A Landowner's Guide to Coastal Protection

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Atolls are unique coastal environments that are home to a diverse range of marine species, landforms and nations. However, combining the permanent infrastructure of a modern civilization with a dynamic atoll environment forces limits on natural processes and can result in issues like inundation and coastal erosion. Natural shorelines can be highly mobile in response to changes in wave height or sediment supply, but when a solid structure is placed in the dynamic beach zone, erosion occurs and causes problems, eventually, for the people on the entire atoll.

Erosion and inundation are serious issues for developed atoll nations, especially since sea levels are expected to continue rising. There are numerous shore protection methods used worldwide that attempt to control the interaction of the sea and the land. This series on atoll-specific shore protection aims to enable landowners and communities in the Marshall Islands to better understand coastal processes and manage shore protection issues.

Following this introduction, the guide introduces "hard" and "soft" methods of shore protection and where each option is suitable. The guide then outlines how to choose the most appropriate method of shore protection and the flow-on effects of different methods. Finally, some of the benefits of working together within the coastal zone to achieve a positive outcome are outlined.

Outline of the Atoll Shore Protection Series

1. Introduction: Atolls, shoreline dynamics, processes and about the guide.
2. Do you have an erosion problem?
3. Hard protection: seawalls, revetment, groynes and breakwaters.
4. Soft protection: Vegetation planting, beach nourishment, and community adaptation.
5. Selecting protection options based on the physical environment.
6. Working together to achieve a better result.

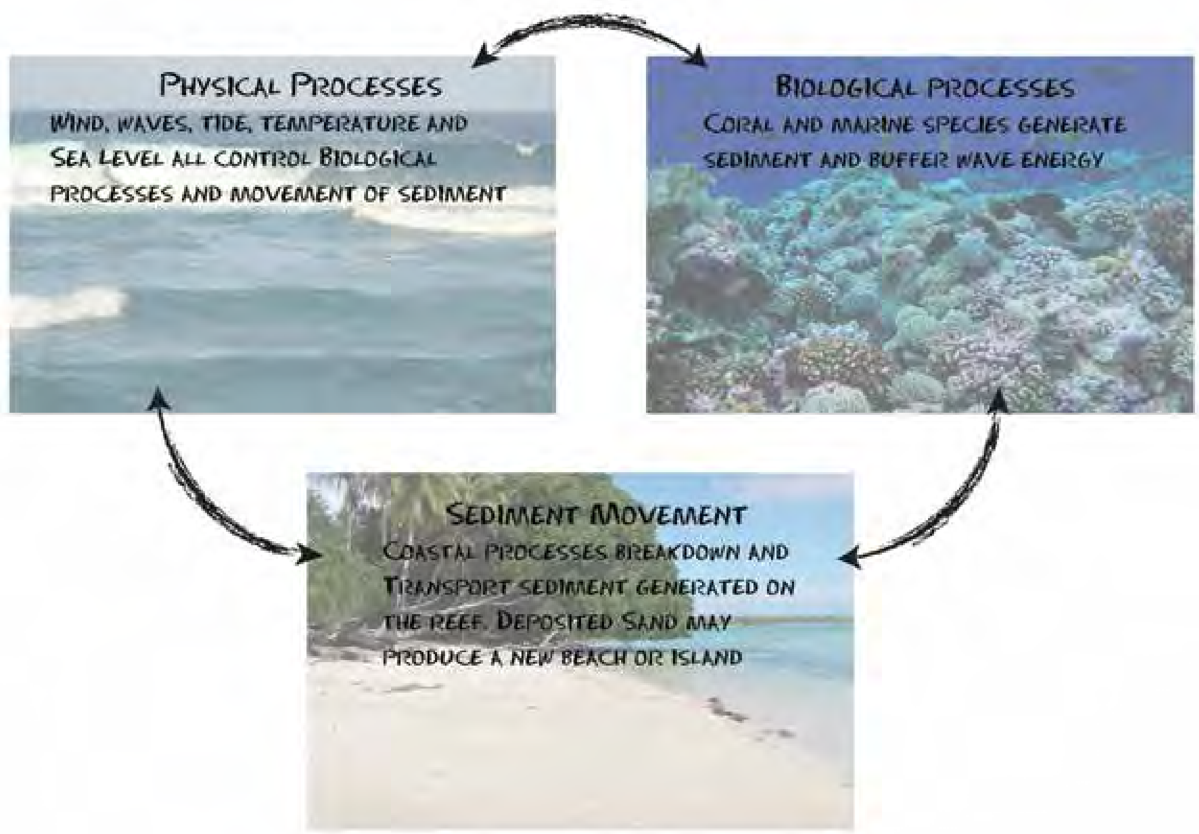
When important assets such as roads and infrastructure are threatened by storms and sea-level rise, careful thought must be given as to how to effectively protect the shoreline. Working in an environment that is constantly changing is difficult and requires careful planning before implementing coastal protection.

Working with Nature

In order to manage atoll shorelines, it is important to consider some of the natural processes involved. Working with nature will prove much more successful than working against nature. Reef islands are naturally dynamic features, with shorelines moving as a result of changes to the physical and biological environment. Reef islands are made up of sediment that is generated by the breakdown of living material on the adjacent reef. Wind, waves, and the tide drive currents and deposit sediment to form reef islands. However, wave energy may also move sand off of the island and deposit it elsewhere.

Reef structure provides the greatest control on the atoll shoreline. This is because reef width and elevation determine how much wave energy can reach the shoreline. Under stable sea level conditions, a healthy coral reef will continue to generate sediment that may be added to the island. On the other hand, an unhealthy reef may not be able sustain a continuous supply of sediment to the island. It is important to understand that reef islands and their shorelines are dynamic and prone to change over many time scales, from short-term events like storms to long-term geological processes.

To highlight the fact that reef islands are dynamic at event time scales—large storm events may wash sediment off of the reef onto the shoreline (building the shore) or wash sand away from the shoreline onto or off of the reef (eroding the shore). A healthy coral reef that is not damaged by over-fishing, pollution, bleaching, or physical impact is the first line of defense for protecting the shoreline of a reef island. Not only does the reef buffer wave energy, it also generates sediment to continually grow or renourish adjacent islands. A healthy reef may also be able to grow upwards as sea level rises—providing an autonomous adaptation and resilience to sea-level rise.



Atoll islands are maintained by the interaction of physical and biological processes and are constantly adjusting to change.

Before managing the coastal zone, it is important to understand the atoll environment as a dynamic system where all components interact in a complex harmony. The formation of a reef island is dependent on the interaction of coastal processes, biological processes, and the movement of sand and gravel. Sediment generated by the interaction of waves with coral reefs is moved by nearshore currents. Depending on reef width and how much sediment is transported, an island may form on an atoll reef. Tides control the water level generally, allowing higher waves to reach the island at high tide.

Tips for Regenerating a Healthy Reef

- Avoid overfishing—many fish graze on algae, which prevents the overgrowth of coral.
- Use natural or existing channels for boating to avoid running over the reef.
- Avoid standing on submerged corals.
- Remove coral invaders such as Crown-of-Thorns starfish.
- Avoid pollution and nutrient run-off into the lagoon and ocean.
- Limit mining of living coral reefs.

The hard, concrete-like platform found on the ocean side of many islands is a very effective natural protection against wave attack. It is important that this feature is preserved whenever possible.

ATOLL ISLANDS

Island shape or 'morphology' shows that the highest elevation of a reef island is generally located at an ocean side ridge (berm). This is usually where larger waves are able to transport larger sediment (rubble and shingle), forming an ocean-side ridge made up of coarse material. Ridge height is proportional to wave height—higher waves can push sediment further up the beach, increasing the height of the shore. Lagoon shorelines are exposed to smaller waves, resulting in smaller ridges made up of fine sediment. Between the lagoon and ocean ridges there is often a central island depression in elevation. Once palm trees, coastal forest, shrubs, and mangroves have colonized reef islands, the sediment stabilizes and makes the island resistant to change and erosion.

As a result of larger waves in the ocean compared to the lagoon, the ocean side of atoll islands is generally higher in elevation than the lagoon shoreline. This ridge is often made up of coral gravel washed up during storm events.

The amount of wave energy impacting the shoreline helps controls the makeup of the coastal zone. Low-energy lagoon shorelines require different shoreline protection strategies to high-energy, ocean-facing coasts.

When coastal and marine processes start to interact with a community, land, or property and the need to implement shoreline protection arises, there are important factors to consider.

Identify what needs protecting. A house, road, school, garden, park, or just the natural character of the coast. The value of the asset being protected will determine the project budget.

Assess the setting. A first distinction is between ocean-facing shorelines and lagoonal shorelines. Ocean-facing shorelines are exposed to higher energy waves, while lagoonal shorelines may only be exposed to small waves (depending on width and climate). Reef width is also important; a wide reef will significantly reduce the wave energy at the shoreline but a narrow or low elevation reef will allow larger waves to reach the shoreline.

Energy Settings

Shorelines can be referred to as being high energy, medium energy, or low energy. Understanding the shoreline energy conditions will dictate the suitable shore protection options and designs for your coast. The coast's energy conditions will depend on where the atoll is, where on the atoll the island is, and where on the island the shoreline is. Lagoon shorelines are generally low energy, but can be exposed to locally generated waves in the lagoon. Ocean-side shorelines are exposed to larger waves, but the energy conditions will depend on the angle of waves relative to the shoreline. The image to the left matches each shore protection method with the appropriate energy settings.

Choose a protection method. This method can be chosen based on setting, processes, and what needs protecting. In many places, leaving the shoreline alone is the best option. In more natural settings a healthy beach is the best protection for the island.

Consider the effects of implementing protection. Practices may have negative effects and influence the use of a shoreline; e.g., building a sea wall to replace a beach will limit recreational areas and cause erosion to neighboring properties.

A range of coastal protection options are used around Majuro. Some designs are highly effective at protecting assets. Others are likely to fail and increase the risk of further erosion.

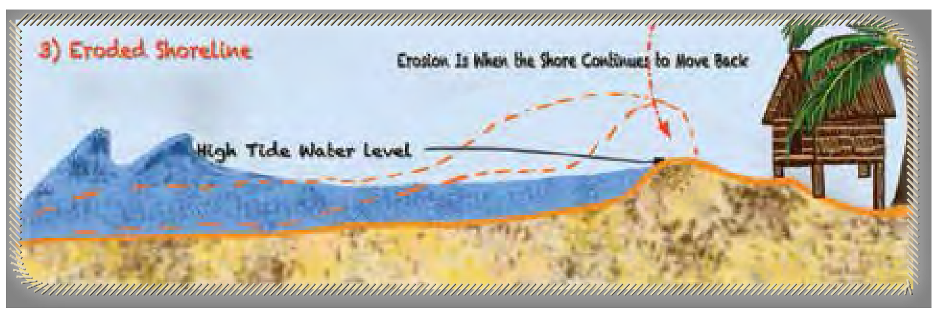
Do You Have an Erosion Problem?

Shorelines are naturally dynamic and will change in response to environmental conditions. There is a significant difference between erosion and the way a shoreline responds to storm waves.

1. Original Shoreline. The original shoreline is shaped by 'normal conditions' with no significant storm waves.

2. During a Storm. During larger wave conditions sediment may be washed off the beach. This gives the beach a storm profile, where sediment is moved offshore. When 'normal conditions' return, sediment will also return and rebuild the original beach. This is not erosion, but the natural way a shoreline responds to changing conditions. It may take months or years for a shoreline to recover naturally.

3. Erosion. Erosion occurs when storm waves continue to wash sediment away, with no recovery. Eroded shorelines will have a severe loss of sediment and a steep, scoured profile.



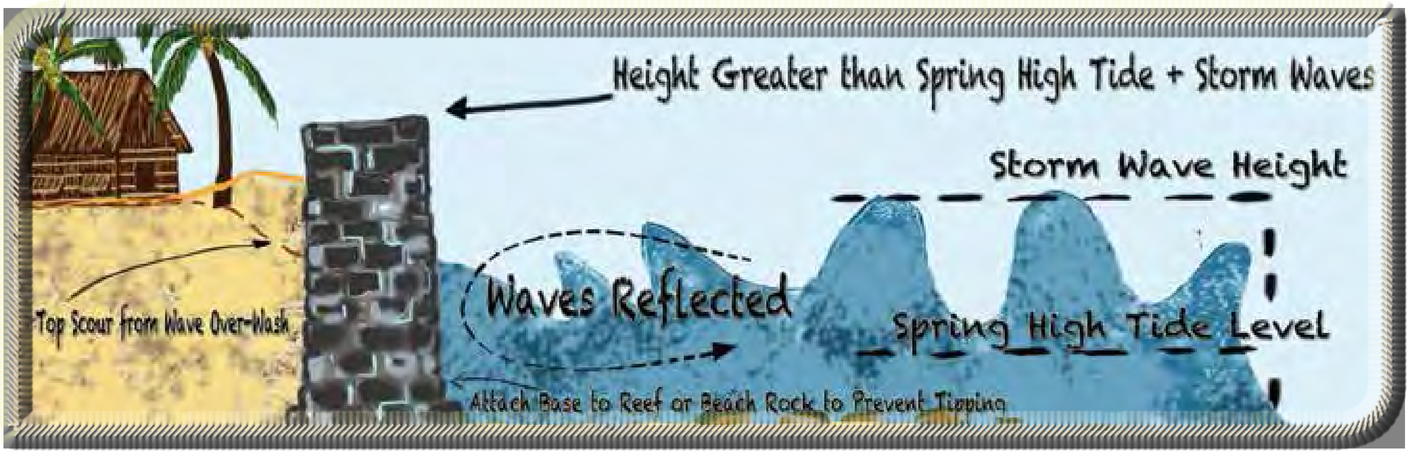
Monitoring the Shoreline

The best way to know if the shoreline is eroding is to monitor it. This can be done by measuring the shore profile or just by measuring the shoreline width from a stable landmark.

It is easy to survey the beach to determine if it is eroding. The coastal team at the RMIEPA has all the equipment needed to undertake regular surveys. Contact the RMIEPA for further help with erosion monitoring.

Hard Protection: Seawalls

Seawalls are self-supporting hard structures that are built parallel to the shoreline. A properly built seawall will protect the land and property behind it. Seawalls do not solve the cause of erosion. However, a badly built seawall will cause other erosion problems. Seawalls require ongoing maintenance.



Seawalls act to block waves and water motion from interacting with land. Seawalls reflect wave energy away from the shore.

Materials

Seawalls can be built using concrete block or gabion baskets filled with reef blocks. Cement or sand bags may work in some locations. Materials will depend on availability, funding and waves conditions.

Be a good neighbour. Building a seawall in front of your property might protect your land. But this approach might cause problems for your neighbour. Before building any seawall, talk to your neighbour. A more effective and possibly cheaper solution might be possible.

Design Considerations

A seawall needs to:

- Be high enough so waves cannot go over the top (higher than spring high tide and storm wave run-up levels).
- Have foundations that cannot be scoured.
- Extend a sufficient length along the shore—for example, not just to the boundary of a single property.
- Be properly connected to the land at each end (tieback).
- Be strong enough to withstand maximum wave height and debris.

Impacts of Seawalls

If seawalls are not well constructed they can cause more erosion problems. Specific problems can include:

- Scour or destruction of foundations and collapse of the seawall.
- Increased erosion at the ends of the wall.
- Overtopping, erosion of land and flooding.
- Loss of sand in front of the wall.

Hard Protection: Revetments

Revetments are sloping structures that are supported by sand and gravel and built parallel to the shore. Revetments are generally constructed by piling large rocks or gabion baskets to form sloping armor on the shoreline. A properly built revetment will stop wave energy, but not necessarily inundation. Revetments require ongoing maintenance.

Revetments stop wave energy from interacting with land by absorbing and reflecting wave energy away from the shore. Depending on material and construction, revetments may not be high enough to block extreme water levels.

Materials

Revetments can be built using layered rock armour, concrete blocks, gabion baskets filled with reef blocks and cement bags.
It is a good idea to plant cuttings of local plants in revetments which help to trap sand and provide further protection.

As with seawalls, revetment walls can have major impacts to your neighbours' land. Be a good neighbour and discuss any construction to minimise future impacts.

Design Considerations

A revetment needs to:

- Be high enough so waves cannot go over the top (higher than spring high tide and storm wave run-up levels).
- Have foundations that cannot be scoured; place a filter cloth first.
- Extend a sufficient length alongshore with proper land connections on either side.
- Have a max slope of 1:2 (height: width) or roughly 30 degrees.
- Be structurally secure for withstanding maximum wave height and debris without collapsing.

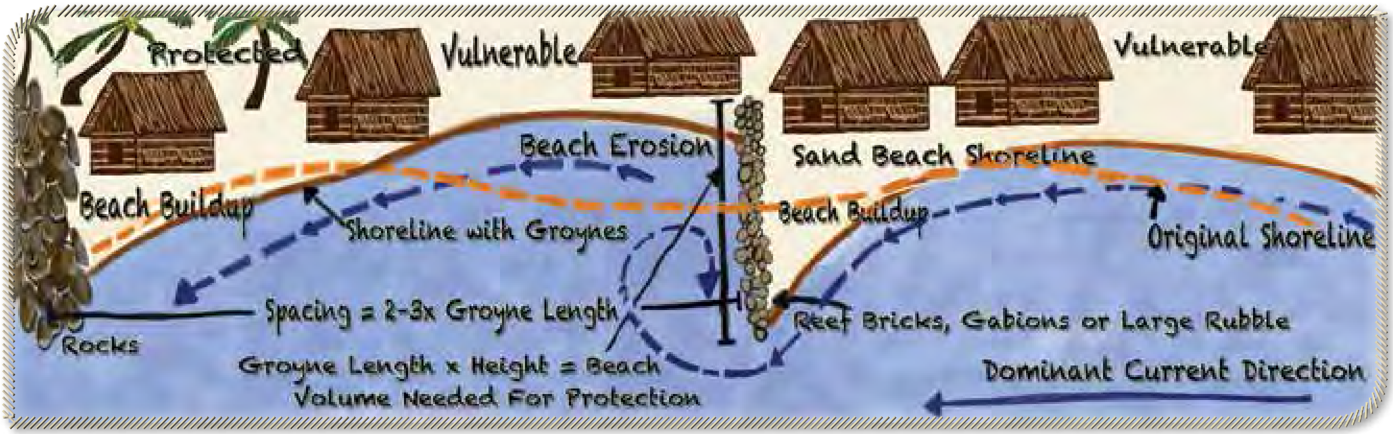
Impacts of revetments

If revetments are not well constructed they can cause more erosion problems including:

- Rock slumping or scour may cause rocks to slip and become unstable, leading to wall collapse.
- Increased erosion at the ends of the wall.
- Overtopping can allow erosion and flooding to continue.
- Loss of sand in front of wall.

HARD PROTECTION: GROYNES

Groynes extend seaward from the shore and trap sediment that is being transported along the shore. A properly built groyne or series of groynes will trap sediment to increase beach volume, forming an effective buffer against wave energy. Groynes are best suited to sandy shorelines where one alongshore drift direction dominates. By trapping



Groynes trap sediment from traveling along the shore. Trapped sediment accumulates to increase beach area that is up-drift of the structure. This is often balanced by erosion leeward of the groyne and at down-drift shores.

sediment from moving alongshore, groynes stop sediment from reaching other areas of the atoll, causing erosion elsewhere.

Materials

Groynes can be built using large rocks, concrete blocks, or gabion

baskets and are suitable for low and medium energy settings. Ongoing maintenance is required to ensure a successful groyne field.

Design Considerations

A groyne needs to be:

- High enough to trap sand so it can form a shore protection buffer. Once enough sand is trapped, the groyne will be buried so sand can travel down drift.
- Long enough to build an effective beach volume. If it is too long, down-drift erosion will increase.
- Spaced appropriately in a groyne field. It is recommended that the distance between groynes is two to three times groyne length.
- Structurally secure for withstanding debris impact and scour. A filter cloth should be placed if the groyne is placed on sandy material.

Impacts of Groynes

If groynes are not well constructed they can cause more erosion problems, especially:

- Rock slumping or scour, which can force structural collapse.
- Increased erosion directly leeward of the groyne.
- Transfer of the erosion problem along the coast.

Hard Protection: Breakwaters

Breakwaters are offshore structures designed to dissipate or prevent wave energy from reaching the shoreline. When built in the right location, a breakwater can form a bulge in the shoreline. Shoreline protection is given by dissipating wave energy offshore and increasing beach volume. Breakwaters may change nearshore processes and cause erosion elsewhere.

Breakwaters work to protect the shore in two ways: 1) By dissipating wave energy offshore, before waves reach the shore. 2) By changing nearshore processes, breakwaters cause sand to build up behind them (only if there is a sandy shoreline).

Materials

Breakwater material needs to withstand wave and debris impact and be stable enough to force wave breaking. Concrete blocks, cement bags, gabion baskets, and large reef material can be used.

Design Considerations

A breakwater needs to be:

- High enough to break incoming waves. Most erosion is by storm waves at high tide; the design should focus on this.
- At an appropriate distance from the shore to dissipate waves and allow a beach bulge to form.
- Long enough to dissipate wave energy along a section of shore.
- Structurally secure for withstanding impact and scour. A filter cloth should be placed if the breakwater is placed on sandy material.
- Breakwaters may remain submerged on deeper reef flats. These can be planted with coral, which is good for the atoll ecosystem.

Impacts of Breakwaters

If breakwaters are not well constructed or are not constructed in an appropriate environment, the following issues may result:

- Rock slumping or scour can lead to structural collapse.
- Preventing waves from reaching the shore can stop sediment being supplied from the reef to shore.
- Breakwaters can change the configuration of the shoreline; increasing beach width behind the breakwater can be balanced by erosion on either side.

Soft Protection: Vegetation Buffer

Planting vegetation can be an effective way to buffer wave energy before it reaches the shore. Planting mangrove fields is suited for flat intertidal shores with fine sediment. Dense shrub can help stabilize and build sandy shorelines.

Vegetation works by buffering wave energy before the shoreline. Mangroves can grow in dense communities with strong stable roots in fine intertidal sediment. Mangroves form a natural wave buffer in some atoll shorelines and can be planted in others as a shore protection method.

Materials

Planting requires suitable mangrove or shrub seedlings.

Design Considerations

Successful mangrove planting requires the following:

- A sheltered coastline with fine intertidal sediment, such as lagoon shores or areas where mangroves grow naturally.
- Mangrove seedlings need to be planted in season; most failures occur in the wet season.
- Seeds taken from other mangrove sites can be stored for three days in a moist bag.
- Planting should be done between mean water level and mean high water level.
- Mangroves are best planted in 0.5 meter intervals forming a field that is three to six mangroves wide, but the field can extend a good distance alongshore.
- Mangroves require a site with good drainage and nutrients, but they need to be away from barnacles, sewage outflow, seaweed, and debris impact.

Impacts of Planting

- Mangrove planting takes a long time to form a useful buffer. In the right environment mangrove seedlings can grow to 20 cm in one year, 50 cm in two years and up to 1.2 m in three years.
- An unnatural mangrove field may decrease the supply of sediment from reef to island.

Planted vegetation can also provide food and improve the natural character. Mangroves can potentially provide shelter and nursery grounds for marine species.

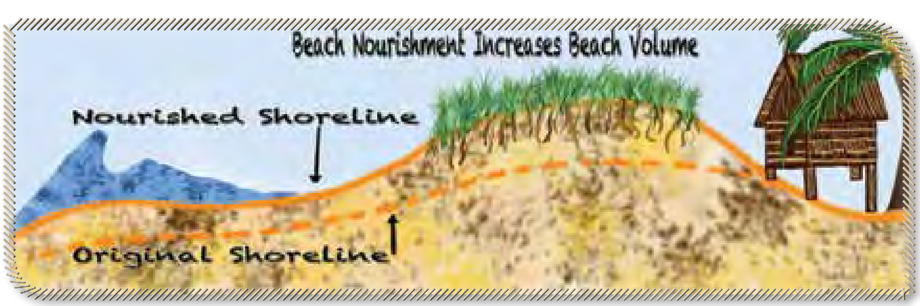
Soft Protection: Beach Nourishment

Nourishment involves the addition of sediment to the shore, increasing the shoreline area that buffers wave energy. Nourishment material may be sourced locally or imported. Nourishment is a popular shore protection option where there is a demand for a recreational beach area. Nourished material is not suitable on high energy shorelines where it will be quickly eroded.

Nourishment works by increasing beach area that buffers wave energy. Nourishment is simply adding sediment volume to the shoreline.

Materials

Nourishment requires a large supply of sediment with a grain size equal or greater than that of the coast being nourished.



Design Considerations

Successful beach nourishment requires:

- A suitable low-medium energy shoreline where sediment is expected to be retained.
- A suitable quantity of sand, which is needed to protect the beach. The volume of nourishment material needed should be calculated based on beach length and the optimal beach width and depth needed for shore protection.
- Material should be sourced sustainably; taking sand from another beach only shifts erosion. Sand can be stored locally and moved on to the beach at high tide.

Impacts of Planting and Nourishment

Environmental issues of beach nourishment include:

- Extracting sediment from within the atoll may result in erosion issues being transferred elsewhere.
- If the shore cannot retain the nourished material it may be washed off and be deposited on coral reefs.

Beach nourishment can help maintain a sandy beach system; the challenge is finding sustainably sourced sediment to add to the beach.

Soft Protection: Community Adaptation and Managed Retreat

Adaptation may be the best option if erosion issues are becoming increasingly frequent or if hard-line structures have failed to protect property. If the cost of successfully blocking or buffering against erosion outweighs the cost of adapting property, it may be more beneficial to raise floor levels or to set back property from the shore.

Profile view of an island with lagoonal and oceanside setback zones and raised floor levels; these measures allow for natural island movement.

How to Adapt Property

Basic ways to adapt a community against erosion include a setback from the shoreline and raising property levels. Setback zones allow a shoreline to shift and move according to seasons and storm events. Setback zones should be considered for new developments on lagoonal and ocean shorelines. Raising the floor level allows flood water to flow under property with minimal damage or risk.

Design Considerations

- A risk assessment should be carried out along all shorelines, evaluating the state of erosion or risk of inundation.
- Evaluate the potential for raising floor levels or creating setback zones at areas of medium or high risk.
- Using stilts to raise the floor level by 1 m will make a property much less vulnerable to coastal flooding.
- Setback distance will depend on energy setting. Higher wave settings will require a larger setback, and low wave settings can be developed close to the shore. It is also important to consider historic erosion rates to establish how much erosion may occur in the future.
- Leaving a native vegetation buffer will increase the level of protection and stabilise the shoreline.

Impacts of Adaptation

- Adaptation is the most 'eco-friendly' approach to coastal protection. There are very minimal or no environmental effects of adaptation. However, there are social effects associated with a changing community infrastructure.

Poorly designed and constructed coastal protection usually fails, often costing more to repair than the cost of construction.

Managed Retreat?

Managed retreat is a favorable option if a property is extremely vulnerable or has already been seriously damaged by erosion. Managed retreat is the strategic relocation of vulnerable property. Buildings can be relocated or rebuilt in a low-risk setting. New developments should use raised floors and setback zones.

Choosing the best option for your shoreline

Not all shore protection methods suit all shorelines. It is important to match the right option with your shoreline. Choosing the appropriate protection method to match a setting will prolong successful shore protection. The following table will help assess the use of each option. The best protection may come through a combination of methods.

	Seawall and Revetment	Groyne	Breakwater	Vegetation	Nourishment	Adapt / Retreat
High energy	✓	✗	✓	✗	✗	✓
Medium energy	✓	✓	✓	✓	✓	✓
Low energy	✓	✓	✗	✓	✓	✓
Suited shore type	Any	Sand only	Sand only	Sand only	Sand only	Any
Relative Cost	High	Medium – High	Medium – High	Low	Low – Medium	Low – High
Protection Level	High	Low – Medium	Medium	Low – Medium	Low	High
Coastal Impact level	High	High	Medium	Low	Low	Low
Cost of failure	High	Medium	Medium	Low	Medium	Low
Construction Difficulty	High	High	High	Low	Medium	Medium
Development level of shoreline	High	Medium	Medium	Low	Low	Any
Material Accessibility	Local / Import	Local / Import	Local / Import	Local	Local / Import	Local
Maintenance requirements	5 – 10 years	1 – 2 years	1 – 2 years	Monitor natural growth	Monitor and top up when needed	General property maintenance
Design Life (quality design)	Reinforced Concrete = 50+ years Low quality = up to 10 years	Reinforced Concrete = 50+ years Rubble gabion = 10 - 50+ years	Reinforced Concrete = 50+ years Rubble gabion = 10 -50+ years	Indefinite if in suitable setting	Days – indefinite Depends on setting and top up supply	Depends on location, design and sea level

Communities Working Together

Most shore protection methods are best suited to a scale greater that one household or property. It may be best to work together as a community to provide effective protection to all properties. If each property on the beach front works separately with different methods, erosion issues may continue or become worse between disconnected structures.

A household protecting itself may increase the vulnerability of its neighbors. Working together can give better protection and will be easier to bring together resources.

Combining Shore Protection Methods

Sometimes the best protection can come from a combination of protection methods. For example if a seawall is needed to protect property but beach area is desired, a seawall can be built landward from high water level. The wall can be buried with nourishment material and planted with vegetation. This provides a ‘natural buffer zone against seasonal beach movement, but secure protection against extreme storm waves.

Sometimes the best option involves a combination of various elements of coastal protection.

Avoid Doing More Harm Than Good

Poorly implemented coastal protection can increase erosion and leave more property vulnerable to future erosion and flooding. Be sure to consult with neighboring landowners and consider the impacts of coastal development on the entire coastal system. It is usually cheaper and more effective to work together towards common goals than looking after individual properties.

Careful planning, design and implementation are key for effective coastal protection; poorly planned protection can cause more harm than good.

Planning for Successful Coastal Protection

- Assess the shoreline processes:
  - Is it a high, moderate or low energy setting?
  - What is the dominant sediment type? Sand? Gravel? Boulders?
  - Is there an existing erosion issue?
- Assess the shoreline properties:
  - Are you in a "natural" or "pristing" setting that might by harmed by costal protection?
  - What needs protecting?
  - Is there room for a setback zone?
  - Can the floor level be raised?
  - Is relocation an option?
- Thoroughly investigate both soft and hard solutions, including adaption options.
- Seek expert advice before building a large structure or spending a lot of money to protect the shore.
- Contact the EPA to see what permits you may require—this is an essential step!
- Monitor how effective the structure is at providing protection and assess any changes caused to the natural environment. Take the lessons learned and use them in future coastal protection.

Using trash and scrap material to build shoreline protection has many negative impacts on the coast and surrounding ecosystem and should be avoided.

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