Pacific Region Infrastructure Facility

Developing Guidance on Managing Coastal Protection Structures in Pacific Island Countries

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Tonkin+Taylor

INTER COASTAL

Presentation Outline

- Coastal processes and hazards in Pacific Islands Countries – *why protection works may be needed*
- Responses to coastal hazards in PICs – *what is being done*
- Management of coastal protection works as assets - *Why guidance is needed*
- PRIF Guidance overview – *Using the guidance*
  - Assessing condition and performance
  - Assessing effects
  - Assessing risk
  - Response selection
- Guidance release and training

Pacific Island Coasts

Coastal protection structures exist because:

1. Coastal land is valued and a focal point for development in the Pacific.
   - Lifeline infrastructure
   - Transport networks
   - Community
   - Valued landscapes and ecosystems

2. Coastal processes and environmental change pose a hazard to coastal land and assets.
   - Erosion
   - Inundation

Natural features that regulate coastal hazards

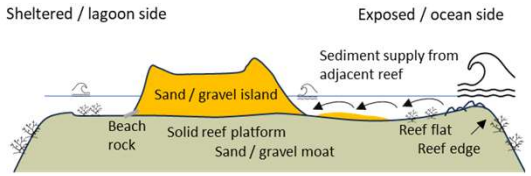
- Coral reefs, sand dunes, wetlands

Suva, Fiji

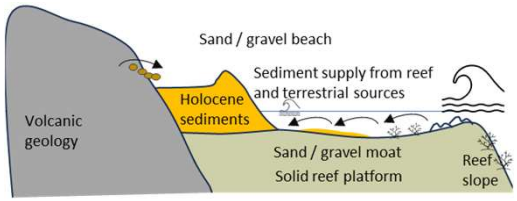
Majuro,
Marshall Islands

Types of coastline in the Pacific Islands

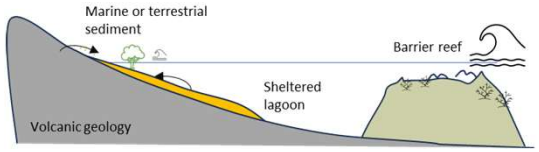
Reef top Islands (including atoll islands)



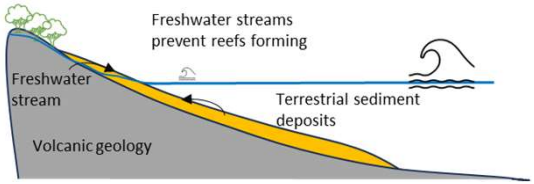
Fringing reef beaches



Barrier reef / harbour coast

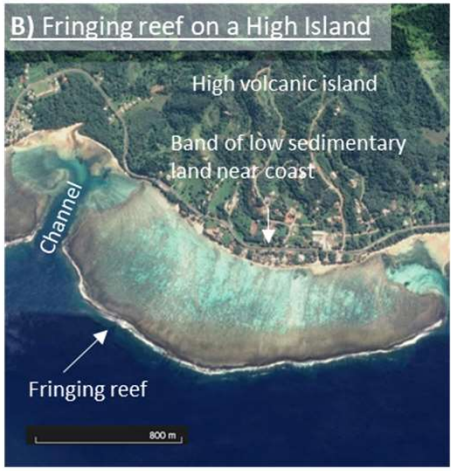


Valley shorelines



Key coastal features:

- Exposure
- Sediment supply
- Ecosystem
- Underlying geology



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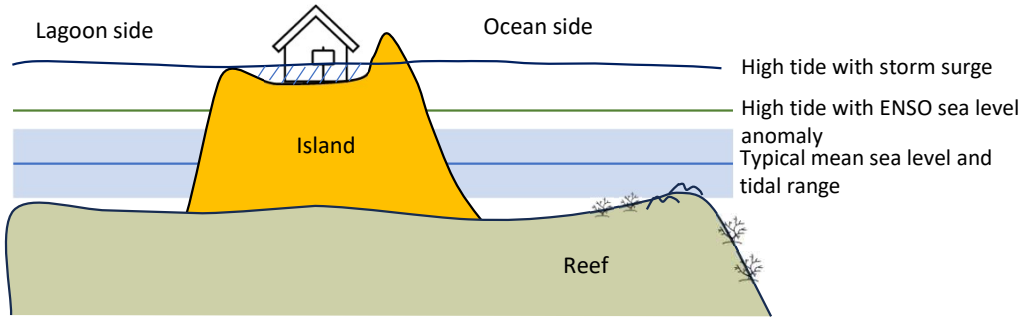
Coastal Hazards: Inundation



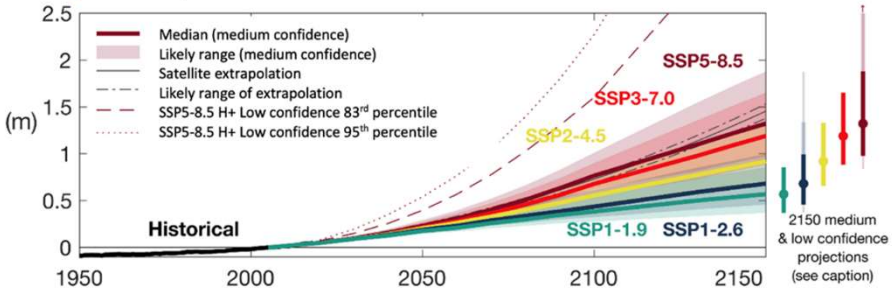
Rarotonga, 2022

Funafuti Tuvalu

Key processes:

- Mean sea level
- Tide
- Climate oscillations
- Storm surge
- Wave effects

Figure 3.2: Projected Global Mean Sea Level under Different SSP Baseline Scenarios



https://theprif.org/sites/theprif.org/files/documents/PRIF_SLR-Report_DigitalV2.pdf

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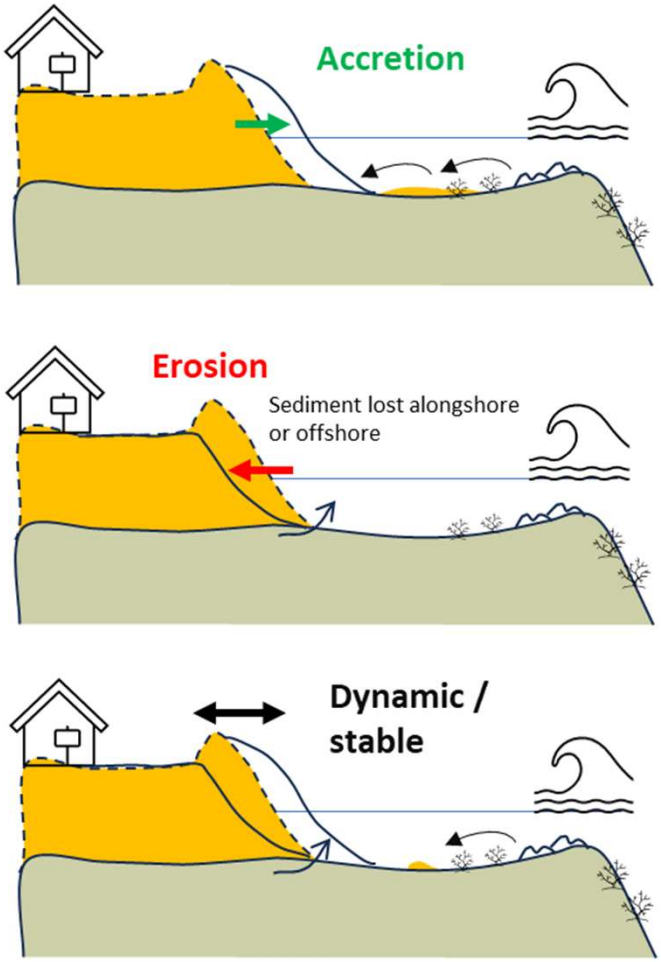
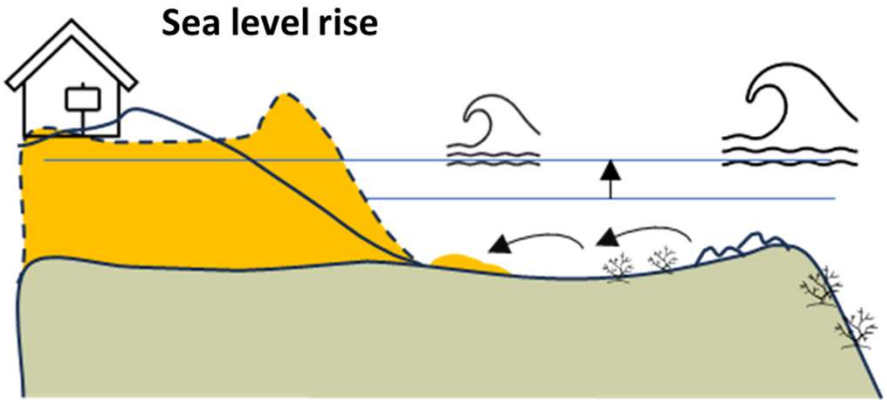
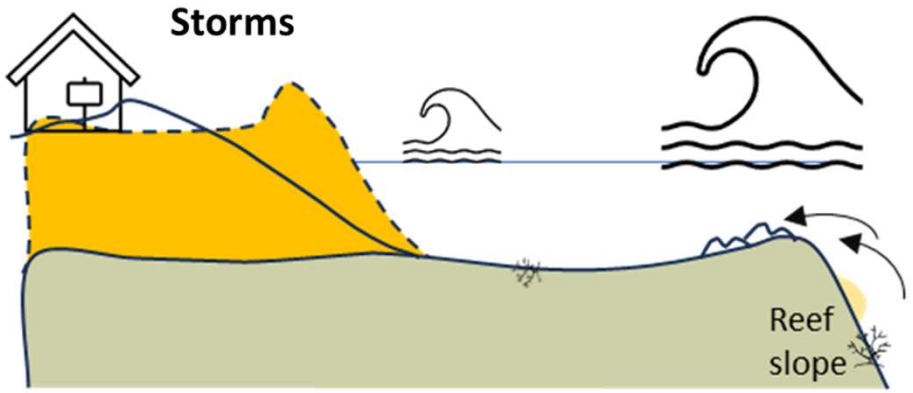
Coastal hazards: Erosion

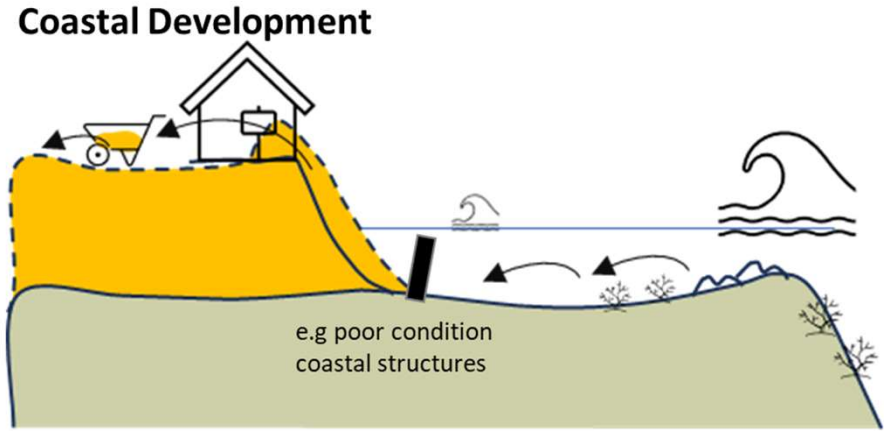
Samoa, 2024

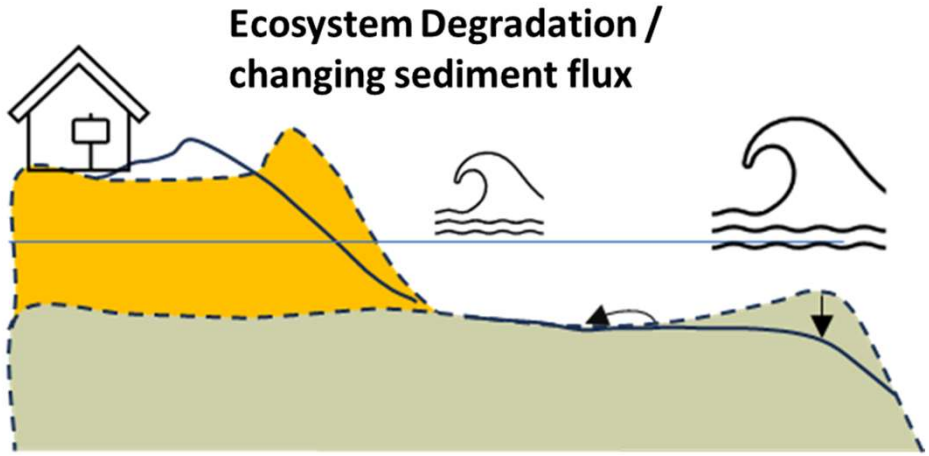


Factors influencing coastal hazards









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Impacts of coastal hazards

- Loss of land
- Damage to buildings
- Damage to food and water supply
- Damage to infrastructure
- Disruption to services and movement
- Impacts on community, amenity and cultural values
- Safety of people

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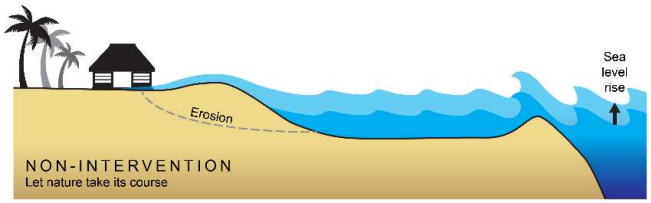
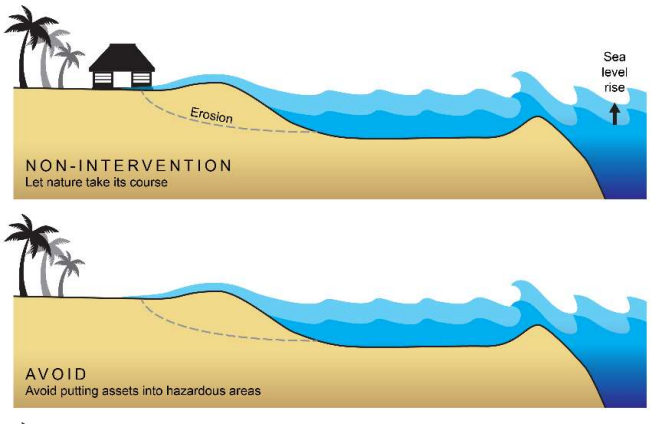
Responses to coastal hazards



- **Non-intervention**

A non-intervention or "do nothing" option allows natural coastal processes to proceed without interference

Responses to coastal hazards



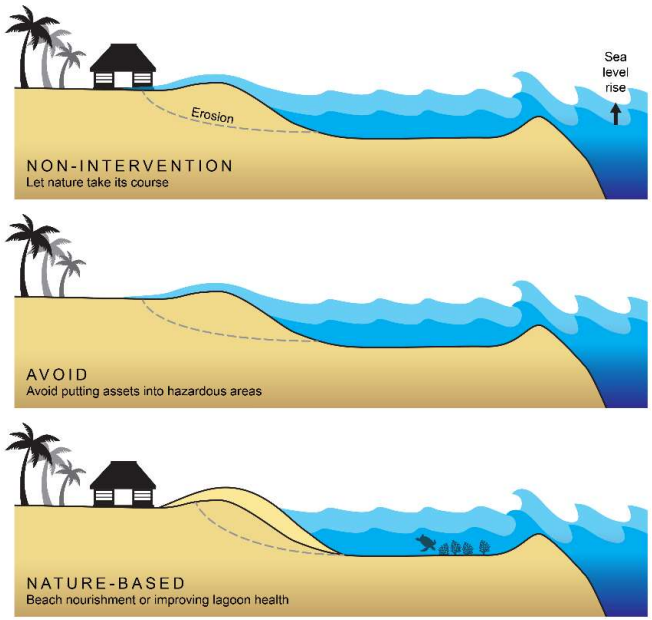
- Non-intervention
- **Avoid**

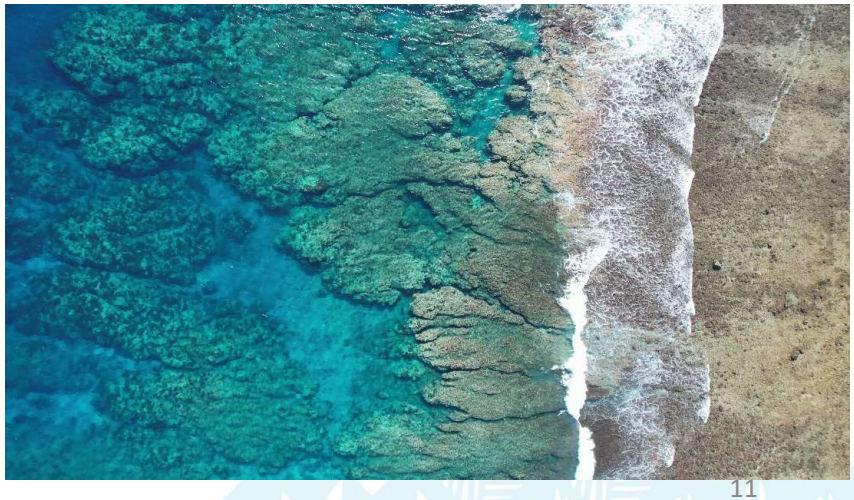
Avoiding coastal erosion hazards primarily involves planning measures which prevent people and assets from being exposed to coastal hazards

Responses to coastal hazards

- Non-intervention
- Avoid
- **Nature-based**

Nature-based solutions aim to protect the shoreline from coastal hazards by replicating natural processes and/or by maintaining healthy ecosystems





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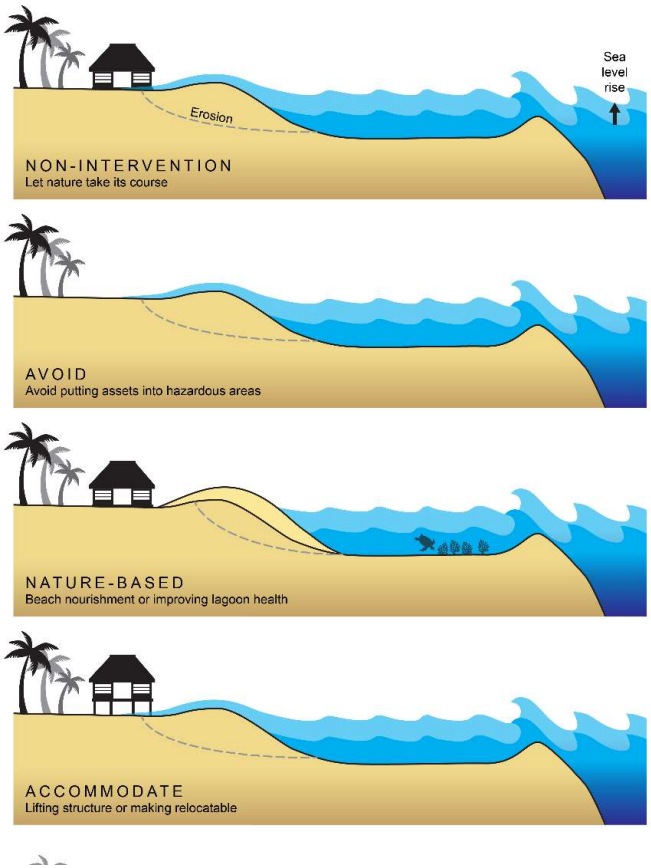
Responses to coastal hazards

- Non-intervention
- Avoid
- Nature-based
- **Accommodate**

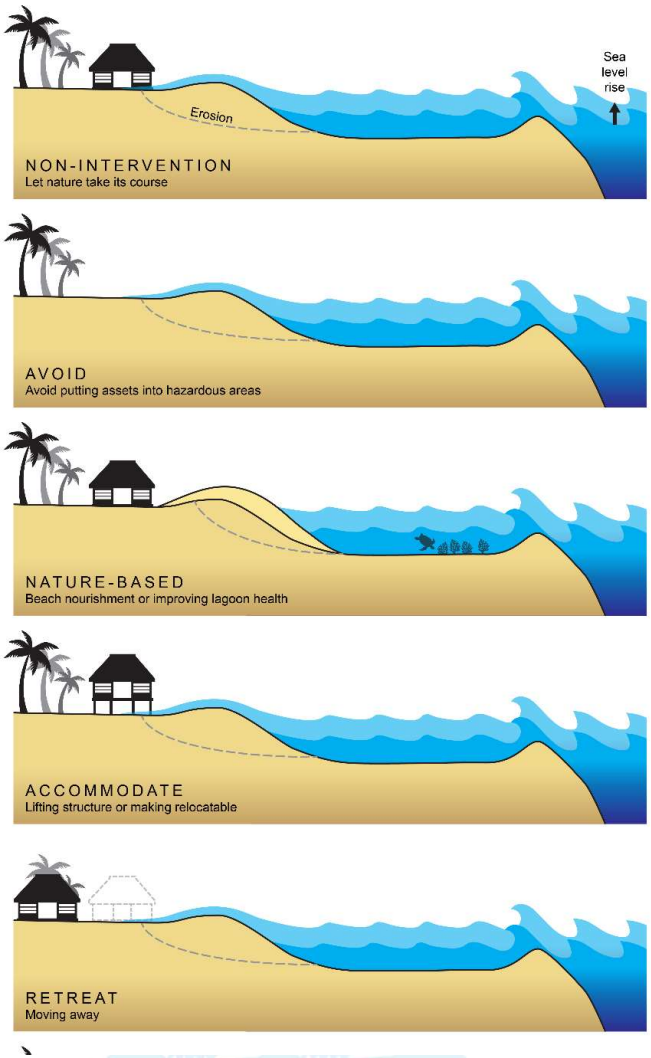
Accommodating coastal hazards enables the ongoing use of coastal land by modifying existing assets/ developments or designing new developments to accommodate coastal hazards



Responses to coastal hazards

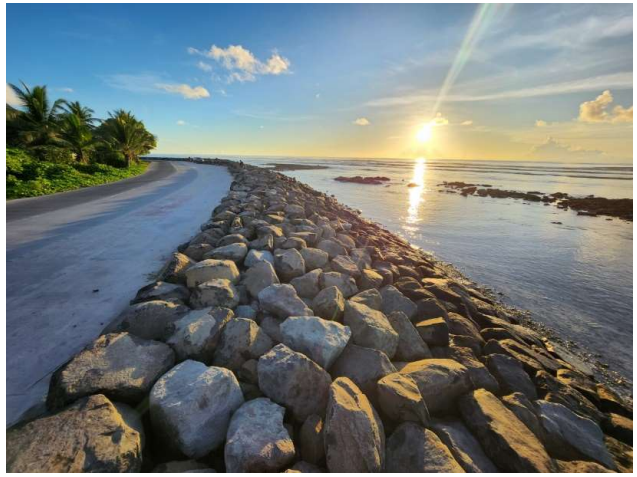
- Non-intervention
- Avoid
- Nature-based
- Accommodate
- **Retreat**

Managed retreat applies to existing development and involves moving assets, infrastructure or people and activities away from areas which are susceptible to coastal hazards.

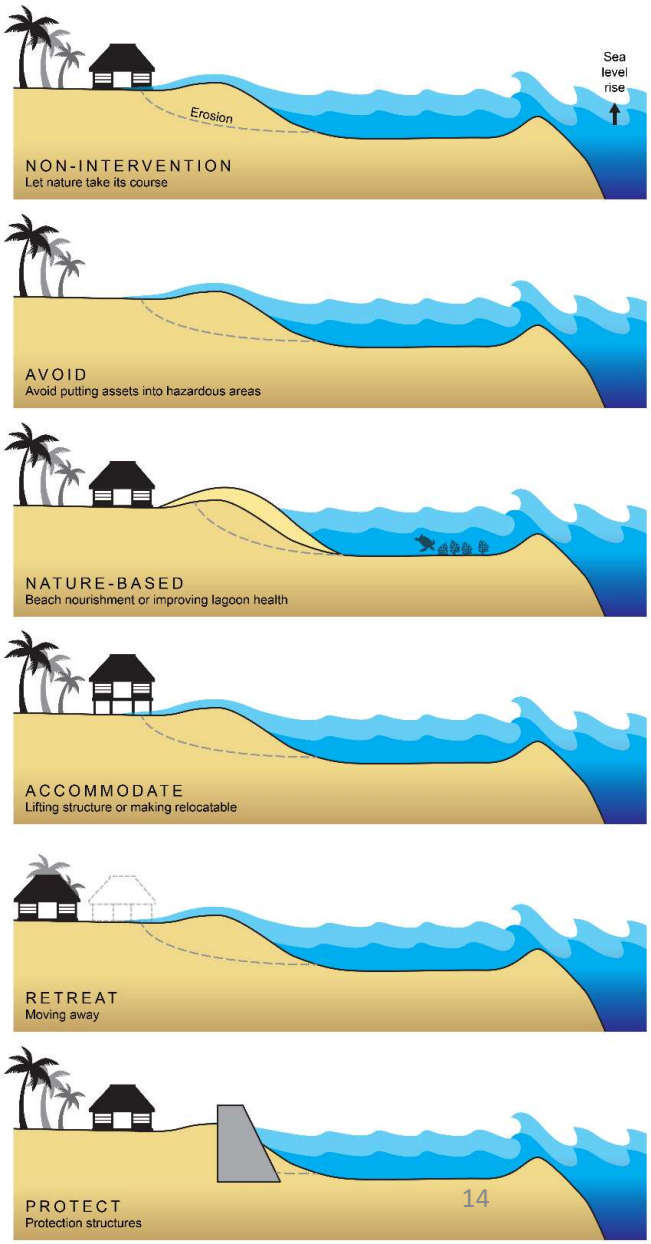


Responses to coastal hazards

- Non-intervention
- Avoid
- Nature-based
- Accommodate
- Retreat
- **Protect**



Coastal protections are implemented when a decision is made to invest in defending coastal land or coastal assets over the short to medium term.



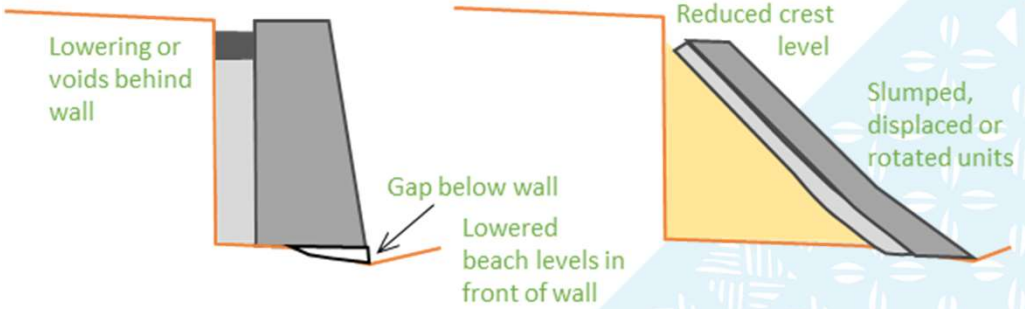
Responses to coastal hazards

Stacked Coral Walls
Planting Or Other NbS
Groynes
Alternative Land Use
Grout
Concrete Armour
Brushwall
Managed Retreat
Gabions
Rock Revetments
Bioengineering Methods
Timber Walls
Reinforced Concrete
Catchment Management
Sheet Piling
Beach Nourishment
Geobags
Breakwaters
Flexible Scour Protection
Steerpile Walls With Concrete Capping
Filled Bags
Mass Concrete
Geotextile Containers

Typical failure mechanisms

- **Toe erosion**

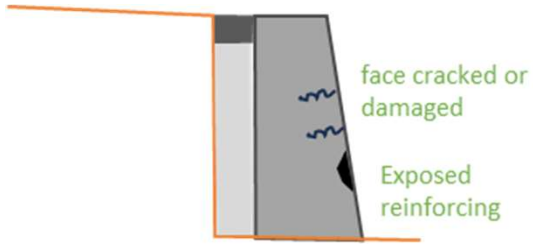
Where the level of the beach or foreshore in front the structure drops below the footing of the structure, causing the wall to subside and/or collapse into the hole.



Typical failure mechanisms

- Toe erosion
- **Structural degradation**

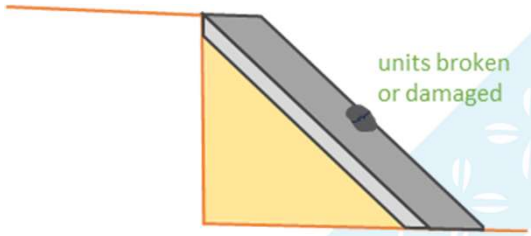
Degradation to the face of rigid seawalls or access steps, or the concrete cap or crown wall including corrosion, abrasion, cracking, spalling. Over time may lead to loss of strength in the wall and eventual collapse or loss of internal material.



Typical failure mechanisms

- Toe erosion
- Structural degradation
- **Armour damage**

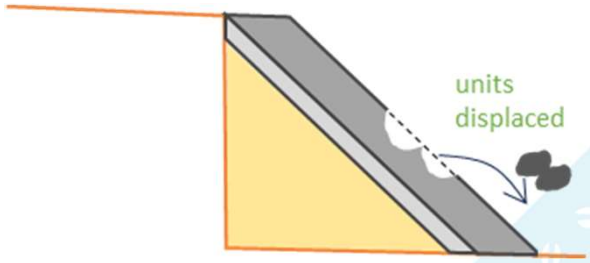
Damage of individual units/rocks/bags within a revetment. May be due to poor rock or armour unit quality, poor placement or interlocking causing rocking, or due to incorrect filling or placement of geotextile containers or vandalism.



Typical failure mechanisms

- Toe erosion
- Structural degradation
- Armour damage
- **Armour displacement**

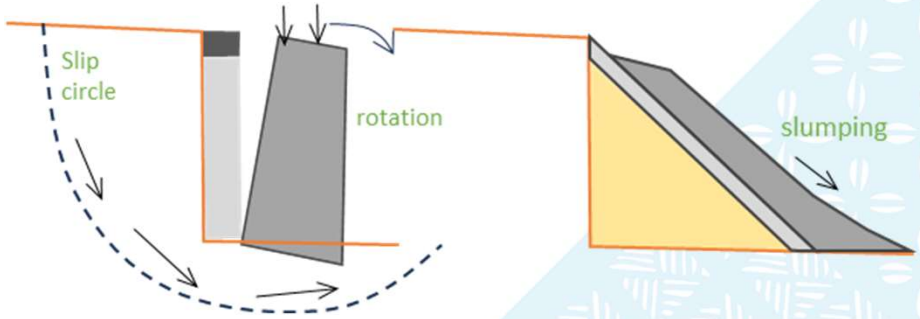
Displacement or loss of individual units within a revetment. May be due to undersize or incorrectly placed rock or armour.



Typical failure mechanisms

- Toe erosion
- Structural degradation
- Armour damage
- Armour displacement
- **Geotechnical failures**

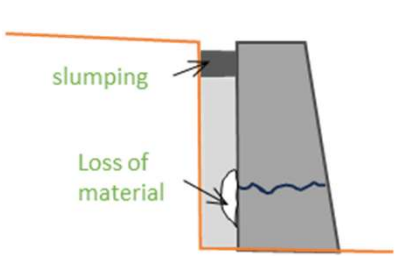
Failures associated with movement of the structure on the ground below including settlement (sinking into the ground), outward rotation (where the crest rotates out), or slip circle failures (where the toe rotates out).

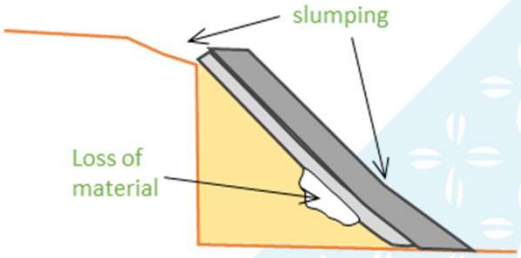


Typical failure mechanisms

- Toe erosion
- Structural degradation
- Armour damage
- Armour displacement
- Geotechnical failures
- **Loss of internal materials**

Loss of materials from within or behind the structure due to piping and/or failure of the geotextile causing a lowering of land levels at and behind the structure crest and/or the structure to slump or crack

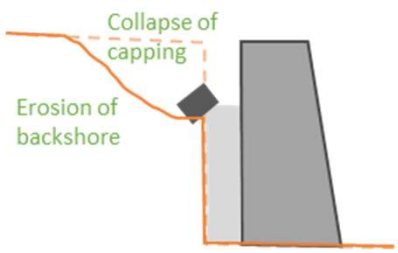


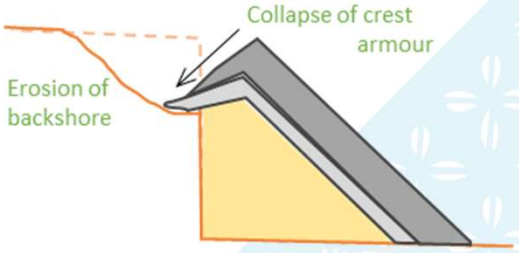


Typical failure mechanisms

- Toe erosion
- Structural degradation
- Armour damage
- Armour displacement
- Geotechnical failures
- Loss of internal materials
- **Crest damage**

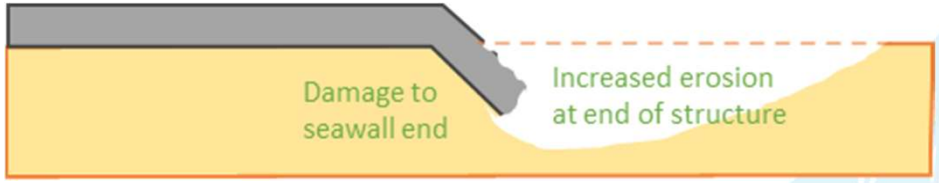
Damage to the crest of the structure and backshore caused generally by wave overtopping resulting in scour and potential collapse of the crest.





Typical failure mechanisms

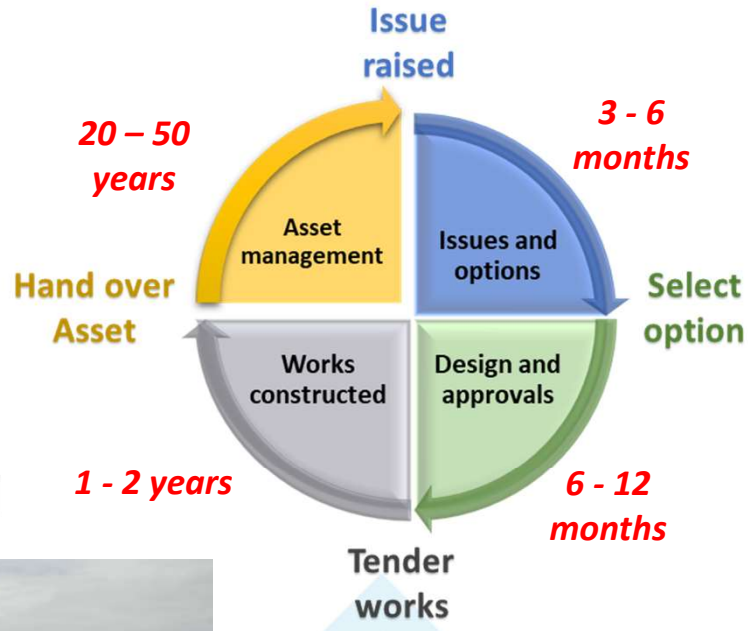
- Toe erosion
- Structural degradation
- Armour damage
- Armour displacement
- Geotechnical failures
- Loss of internal materials
- Crest damage
- **Outflanking and end erosion**



Erosion adjacent to a structure which may be exacerbated by turbulence at the structure ends causing the structure to be 'outflanked' with loss of support behind the structure and collapse

Management of coastal protection works as assets

- What is asset management?
  - Occurs following asset handover and continues over the design life
  - Ensuring
    - the structure is performing as intended
    - is maintained in good order to meet or exceed its intended design life
    - is then replaced or upgraded without placing the asset that it protects at risk (i.e., through failure and unplanned replacement)
  - If you own it – look after it.



Management of coastal protection works as assets

- What is asset management?
- Why is it important for coastal structures (in the Pacific)?
  - The coastline is (or can be) high energy
  - The coastline is dynamic and non-stationary
  - The environment is changing

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  - Structures are often constructed using what is available rather than what is required

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  - Coastal structures are expensive.

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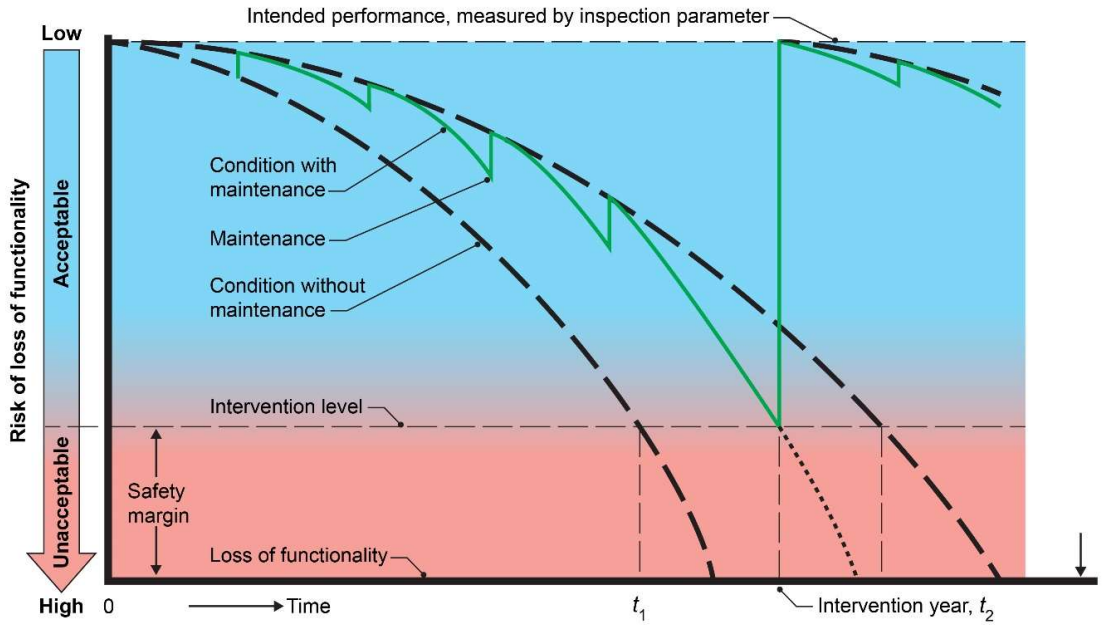

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  - The coastline is dynamic and non-stationary
  - The environment is changing
  - Structures are often constructed using what is available rather than what is required
  - Coastal structures are expensive
  - Structures are often protecting communities and critical infrastructure

Management of coastal protection works as assets

- What is asset management?
- Why is it important for coastal structures (in the Pacific)?
- What currently happens?
  - Wide range of both engineered and non-engineered structures
  - Inspections are undertaken at a range of frequencies, but often ad-hoc or following storms/damage
  - Asset management databases for coastal protection works are not well used
  - Range of guidance available but generally NZ, Aus or European – detailed and technical
  - Inspections almost always include the condition of the structure, less often the effect of the structure on community and environment

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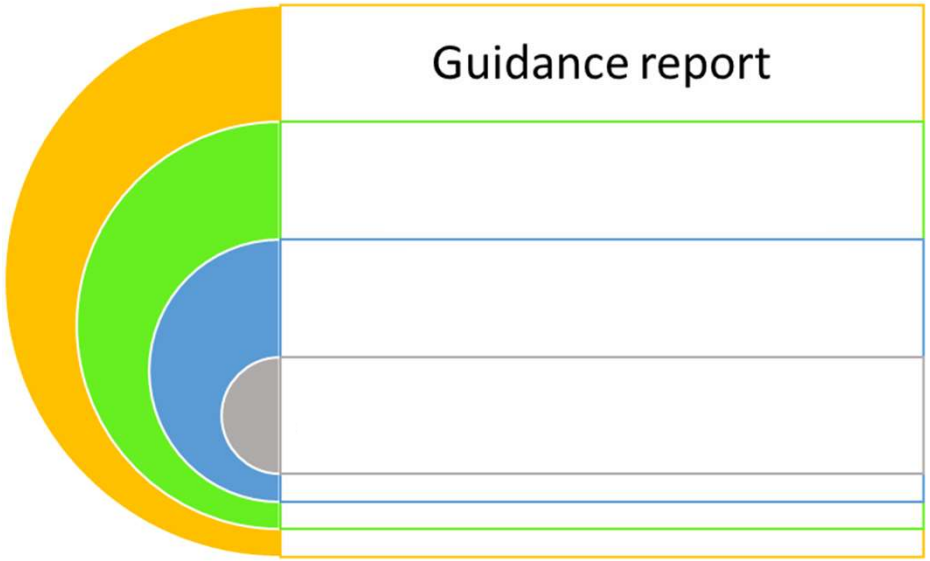
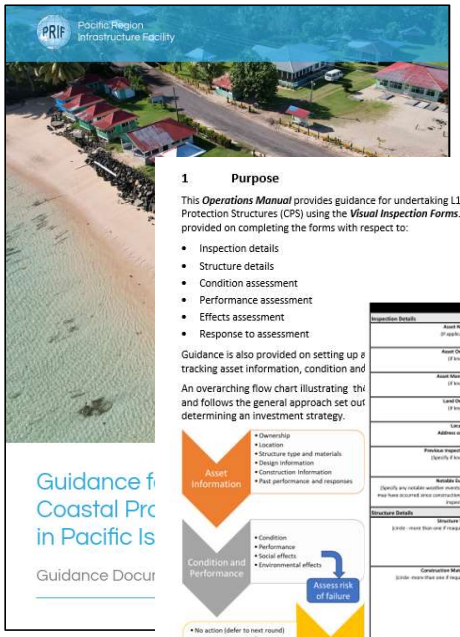
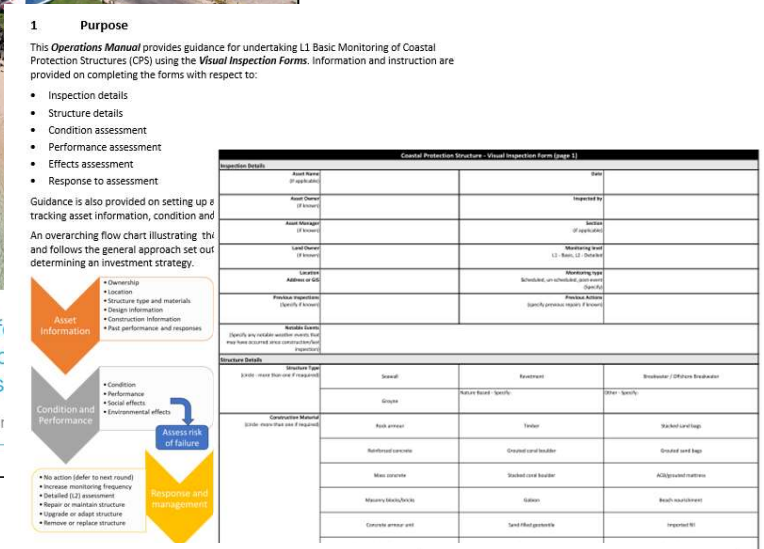
PRIF guidance overview

- There is a need for
  - Something local
  - Something useable
  - Something useful
- Sits between existing PRIF guidance

PRIF guidance overview







1 Purpose

This ***Operations Manual*** provides guidance for undertaking L1 Basic Monitoring of Coastal Protection Structures (CPS) using the ***Visual Inspection Forms***. Information and instruction are provided on completing the forms with respect to:

- Inspection details
- Structure details
- Condition assessment
- Performance assessment
- Effects assessment
- Response to assessment

Guidance is also provided on setting up a tracking asset information, condition and

An overarching flow chart illustrating thi and follows the general approach set out determining an investment strategy.

Asset Information
- Ownership
- Location
- Structure type and materials
- Design information
- Construction Information
- Past performance and responses

Condition and Performance
- Condition
- Performance
- Social effects
- Environmental effects

Assess risk of failure

Response and management
- No action (defer to next round)
- Increase monitoring frequency
- Detailed (L2) assessment
- Repair or maintain structure
- Upgrade or adapt structure
- Remove or replace structure

Coastal Protection Structure - Visual Inspection Form (page 1)

Inspection Details

Asset Name (if applicable)		Date	
Asset Owner (if known)		Inspected by	
Asset Manager (if known)		Section (if applicable)	
Land Owner (if known)		Monitoring level L1 - Basic, L2 - Detailed	
Location Address or GIS		Monitoring type Scheduled, un-scheduled, post-event (specify)	
Previous Inspections (Specify if known)		Previous Actions (specify previous repairs if known)	
Notable Events (Specify any notable weather events that may have occurred since construction/last inspection)			

Structure Details

Structure Type (circle - more than one if required)	Seawall	Revetment	Breakwater / Offshore Breakwater
	Groyne	Nature Based - Specify:	Other - Specify:
Construction Material (circle - more than one if required)	Rock armour	Timber	Stacked sand bags
	Reinforced concrete	Grouted coral boulder	Grouted sand bags
	Mass concrete	Stacked coral boulder	ACB/grouted mattress
	Masonry blocks/bricks	Gabion	Beach nourishment
	Concrete armour unit	Sand-filled geotextile	Imported fill

Asset Information			Notes/Instructions
Asset General Information	Asset Name (if applicable)		*If it has a name*
	Asset Owner		*Owner of the asset*
	Asset Manager		*Manager of the asset*
	Land Owner		*Owner of the land (may differ)*
	Location (GIS)		*Location of the centre of the structure in E/N or Lat/Long*
	Location (Address - if applicable)		*Closest street address to centre of the structure (if applicable)*
Asset Specifications	Structure Type		*Type of structure*
	Construction Material		*Material structure constructed from*
	Engineering Standard		*Standard structure was constructed to*
	Asset Intent (reason)		*What function is the asset performing*
	Asset Importance Rating		*What is the importance of the structure*
	Material Specifications		*Armour/facing/member sizing, interface, layout, etc*
	Structure Slope (H:V)		*Slope of structure face (Horizontal:Vertical)*
	Length of Structure (m)		*Overall length of structure (m)*
	Typical Height of structure (m)		*Height of structure from toe to crest (m)*
	Crest Height (above high tide)		*Height of structure crest above high tide (m)*
	Coastal Environmental Setting		*What is the coastal environmental setting of the structure*
	Structure Position on Beach/Foreshore		*Position of the structure toe on the beach or foreshore*
Design and Hand-over Information (if available)	Construction Date		*Date of construction completed if known*
	Design criteria		*What were the design criteria (i.e. overtopping less than X l/s/m or damage less than %X during*
	Design event		*Exceedance design event (i.e. 10 or 100 year ARI at what time inc. what SLR allowance)*
	Design life		*What was the estimated design life of the structure*
	Future adaptation		*Is any future adaptation planned and what are the triggers*
	As-built or design drawings		*Are as-built drawings of the structure available (and if so where saved)*
	As-constructed imagery		*Are images of the structure immediately following construction available (and if so where saved)*
	Target Monitoring Schedule		*What is the target monitoring frequency*

Insert asset photo here:	Insert GIS aerial here (include scale if possible)

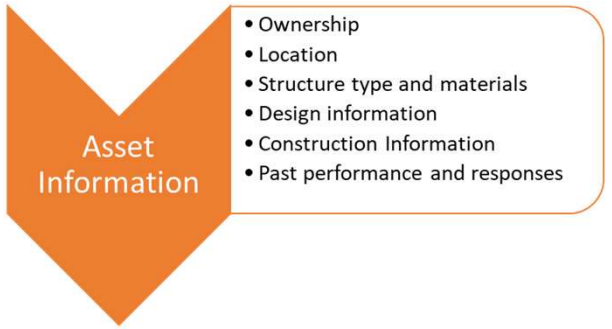
Asset Specification | Asset Inspection-yyyymmdd | Response Lists

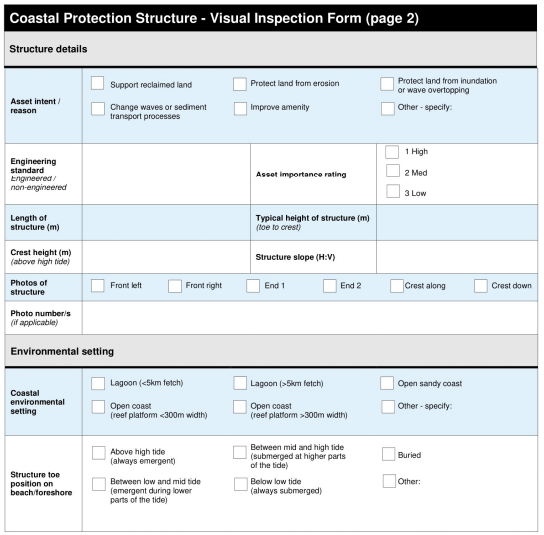
Using the guidance

- Asset information
  - What type of asset, what is it made from?
  - Where is the structure, ocean/lagoon/estuary, is it underwater?
  - Who owns the asset?
  - How long has it been there?
  - What is it supposed to be doing?
  - How important is it?

This information will not change.

It is the basis of the Asset Management Database





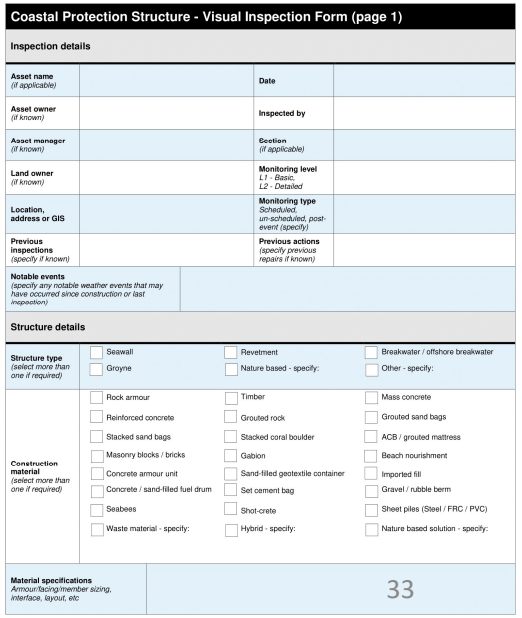
Coastal Protection Structure - Visual Inspection Form (page 2)

Structure details

Asset intent / reason	☐ Support reclaimed land ☐ Protect land from erosion ☐ Protect land from inundation or wave overtopping ☐ Change waves or sediment transport processes ☐ Improve amenity ☐ Other - specify:		
Engineering standard *Engineered / non-engineered*		**Asset importance rating**	☐ 1 High ☐ 2 Med ☐ 3 Low
Length of structure (m)		**Typical height of structure (m)** *(toe to crest)*	
Crest height (m) *(above high tide)*		**Structure slope (H:V)**	
Photos of structure	☐ Front left ☐ Front right ☐ End 1 ☐ End 2 ☐ Crest along ☐ Crest down		
Photo number/s *(if applicable)*			

Environmental setting

Coastal environmental setting	☐ Lagoon (<5km fetch) ☐ Lagoon (>5km fetch) ☐ Open sandy coast ☐ Open coast (reef platform <300m width) ☐ Open coast (reef platform >300m width) ☐ Other - specify:		
Structure toe position on beach/foreshore	☐ Above high tide (always emergent) ☐ Between mid and high tide (submerged at higher parts of the tide) ☐ Buried ☐ Between low and mid tide (emergent during lower parts of the tide) ☐ Below low tide (always submerged) ☐ Other:		



Coastal Protection Structure - Visual Inspection Form (page 1)

Inspection details

Asset name *(if applicable)*		**Date**	
Asset owner *(if known)*		**Inspected by**	
Asset manager *(if known)*		**Section** *(if applicable)*	
Land owner *(if known)*		**Monitoring level** *L1 - Basic, L2 - Detailed*	
Location, address or GIS		**Monitoring type** *Scheduled, un-scheduled, post-event (specify)*	
Previous inspections *(specify if known)*		**Previous actions** *(specify previous repairs if known)*	
Notable events *(specify any notable weather events that may have occurred since construction or last inspection)*			

Structure details

Structure type *(select more than one if required)*	☐ Seawall ☐ Revetment ☐ Breakwater / offshore breakwater ☐ Groyne ☐ Nature based - specify: ☐ Other - specify:		
Construction material *(select more than one if required)*	☐ Rock armour ☐ Timber ☐ Mass concrete ☐ Reinforced concrete ☐ Grouted rock ☐ Grouted sand bags ☐ Stacked sand bags ☐ Stacked coral boulder ☐ ACB / grouted mattress ☐ Masonry blocks / bricks ☐ Gabion ☐ Beach nourishment ☐ Concrete armour unit ☐ Sand-filled geotextile container ☐ Imported fill ☐ Concrete / sand-filled fuel drum ☐ Set cement bag ☐ Gravel / rubble berm ☐ Seabees ☐ Shot-crete ☐ Sheet piles (Steel / FRC / PVC) ☐ Waste material - specify: ☐ Hybrid - specify: ☐ Nature based solution - specify:		
Material specifications *Armour/facing/member sizing, interface, layout, etc*			

Using the guidance

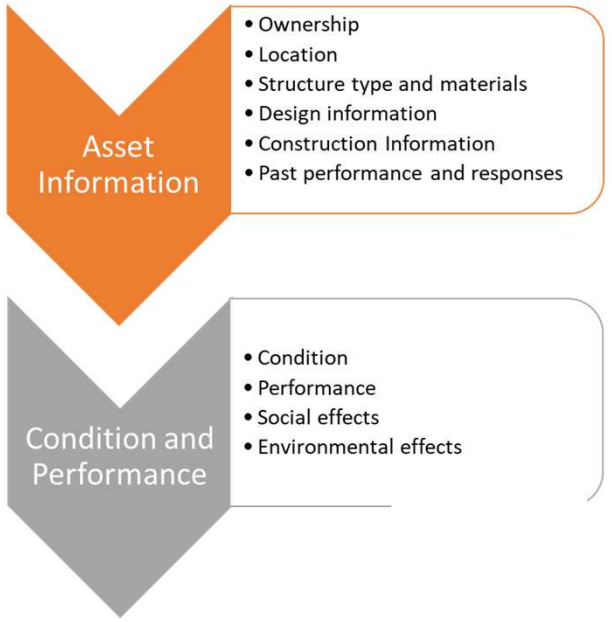
- Asset information
- Condition of the asset
  - How closely the structure represents the as-built or new structure
  - Elemental assessment
  - Condition rating A - E

Coastal Protection Structure - Visual Inspection Form (page 3)

Elemental assessment	Considerations depending on structure	Notes on element (take photos of each element where possible)
Toe / Foundation	☐ Is the toe founded on hard strata? ☐ Is the surrounding ground higher than the toe? ☐ Are there signs of scour? ☐ Is the toe buried? ☐ Is there a gap between the bottom of the structure and the ground? ☐ Is there evidence of bed lowering since construction?	
Structure facing	☐ Are there displaced armour rocks/units? ☐ Are there gaps in the armour/outer layer? ☐ Is there visible cracks in the façade? ☐ Is there exposed reinforcing? ☐ Is there exposed reinforcing? ☐ Is there signs of deterioration (cracked concrete, rust, ALWC, splitting/worn timber)? ☐ Are there discontinuities in the outer surface? ☐ Are there visible splits in geotextile containers? ☐ Is the geotextile partially empty, flapping?	
Filter layers / geotextile	☐ Can you see a geotextile underlayer? ☐ Is the geotextile underlayer intact? ☐ Is the geotextile of sufficient thickness/high quality? ☐ Is there more than one layer of armour rock/units?	
Backfill	☐ Are there signs of migration of fill through the structure? ☐ Is there holes or slumping behind the structure? ☐ Is the land lower immediately behind the structure?	
Crest	☐ Is there evidence of overtopping, vegetation die-back / salt burn? ☐ Is there signs of submergence on higher tides; algae, darker colour elements? ☐ Are units at the crest of the structure displaced? ☐ Is the capping beam cracked / deteriorated?	

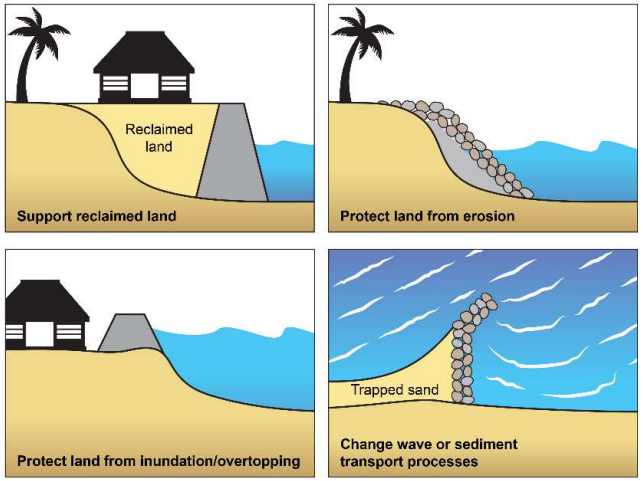
Coastal Protection Structure - Visual Inspection Form (page 4)

Elemental assessment	Considerations depending on structure	Notes on element (take photos of each element where possible)
Drainage	☐ Is ponding present behind the crest? ☐ Are there weep holes in the face of the structure? ☐ Is the structure blocking creek/inlet or landward flow path? ☐ Is there evidence of flow through/under the structure at low tides?	
Slope	☐ Does the structure appear to be slumping/ becoming flatter? ☐ Does the structure appear to be leaning forward or back? ☐ Are any geotextile containers emptying or moving?	
Alignment	☐ Are sections of the structure out of alignment with the rest? ☐ Does there appear to be wash-throughs / or blow-outs along the structure? ☐ Are there signs of increased erosion at either end of the structure? ☐ Is beach nourishment maintaining its design shape/planform?	
Fixings	☐ Does the structure have fixings; mooring points/bollards, stormwater pipes, a footpath or furniture/lighting connected to the structure? ☐ Are the fixings in good working order?	
Access	☐ Is there safe access to and from the coast both over and along the structure? ☐ Is there safe access to maintain the structure? ☐ Is the structure safe for the community to interact with, sit/walk on?	
Nature-based	☐ Is vegetation planted as part of a NbS in good condition? ☐ Is there evidence of dieback or sparsity in vegetation? ☐ Is the planting securely founded/rooted on the bed? ☐ Are other NbS components in good condition	

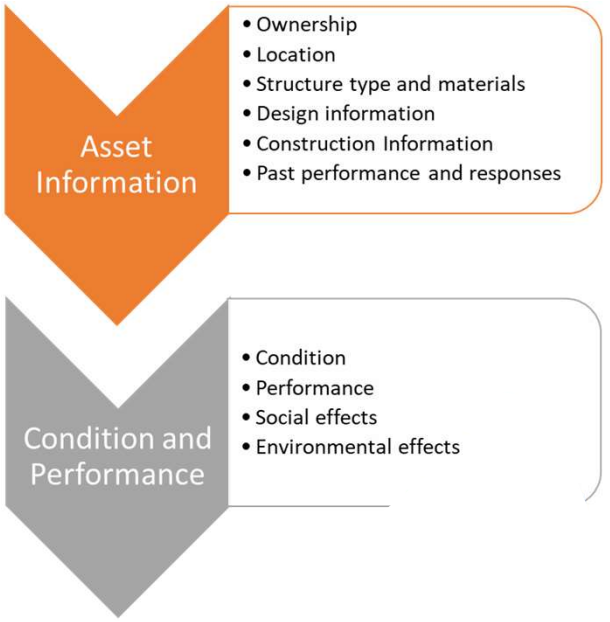


Using the guidance

- Asset information
- Condition of the asset
- Performance of the asset
  - Is it performing as intended?
  - Performance rating A - E



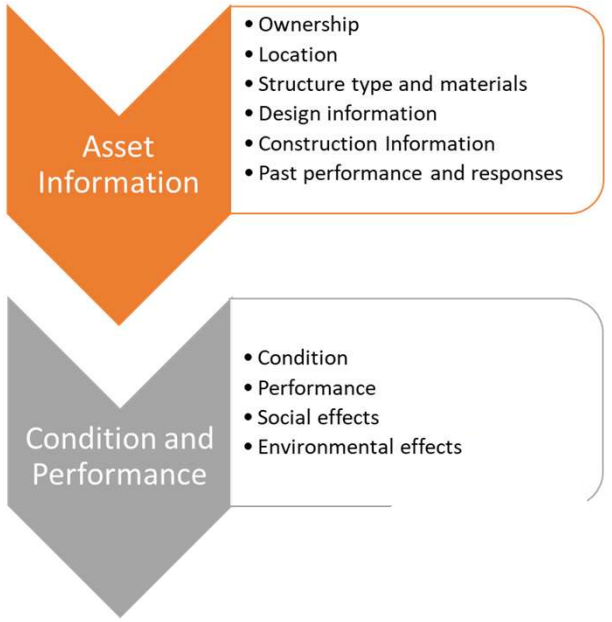
Coastal Protection Structure - Visual Inspection Form (page 5)		
Structure rating		
Potential failure mechanism	From the elemental assessment, are you able to determine a possible future failure mechanism that may occur before next inspection? i.e: - Toe erosion - Structural degradation - Geotechnical failure - Armour damage or displacement - Loss of internal materials - Crest Damage - Outflanking and end erosion Refer to Operations Manual and Guidance Document for Defects-Failure linkages	**Notes on potential failure:**
Performance rating: A - Excellent B - Good C - Fair D - Poor E - Very poor/failed	**Notes on performance** (based on results of elemental assessment):	
Condition rating: A - Excellent B - Good C - Fair D - Poor E - Very poor/failed	**Notes on condition** (based on results of elemental assessment):	



Using the guidance

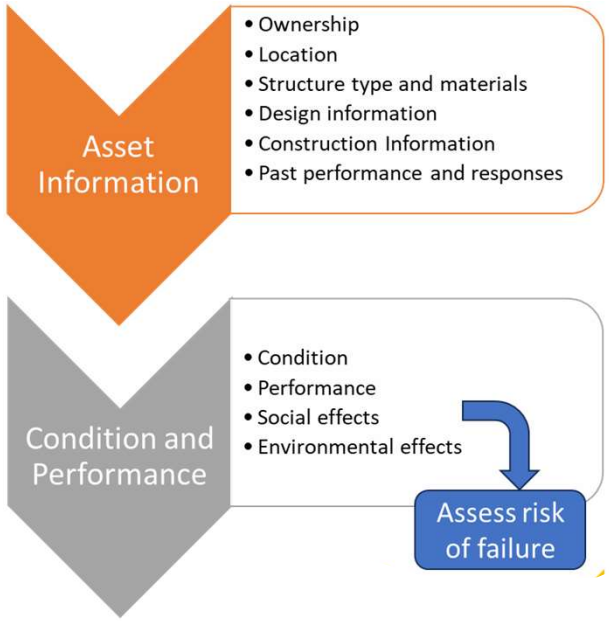
- Asset information
- Condition of the asset
- Performance of the asset
- Effects of the asset
  - Effects on communities
  - Effects on the environmer
  - Positive as well as negativ
  - Are these intolerable?

Effects assessment			
Effects on community	**Positive** ☐ Improved coastal access ☐ Provision of new meeting/social location ☐ Improved fishing/fossicking ☐ Improved recreational amenity; walking, sunbaking, diving, surfing, etc ☐ Reduction in wave overtopping/inundation	**Negative** ☐ Exposed steel/wire ☐ Unstable rocks ☐ Loss of access to or along beach ☐ Flooding caused by seawall blocking return flow ☐ Is the structure having adverse outcomes for any particular group ☐ Use as a refuse point	**Other - specify:**
Effects on the Environment	**Positive** ☐ Improved water quality ☐ Improved flora or fauna habitat ☐ Reduced rubbish/debris ☐ Training of creek/inlet	**Negative** ☐ Increased erosion in front of the asset (i.e. beach is lowering) ☐ Increased erosion next to asset (i.e. end effects or downdrift erosion) ☐ Affecting lagoon currents or stream flow processes ☐ Affecting wave processes (i.e. increased reflection) ☐ Affecting ecology (specify) ☐ Blocking flow path ☐ Trapping debris/waste	**Other - specify:**



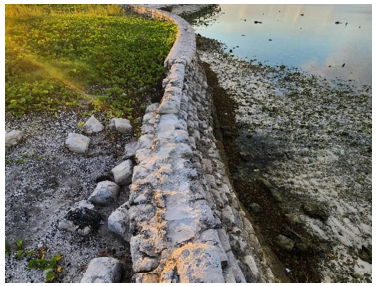
Using the guidance

- Asset information
- Condition of the asset
- Performance of the asset
- Effects of the asset
- Risk
  - Function of the consequence of failure and the likelihood of that failure occurring



Using the guidance

Protects or support remote area of public land or beach. Failure will lead to moderate/low costs



Protects or supports small area of private land or public roads. Failure will lead to significant costs

Protect or supports vital infrastructure or key community asset. Failure will lead to significant costs or loss of life

		Importance of structure		
		3: Low	2: Medium	1: High
Condition / Performance	A – Excellent	Very Low	Very Low	Low
	B – Good	Very Low	Low	Low
	C – Fair	Low	Moderate	Moderate
	D – Poor	Moderate	Moderate	High
	E – Very Poor	Moderate	High	Very High

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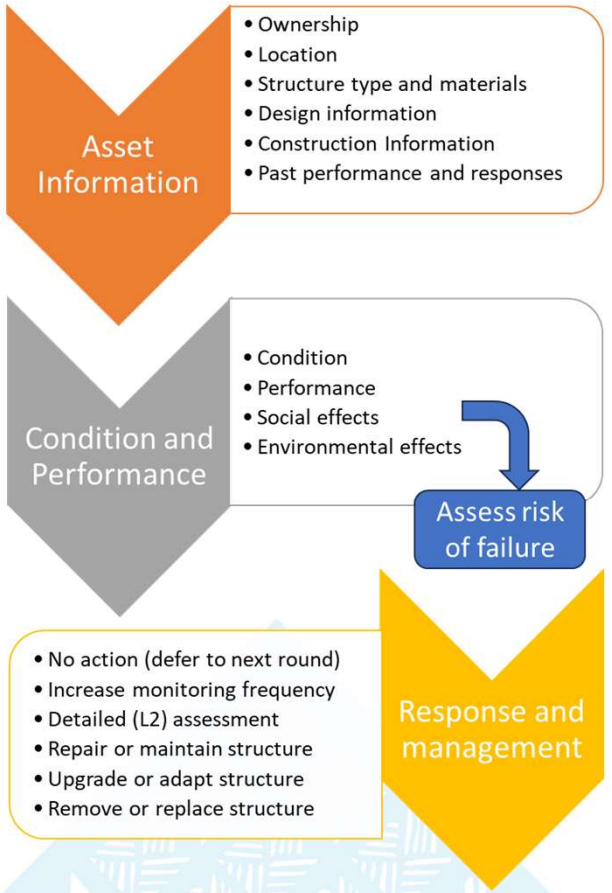
Using the guidance

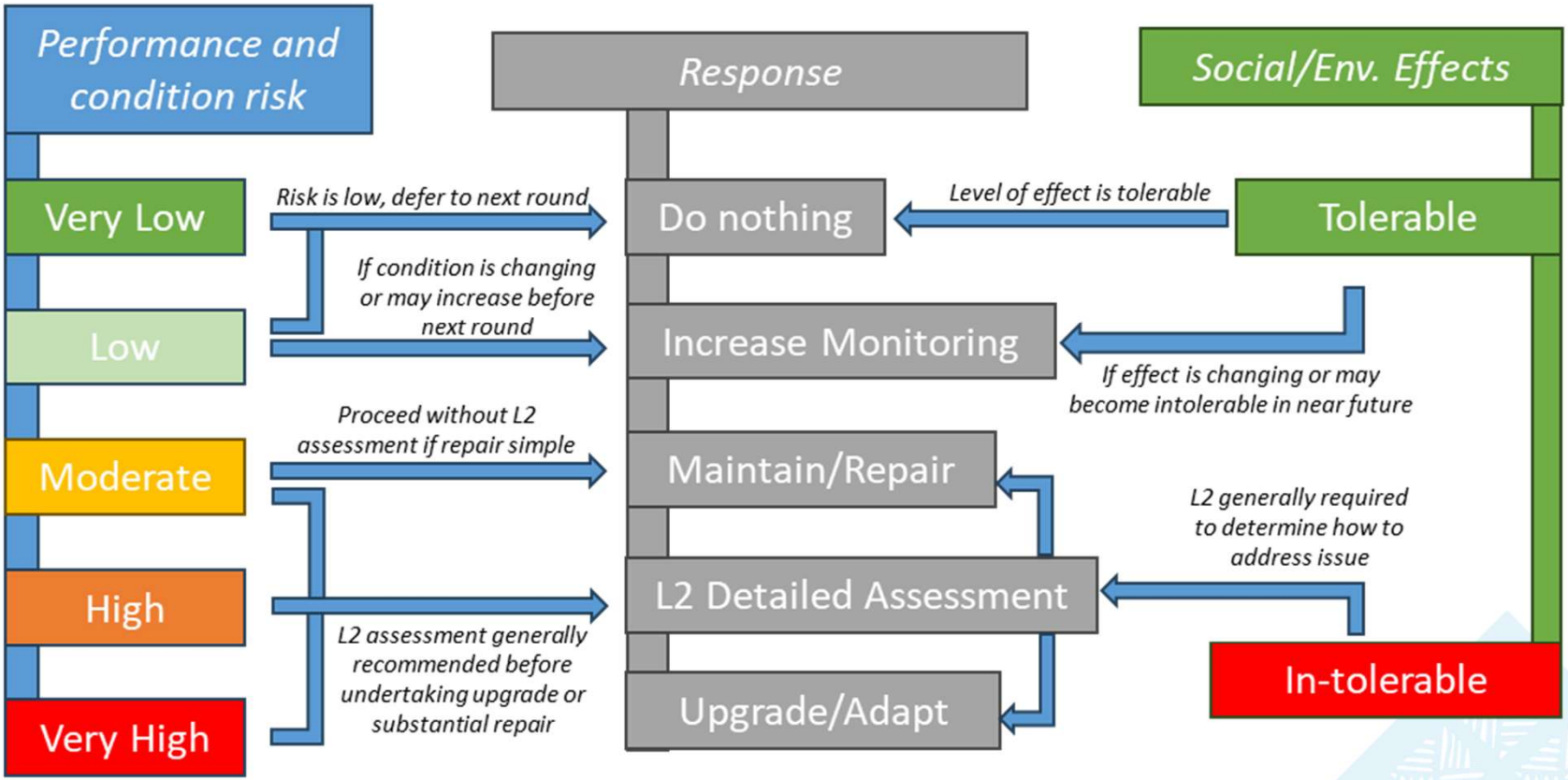
- Asset information
- Condition of the asset
- Performance of the asset
- Effects of the asset
- Risk
- Response
  - What now?
  - *Asset is maintained in good order to meet or exceed its intended design life*
  - *Asset is then replaced or upgraded without placing the asset that it protects at risk (i.e., through failure and unplanned replacement)*
  - Is not causing adverse effects people or the environment



Using the guidance

- Response options
  - Do nothing
  - Increase monitoring frequency
  - More detailed assessment
  - Maintain structure
  - Repair structure
  - Upgrade structure
  - Adapt structure

Using the guidance



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- Survey respondents and course participants

Guidance available here
https://www.theprif.org/document/regional/coastal-protection/guidance-for-managing-coastal-protection-works-pacific-island

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