have been exposed for more than ten years. There are currently remnants of at least one or two large trees lying in the intertidal area, and locals report that more than a few large trees have been lost over the years.

Additionally, some areas of the road and coastal lowlands (where leased homes are located) have been flooded during major storm events. A section of the road collapsed in 2009 and required a re-routing some distance away. These low-lying shoreline areas where trees, the road, homes, and the cemetery are located are already prone to erosion and flooding impacts of coastal change. Additionally, these impacts will worsen in the long term from pressures of local mining of sand, as well as sea-level rise and extreme weather events from future climate variability and change scenarios.

### CURRENT AND FUTURE COASTAL IMPACTS

While the majority of income is generated from land leases, the development boom around Port Vila in the 1980s drove the demand for sand and therefore the establishment of large and small sand-mining operations, which continue to this day. Large-scale operations are carried out by contractors using machinery that can remove significant quantities of sand in a short amount of time. This type of extraction occurs periodically next to the cemetery on Mele Beach, but usually not elsewhere along the beach. It does, however, take place along Blacksands Beach to the east, where sediments coming out of the rivers are targeted. Small-scale sand mining also occurs, often on a daily basis, by individuals and small contracting companies collecting in cement and rice bags and loading up trucks for small construction projects. Loss of land (e.g. erosion) was identified shortly after beach mining became a frequent activity in the area.



Homeowners that lease the lands on the land side of the road behind the west section of Mele Beach are very concerned about the beach mining. The coastal erosion is impacting the road, which is their only access in and out of the area. The residents at the east end of the beach are also threatened, but less so, and despite being low lying they have a different access road.

## COASTAL MANAGEMENT ACTIONS

The main actions identified for the community to consider as ways to minimize the impacts of coastal change, now and into the future, at Mele Beach include:

- Participatory community planning that includes all stakeholders (e.g. community members, homeowners, and investors such as tourism operators). This would include activities to plan for long-term changes and support community resilience. This could include:
  - o Raising awareness about coastal processes, the importance of natural defenses, and causes of coastal change.
  - o Developing policies to regulate beach mining that either prohibit mining or significantly reduce the level of mining to mitigate impacts.
  - o Exploring alternative sources of sediment to reduce the need for mining at Mele Beach.
  - o Revegetating both shoreline and inland areas to improve natural defenses and protect homes as well as road access.
  - o Developing rules to foster development that consider long-term sea-level rise. This could include developing building codes that clarify location and design for any new development.
  - o Improving community compliance with regulations.
  - o Developing a long-term managed retreat plan to move the road inland, to provide access to coastal homeowners and potentially to relocate homes.
  - o Expanding the existing locally managed marine area to provide further protection of reefs as a source of sediment and natural defense.
  - o Monitoring coastal changes over time, specifically after major erosion or inundation events. This can also include regular monitoring, such as beach profiling or measuring of fixed locations on the road to the vegetation line on the beach, to understand the relevance of regular tidal/seasonal cycles.



These actions have been identified as potential community based actions that could help mitigate and adapt for coastal-change impacts on community residents and stakeholders. A dispute about title for paramount chief in the Mele community is currently impeding the ability to develop rules and management activities to address many of these issues. This may be resolved in the near term. Even if it is not fully resolved, the community hopes to move forward with coastal-zone planning to limit further destruction of natural coastal defenses and to build the resilience of Mele Beach and the local community.

PHOTOS BY KARL FELLENIUS

Coastal Story developed through information provided at the Coastal Erosion/Sea Level Rise Climate Services Dialogues workshop in Vanuatu, hosted by Vanuatu Meteorology and Geo-Hazards Department (VMGD) with writing support provided by Karl Fellenius.

## POOR COASTAL DEVELOPMENT PRACTICES

Many traditional communities did not live permanently along the shore and instead only had temporary structures in this area. Today, many islands have roads and other infrastructure placed near hazardous areas of the coastal zone (e.g. low-lying coastal, filled wetlands or reclaimed lands, and the active shoreline). In many places it was the arrival of the missionaries in the mid-to-late 1800s that resulted in communities moving closer to the shoreline. However, on many islands, significant permanent development along the shoreline began during World War II by occupying forces, as a means to move around easily.

Over time, infrastructure built during the war encouraged the placement of homes and other permanent buildings in these areas by local communities. Once permanent homes were built near the shoreline, people become emotionally attached to these areas despite the fact that they are naturally hazardous areas because they are directly exposed to storms, high tides, waves, flooding, and shifting lands. Additionally, as villages and towns grow and development began to sprawl out from the economic centers, the economic opportunities attracted others (for example, from outer islands) to the urban centers. With land areas scarce, people increasingly moving into ever-more-exposed locations, such as low-lying coastal areas or active shorelines, leading to high vulnerability of these residents, buildings, and infrastructure.

Changes in Coastal Development Over Time



Coastal development practices refer to both **where** development is placed and **how** it is built. Hazardous coastal development practices include:

**Where** people build:



- a. Building infrastructure (e.g. roads, bridges, water lines, or power lines) or community services (e.g. health centres, churches, schools) within low-lying coastal lands, in areas prone to coastal change, on filled wetlands or reclaimed land, or over the active shoreline. Where infrastructure and community services are located often has a strong influence on where people develop homes and businesses, and vice versa.



- b. Placing homes in low-lying coastal lands, reclaimed areas, or active shorelines that are exposed to coastal hazards like erosion or flooding.

**How** people build:

- c. Buildings or infrastructures that are not built to adequately withstand potential coastal (or other) hazards that they may be exposed to over their lifetime.



### Questions to Consider

- Are there buildings or infrastructure on low-lying coastal lands, filled wetlands or reclaimed lands, or the active shoreline in your community?
  - o If yes, when were they built occur? Why?
  - o Identify and count how many buildings and types of infrastructure (if any) are located in areas exposed to coastal hazards.

# Community Coastal Story

## MELEKEOK, PALAU

### COASTAL VALUE AND USES

The Melekeok community is situated on the western side of Babeldaob Island in Palau. Melekeok community members take pride in living a “small village lifestyle,” which is defined by living near the reef, eating local fish, and knowing their neighbors. The reef fronting the community is several hundred meters from shore, reducing wave energy and allowing calmer reef flats and seagrass beds to survive in the near-shore area. These reef flats and seagrasses trap sediment from land and also slow down currents that move sediment. The long-shore current moves from north to south. The community values the shoreline for recreation, as an access point for fishing in the reef area, and as the place where the majority of current state infrastructure and housing is located.

### COASTAL FEATURES AND CONDITIONS

The shoreline in Melekeok is narrow, with only a small strip of flat land that is buildable in front of steep hills, which are not suitable for structures. Residents traditionally lived inland but moved closer to the shoreline when the Japanese built a school in the 1950s. Today the main road is paved and follows the shoreline, with most homes on the inland side of the road and some structures on the shoreline side of the road.

There is also a very long pier (approximately 100 yards in length) that was built more than 100 years ago and is a



symbol of strength of the community. There is a brief break in the pier midway along it. A community summer house (pavilion) was placed right on the beach area on the north side of the pier, and the state office is located on the inland side of the road across from the community summer house.

### COASTAL CHANGES OVER TIME

Much of the shoreline is already reinforced with seawalls aimed at protecting the road and homes. There are government-built walls, as well as a variety of walls built by private landowners with different materials and techniques. This demonstrates how when one seawall is added it impacts shoreline nearby, causing erosion; this can cause the need for additional seawalls.

The community was severely impacted by Typhoon Bopha in 2012 and noted that the water came over the road and flooded the state office and local homes. The beach in front of the community summer house was eroded away and the pier severely damaged. To address the damage, the community pulled together to rebuild the pier. They also built a small seawall on the beach roughly 10ft in front of the community summer house, in an attempt to stop further erosion of the sediment under the foundation of the building.



## CURRENT AND FUTURE COASTAL IMPACTS

An informal assessment of the area revealed the following:

- **Impact of pier:** One of the most obvious features noted in the area was the large amount of sand built up on the northern side of the pier, versus the southern side where there was no beach and the shore was eroded back to the seawall, next to the road. The pier was trapping sediment from the long-shore current and allowing it to pile up against the pier. However, this was also stopping sediment from moving down current, so the northern side is accumulating sediment while the southern side is losing sediment and eroding.
- **Community summer house:** After the Typhoon in 2012, there was a new seawall built to protect the community summer house from erosion. However, based on the current and sediment movement and historical observation, it is likely that the sediment will naturally return to that area over time; therefore, the seawall is not really needed.



Additionally, the seawall was built out on the beach about 10 feet away from the summer house, and may actually prevent sediment from moving inland close to the building.

- **Shoreline development:** People moved into this highly dynamic area in the recent past without fully understanding how the area might shift/move and become dangerous during coastal-hazard events. Additionally, it was noted that these low-lying areas that are inundated in storm events will get worse over the next few generations as sea levels rise. With the coastal road as the only access road out of the village, this can be particularly dangerous during storm events such as typhoons, as leaving the area in emergencies can become impossible.

## COMMUNITY ACTIONS

Upon assessing the area, the following actions were identified as some for the Melekeok community to consider:

- **Managed retreat of shoreline homes over the next few generations:** This could include government incentives to help people move out of hazard-prone areas. As the coastal road provides the means for utilities such as power, water, and Internet, the group felt it would be important for the government to consider moving infrastructure such as roads and power to an inland location to provide incentives for people to move over time. This would also include working with people who don't have land inland, and the need for discussions among clans to determine how people could possibly move back to familial property.
- **Community summer-house building:** Ideally, the community summer-house building would have been built further inland, where the parking lot is currently located, to avoid such close proximity to the dynamic beach area. However, given that it is an open structure only used for temporary functions and that sand naturally accumulates in the area where the building is located on the northern side of the pier, the building should be OK in the near term where it is already located.
- **However, the seawall was aimed at trying to stop further erosion from the building's foundation.** This hard structure will likely cause more damage and prevent sediment from naturally piling up in front of the structure. As a result, removing the seawall may help sediment move further inland and build up over time. Additionally, reinforcing the building's foundation and possibly placing a wall directly against the building could provide further support and protection to the structure while also allowing for the beach to naturally gain sediment. There was also the idea to create some new beach by bringing in some sand to replenish the area, as it will be trapped by the pier and likely to stay there unless there is a large storm event.
- **The coastal road:** The coastal road is highly vulnerable to storm over-washing and then flooding of homes and buildings on the inland side, which are lower lying. It was recommended that in the short term, building a low wall on the landward side of the road could help to keep storm water from reaching homes.
- **Protect the reef flat:** The Melekeok community already protects the marine and reef area in front of the village through a community conservation area. The reef flat in this area is an important source of sand and should continue to be protected from any overfishing or destructive practices that would impact the reef.

PHOTOS BY DOUG RAMSAY

Coastal Story developed through information provided at the Coastal Change tool development workshop in the Republic of Palau, hosted by the Palau Office of Environmental Response and Coordination and the Melekeok, Ngaraard, and Koror State Communities.

# HARD DEFENSES AND OTHER STRUCTURES ON THE SHORELINE

One of the biggest challenges on islands today is that humans have placed homes, buildings, and roads within naturally low-coastal areas, on filled and reclaimed land within wetland and mangrove areas, and within or near active shorelines. These are all areas that are naturally exposed to the effects of coastal hazards. As people invest in these areas, both financially and emotionally, they typically try to prevent coastal hazards from affecting their investments. As a result they often try to engineer the shore (usually with seawalls) to prevent it from moving or flooding, in order to protect their assets. However, such hard structures often lead to more shoreline change occurring and over the long term and do not address the root causes of the problem.

Hard defenses are considered to be any “hard” object that is placed in the coastline that is aimed at either directly protecting land or influencing the longshore transport of beach sediment. These include seawalls, made from many different types of materials (for example, rocks, concrete, and gabion baskets); groynes or other perpendicular structures that cross the beach/nearshore; and breakwaters.

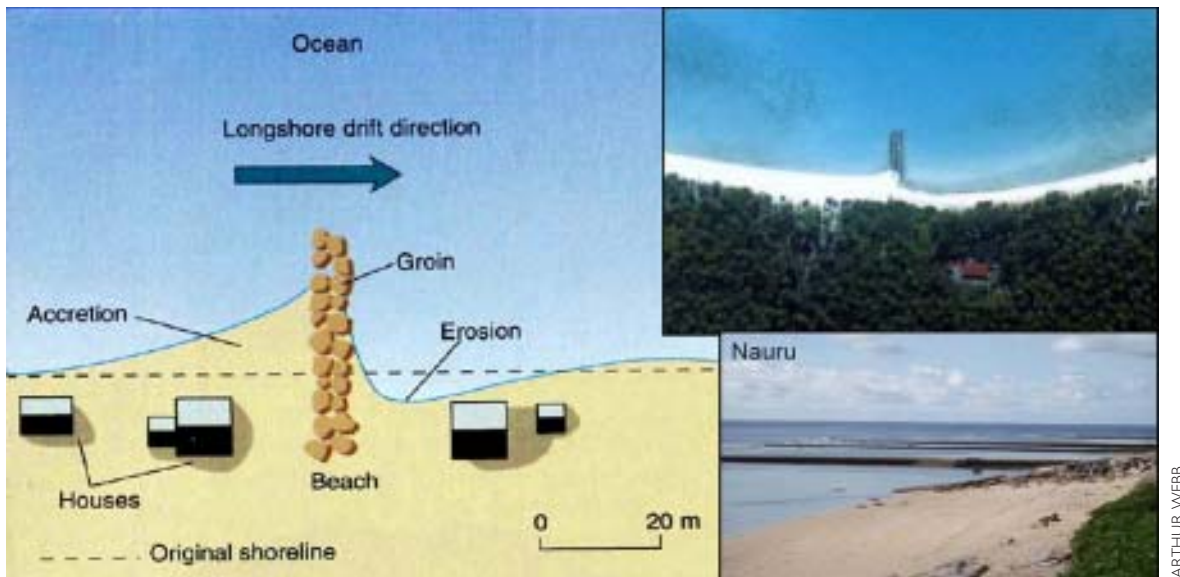


In many cases, hard defenses on beaches increase erosion problems along sections of the active shoreline adjacent to the defenses. This often leads to further defenses being built and an ever-increasing need to protect increasing lengths of the shoreline. Once structural responses to erosion control have been started, it's hard to stop. Hard structures get bigger and impact larger sections of coast. In many cases it is not shoreline changes that are the problem, but rather the original development that has been located in hazardous coastal areas.

Examples of hard defenses and their impacts include:



- a. Seawalls: Seawalls in the Pacific are often vertical or sloping walls built along a shoreline in front of important buildings or infrastructure. Seawalls prevent waves from moving further up the beach and “fix” the position of the shoreline. When waves hit the wall much of the energy of the wave is reflected, pulling away sand and causing erosion; this is called scouring. During storms, larger waves can increase the speed of erosion near and in front of the seawall, which—if it is not built correctly—can collapse and expose buildings or assets behind the wall to damage. Gabion baskets (walls created from stones held in wire baskets) and sand bags can have similar impacts as rock/concrete seawalls. Typically, gabions have a limited lifespan, as the steel wire they are made from will eventually rust. Once they break down the protective wall is lost, exposing the land and assets behind to damage. Seawalls can protect structures directly behind them if built properly—but it’s often at the expense of the beach, which may also be of value (for tourism, as a soft landing for local fishing canoes, etc.). The photos below show a seawall looking from both directions. You can see that beyond the end of the seawall the land has been severely eroded (known as downdrift erosion).



- b. Groynes: Groynes are hard defenses placed perpendicular over the active beach. On a beach, groynes can trap and hold sediment being moved along a beach in each groyne compartment (like a small sediment cell). Groynes usually build up beach sediments on one side, but at the expense of the beach at the other side of the structure. Like seawalls, once a groyne or similar structure is built and causes erosion on the down-drift side, the next person either builds a seawall or a groyne to protect their land; eventually the whole natural beach is lost. Solid piers, land reclamation over the active beach, or other structures can also have this same effect.



- c. **Breakwaters:** Breakwaters are hard defenses placed in the sea, parallel to the shoreline, to break up wave energy before it reaches the shoreline. However, like other structures breakwaters also influence long-shore movement of beach sediment, with sediment often building up behind the structure at the expense of the beach areas on either side.

This figure shows a typical cycle where a community that begins living in the active coastal zone becomes aware of the risks to their assets—for example, buildings and infrastructure—from the impacts of a coastal hazard event like a severe storm. The response is often to then construct hard defenses like seawalls to try and protect these assets. Often these assets are then considered “protected,” and from this sense of security more buildings are constructed over time. However, a larger cyclone event then occurs, or the wall does not protect the assets sufficiently, and there is demand for a larger and stronger wall. This cycle continues, with the amount of assets located in an area exposed to coastal hazards ever increasing. The root cause of the issue—that people are developing in an area exposed to coastal hazards—is not being addressed.



Additional negative impacts of hard defenses include:

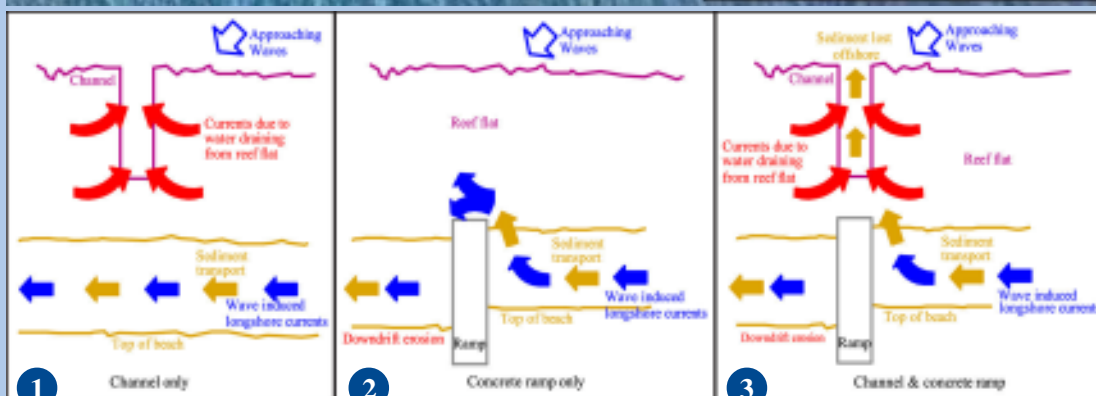
- It's a very expensive approach. Most communities can't afford to protect everything—in fact, it's usually difficult to afford to build any properly designed seawall.
- Like all engineering, the structure will need to be continually maintained. This leads to an ever-increasing financial commitment to maintain and upgrade such defenses in the long term. Therefore, hard defenses require a lot of financial resources to maintain over time; they are NOT a one-off investment.
- Hard defenses are only a short- to medium-term solution, even if well built. Unless these structures are extremely well-designed, they will not be capable of dealing with the types of coastal change and flooding that will occur by the latter part of this century due to climate change. They will become increasingly ineffective or unaffordable to maintain and upgrade.



### Questions to Consider

- What hard defenses have been used in your community and why?
- Have any changes been noticed since the hard defense was implemented?

## Niutao, Tuvalu



In Niutao, Tuvalu, small boat channels were dredged in the fringing reef to allow boats to move in and out over the reef more easily and safely. Image 1 shows how waves break over the reef, pumping water on to the reef that then drains back out back out the channel. It also shows how the waves create a long-shore current moving sediment along the beach from left to right. When the reef channels were created there was very little disturbance to the beach, as the channel was deliberately stopped well clear of the beach.

A donor initiative assisted the communities to put in a concrete boat ramp that extended from the shoreline out toward the channel. This was done to assist with unloading cargo (Image 2). Image 2 shows the effect the ramp alone would have in blocking longshore currents and transport of beach sediment. The concrete ramp would trap the sediment on one side but cause some erosion on the other side. However, over time as beach sediment built up against the ramp it would eventually build up to a sufficient amount to enable the sediment to be moved over the ramp, thereby limiting the magnitude of erosion along the shoreline on the other side.

However, Image 3 shows how the ramp and channel combined to create a much more significant problem. The long-shore transport of beach sediment was deflected out over the reef flat by the ramp which was then picked up by the water draining off the reef flat via the channel. This caused the sediment to be permanently lost from the beach system making the erosion on the other side of the ramp much worse. The community noticed the shoreline eroding severely after the ramp was constructed. As the erosion continued to impact on an ever increasing length of the island's shoreline, the community ultimately decided to remove the concrete ramp to reduce the impacts and loss of land.

ILLUSTRATION & PHOTOS BY DOUG RAMSAY

## Sandy Beach Hotel in Kosrae, Federated States of Micronesia

The Sandy Beach Hotel, located on Kosrae, Federated States of Micronesia, was almost lost as a result of a series of hard defenses placed nearby over several decades. The hotel was the first resort in Kosrae, constructed in 1982 behind a white-sand beach on the wind-ward northeast corner of the island.



The basis of the erosion problem on the northeast coast of Kosrae dates back over a number of decades, when large quantities of coral rubble were removed from the intertidal fringing reef during the initial development of the coastal road around the island. The initial removal of coral rubble for the road happened long before the Sandy Beach Hotel was constructed. However, during the widening of the coastal road in the late 1980s, erosion problems began to occur in the area by the hotel. Widening the road extended it out to the upper part of the beach, and rock rubble was placed on the beachside of the road to protect it. This rock armour was too small and the defense was quickly broken down.



Over the subsequent decade, various gabion defenses were installed to protect sections of the road, with the length of the defense increasing over time. However, the gabion baskets quickly broke down, releasing volcanic rock that ended up covering the beach in front of the hotel. This resulted in a legal case brought by the hotel against Kosrae State asking for the rocks to be removed from the hotel beach.

A more substantial and longer rock armoured revetment extending to the eastern boundary of the Sandy Beach Hotel was completed in 1998. In the months following the construction, erosion became worse immediately to the western end of the rock revetment, damaging the Sandy Beach restaurant foundation

## CASE STUDY 6 CONTINUED

and resulting in a net loss of beach in front of the hotel. High tides and waves during December 1999 resulted in further loss of the beach, threatening most of the hotel property.

While the hotel owner had permission to construct a rock revetment along the front of the property, doing so would have continued to move the erosion problem further along the coast. Additionally, the last remnants of the sandy beach from which the hotel took its name would also have been lost. In another legal case brought against Kosrae State by the hotel owner, the judge ruled that the state had the obligation to re-instate the sand beach and the protection it provided to the hotel.

To protect the hotel from further damage, a rock breakwater structure was designed by coastal scientists to control the future shape and stability of the beach in front of the hotel, and to minimize any further impacts of the defenses in exacerbating erosion on adjacent sections of the beach. Beach nourishment (e.g. bringing in sand from other areas/sources) was conducted to replenish the beach sand that had been lost due to erosion. The scheme was constructed in 2001 and has successfully maintained the sandy beach in front of the hotel. It has withstood a number of storms and has provided effective protection to the hotel, and prevented the rock and sand movement problems that had occurred previously.

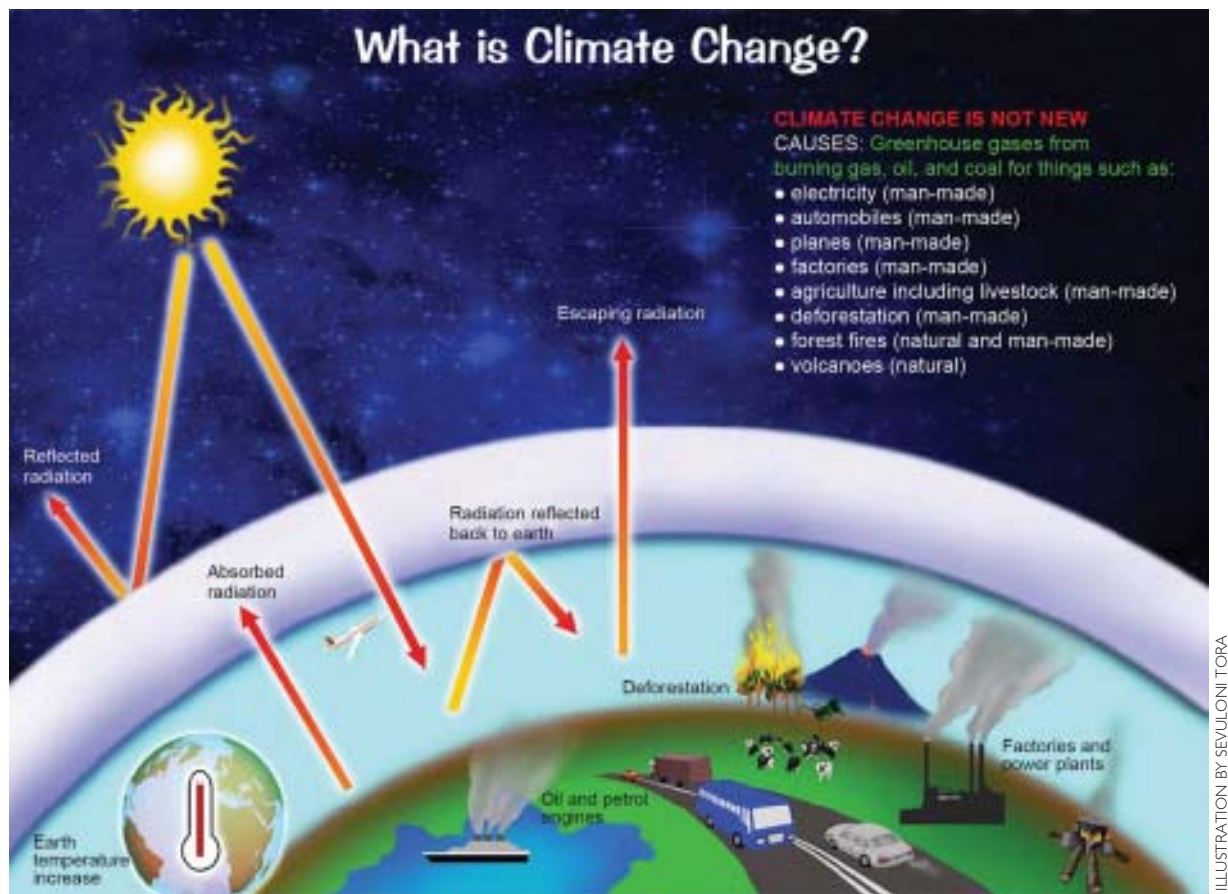
This case study shows how hard defenses that are poorly designed can interfere with the natural movement of sediment and increase the rate of beach erosion, both in front of the hard defenses and beside them. The solution in this case required highly expensive approaches (beach replenishment and construction of a breakwater), which were paid for by the state government

through legal obligation. Wisely, a coastal expert was hired to design a breakwater that worked with the natural beach processes to provide protection to the hotel but minimise any further ongoing erosion impacts on adjacent sections of beach. These problems and costs could have likely been avoided had the road and any hard defenses initially been built further from the active shoreline (Ramsay, 2007).



PHOTOS BY DOUG RAMSAY

# CLIMATE CHANGE



Human activities that influence coastal change include climate change, which is a long-term change in average climate patterns all around the world due to an increase in the average temperature of the Earth. Climate change will have an impact globally on all natural systems and communities, including those in the coastal zone.

Human activities are causing the Earth's temperature to increase, which is causing the climate to change across the world. While the average climate has always changed naturally over long periods of time, the climate is now changing at a much faster rate due to human activities. The main activities that contribute to climate change include deforestation, agriculture, and the burning of fuel to produce electricity and power vehicles. All of these activities release gases that accumulate in the atmosphere and trap heat from the sun, causing the global temperature to rise. Human activities are the main sources of the gases and the associated increase in the average global temperature. This increase in temperature is causing changes in climate patterns around the world.

In many cases, climate change will increasingly exacerbate existing coastal hazards and their resulting impacts on coastal communities. Examples include:

- **Sea-level rise:** As the earth's temperature increases, ice that has long been frozen on land is melting, thus causing the level of the sea to rise. As discussed previously, sea levels have a major influence on coastal change. Studies show that the sea level has already risen around the

world by four to eight inches (10 to 20 centimeters) over the past 100 years. The sea level is projected to likely rise by around:

- o 13 cm (5 in) over the next generation (2030s),
- o 28cm (11 in) over the next two generations (2050s),
- o and 100cm (40in) or more by the end of the century (2100 or four generations).

- As the sea gets higher, areas that currently flood due to high tides or storm events will flood ever more frequently, with areas that are just above present-day flood levels increasingly experiencing flooding. The sea is rising gradually and impacts will be felt over the long term (20+ years).
- Change in weather patterns: It is not always clear how climate change will change regional weather patterns. It is thought that the average number of typhoons/ cyclones experienced in the Pacific may reduce slightly by the end of the century, but that the strongest events may become even more damaging. More extreme rain events will be experienced everywhere in the Pacific with increasing temperatures, resulting in more frequent and significant flooding of low-lying coastal and other areas that currently flood due to heavy rainfall.
- Increased sea-surface temperature: As the air becomes hotter, the average temperature of the sea surface will also increase. This increase in temperature can cause coral bleaching, which can make corals weaken or die. This can lead to a loss of coastal protection from storms and waves, as well as a loss of habitat and nursery grounds for fish and marine life.

#### What Changes Can We Expect to See in the Region?

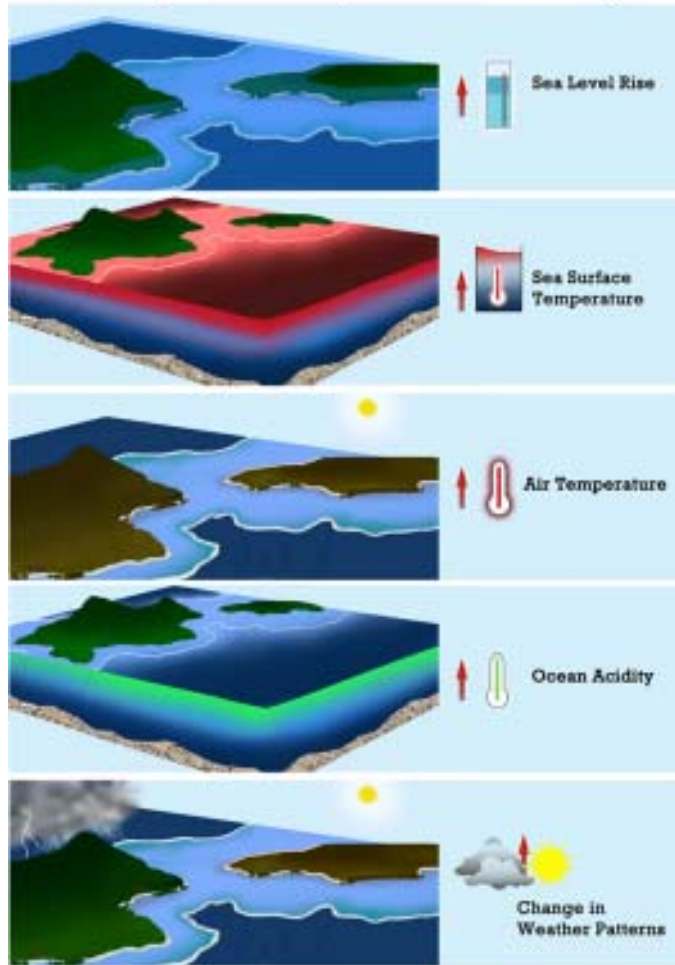


ILLUSTRATION BY SEVULONI TORA

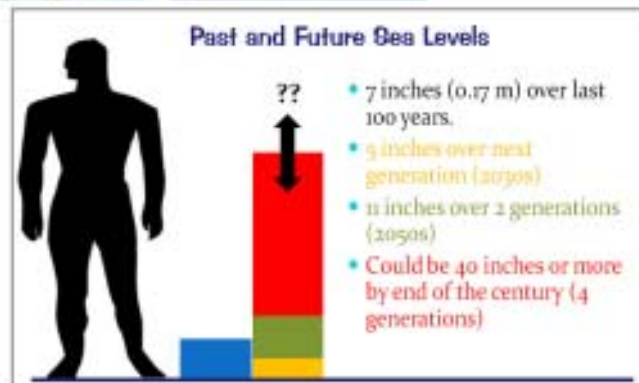


ILLUSTRATION BY DOUG RAMSAY

## Lifuka, Tonga

In May 2006, a magnitude 7.9 earthquake caused the western coastline of Tonga's Lifuka Island to subside or sink downwards by 23cm (9 in) very rapidly. This caused seawater to quickly move further inland; on the island this appeared as very fast sea-level rise. For this reason, Lifuka was chosen to be studied by coastal scientists as a way to better understand how future sea-level rise (due to climate change) may impact Pacific Island communities, and how they can adapt to these changes.

Coastal scientists completed technical assessments and worked directly with the community to explore the advantages and challenges of three adaptation options. They are 1) managed retreat of homes and infrastructure inland to safer areas, 2) replenishing the beach with new sediment, and 3) construction of an engineered revetment or seawall.

Scientists recommended option 1 to ensure long-term safety of community members, buildings, and infrastructure from coastal change (e.g. flooding and erosion). Some community members felt this approach would be the safest option after experiencing property damage from the recent changes to the coastline. The cost and technical equipment needed for option 2 proved to be too much for the community to be considered feasible. Finally, several community members were interested in option 3. However, the cost of construction and maintenance of a seawall or revetment would be challenging for the community/government and would not provide long-term protection from storm surges and flooding, according to coastal scientists.

A film was developed to document this assessment and the challenging choices communities need to make to adapt to changing coastlines now and into the future: <https://www.youtube.com/watch?v=VJnEvyg5aj0>. This project was supported by the Australian-funded Pacific Adaptation Strategy Assistance Program.



### Questions to Consider

- What existing coastal change hazards might get worse with climate change in your community?

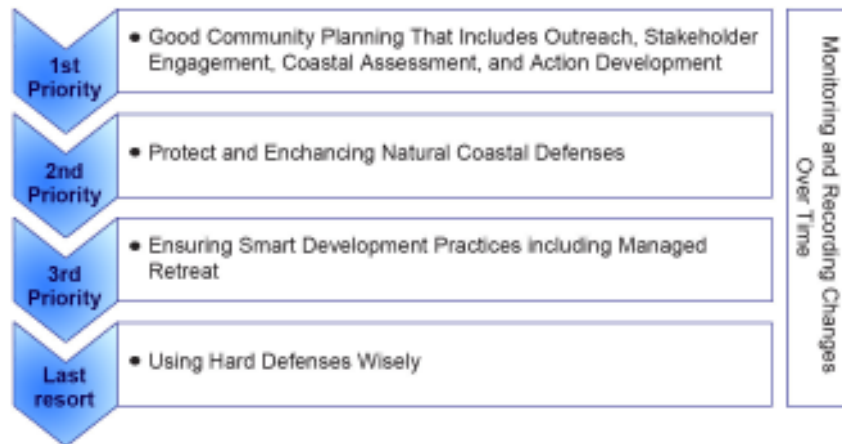
## SESSION 3 KEY MESSAGES

- Destructive practices that damage natural defenses will reduce both the protection provided by these defenses and the role they play in maintaining the balance of sediment within the coastal system.
- Coastal development practices refer to both where development is placed and how it is built. Hazardous coastal development practices include placing buildings and infrastructure within low-lying coastal areas; on filled wetlands or reclaimed lands; or on or near active shorelines, which are exposed to coastal change.
- Many traditional communities did not live along shore but only had temporary structures in this area. In modern times, development in areas exposed to coastal hazards has become much more common, placing many communities at risk for the negative impacts coastal flooding and shoreline change.
- Hard defenses such as seawalls are often perceived as the best approach for addressing coastal erosion and flooding problems in a community. However, hard defenses can cause further erosion problems for shorelines adjacent to them, and may not be effective over the long term. They also require a high level of funding to design, build, and maintain over time. If they are to be built, coastal engineers are required to develop appropriate designs to ensure protection from all hazards and cause the least amount of interference with natural processes.
- Climate change will cause long-term permanent shifts in climate conditions, which will have significant impacts on the coastal zone.
- Climate change will very likely make existing threats and hazards to coastal communities worse over the long term. For example, an area that already has problems with flooding of low-lying lands during king tides is likely to experience more severe flooding with long-term sea-levels rise due to climate change.

## SESSION FOUR:

# WHAT ACTIONS CAN WE TAKE TO REDUCE THE NEGATIVE IMPACTS OF COASTAL CHANGE ON OUR COMMUNITY?

This session summarizes various actions communities can take to plan for changes to their coastline and to reduce the impacts from hazards that threaten human well-being. These actions are recommended by coastal experts and collectively will provide the best chance of building resilient communities, now and into the future.



There is no one action or “solution” that will address all the impacts that coastal change will have on communities. Typically, a combination of actions is required.

Firstly, continue to develop the community’s understanding of how their coastline changes over time including trends, impacts from natural events and human alterations, and impacts from community actions. This assists the community in making informed decisions about development.

There are also many actions that can be considered “optimal or priority actions” as they aid the long-term protective function of coastlines as well as providing many other benefits to communities from services provided by healthy marine and coastal environments. Many of these actions can be implemented with relatively small costs. It is important to adopt these “priority” strategies as the foundation and ongoing actions as a basis for improving coastal community resilience in the long term.

Hard defenses may be necessary in certain situations as a last resort, for example, where critical infrastructure is threatened by erosion and flooding AND it cannot be moved (e.g. due to steep slopes to the landward side of the island). In these cases, hard defenses should always be pursued with support from a coastal engineer with an understanding of coastal processes and the importance of minimizing negative impacts to natural defenses.

Finally, all communities should consider ways to improve their understanding of how their coastline changes over time including trends, impacts from natural events and human alterations, and impacts from community actions.

All of these actions are discussed below in more detail in order to help communities understand their options. Once they understand the optional actions, the Planning Section of this document helps communities identify a combination of potential actions by assessing their own specific situation. Appendix A provides more detailed information about each specific action including benefits, challenges, technical expertise needed, general cost, and examples of successful and unsuccessful use of the action. This appendix has important details that can help communities select actions, make decisions, and develop appropriate plans to guide these actions over time.

## GOOD COMMUNITY PLANNING THAT INCLUDES OUTREACH, STAKEHOLDER ENGAGEMENT, COASTLINE ASSESSMENT, AND ACTION DEVELOPMENT



MEGHAN GOMBOS AND DOUG RAMSAY

There are big and difficult challenges and changes facing Pacific Island communities moving forward, which means that good planning is critical. This includes priority actions such as outreach and engagement activities that can help the community better understand their coastline and develop an appropriate combination of responses. The benefits of good planning and implementation include:

- Improved safety from natural hazards and climate change impacts.
- Improved ecosystem services such as habitat for fisheries and protection from storm surges.
- Long-term peace of mind. Planning now for future impacts to the coastline can reduce the need for future generations to undergo stress about safety and health hazards related to living in areas highly prone to natural-hazard impacts.
- Encouraging people to work with nature and prevent activities that damage natural defenses.

Before making any decisions on taking actions to reduce the negative impacts of coastal change, it is critical to understand:

- How you value and use your coastline.
- How your coastline works and where your sediment comes from and goes.
- How natural defenses have changed over time.
- How development has changed over time.
- Which weather, seasonal, and natural-hazard events have the biggest impact on the active shoreline and low-lying coastal areas.
- Which human alterations have had the biggest impact on the active shoreline and low-lying coastal areas.
- How climate change might impact your coastline.

The best results are achieved from community planning when all stakeholders are informed and engaged throughout the process. These stakeholders include community members, local businesses, government officials who can support long-term efforts, and coastal experts who can provide technical guidance.



### Questions to Consider

- Does the community want to carry out planning to determine the best actions to support long-term coastal resilience?
- Are there existing plans or programs that could be expanded to include actions that support long-term coastal resilience?

## CASE STUDY 8

### Kemur Beab Beach, Rock Islands, Palau



The beaches on certain rock islands in Palau are mainly valued as a place for tourists to enjoy. The island of Kemur Beab was especially important for dive operators, as it was the closest island with a beach to most of the popular dive sites. Because of this, structures were built on the island for tourists, who would stop there for lunch. A composting toilet building was built on the beach area to accommodate these tourists.

Over the past several years, the Rock Island Management Authority became concerned over “erosion problems” they noticed on some of the beaches, specifically serious loss of land that threatened the composting toilet structure. To address this issue, they built a seawall in front of the structure to protect it from falling into the sea. However, the erosion continued and the seawall did not seem to stop to

## CASE STUDY 8 CONTINUED

problem. At this time they asked coastal scientist Arthur Webb to carry out an assessment of the island to better understand the erosion issue and develop recommendations for management.

Through the coastal expert assessment and reviews of historical images, it was clear that the natural movement of sediment around the island is based on predominant wind conditions, and the sandy part of the island is dynamic. Old tree vegetation on the island marked areas that were stable over time, whereas new vegetation (ground shrub vegetation, young coconut trees) marked new land. The sandy beach areas shifted around over time and the beach shape was actually in a similar shape back in the 1960s as it is today—but in between those times, the beach has moved significantly.



ARTHUR WEBB



ARTHUR WEBB



FENNO BRUNKEN

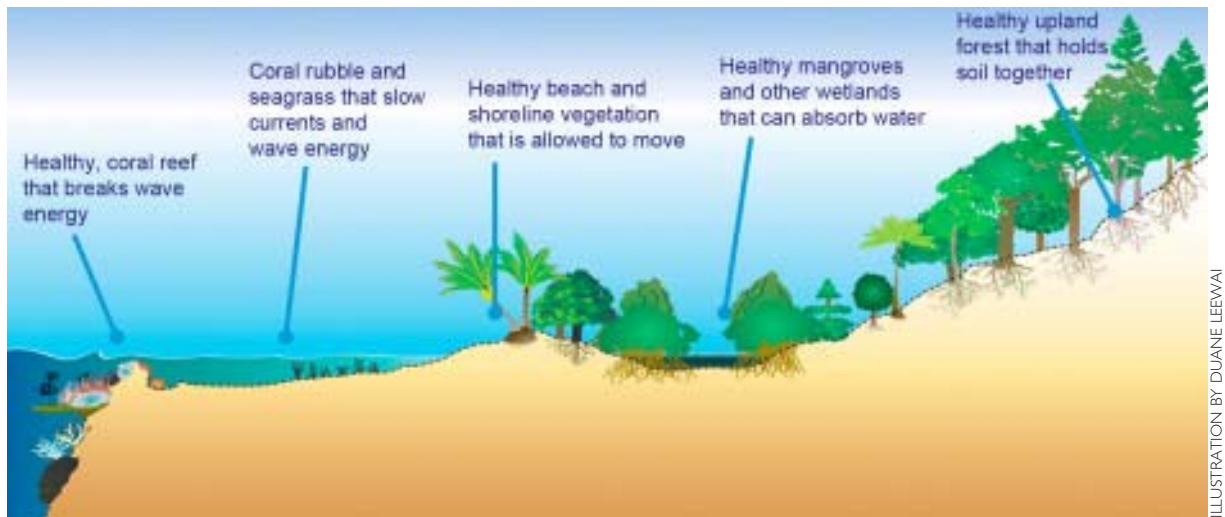
Unfortunately, the site that was chosen for the composting toilet was in the highly active zone that has shifted around regularly. While it appeared there was an “erosion” problem, the sand was merely moving through its natural process to a different location just south of the structure, based on shifting wind conditions. While the movement of sediment was threatening the structure itself, the sediment had not been lost.

Tourists using the beach did not seem to care if the sandy beach was in one location or another and were still able to enjoy the beach area while visiting. Therefore, the problem really stemmed in the placement of the composting toilet building, which was put in the active shoreline because it had good ventilation. The “seawall” that was placed in front of the structure was also in this highly active shoreline and was falling apart, causing further erosion down current from it.

This story demonstrates how understanding that shorelines are naturally active areas is critical for good planning. The main value of the island was for tourism, and the movement of the sandy beach did not impact tourist perception of the area. Therefore, the changes were not really a “problem” and the main value was maintained. However, it was recommended that the composting toilet structure be moved back closer to the rock part of the island which was more stable, as signified by old vegetation. Additionally, any structures that will be added should be built in the more stable area near the rock wall—or if they built in the more active shoreline area, they should be constructed in such a way that they can be easily moved around as the shoreline naturally changes (Webb, 2012).

Coastal Story developed through information provided at the Coastal Change tool development workshop in the Republic of Palau, hosted by the Palau Office of Environmental Response and Coordination and the Melekeok, Ngaraard, and Koror State Communities.

# PROTECT AND ENHANCE NATURAL COASTAL DEFENSES



This approach includes actions that naturally stabilize coastlines and provide low cost long-term protection.

Nature provides the best protection from coastal flooding and erosion. Destructive practices and other threats that compromise natural defenses will significantly increase the potential for shoreline change (and loss of land) and coastal flooding. Actions that protect and enhance natural defenses are optimal and provide long-term benefits to the community through coastline protection and protection of natural habitats, resources, and fisheries.

The following actions are the first set of priorities recommended by coastal scientists:

1. Raise awareness of community members to ensure that all stakeholders have a good understanding of:
  - a. the benefits of natural defenses in helping to manage the sediment balance and protect coastlines.
  - b. the differences they can make by avoiding activities that impact on these natural defenses.
2. Develop community agreements or rules, where needed, to prohibit destructive practices and other threats to natural defenses including:
  - a. damaging coral reefs (e.g. destructive fishing practices, pollution, sedimentation).
  - b. nearshore dredging or beach mining.
  - c. developing land close or within the active shoreline.
  - d. clearing or filling mangroves/wetlands.
  - e. clearing upland forests.
  - f. blocking or changing natural waterways.
3. Develop a Locally Managed Area (LMA) that is multi-purpose, not only to protect and enhance local marine resources but also coastal protection from natural defenses such as reefs, mangroves, seagrass beds, wetlands, and upland forests.



ILLUSTRATION BY SEVULONI TORA

4. Develop buffer zones along the coast by planting native coastal vegetation in areas where it historically grew. Enhancing native vegetation in areas where it once grew can help to stabilize coastlines and reduce the loss of land.
5. Restore mangroves where they historically grew and allow space landward of mangrove areas to enable them to adapt naturally to sea-level rise.
6. Develop buffers of natural vegetation around rivers and streams, and protect the natural functions of river and stream catchments and wetland areas.



### Questions to Consider

- Are there sufficient agreements, rules, or programs in place to protect or enhance natural defenses?
  - If no, what are the gaps?
  - What can your community do to enhance protection of natural defenses?

## Tarawa, Kiribati

Due to the ever growing domestic demand for building aggregate, local beach mining is now tragically common in South Tarawa. Dozens of bags of harvested gravel stand ready for sale in many locations. This persistent sand and gravel removal has destroyed a number of beach systems and caused many metres of erosion. The picture on the left, shows gravel and sand mining in 2007; while the picture on the right, shows the same beach in 2013. Note the complete removal of the high protective berm. The potential natural recovery of such damage will take decades (Webb, 2013).



Due to increasing situations like this, a long standing demand for urban construction aggregates, and concerns over sea level rise in these atoll environments the Kiribati Government received funding from the EU for the development of an alternative aggregates company for South Tarawa or the “Environmentally Safe Aggregates for Tarawa Project (ESAT)”. The ESAT Project follows on from earlier technical work in Tarawa to characterize a lagoon basin resource area from which sustainable aggregate material could be mined. To date the following have been accomplished through this project:

- a sustainable resource area with a 50 year supply has been identified in the lagoon basin. The photo on the right shows the ESAT resource area in yellow (50 year supply) - the dot is the size area which could be mined in any given year. The photo next to it shows the type of substrate (bottom sediment) in the resource area.
- a state owned operation “Atinimarawa” has been developed,
- a dredge vessel the “MV Tekimarawa” has been out-fitted and completed
- a captain and engineering staff are in place
- an unexploded ordinance survey complete
- a environmental license to permit dredging for aggregate granted
- aggregate is now being dredged and provides raw materials to the local South Tarawa community.



This project required a high level of coordination among government, international donors (European Union), regional agencies (Secretariat of the Pacific Community - SPC) and community stakeholders to be implemented. Additionally several millions of dollars were required to complete the necessary research, equipment, and management of the project. While this can be a model for the Pacific region to develop sustainable alternatives for building aggregate, it will require a high degree of human and financial capacity to fund and implement a similar effort.



PHOTOS BY ARTHUR WEBB

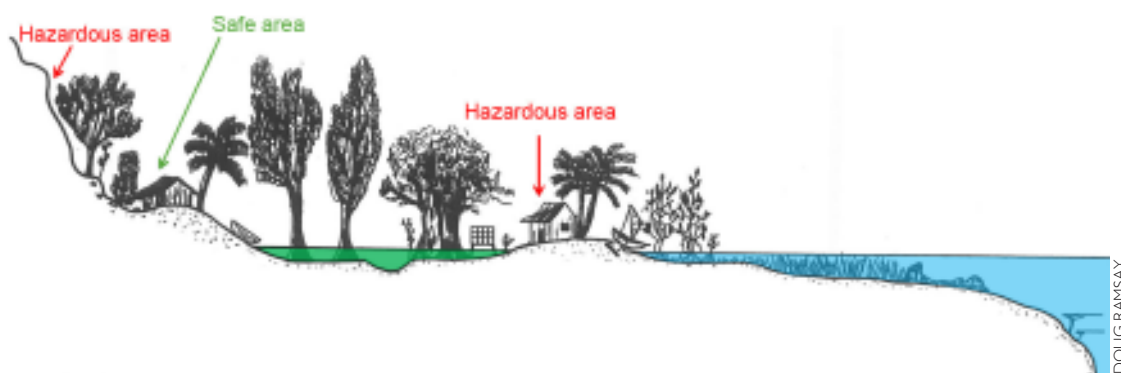
\*This information was developed through various summaries reports on ESAT through SOPAC.

# ENSURE RESILIENT DEVELOPMENT PRACTICES

Developing in areas known to be experiencing coastal change (e.g. erosion and flooding) will decrease safety and increase health hazards. Raising awareness and establishing community agreements or rules that control where and how to build are effective ways to build resilience to existing and future coastal hazards like flooding and loss of land. Ensuring that development is located outside areas exposed to coastal hazards, both now and over the lifetime of the development, is the only sure way of ensuring that the development is not impacted by coastal hazards and sea-level rise over the long term.

These actions are recommended by coastal scientists as high priority:

- I. Raise awareness to ensure that all stakeholders have a good understanding of:
  - a. the benefits of developing in safe areas, away from low-lying coastal areas or the active shoreline.
  - b. the differences they can make by considering long-term coastal changes in choosing where and how to build.



2. Create a community coastal “setback zone” that prohibits new development in specific zones, such as areas where sea-level rise and storm waves will impact in the next 50 years or areas close to the coastal or mangrove vegetation line, the top of seawall structures, or any river/ stream waterway.
3. Prohibit upgrading/expanding of non-critical structures (old homes/buildings/seawalls) that are damaged and are currently within the setback zone.
4. Build or place homes where there is no option but for them to be located within the setback zone and just beyond, on stilts or with other approaches to raise floor levels if coastal flooding is an issue.
5. Prohibit clearing of, or construction on, steep land or on land with a potential landslip risk.



## Develop a Plan For Managed Retreat



Erosion and flooding of coastal areas from storms, waves, and/or high tides will only get worse over time due to sea-level rise. However, this is a gradual change. **Managed retreat plans** are part of resilient development; they describe when and how new homes and buildings currently located in hazard-prone areas will be relocated. These plans usually focus on how to move critically threatened infrastructure in the next five to 10 years, and less-threatened infrastructure over a longer period of time like one or two generations. Resilient development practices include “priority” actions that can save a significant amount of time and money, while also reducing the level of stress placed on future generations.

Approaches and actions that should be included in a managed retreat plan include:

- Begin and maintain the discussion with communities. Making decisions on relocating takes time and consideration.
- Create a sense of hope. Relocation discussions are always difficult and often seen as a negative activity. Work with the community to identify options and develop choices for them.
- Create an enabling environment for relocation to happen. This may require support and an integrated approach from all levels of government and communities, and therefore could involve activities like:
  - Identifying land-swap opportunities.
  - Availability of freehold or government land.
  - Funding mechanisms and incentives.
  - Planning and relocating critical infrastructure, such as roads, or community buildings, such as schools and churches, to make it easier for community residents to move over time.
- Prioritise only where necessary, but ensure that communities understand their present exposure to coastal hazards, the impacts that may occur, and how this may change over the foreseeable future. Give community members control over how and when they relocate. Most relocation does not need to happen tomorrow but can be conducted over time or generations as buildings, community facilities, or infrastructure are either built, replaced, or upgraded.

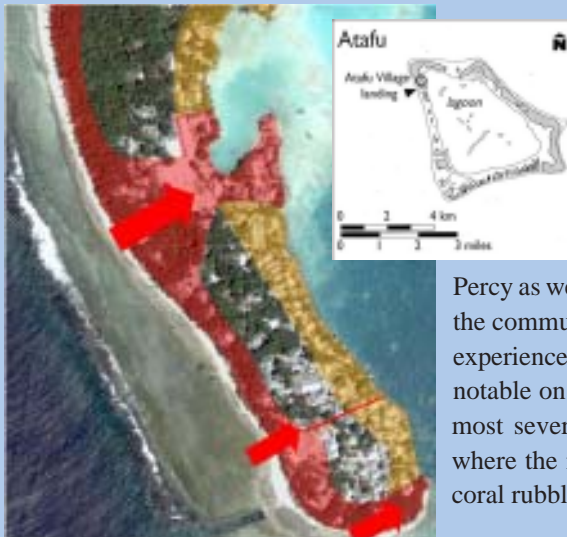
## Atafu, Tokelau

On February 25, 2005, Cyclone Percy affected the three atolls of Tokelau. The cyclone resulted in widespread damage, with wave overwashing and flooding experienced in all the villages on the three atolls, with the village on Nukunono particularly affected. The occurrence of the cyclone and magnitude of the flooding experience was influenced by:

1. A strong El Niño event (cyclones are much more likely to affect Tokelau during El Niño events),
2. The cyclone coinciding with a high spring tide,
3. Storm surge and wave set-up raised the level of the sea even further over the reef and at the shoreline, and
4. The high water levels over the reef allowed larger waves to reach the shoreline, causing wave run-up, overwashing, and flooding of the atolls from ocean to lagoon side.



TOKELAU PUBLIC WORKS



DOUG RAMSAY

Due to the widespread damage after Cyclone Percy, coastal scientists were asked to assist the government and people of Tokelau to develop approaches to reduce the impacts of coastal hazards, such as storm surge and flooding, on people, buildings, and the environment on each atoll. Atafu is one of the atolls that had experienced overwashing during cyclone Percy as well as during other storms. The scientists worked with the community to identify the areas of the village of Atafu that experienced the most frequent flooding and overwashing. It was notable on all the atolls that the areas where overwashing was most severe during cyclone Percy corresponded to the areas where the most significant clearing of vegetation or taking of coral rubble had occurred.

The village worked collaboratively with the scientists and developed several actions within four approaches to reduce risk of coastal hazards on the village in Atafu. The four approaches are: 1) protecting and enhancing natural coastal defenses (such as coral reefs, beaches, and coastal vegetation); 2) village land management planning to avoid new development in hazardous areas and move existing buildings and infrastructure currently located in hazardous areas to safer areas; 3) building design to reduce the risk of damage to property and possessions; and 4) identifying locations for protection measures, including maintenance of existing gabion walls and construction of new walls placed inland of the shoreline, that take natural processes into account and are more sustainable over the long term.

### *1. Protecting and Enhancing Natural Defenses*

The importance of maintaining the effectiveness of the natural defenses was seen as a priority for Atafu, as they provide the first line of defense against coastal hazards. Through discussions and a walk over of the village island with community members, examples of good and bad practice were identified—for

example, areas of natural vegetated buffers behind the shoreline (good practice) and removal of sand from the beach for construction (bad practice). Village-appropriate ways of regulating and discouraging practices such as removal of sand and coral rubble and clearing coastal vegetation were identified. Additionally, recommendations included re-planting shoreline vegetation and acquiring a pump to remove sand from the lagoon as an alternative to taking it from the beaches.

## **2. Village Land Management Planning**

Avoiding development in areas of the village that are most prone to overwashing and flooding was also identified as a highly effective way to reduce risk. This included restricting development of community



buildings, infrastructure, and homes in areas identified as high risk on the ocean side. On the lagoon side, new development would be allowed in the high risk area only if 1) no other option was available, 2) the floor level was raised 1m above ground, 3) homes were built as far inland as possible, and 4) no land reclamation occurred. It was recommended that a buffer zone of shoreline vegetation be maintained as a natural defense in areas not currently developed, and any new development occur inland of those areas. Critical village facilities were also identified and those located in very high-risk areas were identified to be moved to safer locations, and scientists recommended that over time other community buildings (such as the school and hospital) be re-designed and/or relocated to be more resilient. Discussing and developing plans for families to find suitable areas for relocation was also identified as a priority where their land was located in high risk zones.

## **3. Building Design**

Many homes on Tokelau had been built with concrete water tanks below the house or raised on concrete columns. Few of these homes reported significant flood damage from Cyclone Percy. Many of these homes were built within 10-15 years and funded through a Housing Grant Scheme, which required that water tanks be built as part of the property. The concrete tanks and raised floor levels provided significant protection from cyclone overwashing and flooding, protecting both the property and the contents within from significant damage. Continuing the Housing Grant Scheme with an emphasis on rebuilding or strengthening homes that were in areas of higher flood risk was also identified as a priority, particularly where there was no option to relocate housing in these areas.



## **4. Protection Measures**

Maintaining the existing coastal protection structures was also seen as a priority, as degradation of the existing gabion walls would result in loss of property located behind them. Interestingly, coastal scientists also learned that pig pens built decades ago on Atafu, with small walls that were located back behind coastal vegetation and the beach edge, were not flooded during cyclone events. By using this example of

## CASE STUDY 10 CONTINUED



good coastal defense design practice, designs for any new defenses were developed to be located some 15-25m behind the shore vegetation line, close to the crest of the beach. This approach enabled the natural defenses to continue to function and allowed coastal processes to remain undisturbed, while the built defenses reduced the potential for waves to wash over to the lagoon side, reducing the exposure of the village buildings to wave overwash and flooding. This recommendation provides an example of how constructing protection measures to work with the natural defenses can be accommodated, even though the land on the atoll was not very wide.

This process demonstrates that there is no one solution to coastal hazard problems. On Atafu, as on the other two atolls on Tokelau, effective risk reduction needs to be a combination of all four approaches (Ramsay, 2006).



### Questions to Consider

- Are there rules in place to ensure that development is carried out safely and does not increase the rate of coastal change?
- Does your community have any plans for managed retreat from hazardous to less-hazardous areas?

## USE HARD DEFENSES WISELY

Hard defenses such as seawalls are often seen as ‘the solution’ to addressing coastal erosion and flooding problems. However, there are many drawbacks to using hard defenses and they should be used only when absolutely necessary—which in most cases means when there are no other options. If built properly, hard defenses can, for a period of time, protect structures directly behind them. This can be particularly important when critical infrastructure is threatened and unable to be relocated.

However, there are many drawbacks of hard defenses including:

- Hard defenses can impact on active shoreline processes and on beaches, often causing further erosion along sections of the shoreline adjacent to the defenses.
- Hard defenses require a high level of technical expertise to design and build them in order to ensure they perform as required and do not cause negative environmental impacts.
- Hard defenses require a high level of funding to design, build, and maintain them over time. Without proper maintenance and upgrading they will become less effective over time.
- Hard defenses can be addictive. When one is put in place, others typically soon follow. This is because each hard defense can cause further negative impacts to nearby shorelines, creating the need for that shoreline to also be protected by a hard defense.
- While hard defenses can protect critical infrastructure they are often built on or over beaches or cause the loss of beach in front of them, which can impact on other important values (like landing areas for boats) or economic impacts (like the loss of a tourist beach).

Hard defenses may be necessary in certain situations, such as where critical infrastructure is threatened by erosion and flooding AND it cannot be moved—for example, due to steep slopes to the landward side of the island. These decisions are often based on economics; for example, if an important building will cost half as much to move as it would cost to protect, then it makes more sense to plan to move

the building out of harm’s way. When it is decided to use a hard defense, it is critical for communities to ensure the technical expertise of coastal engineers is used to design hard defenses that will not create more problems.



All hard defenses should:

- Work with natural processes and enhance the natural coastal protection.
- Allow the beach to continue to respond in a natural manner, both during storm events and over the long term.
- Reduce the potential for coastal flooding from waves overtopping the beach crest.
- Limit the exposure of the structure to any significant wave attack, toe, or crest damage, hence increasing the lifespan and effectiveness of any such structure.

Community rules can be developed to prohibit the use of hard defenses in cases where other options are available (e.g. structures can be moved) and/or to ensure coastal engineers are used when hard defenses are needed.

# MONITORING AND RECORDING COASTAL CHANGE

Active shorelines (e.g. beaches) are constantly changing, so it is important to monitor and record how your shoreline changes. This will help you understand trends and impacts from natural events, human alterations, and community actions.

Shoreline change can sometimes appear as erosion, but over time the beach recovers back to its original shape or position. To choose the most appropriate actions for your coastline, it is best to first try and understand how it functions and changes over long periods of time. Sometimes, the best approach is to wait and see.



Monitoring and recording how your shoreline changes over time can help communities better understand if:

- Changes are part of a regular, predictable process (such as seasonal changes), or if a long-term loss of sediment is occurring (erosion).
- Specific actions you've taken are successful. For example, if the community restored mangroves where they previously grew, monitoring over time could help them see if new mangroves are growing well and spreading on their own, therefore creating a stronger barrier to storm waves.

## SESSION 4 KEY MESSAGES

There is no one action that will address all of the impacts coastal change will have on communities, so implementing a combination of actions is recommended to effectively build long-term resilience. Coastal scientists recommend the following actions in priority order:

- **Priority One: Good community planning to:**
  - Raise awareness about coastal change.
  - Complete engagement activities that use historical and local knowledge (ideally combined with technical expertise) to determine the best set of actions for the local situation.
- **Priority Two: Protect and enhance natural defenses to:**
  - Help slow the rate of erosion, reduce impacts from flooding, and manage the sediment balance.
  - Provide long-term protection of coastlines with relatively low costs, along with several community benefits, by improving the health of marine and coastal environments—with few, if any, drawbacks. Actions that protect or enhance natural defenses are all considered optimal and high priority by coastal scientists.
- **Priority Three: Resilient coastal development that:**
  - Prioritises where and then how to build to keep the community members and the coastline healthy and safe over the long term.
  - Encourages building away from areas that could be damaged from coastal hazards now and in the future, and that does not interfere with sediment movement.
  - Includes managed retreat plans, which plan out where and how to move homes, buildings, and critical infrastructure in hazardous areas into safe areas over the next several generations.
- **Last Resort: Use hard defenses wisely:**
  - Ensure that all stakeholders understand the drawbacks of using hard defenses.
  - Use them only for critical infrastructure that cannot be moved.
  - Use coastal engineers to develop appropriate designs to ensure they protect from all hazards and cause the least amount of interference with natural processes.
- **Monitoring and Recording Coastal Change:**
  - Develop monitoring programs to match the type of information your community wants to collect and how you will use the information.

## Kosrae Shoreline Management Plan

The island of Kosrae, the easternmost island in the Federated States of Micronesia, is a high-volcanic island surrounded by a narrow fringing reef and, along less-exposed sections, well-developed coastal mangroves. Coastal erosion leading to a loss of land has intensified over the last 50 years, leading to a landward retreat (between five to 50 meters) of the shoreline, particularly along the eastern coast. This retreat is of concern, as much of Kosrae's development and infrastructure is located on the coastal berm along this eastern side of the island.



To understand why these coastal changes are occurring, it is necessary to look back to the end of the 19th century. Kosrae is rarely affected by cyclone events, with the main tracks located to the north and west of the island. The last major cyclone was in

1905, but it was a cyclone in 1891 that resulted in a bank of coral rubble being deposited on to the reef flat along much of the eastern coastline. In places, it was so high that the breaking waves could not be seen (Buck, 2005). This bank of coral rubble acted as a breakwater, blocking a substantial amount of the wave energy that would have normally reached the shoreline. This sheltered environment enabled the shoreline to gradually build out and fringing reef mangrove strands to develop at the mouths of streams over much of the early to mid-part of the last century.



However, it was in the decades after World War II when considerable development commenced, including the circumferential road around the low-lying coastal area and the widening of a causeway. These projects used large amounts of coral rubble sourced from these banks. Prior to this time, most communities lived inland on the volcanic part of the island; however, as infrastructure increased along this relatively

new shoreline area most communities became situated on the shoreline area of their municipalities, with low-lying swamps situated between the shoreline and upland volcanic areas.

Over the subsequent decades after WWII, these rubble banks gradually broke down but continued to provide a substantial level of protection to the eastern shoreline. Today, however, much of the coral rubble is gone and shoreline is once again exposed to higher wave energy, storms, and tides. Seawalls have been placed in some areas of the shore, altering the way sediment can move around the shoreline and causing higher wave energy to negatively impacts nearby areas. There is a limited source of new sediment coming into the shoreline, and sediment is lost due to on-going wave action and sand mining, and disturbed by hard defenses. Therefore, the shoreline where most communities are situated is slowly eroding and coastal homes and roads are experiencing frequent flooding during high tides and storms. Climate change is expected to negatively impact existing



natural defenses such as coral reefs, seagrass, and mangroves, and sea-level rise will make erosion and flooding issues worse over the next few generations.

To address these coastal change issues, the Kosrae Island Resource Management Authority (KIRMA), with support from coastal scientists, developed a Kosrae Shoreline Management Plan (KSMP) in 2000 to plan for short- and long-term changes like erosion and flooding; identify and protect natural defenses; minimize negative impacts from coastal change; and monitor change over time. The KSMP was recently updated and revised to reflect new data, increase long-term adaptation focus, and guide community decision-making for adapting to future changes.

To do this, the plan outlines a series of principles and strategies to support long-term planning that will improve community adaptation to coastal change and climate change impacts. It recognizes the need to plan both for adaptation to current coastal hazards and plan for future impacts, which will only get worse. Planning now both reduces risks from future hazards and takes advantage of existing financial resources aimed at climate change adaptation.

The plan includes the following strategies, emphasizing that there is no one solution that can solve existing and future coastal change issues:

- **Strategy 1:** Continued strengthening of community awareness, including outreach activities, with a focus on effective natural coastal-defense and Kosrae-relevant climate change impacts and adaptation options.
- **Strategy 2:** Amendment of the KIRMA Regulations for Development Projects to incorporate climate change considerations, and strengthening of regulation implementation to support successful long-term risk reduction and adaptation.
- **Strategy 3:** Over the next one to two generations, the primary coastal road network and associated infrastructure currently located on the beach/storm berm will be developed inland, away from long-term erosion and coastal-flooding risk.
- **Strategy 4:** Ensure new development (property, infrastructure) is located away from areas at risk from present and future coastal hazards, or is designed with coastal hazards in mind.
- **Strategy 5:** Implement a program to encourage existing residential property owners to reposition homes away from areas of high risk from present and future hazards. This may be a staged approach over time as homes are routinely replaced or renovated.
- **Strategy 6:** Incorporate a grant component into the housing loan program to help encourage new property to be constructed in areas not exposed to coastal, river floor, or landslide hazards.
- **Strategy 7:** Commence community and state discussions to develop a relocation strategy and identify potential approaches to support relocation from areas exposed to coastal hazards where no alternative land is available.
- **Strategy 8:** A strategic approach is adopted for the ongoing provision of coastal defenses. These should be considered only where:
  - o it is a sustainable long-term option, or
  - o where it is accepted as a transitional approach to protecting areas over the short-to-medium term to enable relocation strategies to be implemented (Ramsay et. al., 2014).



PHOTOS BY DOUG RAMSAY

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# Key Concepts

**Active Shoreline or Shoreline** — The active shoreline is the area of land within the coastal zone that directly interacts with the sea and is rapidly changeable. It includes the beach area, extending from at or below the low-tide mark to where the biggest waves run up, including wave overwash from periodic large storms. Some shorelines are more active than others. Generally, there are three types of common shoreline in the Pacific: 1) soft shore (made of sand, gravel, or rubble), 2) mangrove shores, and 3) rocky shores. Mangrove and rocky shorelines are relatively stable and do not change position or shape quickly. On the other hand, soft shorelines or beaches can be highly active, consisting of loose sediment that can be constantly shifting in response to the environment around it—specifically the combinations of wind, waves, tides, storms, and other factors such as heavy rain and river and stream flows—and the effects that humans have on the active shoreline.

**Coastal Change** — This refers to:

1. Flooding of coastal lowlands from any of the following events, or from a combination of any of them: high (king) tides, storms or large ocean swells, and river overflow.
2. Gain or loss of land along the shoreline, which is the area of the coastal zone that directly interacts with the sea and is changeable (e.g. sandy beaches, mangroves, cliffs).

**Coastal Zone or Coastline** — This refers to the entire area from the upland forest out to the reef edge. The entire area of many Pacific Islands (particularly on small low-lying islands and atolls) can be considered coastal zone, because most land on these islands is closely connected to and interacts with the sea. The coast is typically formed from many different components (ecosystems) and can include some or all of the following: reefs and reef flats, lagoons, beaches (of different types), seagrass beds, mangroves, mudflats, cliffs. These components all act together to provide natural functions, such as protection from waves and storms, or important habitats for other marine resources.

**Long-shore Movement** — Currents that run along the beach are generated by the predominant wind/wave patterns that meet the shoreline. These currents move sediment in one direction. As sediment from a particular part of the beach is lost, it enters another part of the beach in the direction of the current. This is referred to as **long-shore movement**.

**Natural Defenses** — Natural defenses refer to the natural-resource components of a healthy coastal ecosystem (e.g. coral reefs, seagrasses, beaches, mangroves, wetlands, and upland forests) that in combination can slow the rate of shoreline change and limit the amount of coastal flooding.

**Resilience** — The guide focuses on supporting local communities to improve and maintain the long-term health and abundance of coastal resources that support communities living in the coastal zone. This is often referred to as "building resilience" to climate change and other threats. A social or natural system is resilient when it is able to successfully survive, adjust to, or recover from an event that causes stress or damage. Stress or damage can come from human activities, such as destructive fishing; from natural events, such as earthquakes and storms; and from climate change impacts, such as increasing sea-level rise and changing weather patterns. A strong and healthy system is likely to recover more quickly than an unhealthy system; in other words, a healthy system tends to be more resilient than an unhealthy system. Certain factors lead to resiliency in natural or human systems, promote long-term health, and encourage proper functioning. Maintaining good ecosystem health helps a system

to be more resilient. A growing number of communities are taking action to protect themselves against both local threats and climate change impacts. By planning for future changes and reducing negative impacts from local threats and natural events, communities are improving the overall health of their resources and ecosystems. This in turn helps them to become more resilient. Put simply, keeping resources healthy and abundant helps to keep them resilient (Gombos et al., 2013).

**Sediment Cell —** Each shoreline is made up of “sediment cells” or specific areas along the shoreline where local sediment moves around but does not leave. In other words, it is hard for sediment outside of the cell to move in, and hard for sediment from inside the cell to move out. Each sediment cell has its own source of new sediment, which is usually the nearby reefs and sandy bottom areas and the land behind the sediment cell. There are also sediment sinks in each cell, which is where sediment moves to and is lost from the shoreline.





Actions that protect and enhance natural defenses are optimal and provide long-term benefits to the community through coastline protection and protection of natural habitats, resources, and fisheries.

**Nature provides the best protection from coastal flooding and erosion.**