PACC TECHNICAL REPORT 13

MARCH 2015

PACC

Building Resilience to Climate Change in Pacific Communities

PACC Demonstration Guide: 'Climate proofing' coastal development on Mangaia Island, Cook Islands

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PACC Demonstration Guide: 'Climate proofing' coastal development on Mangaia Island, Cook Islands. Apia, Samoa : SPREP, 2015.

36 p. 29 cm. (PACC Technical Report No.13)

ISSN 2312-8224

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This publication is also available electronically from SPREP's website:
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TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This report is an output of the Cook Islands PACC project. It was written by Jonathan McCue, and reviewed by Paul Maoate (Cook Islands PACC Project Coordinator), Peni Leavai (SPREP), Netatua Pelesikoti (SPREP), Herman Timmermans (SPREP), Damien Sweeney (Pacific Research and Evaluation Associates) and Martin Pritchard (Pacific Research and Evaluation Associates).

EXECUTIVE SUMMARY

In the Cook Islands, the PACC project focuses on coastal zone management on Mangaia Island. The objective of the project is to 'climate proof' coastal infrastructure, both through on-the-ground activities and also by mainstreaming climate risk into relevant policy and planning for the coastal zone. After early consultations, climate proofing of Mangaia harbour became the main focus for the demonstration project. This report provides a comprehensive description of the demonstration project, from inception and early planning stages through design and implementation, and monitoring and evaluation. It also presents best practices and lessons learned along the way that could guide others carrying out similar adaptation activities.

The harbour is the transportation hub and main entry point for all supplies to the island, but had been badly damaged by tropical cyclones in 2005. The aim of the PACC project was thus to develop a stronger and safer harbour that could withstand more intense storm waves and raised sea levels. In parallel, the project has been helping to develop an integrated coastal management policy and plan for Mangaia.

Project activities began in 2011. Community consultations were held, and a 'geospatial assessment' was carried out to help assess possible impacts on the coastline of Mangaia. This included the development and use of a new climate tool, the Cook Islands Coastal Calculator. The assessment brought together external technical experts with the community of Oneroa, to share knowledge and develop an understanding of the current and future risks posed by the ocean, climate variability and climate change on coastal infrastructure, so that the community could make the best decisions for managing their coastal zone. A cost–benefit analysis was also carried out, which found that the project activities would be worthwhile, and highlighted the importance of developing and implementing a proper maintenance programme for the harbour.

These steps helped to refine the design of the harbour, and implementation began early in 2014. Activities included widening and deepening of the channel, clearance of the spending zone, construction of a new ramp, quay platform extension, construction of southern and northern seawalls, and backfill of the old ramp and increasing the quay platform working area. The new harbour was completed and officially opened in April 2014.

Community engagement on Mangaia Island was a critical part of the project, and was guided by a communications plan developed early in the project.

The Cook Islands Coastal Calculator was a key output of the project, and added to the effectiveness and sustainability of the project. This tool can assist designers, engineers and others to better understand inundation risk, which is a critically important aspect of engineering design on the coast. It can be applied for all the 15 islands in the Cook Islands, and has already been used in several other similar projects in the Cook Islands.

The main lessons learned from the process and implementation of the PACC project include:

- The value of cost–benefit analysis early in the project, which supported implementation of the project and highlighted some areas that needed attention, such as a good maintenance programme once the harbour was improved;
- An improved/climate proofed harbour should be regularly maintained with regular inspection according to a maintenance plan;
- The value of technical tools – specifically the geospatial assessment and the Cook Islands Coastal Calculator, which enhanced planning and design steps of the project, and the overall project outcome in terms of a resilient harbour that should withstand climate and sea impacts in the coming decades;
- The importance of recognising and respecting both local knowledge and external technical expertise, which can work together to bring enhanced results, in this case through informed decision making;
- The need to consider gender from the very beginning of a climate change project, and maintain a gender perspective throughout;
- Projects such as the climate proofing of coastal infrastructure should not be carried out as stand-alone efforts – they need to be part of comprehensive coastal management planning within an integrated coastal management policy, and backed up by appropriate and effective legislation;
- Good, well-planned and adequately resourced communications and knowledge management are vital if the experiences and lessons from a project are to be useful for future projects.

ABBREVIATIONS

CBA	Cost–benefit analysis
BCR	Benefit to cost ratio
CI NIIP	Cook Islands National Infrastructure Investment Plan
EEZ	Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
ICI	Infrastructure Cook Islands
ICM	Integrated coastal management
JNAP	Joint National Action Plan for Disaster Risk Management and Climate Change Adaptation
MMR	Ministry of Marine Resources
MOIP	Ministry of Infrastructure and Planning
NES	National Environment Service
NESAF	National Environment Strategic Action Framework
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NPV	Net present value
NSDP	National Sustainable Development Plan
PACC	Pacific Adaptation to Climate Change [project/programme]
PACCSAP	Pacific–Australia Climate Change Science and Adaptation Planning [program]
PCCSP	Pacific Climate Change Science Program
SPCZ	South Pacific Convergence Zone
SAM	Southern Annular Mode

1. INTRODUCTION

1.1. Overview

The Pacific Adaptation to Climate Change (PACC) programme is the largest climate change adaptation initiative in the Pacific region, with projects in 14 countries and territories. PACC has three main areas of activity: practical demonstrations of adaptation measures; driving the mainstreaming of climate risks into national development planning and activities; and sharing knowledge in order to build adaptive capacity. The goal of the programme is to reduce vulnerability and to increase adaptive capacity to the adverse effects of climate change in three key climate-sensitive development sectors: coastal zone management, food security, and water resources management. The programme began in 2009 and is scheduled to end in December 2014.

In the Cook Islands, the PACC project focuses on coastal zone management on Mangaia Island. Mangaia is the southernmost and second largest of the Cook Islands, and has a population of about 570 people. The project is helping to develop 'climate-proof' coastal infrastructure, and to develop an integrated coastal management (ICM) policy and plan for Mangaia.

This demonstration guide provides a comprehensive description of the Cook Islands PACC project, from inception and early planning stages, through design and implementation, and monitoring and evaluation. Aimed primarily at climate change practitioners across the Pacific region, it gives details of the planning and execution of this coastal zone adaptation project, with a focus on best practices and lessons learned along the way. As with the demonstration guides from the other PACC projects, the hope is that future projects can learn from and apply PACC lessons, to improve project results and outcomes.

1.2. The PACC demonstration project

The goal of the PACC project in the Cook Islands is 'to contribute to reducing vulnerability and increasing adaptive capacity to adverse effects of climate change in Cook Islands'.

The project stakeholders identified coastal zone management as the priority sector early in the project negotiations, and further selected redevelopment of Mangaia harbour for the demonstration project (details of the selection process are given in Section 4.2.1). The harbour is the transportation hub and main entry point for all supplies to the island, and also provides safe ocean access for Mangaia fisherman, the main providers of fish and protein for Mangaia Islanders. However the harbour was badly damaged by two tropical cyclones in early 2005. The aim of the PACC project was to develop a stronger and safer harbour that could withstand more intense storm waves and raised sea levels, extending its accessibility and operational utility in stronger wind and wave conditions. In parallel, the project has been helping to develop an integrated coastal management policy and plan for Mangaia.

Project activities began in 2011, with most studies and modelling work being carried out during 2012. These included carrying out a 'geospatial assessment' and the development of a new tool, the Cook Islands Coastal Calculator, to help assess possible impacts on the coastline of Mangaia. The assessment brought together external technical experts with the community of Oneroa, to share knowledge and develop an understanding of the current and future risks posed by the ocean and the climate on coastal infrastructure, so that the community could make the best decisions for managing their coastal zone.

By mid-2013, the project had completed extensive preparatory work and was ready to begin construction of the new 'climate-proof' harbour. The new harbour was completed and officially opened in April 2014.

1.3. Mainstreaming climate risk into policy and planning

Alongside the practical demonstration project, the Cook Islands PACC team also devoted efforts to the mainstreaming of climate change into policy and planning at both island and national level. The aim was to help develop climate-responsive policy that facilitates effective and sustainable coastal management, and that ultimately all coastal development will be both sustainable and resilient to climate risks.

The project contributed to three main outputs in this area:

- The Mangaia Island Coastal Management Policy Framework (draft, 2014);
- The Cook Islands National Infrastructure Investment Plan (CI NIIP) (draft, 2014);
- The ICI Business Plan 2014/15.

The Mangaia Coastal Policy Framework provides a policy setting in which management of the coastal and marine environment can take place. The Framework was developed through consultations with island and national stakeholders; a review of national and sectoral policies, plans and legislation; and an assessment of the current status of the coastal areas of Mangaia.

The main purposes of the Coastal Policy Framework are to:

- Establish a vision and principles to guide the future development of the coast with respect to land use, management of coastal resources and ecosystems and environmental protection;
- Guide the future form and development of the coastal area and advise the communities, businesses and government on the best use and best practices for use of coastal resources;
- Provide guidelines for public and private works and actions that impact on the social, environmental, economic and physical well-being of the residents of coastal communities of Mangaia; and
- Foster the economic, social, environmental and physical well-being of the residents of coastal communities in Mangaia.

Integrated coastal management in Mangaia is envisaged (in time) to be supported by an ICM implementation framework that comprises a baseline assessment of the state of the coast, a legal definition of the coastal zone in Mangaia, coastal management legislation, institutional arrangements for coastal management and a Coastal Management Plan. These elements would all work together to provide for the logical and integrated development of the coastal area of the island whilst supporting the vision and objectives already set out within the Te Kaveinga Nui (National Vision).

2. BACKGROUND AND CONTEXT

2.1. The Cook Islands

The 15 Cook Islands are spread over 1.8 million km^2 of ocean (Figure 1). The Northern Group is mainly low-lying atolls. The Southern Group, where the majority of the population lives, includes the high volcanic island Rarotonga which is the largest island, the lower island of Aitutaki, and raised limestone islands Mitiaro, Atiu, Mauke and Mangaia. These four islands have central volcanic hills surrounded by *makatea* – ancient raised limestone reefs up to 2 km wide.

About 70% of the Cook Islands population of 20,000 lives on Rarotonga, which has a land area of 67 km^2. Rarotonga is the capital and main commercial and government centre.

The Cook Islands became a British protectorate in 1888. By 1900, administrative control was transferred to New Zealand. In 1965 residents chose self-government, in free association with New Zealand. As a result, the Cook Islands is fully responsible for internal affairs, while New Zealand retains responsibility for external affairs and defence, in consultation with the Cook Islands.

Black pearls are the Cook Islands' leading export. Manufacturing activities are limited to fruit processing, clothing, and handicrafts. Marine industries (aquaculture, tuna long-line fisheries, marine tourism) have been growing steadily over the past decade. Both the aquaculture and tuna industries are export-oriented, and all three marine industries are major providers of jobs. The long-line fishing and the fishing industry generally have developed in recent years, with mostly foreign-owned and operated fishing vessels. The establishment of three medium- sized pack-house facilities provides support for processing value-added products locally.

Tourism has remained the Cook Islands' largest source of foreign exchange for the last decade.

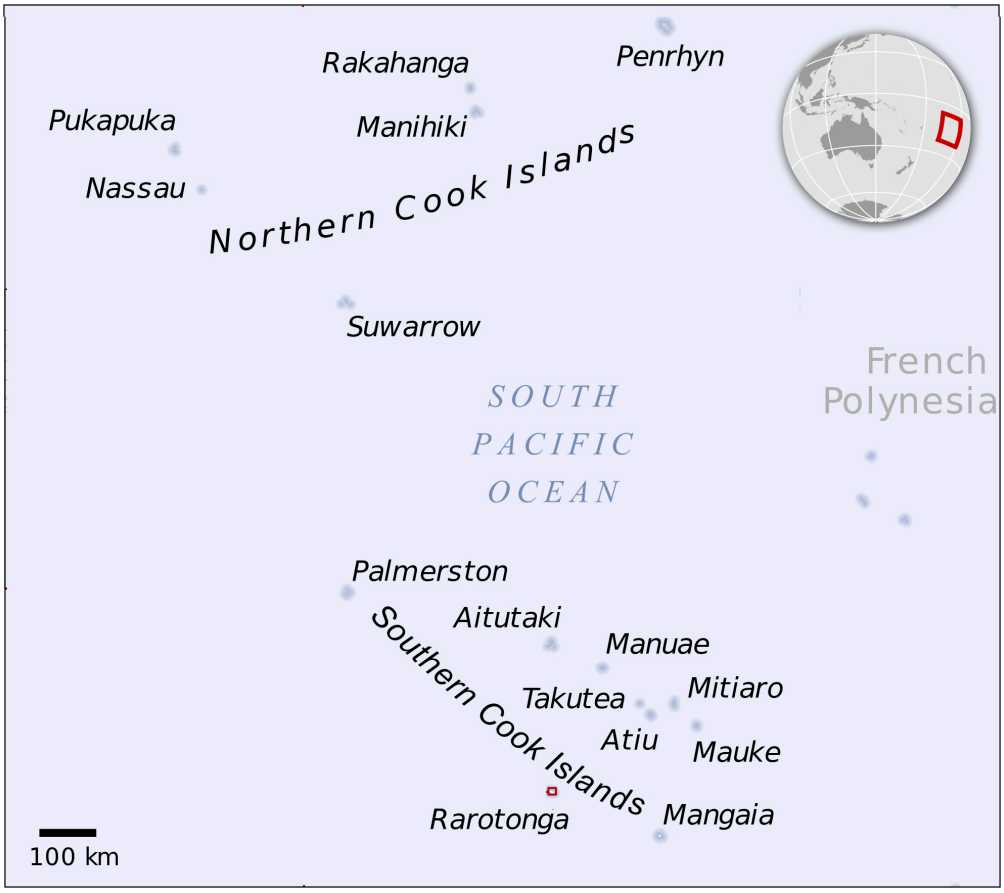

Figure 1. Map of the Cook Islands. (Source: CIA World Factbook.)

2.2. The coastal zone

In terms of coastal and ocean management, the Cook Islands has rights and responsibilities for over 1.8 million km^2 of ocean, its exclusive economic zone (EEZ). This area is of considerable ecological, economic, social, scientific and cultural importance. The coastal area, including coastal waters and lagoons, is directly affected by land-based and inshore activities, thus, although the coastal and outer areas fall under the jurisdiction of the Ministry of Marine Resources (MMR), the Environment Service and other institutions have an important role to play.

The ocean and coastal areas of the Cook Islands are in relatively good condition on an international scale. They have, however, experienced localised degradation. The ocean and coastal systems are under increasing demands from many users, such as commercial and subsistence fisheries, shipping, tourism and recreational activities. These activities give rise to significant environmental pressures, including from tourism infrastructure development, fisheries by-catch and introduction of invasive marine species.

From the marine environment perspective, the fish, corals and lagoons are among the nation's major assets supporting the tourism sector. Care is required in reef and lagoon management to ensure that their biodiversity is preserved and they remain attractive for diving and snorkelling. Coral reefs support fish and shellfish which are very important in the diet of Cook Islanders. The reefs also provide protection of the shoreline from wave energy and erosion.

2.3. Policy and institutional context

There is currently no national coastal zone management policy that addresses all of the Cook Islands. Coastal development is regulated to some extent by the Environment Act (2003) though this relates to construction above the high water mark.

Key national policies of relevance to the coastal sector include the following:

- Te Kaveinga Nui (National Vision);
- National Sustainable Development Plan (NSDP);
- Joint National Action Plan for Disaster Risk Management and Climate Change Adaptation (JNAP) 2011–2015;
- National Environment Strategic Action Framework (NESAF).

The National Vision – Te Kaveinga Nui - of the Cook Islands is "To enjoy the highest quality of life consistent with the aspirations of our people, and in harmony with our culture and environment". The NSDP has been set up pursuant to this vision. All sector and government agency planning must be aligned with the NSDP strategies, which are national priorities. Strategic Goals of particular relevance include Goal 4 "Sustainable use and management of our environment and natural resources", Goal 5 "Strengthened and affordable basic infrastructure, transport and utilities to support national development", and Goal 6 "A safe, secure and resilient community". The NSDP furthermore is aligned with the nation's regional and international commitments such as the Pacific Plan, Millennium Development Goals, Mauritius Strategy, and multilateral environmental agreements such as the UN Framework Convention on Climate Change and Biodiversity Convention.

The Government of the Cook Islands has developed, as its main policy response to climate change, the JNAP 2011–2015. The JNAP effectively draws together climate change adaptation and climate change mitigation with disaster preparedness and response. It stresses four strategic areas: (a) governance; (b) monitoring; (c) disaster management; and (d) risk reduction and climate change adaptation. The JNAP identifies a range of actions to mainstream climate change in other areas of national policy and planning, including developing an integrated coastal management framework, a national water supply strategy, a land use policy, and a fuel security strategy to progressively replace fossil fuels with renewable energy.

The NESAF is the overarching strategy for environmental management in the Cook Islands. The framework provides guidance and direction for achieving sustainable social and economic progress for the Cook Islands by utilising natural resources and the environment wisely. It aims to sustain efforts generated from growing environmental awareness to protect, conserve and manage the environment and natural resources. NESAF includes a goal to

increase resilience by strengthening national capacities for responding to climate change and climate variability, including both adaptation and mitigation responses. The National Environment Service (NES) has the lead in coordinating the activities of all government agencies to comply with the NESAF.

2.4. Climate

Climate information is taken from the Pacific Climate Change Science Program (PCCSP) and the Pacific–Australia Climate Change Science and Adaptation Planning Program (PACCSAP) (Australian Bureau of Meteorology and CSIRO, 2011, 2014).

2.4.1. Current climate

In the Northern Cook Islands temperatures are fairly constant throughout the year, while in the Southern Cook Islands there is a difference of around 4°C between the warmest and coolest months (Figure 2). Warming trends are evident in annual and half-year maximum and minimum air temperatures at Rarotonga (Southern Cook Islands) for the period 1934–2011. For the period 1941–1991 there was no trend in annual mean temperature at Penrhyn (Northern Cook Islands).

The wet season in the Cook Islands is usually from late November to April or May but is longer in the Southern Cook Islands (Figure 2). Year-to-year rainfall variations are high in both the Northern and Southern Cook Islands, and much of this is due to the El Niño-Southern Oscillation (ENSO), particularly in the wet season. El Niño years tend to be drier and La Niña years wetter than normal. Annual and half-year rainfall trends show little change at Rarotonga since 1899 and Penrhyn since 1937. There has also been little change in extreme daily rainfall at both sites since the mid 1930s.

The sea-level rise measured by satellite altimeters since 1993 is about 4 mm per year.

Tropical cyclones affect the Cook Islands mainly between November and April. An average of 18 cyclones per decade developed within or crossed the Cook Islands exclusive economic zone (EEZ) between the 1969/70 and 2010/11 seasons. Tropical cyclones were most frequent in El Niño years (28 cyclones per decade) and least frequent in La Niña years (6 cyclones per decade). Seventeen of the 53 tropical cyclones (32%) between the 1981/82 and 2010/11 seasons became severe events (Category 3 or higher) within the Cook Islands EEZ. Available data are not suitable for assessing long-term trends.

Wind-waves in the Cook Islands are dominated by trade winds and the South Pacific Convergence Zone (SPCZ) seasonally, and the ENSO and Southern Annular Mode (SAM) interannually. Larger storm waves are seen in the Southern Cook Islands than in the Northern Cook Islands.

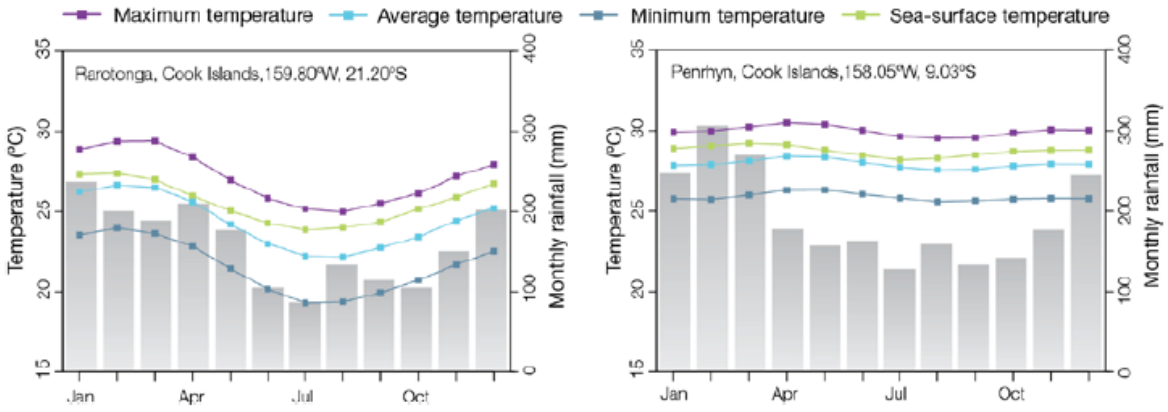

Figure 2. Mean annual rainfall, air temperatures and sea-surface temperatures for Rarotonga and Penrhyn. (Source: Australian Bureau of Meteorology and CSIRO (2011), reproduced with permission.)

2.4.2. Climate projections

According to PCCSP and PACCSAP, over the course of the 21st century:

- Surface air temperature and sea-surface temperature are projected to continue to increase (very high confidence).
- Annual and seasonal mean rainfall is projected to increase (low confidence).
- The intensity and frequency of days of extreme heat are projected to increase (very high confidence).
- The intensity and frequency of days of extreme rainfall are projected to increase (high confidence).
- The incidence of drought is projected to decrease (moderate confidence).
- Tropical cyclone numbers are projected to decline in the south-east Pacific Ocean basin (0–40°S, 170°E–130°W) (moderate confidence).
- Ocean acidification is projected to continue (very high confidence).
- Mean sea-level rise is projected to continue (very high confidence).

2.5. Risks and vulnerabilities of the coastal sector

2.5.1. Climate-related risks and vulnerabilities

The coastal zone is vulnerable to sea level rise, and extreme weather events such as intense rainfall events. The impacts of these threats will almost certainly include accelerated coastal erosion, saline intrusion into freshwater lenses, and increased flooding from the sea.

In some areas of the coastal plain there are low lying areas behind the beach ridge which are prone to flooding from storm surges. In addition, there are areas of intensive infrastructure development with poor water drainage systems that are prone to flooding during rainstorms. Even the high *makatea* islands are not as resilient to sea level rise as might be expected. Despite limestone cliffs seemingly protecting the agricultural growing areas, sea storm surges and cyclones can still lead to saltwater intrusion into the low-lying swampy areas.

Over recent years, the Cook Islands has been badly affected by several extreme climate events. Cyclone Sally extensively damaged Rarotonga in January 1987; in November 1997, Cyclone Martin destroyed 90% of the houses and killed 19 people on Manihiki atoll; in January 2004, Cyclone Heta induced a storm surge causing significant foreshore damage despite 'missing' the Cook Islands; while in 2005 five tropical cyclones affected the islands, and two of them, Cyclones Meena and Nancy, badly damaged coastal infrastructure on the island of Mangaia (see Section 3.2).

Coral reefs provide natural breakwaters for Cook Islands coastlines and they will become increasingly important to provide storm protection as the sea level rises, though they themselves are vulnerable (see below). All islands are experiencing coastal erosion, and changes in intensity or frequency of storms are likely to worsen these problems. Although it is not likely that all of the Cook Islands would disappear under the sea even with the highest projected rates of sea level rise, the effectiveness of the reefs in protecting coasts might be affected.

The coastal zone and coral reefs are vulnerable to the effects of increases in seawater temperature; most notably this leads to 'coral bleaching', as seen in past El Niño events. During El Niño events, surface temperatures frequently exceed the temperature tolerance level of coral species (25–29°C). The coastal protection provided by such stressed reef habitats is reduced, while opportunities for ciguatera dinoflagellate organisms to colonise the coral surfaces are increased, making the reef fish that feed on it poisonous for humans. Coral death and bleaching also threaten marine biodiversity, reduce fish supplies for local communities, and diminish the attractiveness of reefs to tourists.

2.5.2. Non-climate drivers of vulnerability

Non-climate factors contributing to vulnerability of the Cook Islands' coastal zone include the following:

- Poor sectoral governance of the coast and poor regulatory enforcement practices are the main issues for the coastal sector in the Cook Islands. Poor governance exacerbates other risks such as pollution and population growth as well as climate-related risks.
- Population growth, especially in the main urban centres on Rarotonga, is increasing the pressure to develop coastal areas. This is also competing with tourist development.
- Pollution: contamination of the groundwater with sewage effluent is a recurrent issue on many islands with no reticulated sewage system in place.
- Lack of technical knowledge on integrated coast management practices.
- On some islands, including Mangaia, sand mining from beaches is contributing to lowering foreshores and exacerbating coastal erosion. The sand is used for road maintenance and house construction.

While the PACC project focused on the vulnerabilities due to climate, these non-climate factors were also considered and assessed in the early stages of the project, and efforts to address them incorporated where feasible. For example, mainstreaming work aimed to address some of the poor governance issues, among others.

3. MANGAIA ISLAND

3.1. Brief description

The island of Mangaia (Figure 3) is unique in its formation and acclaimed as one of the oldest volcanic atolls in the Pacific, dated around 19 million years. Approximately 70% of the island's land consists of steep sloping lands, wetlands, fernlands and escarpments. While the coast is surrounded by razor sharp coral fossils (*makatea*), the middle of the island is a valley of rich agricultural land, where residents plant taro and other crops.

In the 1950s and 1960s, Mangaia was the citrus and pineapple hub of the Cook Islands and supplied the Raro Juice canning factory in Rarotonga. However, this ceased when the factory closed down in the 1970s. Because the abandoned land became exposed and subject to erosion, several species of plants with commercial uses (mainly *Pinus* spp.) were introduced and are now the dominant canopy within the interior of the island.

Most land in Mangaia (including coastal lands) is held under customary tenure. Under the traditional system, responsibilities for decision making on land were vested in family, clan or tribal elders. A landholder's right is not to the land itself, but as a member of a descent group, they have usufruct rights: to use the land for building, gardening, hunting, gathering and other activities. Native land in Mangaia cannot be bought or sold, except to the Mangaia Island Government for public purposes (e.g. the construction of infrastructure). It may however be leased for up to 60 years at a time.

Mangaia's total resident population from the last census in 2011 was 562, yet more have migrated overseas since then. Like all the other islands of the Cook Islands, Mangaia suffers from depopulation especially of the younger age group who are drawn away by higher wages and better opportunities overseas. With such a dispersed and small population centre, its isolation from markets and trade opportunities makes the delivery of basic economic and social services a significant challenge on the island.

Some key challenges facing Mangaia's natural resources, besides climate change, are:

- Alien species: Introduced animal and plant species on Mangaia include Indian mynas (thought to be interfering with the nesting of the endemic Mangaia kingfisher, *Todirhamphus ruficollaris*); the African ant (*Pheidole megacephala*) which is thought to have directly caused extinction of endemic snail species on Rarotonga and Mangaia; the creeper *Micania micrantha* which is impacting on bird nesting habitats; and the introduced pine trees which have had a significant impact on terrestrial habitats and faunal species variation.
- Land conversion and unsustainable land use: There was a progressive conversion of lowland forests and wetlands in Mangaia to agriculture, plantations, infrastructure and settlements. Consequently, little native vegetation remains in the more accessible lowland zones. Extensive forestry operations in Mangaia have now been discontinued, and tree cover over steep escarpment areas of the islands has remained relatively stable as a result in recent years.
- Unsustainable harvesting of wild resources: Overharvesting of parrotfish, giant clams and coconut crabs is contributing to the decline of these species on Mangaia, and this unsustainable harvesting is thought to be impacting on local food security. There are also some concerns that some international fishing vessels may be breaching their contract with the Government and harvesting products that they are not permitted to and/or fishing in areas that are prohibited under their licence conditions.

3.2. Mangaia harbour

The harbour is the main transport hub for Mangaia Island. It is the main entry point for all supplies to the island, and also provides safe ocean access for Mangaia fisherman, as well as access for recreation purposes.

In early 2005, Mangaia harbour was very badly damaged by two tropical cyclones, Meena and Nancy, leaving the island residents with limited options for bringing goods into the island, and increasing reliance on highly expensive air freight. Mangaia harbour was always considered to be particularly vulnerable to damage from relatively low

intensity cyclone events due to its poor design as well as incomplete construction. In engineering terms, the wave force strength of the harbour was never calculated but was estimated to be roughly commensurate with a 1 in 35 year cyclone event (Tenga Mana, personal communication, June 2012).

The harbour was also considered to be unsafe when winds were greater than 10 knots (Tenga Mana and Josh Taio, personal communication, June 2012). Wind conditions greater than 10 knots were estimated to occur between 57 and 72 days per year on average, and may increase by a small amount in the next 50 years under climate change (Maara Vaiimene, Cook Islands Meteorological Service). When unsafe conditions occurred the shipping line, Taio Shipping, did not operate its cargo service to Mangaia, which in turn caused delays and related losses (Josh Taio, personal communication, June 2012). Also, local fishermen generally did not use the harbour during these times, with some fisherman instead travelling to an alternative ocean access point on the other side of the Island). The Mangaia community viewed safety risks as a significant problem with the harbour.

Figure 3. Map of Mangaia Island.
(Adapted from map published by Department of Lands and Survey NZ.)

4. THE DEMONSTRATION PROJECT

4.1. Objectives, outcomes and outputs

The overall goal of the PACC project is 'to contribute to reduced vulnerability and increased adaptive capacity to adverse effects of climate change in Cook Islands'.

With coastal zone management as its priority focus, the objective is to 'climate proof' coastal infrastructure, both through on-the-ground activities and also by mainstreaming climate risk into relevant policy and planning for the coastal zone.

To achieve this objective, the three outcomes sought by the project are:

- Outcome 1: Policy/plans mainstreamed to build resilience in the context of emerging climate risks.
- Outcome 2: Increased access to Mangaia harbour in the Cook Islands through measures to adapt to climate change impacts.
- Outcome 3: Increased understanding of climate change impacts and awareness of how to adapt and build resilience (at community level).

The following outputs all relate to the above three outcomes and are numbered to reflect the relevant outcome:

- Output 1.1: Sectoral or national policies revised to incorporate climate change risk and resilience aspects (nationally executed activities);
- Output 2.1: Demonstration project delivered to strengthen operability and durability of the Mangaia harbour infrastructure to better withstand more intense cyclone events and general weather conditions (reflecting guidelines);
- Output 2.2: Cook Islands Coastal Calculator developed;
- Output 2.3: Guidelines developed (this report);
- Output 3.1: National PACC communications plan developed and implemented.

The project logframe, including indicators, targets and details of data collection, is given in Appendix 1.

This section focuses on activities under Outcome 2, the climate proofing of Mangaia harbour, with a brief summary of activities under mainstreaming of climate change (Outcome 1) in Section 4.10.

4.2 Preparatory phase

4.2.1. Selection of project and site

The selection of the demonstration project and site was made during initial consultations in 2006. Criteria for identifying the demonstration project and site were:

- A strong alignment with the Government's existing programmes;
- All necessary baseline assessments have been carried out, and additional activities are ready for implementation; and
- Ability to co-finance and ability to deliver.

Based on these three criteria and on stakeholder consultations, which included national and island government and community groups, coastal zone management was selected as a sector for adaptation intervention in the Cook Islands under the PACC project. Among the reasons, the country had been affected by several cyclones the previous year (2005) which had caused serious, widespread damage, including coastal erosion and flooding and structural damage to buildings, wharves, harbours and airports; and there were good opportunities for co-financing to be provided.

Several possible locations were raised for the demonstration pilot project. One option was construction of Avatiu Breakwater in Rarotonga (which had been studied in 2004 as part of the Asian Development Bank's Climate Adaptation in the Pacific (CLIMAP) project); another was redesign and redevelopment of a damaged harbour, road or airport on an outer island.

A short list was identified of the Avatiu Breakwater, Mauke or Mangaia Harbour, integrated coastal management (ICM) and airport redevelopment of Manihiki Island, or ICM of Pukapuka Island. Mangaia Harbour was finally selected as the pilot site based on the criteria listed above. The Cook Islands Government allocated NZD1.8 million to the project as co-financing.

4.2.2. Linkages with strategic plans and processes

The demonstration project closely aligns with national strategic plans and links well with current national policies. For example, Outcome 1 of the PACC project (see Section 4.1), the mainstreaming of climate change into policies and plans, is in line with the Cook Islands JNAP which states the need for mainstreaming climate change into development planning. Outcomes 2 and 3 (see Section 4.1) are similarly in line with both the JNAP and the NSDP, and financial budget lines within the Medium Term Budgeting Framework (MTBF).

The Cook Islands PACC project is expected to strengthen the institutional framework, policies and plans for climate change adaptation, as well as the capacity of key national government and community decision makers to incorporate climate change risks into their sustainable development programmes. The PACC project is helping to develop (in partnership with the Government of the Cook Islands) specific coastal sector guidelines on how climate change assessments and demonstrations can be undertaken.

4.2.3. Institutional framework for the project

The project is coordinated at the national level by the National Environment Service (NES). The Ministry of Infrastructure and Planning (MOIP) was designated as the national implementing agency; in 2013 MOIP was renamed Infrastructure Cook Islands.

The Project Management Unit is located within Infrastructure Cook Islands and has responsibility for practical management of the demonstration project.

4.2.4. Community engagement

In the early stages of the project, a communications plan was developed that provided a framework for community engagement as the project progressed. The purpose of the planned communications activities was to raise awareness of climate change generally, of the need for adaptation, and also specifically about the PACC project. Target audiences included the general public in Mangaia and Rarotonga, decision makers on Mangaia and at the national level, development partners and the media.

The communications plan was ambitious, and not all planned activities were completed. However, some of the community-level activities that were successfully carried out included:

- Production and distribution of 100 PACC tee shirts;
- Production of four PACC pull-up banners and their display at various events;
- Production and distribution of a pamphlet on the Cook Islands PACC project;
- Various activities at Mangaia school, to raise awareness among the students. As well as visits and workshops, an essay competition was held, followed by a debate where around 20 senior students discussed their views on climate change;
- Two videos about the PACC project, one made by a local team in 2011, another made by an international team in 2014 (Vital Harbour);
- PACC attendance and awareness raising activities at several national events, including the Pacific Women's Conference in Rarotonga in 2013, Pacific Water and Waste Conference in 2013, and Lagoon Day in 2014.

4.2.5. Addressing gender

There are gender issues in coastal zone management, for example the use of coastal infrastructure by the different gender groups, such as the use of the Mangaia harbour by men for fishing.

Ideally, a gender perspective would have been included from the very beginning of the project, and carried through all stages to final M&E. In fact, gender issues were mostly overlooked until midway through the project. At this point, efforts were made by the Regional Programme Management Unit to increase gender awareness within the PACC project teams, and to build capacity for integrating gender into project activities.

As a result, the project team developed gender-sensitive indicators that will help to better understand the benefits of the project for women and for men (see Appendix 1).

The project team also worked to support the inclusion of a woman on the Island Council of Mangaia, in 2013. This is the island's highest decision making body, and was previously men-only. This was a small but practical step towards empowering women to have an equal role in decision making for Mangaia Island.

4.3. Situation and problem analysis

4.3.1. Community consultation and site inspection

Consultations with the Mangaia community early in the project helped to clarify the current situation and the problems faced by the people of Mangaia and assess the situation of the harbour. The project team made two visits to the island (2010 and 2011), and this clarified their understanding of community needs as well as the condition and capacity of the harbour.

4.3.2. Geospatial assessment and the Cook Islands Coastal Calculator

A key analysis performed at this stage was the 'geospatial assessment' carried out by a team of experts from the Applied Geoscience and Technology Division of the Secretariat of the Pacific Community (SOPAC) and New Zealand's National Institute of Water and Atmospheric Research (NIWA) in 2011. The purpose was to develop a 'geospatial framework' to support risk-based decision making for the coastal zone of Mangaia.

The approach combined modelling of wave and water levels, assessment of climate change effects, collection of data on the reef and shoreline characteristics, and the development and use of the Cook Islands Coastal Calculator, in order to assess possible impacts on the coastline of Mangaia, specifically at Oneroa village. It brought together experts and the community of Oneroa to share knowledge and develop an understanding of the current and future risks posed by the ocean and the climate on coastal infrastructure, so that the community could make the best decisions for managing their coastal zone.

The Cook Islands Coastal Calculator provides the link between the modelled wave conditions and the coastal inundation that might be expected to occur under different future scenarios. The Calculator is a Microsoft Excel based engineering spreadsheet. It simulates inundation based on information on the 'drivers' of inundation (waves and water levels at the shoreline, wave run-up and overtopping), and how these will change over the next 100 years due to possible climate change and sea level rise.

Defining zones of potential wave run-up under cyclone and swell events was done using the Cook Islands Coastal Calculator, and also community knowledge of past cyclone inundation events within historical memory of the Oneroa community, which helped to verify the performance of the Calculator. Figure 4 shows the final run-up levels derived from the Calculator.

Using the indicative cyclone run-up levels developed, the historical cyclone run-up levels, and assessment of how these run-up levels may change due to sea level rise and changes in cyclone characteristics, the community identified facilities at risk along the Oneroa frontage.

Activities that increased the risk of inundation to the village frontage during cyclone events were also identified. These included increasing the width of the channel at the wharf (or any other channels over the fringing reef);

cutting roads down through the makatea to the shoreline; and removing vegetation between the road and the shoreline.

The development of the geospatial framework and its application to the decision-making process is described in more detail in PACC Technical Report No. 12 (PACC, 2014).

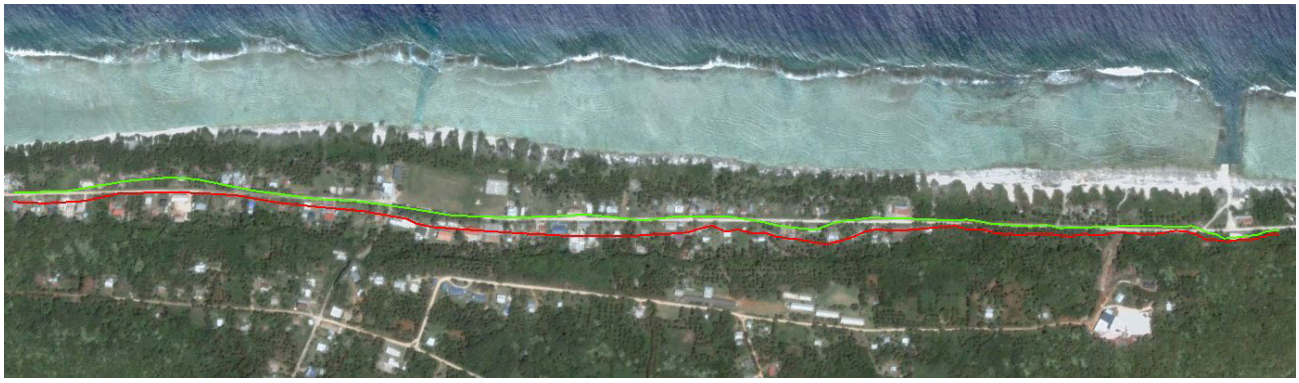

Figure 4. Final cyclone hazard lines developed for the 2030s and 2060s for Oneroa village, Mangaia, Cook Islands. Green line: a possible chance of wave run-up due to a 50 year ARI cyclone event reaching this level over the period from the present to the 2030s; red line: a possible chance of wave run-up due to a 100 year ARI cyclone event reaching this level over the period from the present to the 2060s.

4.4. Solution analysis

4.4.1. Scoping

The geospatial assessment exercise also contributed to the scoping process. The Oneroa community was also consulted by the technical team and staff of MOIP to ensure local knowledge of waves, storms and other relevant matters were shared with the project team. After explanations and discussions on the inundation risks facing the community, risk reduction and adaptation measures were put forward and discussed (Table 1) (PACC, 2014).

Table 1. Risk reduction and adaptation options identified by the Oneroa community (from PACC, 2014).

Key risk reduction/adaptation options
• Improving existing and provision of new evacuation routes inland from the village • Limiting any further new roads down to the shoreline along the village frontage • Encouraging landowners not to build new residential property on the seaward side of the road • Encourage the planting of natural vegetation between the road and the shoreline
Occasionally required/longer term risk reduction/adaptation options
• Rebuilding houses with raised floor levels (e.g. on piled foundations) during any renovations where they are built in areas that could potentially be inundated • Progressively over time move further inland any essential infrastructure or residential property at high risk of damage from inundating waves
Rarely required risk reduction/adaptation options
• If structural measures (e.g. seawalls or boundary walls) were ever deemed necessary to protect infrastructure or property, to have these located as close to the level of the first makatea bench rather than at the shoreline

4.4.2. Cost–benefit analysis

The proposal to carry out 'climate proofing' of Mangaia harbour as a demonstration of adaptation to climate change was made during the initial project stages, as described in Section 4.2. The project team evaluated this decision using cost–benefit analysis (CBA). The purpose was to determine whether the benefits of the proposed improvements to the harbour would outweigh the costs.

The measures proposed for the demonstration project were:

Reduce cyclone risks (by improving strength and durability of harbour structures)

1. Extend the width of the concrete hardstand to reduce degradation of hardstand;
2. Install precast concrete panels along the face of the quay walls to minimise corrosion of steel piling.

Reduce rough seas risks (by improving operational features of Mangaia harbour)

3. Complete the channel widening and deepening works to minimise wave setups in the channel;
4. Relocate the boat ramp to the south of the quay platform to minimise ramp exposure to waves entering the channel;
5. Construct a beach spending zone to the north of the existing boat ramp to dissipate any wave energy and hence minimise turbulence.

The costs considered in the CBA related to the capital construction costs of each of the retrofit measures as well as environmental impacts. Environmental impacts mostly related to the extension or widening of harbour channels and basins in close proximity to the existing harbour.

The benefit streams were considered as five separate categories: benefits from avoided cyclone damages to the harbour from cyclone events; the extended useful life of the harbour infrastructure from general wear and tear (not cyclone damage) – which will push back the timing of investment required in new harbour infrastructure; avoided losses to Taio Shipping due to improved (safe) access to the Mangaia harbour; avoided losses to fisherman associated with increased (safe) access to the Mangaia harbour; and benefits from reduced potential for injury or death whilst using the harbour.

Once the costs and benefits of the project options were quantified, the data were used to determine the net benefit of the proposal. Considering the adaptation measures under the two categories given above, the analysis found a net present value (NPV) of $574,203 for the measures to improve the strength and durability of the wharf, and an NPV of $19,660 for the measures to improve safe access to the wharf during rough seas (2012 NZ dollars). The benefit to cost ratios (BCR) were 2.39 and 1.07 respectively.

A sensitivity analysis was then carried out, which involved changing the magnitude of key variables and measuring impact on the NPV and BCR. The variables tested were: (i) the frequency and intensity of cyclone hazards under future climate change scenarios; (ii) the cyclone/storm surge force threshold of the current harbour design; (iii) the durability of the retrofit harbour if not properly maintained; (iv) combination of ii and iii; and (v) the frequency of windy days which make it unsafe to use the harbour.

The results indicated that retrofit measures to strengthen the Mangaia harbour to cyclones and improve durability to general weather conditions, and to improve access to and safe use of the harbour during rough sea conditions, would be worthwhile for implementation. However, the result was not robust to changes in assumptions about the strength of the existing harbour to cyclone events and the durability of the retrofit design to general weather conditions. The CBA report therefore recommended some further engineering analysis to better inform the likely wave/storm surge force thresholds of the existing and proposed harbour designs before proceeding with construction.

Similarly, the sensitivity results highlighted the importance of developing and implementing a proper maintenance programme for the harbour. To provide for a maintenance programme (as well as eventual infrastructure replacement), it was recommended that a plan to sustainably finance the harbour should also be developed, and part of this financing plan should include a review of user fees/tariffs.

Finally, the CBA highlighted that strengthening harbour structures to cyclone forces is most efficiently undertaken at the design and construction stage for the original structure, and not as retrofit measures to poorly designed harbours.

The Cook Islands PACC CBA was introduced late in the project planning cycle, and there was significant pressure on the Cook Islands PACC project team to start implementing the pilot project. This meant there was little time available to conduct the analysis and it was not possible to undertake further engineering analysis as recommended in the CBA. Another difficulty experienced was that some key stakeholders in the Cook Islands PACC team were not able to be actively engaged in the conduct of the CBA.

A success factor for conducting the Cook Islands PACC CBA was technical input by the Cook Islands MET Director who provided estimates for the frequency of windy days (which make it unsafe to use the harbour). These inputs contributed significantly to the accuracy and hence usefulness of the CBA.

More details on the CBA can be found in PACC Technical Report No. 2 (PACC, 2013).

4.5. Demonstration design

Infrastructure Cook Islands carried out the design of the harbour modifications. The design was based on recommendations from a report produced by the consulting company GHD in 2006, and incorporated results from the application of the Cook Islands Coastal Calculator and discussions and inputs as follows.

In June 2012, MOIP staff visited Mangaia accompanied by the Hon. Teariki Heather and a sea freight consultant, to undertake further discussions with the Mangaia community and finalise the design. The stakeholders agreed on the key features, i.e. widening and deepening of the harbour channel, creating a spending zone, removing the old harbour structure, extending the quay platform, building barrier walls on either side of the harbour along the beach, and relocating the ramp to a sheltered location.

Further adjustments to the design were made in 2013 and early 2014. A study carried out on the Avarua–Nikao coastal area of Rarotonga by the University of New South Wales indicated that the volcanic basalt boulders would be inadequate for Category 3 upwards cyclones, therefore the barrier wall for the Mangaia harbour was changed to a concrete wall. At a further meeting with the Mangaia community in January 2014, it was requested that the current ramp be backfilled and concreted to improve the safety of the harbour.

The final design had seven main measures (Figure 5):

1. Channel widening and deepening: Widening of the channel to 30 m and deepening to 4 m, the main purpose was to allow safe clearance for vessels to safely enter the harbour especially during strong winds and rough sea conditions.
2. Spending zone clearance: This was done to create/allocate an area to allow wave swells to freely run up and down the beach slope, in order to dissipate wave energy.
3. New ramp construction: The new ramp was positioned on the southern side of the quay platform, which is the most sheltered position, with the aim to allow safe berthing for the freight barge and local fishing boats especially during rough sea conditions.
4. Quay platform extension: The quay platform extended a further 30 m upslope, to aid in minimising the impacts of waves backwash/scouring along the platform foundations. The platform on average is 1 m above mean sea level, therefore rough seas frequently will have waves washing across the quay platform.
5. Southern seawall construction: To aid in minimising waves especially longitudinal waves entering around the southern/backside of the harbour platform which also contributes to scouring and transporting loose rocks and sand into and filling the harbour basin.
6. Northern seawall construction: To aid in minimising waves especially longitudinal waves entering around the northern side of the harbour platform, which is the dominant side for waves entering the harbour, and also contributes to scouring of the quay platform and access road.
7. Backfill of old ramp and increase of the quay platform working area.

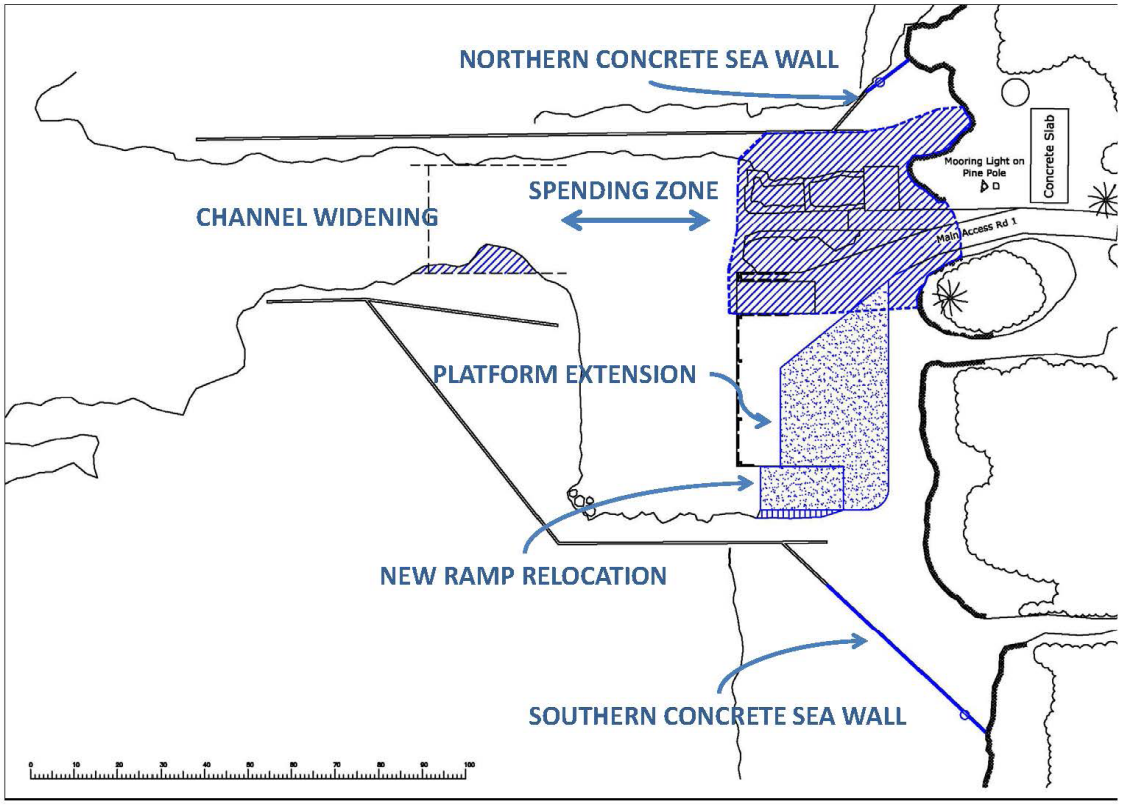

Figure 5. Graphic representation of the main harbour improvements.

4.6. Implementation

A suitable contractor was sought through a tendering process, and the contract for improving the harbour was awarded to Landholding Ltd, a construction company based in Rarotonga. Details of implementation activities are give below. Figure 6 shows implementation in progress.

1. Channel widening and deepening: Blasting was carried out along the southern channel area, loose reef rubble was excavated out and transported to a secure stockpile inland of the harbour site. An existing 5 m of the southern channel seawall was removed to provide access for the drilling rig to facilitate blasting operations. The seawall end was boxed and concreted. Work began 23 January 2014; completed 31 January 2014.
2. Spending zone clearance: The clearance operations took place at the very old/badly damaged previous harbour. The concrete platform, sheetpiles and loose boulders were removed using a hydraulic excavator. Work began 3 February 2014; completed 8 February 2014.
3. New ramp construction: Blasting was required to facilitate excavation works in order to form a 1 in 8 slope ramp. A cofferdam was formed using sheetpiles at the seaward side of the new ramp. Following blasting operations the loose rubble was excavated out and transported to a stockpile site. Construction works comprised ramp footing anchor, ramp concrete slab and concrete side walls. Groundwater seepage was noted following excavation works. The ramp is 10 m wide with a 1 in 8 slope. Work began 15 January 2014; completed 22 February 2014.
4. Quay platform extension: Excavation works were aided using a rock breaker mounted to the 5 ton hydraulic excavator, to ensure a level platform and 250 mm concrete slab thickness. Construction works comprised quay platform slabs (6 m x 6 m grids reducing in size for some areas), perimeter walls with 32 mm diameter rods drilled and grouted to 400 mm embedment. Work began 3 February 2014; completed 27 February 2014.
5. Southern seawall construction: A hydraulic excavator mounted with a rock breaker was required to form the base of the seawall foundation. Following concreting of the base, 32 mm diameter rods were drilled and grouted to 400 mm embedment. Formwork panels were used to form the 1.2 m high seawall. Work began 3 February 2014; completed 26 February 2014.

6. Northern seawall construction: A hydraulic excavator mounted with a rock breaker was required to form the base of the seawall foundation. Following concreting of the base, 32 mm diameter rods were drilled and grouted to 400 mm embedment. Formwork panels were used to form the 1.2 m high seawall. Work began 25 February 2014; completed 28 February 2014.
7. Backfill of old ramp and increase of the quay platform working area: Sheetpiles were driven to form a cofferdam. Two precast concrete panels were built and placed along the quay wall side, and a second barrier wall 600 mm thick was constructed halfway up the slope. Backfilling comprised mass concrete along the reinforcement areas and screened coral sand. A 250 mm thick concrete slab was placed on top, also a 500 x 500 mm concrete beam was constructed above the precast concrete wall. Work began 3 March 2014; completed 22 March 2014.

Figure 6. The harbour construction under way (photo taken on 10 February 2014).

4.6.1. Issues faced with implementation

There were delays to the start of the implementation phase of the project. These were due to limited availability of trained personnel, and of good machinery. It transpired that machinery available on Mangaia had not been maintained, and it was therefore necessary to transport more machinery by barge from Rarotonga before the construction work could start. The availability of aggregates for the concrete works was also an issue, as previous infrastructure projects had used up locally available aggregates. Aggregates therefore also had to be brought in from Rarotonga.

4.7. Monitoring and evaluation

The monitoring and evaluation (M&E) process is an ongoing activity (from day one of project implementation) and a vital part of the demonstration project. The M&E process is used to assess whether or not the project is reaching intended objectives and if not, what could be modified or improved in order to deliver expected outcomes.

The project logframe (Appendix 1) details quantitative and qualitative indicators that have been set so far for the PACC demonstration project. Ongoing monitoring will need to be conducted to assess whether the harbour operations (e.g. allowing ships to berth in rough seas, fishers to launch boats in rough seas) are as per the design.

Under the 2014 Cook Island National Infrastructure Investment Plan (CINIIP), maintenance of the harbour is under the responsibility of the Mangaia Island Government with technical support from Infrastructure Cook Islands. Inspection, monitoring and maintenance assistance will be included in the Infrastructure Cook Islands Business Plan 2015–2016.

All government assets/infrastructure, for example roads, pipelines, government buildings, harbours etc., are under the responsibility of the Cook Islands Investment Corporation. An asset management programme has recently been put in place and includes development of an asset database linked to a GIS system that will capture all records of repairs and maintenance. The Mangaia Harbour is one of the main infrastructure assets included in this programme.

See Section 5 for an overview of the evaluation of the Mangaia harbour project.

4.8. Communications and knowledge management

The project addressed communications and knowledge management at different levels, and both formally and informally.

Community engagement on Mangaia Island has been a critical part of the project, and was guided by a communications plan developed early in the project. Activities for community engagement are described in Section 4.2.3.

Other key target audiences were identified by the project, at both national and regional levels, and communications products were developed and disseminated. Examples include news stories published on the PACC webpages (www.sprep.org/pacc), and further circulated in the online magazine Climate Change Matters; a 'country brief' describing the project and targeting decision makers across the region; the video Vital Harbour produced in 2014 and broadcast at national, regional and international events; and various technical reports targeting primarily other climate change practitioners in the region, such as details of the CBA carried out by the project (PACC, 2013) and of the geospatial assessment and community decision making (PACC, 2014). Information and case studies were also drawn from the Cook Islands PACC project in synthesis publications, in particular the PACC Experiences series (see for example PACC Experience No. 5: Reducing vulnerability of island coasts).

For communications and knowledge management targeting audiences beyond Mangaia Island, the PACC webpages (www.sprep.org/pacc), and in particular the Cook Islands project webpage (www.sprep.org/pacc/cookislands), has been the main dissemination tool used to share information and knowledge generated by the project. Outputs are also being shared through the Pacific Climate Change Portal, and other online information hubs, such as the Climate & Development Knowledge Network (CDKN), Eldis and ReliefWeb.

4.9. Upscaling and replication

The Cook Islands Coastal Calculator can be applied for all the 15 islands in the Cook Islands. To date (December 2014), it has been used by Infrastructure Cook Islands in the following projects:

- Mangaia harbour improvements/climate proofing;
- Climate proofing Tukao and Tauhunu harbours on Manihiki (in progress);
- Improvements to Arorangi Jetty, Rarotonga;
- Several environmental impact assessments.

5. SUSTAINABILITY, RELEVANCE, EFFECTIVENESS AND EFFICIENCY

5.1. Sustainability

The harbour is designed to be sustainable, with resilience to climate and sea impacts built into the design. The Cook Islands Coastal Calculator was specifically developed and used for incorporating current and future inundation risk into the design and engineering.

Features of the design that contribute to its durability include:

- Thickness of the concrete slab of 250 mm;
- Separate concrete slabs with contraction joints (average 6 m x 6 m pads) with individual joints constructed to include steel rods that can be embedded into each pad;
- A double reinforcing mesh on the upper and lower surfaces of the concrete pads;
- Construction joints anchored into the underlying limestone rock;
- Features that help to reduce the effects of wave scour;
- A perimeter 'quay platform' concrete slab, comprising a concrete wall anchored into the underlying limestone rock;
- A concrete barrier wall on either side of the harbour to reduce cross current flows;
- Features that help to minimise wave energy onto the quay platform and new ramp, i.e. a wave energy dissipation zone.

In addition to the durable design, monitoring and maintenance programmes will contribute to sustainability of the harbour.

The Mangaia Island Government is responsible for the operation and regular maintenance of the harbour, with Infrastructure Cook Islands providing technical support and guidance when needed. Engineers on Mangaia have been trained in the performance standards that must be maintained to ensure structure integrity and to keep the harbour operational. Regular inspections of the structure will permit early detection of any problems. The Cook Islands Investment Corporation asset management programme is designed to aid with the planning of maintenance repairs for the harbour, and will forecast when funds will be required to carry out repairs pending inspections. This is funded by the Government of the Cook Islands. The Government has also set aside funds for emergency works arising from extreme events such as cyclones.

At present the project is still under the retention period and a final inspection will be carried out 12 months from completion of the construction, i.e. in April 2015. Should any issues be detected in the design/structure performance, the retention fee will be used to cover repairs or improvements.

The Mangaia Coastal Policy Framework developed under the PACC project will, when operational, also contribute significantly to the sustainability of the project and other coastal infrastructure, as well as broader sustainability for the coastal zone sector on Mangaia.

5.2. Relevance

The intervention at Mangaia under the PACC programme is highly relevant to the national priorities and policies set to address climate change adaptation and resilience. The intervention is also highly relevant to the coastal sector needs and community expectations in Cook Islands and Mangaia respectively. The intervention was developed in close collaboration with national stakeholders in the Cook Islands, and coordinated by the NES. It aligns with key national and sectoral policies, and technical studies and assessments (such as the Infrastructure Sector Forum Report 2010, Climate Change Technology Assessment, island level vulnerability and adaptation assessments

and plans, IWRM, and the UNDP-supported Community-Centred Sustainable Development Programme). The intervention at Mangaia also directly addresses the climate risk related priorities identified in the Cook Islands' Initial and Second National Communications, the Disaster Risk Management National Action Plan and the JNAP. All are fully aligned with the NSDP.

The Cook Islands Coastal Calculator will prove relevant for other climate change projects, as its use is replicated in other locations in the Cook Islands and it is adapted for use in other parts of the Pacific. Ultimately, being able to better understand flood risk inundation is a critically important aspect of any engineering design on the coast, and being able to incorporate climate and sea level projections makes this a highly useful and relevant tool.

5.3. Effectiveness

At December 2014, most of the practical outputs have been achieved. As the M&E process progresses, it will become clearer whether the outcomes have been achieved.

The various project tools all contributed to the project being effective. These include CBA, the Cook Islands Coastal Calculator and the community consultations.

5.4. Efficiency

Efficiency of the demonstration project is linked to sound project management skills, availability of human and technical resources and political support. Each of these faced some challenges during the project process, however the project was completed within the timeframe and within budget.

The CBA found the intervention to be worthwhile from an economic point of view, i.e. efficient.

6. LESSONS LEARNED AND RECOMMENDATIONS

The following are the main lessons derived from the Cook Islands PACC project, which may be used to inform similar projects in the Pacific region in the future.

- Cost–benefit analysis is a very useful tool during the early stages of a project. As well as enabling comparison of the financial costs and benefits of a proposed project or project options, CBA has an important role in bringing together diverse project stakeholders, such as economists, engineers, sectoral planners and meteorologists, which enhances shared understanding of the project and collaboration in project activities. The process also serves to identify key data and knowledge gaps which may be important for making sound, evidence-based decisions about project option selection and design. In this project, the CBA results supported implementation of the project, but highlighted some areas that needed attention, such as a good maintenance programme once the harbour was improved.
- It is important to recognise and respect the value of both local knowledge and external technical expertise. Both are valid sources of information that can be used to address problems and seek solutions. Finding ways to bring these two approaches together, as done during the geospatial assessment carried out under the Cook Islands PACC project, can bring excellent results, in this case in terms of good, informed decision making.
- The Cook Islands Coastal Calculator proved to be a valuable technical tool that enhanced planning and design steps of the project, and also the overall project outcome in terms of a resilient harbour that should withstand climate and sea impacts in the coming decades. Such technical tools should be sought or developed, and applied within adaptation projects in the Pacific, so that communities can benefit from the latest that science and technology has to offer. This is an important facet of empowering communities to adapt to climate change.
- It is important to consider gender from the very beginning of a climate change project, and maintain a gender perspective throughout. This is because women and men have different roles, responsibilities and priorities, and therefore differing vulnerability to climate change, as well as different skills and experiences to contribute to finding solutions. Within the coastal zone, for example, women and men may have different uses of coastal or ocean resources, and may have different needs and priorities for a safe harbour. Addressing gender ensures that different needs and vulnerabilities are considered, with the potential to greatly strengthen the project and its outcomes. Although gender was overlooked in the early stages of the Cook Islands PACC project, gender awareness developed as the project progressed and as this happened, efforts were made to incorporate gender, for example gender-sensitive indicators were developed.
- It is also important to address gender at strategic levels, for example, to support and empower women to play a more equal role in high-level decision making. This will ensure that different groups of society 'have a say' in decisions, which will in turn contribute to benefits being shared more equally. The Cook Islands PACC project actively supported the inclusion of a woman on the Mangaia Island Council for the first time.
- Projects such as the climate proofing of coastal infrastructure should not be carried out as stand-alone efforts – they need to be part of comprehensive coastal management planning within an integrated coastal management policy, and backed up by appropriate and effective legislation. Alongside the demonstration project, the PACC team has worked to develop a policy framework for coastal management on Mangaia Island. However, this also needs to be aligned with national coastal policy (which has not yet been formulated). Other requirements include appropriate governance structures that are well coordinated and that encourage wide participation of all stakeholder groups.
- Good, well-planned communications and knowledge management are vital if the experiences and lessons from a project are to be useful for future projects. Diverse information products that target specific groups, and the use of appropriate dissemination tools, will ensure that the knowledge generated by a project reaches the target audiences. Through careful planning, the Cook Islands PACC project successfully engaged the Oneroa community, who were the main project beneficiaries, with the help of products such as tee shirts, posters, videos, and activities at the community school. Other target audiences, such as regional policy makers, climate change practitioners and development agencies, were engaged through targeted series such as the PACC Technical Report series and the PACC Experiences series, as well as online news stories.
- Ensure that there is contingency built in to the project budget to cover adaptive management measures.

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APPENDIX 1. COOK ISLANDS PACC PROJECT LOGFRAME

The project logical framework as at October 2014. The assumptions column of the logframe was removed in the final year of the project. Additional columns were added to the logframe to assist country coordinators to report on the results they had achieved and to identify remaining gaps and document lessons to share with other coordinators and similar projects.

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
GOAL: To contribute to reduce vulnerability and increase adaptive capacity to adverse effects of climate change in Cook Islands	Number of demonstration projects replicated % of harbours in the Cook Islands that have applied Climate Proofing design Number of projects nationally and regionally informed by PACC	Cook Island National Infrastructure Investment Plan (CI NIIP) draft 2014	Harbours not climate proofed	All coastal infrastructure developments in the Cook Islands climate proofed.	ICI[1] / Replication to: 1 Improvement to the Harbours in Manihiki currently under construction. Funded by Cook Is Govt. 2 Improvement to Penryhn Harbour, document proposal to be submitted August 2014 to access Adaptation Fund. MFEM[2] / Harbours Climate Proofed to date: • (Rarotonga) Avatiu Harbour & Arorangi Jetty • Mangaia Harbour • Mauke Harbour • Mitiaro Harbour • Manihiki Harbours (Tauhunu & Tukao)	Experience The design with respect to climate proofing infrastructure requires a great deal of technical survey, consultation and adequate funds Lesson The time required to adequately collect, collate and undertake assessment is quite lengthy, for PACC Mangaia the assessment was 2-3 years and construction works was 5 months. Recommendations The demonstration guidelines will highlight the general process required to replicate this 'climate proof' project to other coastal areas. Assumptions/Risks The applied design did follow through with the assumptions, it was evident during rough seas that there was very little impact to new harbour compared to the previous one. This process will be applied to other coastal infrastructure projects (as per CI NIIP) to be climate proof ie, roads, airport runways, buildings, agriculture coastal farm and water supply (springs along the coast)

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
Outcome 1: Policy/plans mainstreamed to build resilience in the context of emerging climate risks	Number of on-ground changes informed by revised by policy (practice change from business as usual BAU)	ICI / 1. Mangaia Island Coastal Management Policy Framework, draft 2014 2. Cook Is National Infrastructure Investment Plan draft (CI NIIP), 2014 3. ICI Business Plan 2014/15	No on-ground changes detected that incorporate new CC related policies and plans	Mangaia Island Coastal Management Plan to aid in the development of the Cook Is National Coastal Management Plan	Engaged the services of an experienced Coastal Expert to undertake the development of the Coastal Policy May 2014. Not enough time and funding with regards to consultation with relevant stakeholders	Experience Working with the Policy Division of OPM, a policy development guideline has been developed 2014, to ensure that they are inline with Government directions Lesson Coastal Management Policy developed towards the end of the project, originally planned in 2009 Delays due to limited coastal experts available. The policy will assist with the National Plan. Recommendations Work closely with the Policy Division / Ministry. Carry out good research of projects similar and contact those people to get more information. Assumptions/Risks The Mangaia Coastal Policy is aimed to be driven by the Mangaia Island Council at the end of the project life. Risk are whether this will be implemented
	Number of new projects funded b/c revised national plans/ policies meet donor criteria	1. Manihiki Harbour Upgrade 2014 2. Adaptation Fund for Penryhn Harbour, draft 2014	No coastal development projects funded.	One project funded by 2014	Cook Is Govt funded Manihiki Harbours Upgrade project. A proposal has been developed to replicate the PACC project to the Island of Penryhn, compared to Mangaia, Penryhn is a low lying Atoll and is predominately faced with rising seas and frequent storm surges.	Experience Experienced gained from Mangaia influence Manihiki Harbour Upgrade Lesson Time saved utilizing lesson learnt (real) from previous project and used to fast track implementation of other coastal projects. Recommendations Regular review required to enhance guide. Assumptions/Risks Efficiency of the design dependant on long term monitoring.
	Sector plans (at ministerial/ department level) modified in line with revised policy (Use of policies / Coordination processes)	1. Cook Is National Infrastructure Investment Plan draft (CI NIIP) 2. Preventative Infrastructure Master Plan 3. Mangaia Puna Plans	Sector plans in line with National Sustainable Development Plans.	Once the plan modified by 2014 1 Sector Plan developed in 2014, Cook Is National Infrastructure Investment Plan, 2014	The Cook Is National Infrastructure Investment Plan was developed to identify and prioritize CC & DRM projects, it is a 10 year strategic plan aim to ensure infrastructure projects are inline with NSDP goals, developed May 2014 currently under review.	

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
	Gender sensitive practices	Ministry of Internal Affairs Gender Policy Docs: 2011 National Policy on Gender Equality & Action plan 2012 Stocktake on Gender Mainstreaming Capacity	Gender Policy not used	Existing Gender policy used	The Min. of Internal Affairs have representative on each of the Pa Enua, the representative help feed into the development of the policy and community consultations	
Output 1.1 Sectoral or national policies revised to incorporate climate change risk and resilience aspects (nationally executed activities).	Number of policies/plans (name) that include CCA from PACC project	ICI / Mangaia Island Coastal Management Policy Consultation Report, 2014	No Integrated Coastal Management Policy exists.	Mangaia Integrated Coastal Management Policy approved by the Mangaia Island Council by June 2014.	Mangaia Island Council fully supports the Coastal Management Policy. Currently under review (July 2014) once finalised it will be tabled into Cabinet Submission. OPM will developed the National Coastal Management policy utilising the Mangaia Coastal Policy	During the consultation and development of the Mangaia Island Coastal Management Policy, a community meeting was held and the coastal policy was presented, this highlighted a ridge to reef approach whereby activities inland also impacts the coast, a big emphasis on Environmental impacts. A few weeks later the Mangaia Island Council met and confirmed to be included under the Cook Is Environment Act.
	Climate services used to inform policy/plans	Cook Is Climate Change Division - CC & DRM Tool kit, 2014 Cook Is Coastal Calculator, 2012	No policy or plans informed by climate services.	Policy & Plans informed	Cook Is Climate Change Division have developed a CC & DRM toolkit which captures all CC project with the aim being part of the school studies and proposed certificate / diploma course at USP. PACC Cook contributed through Climate Change Platform Meetings	Gender consideration were raised too late in the policy formation stage
	Number of agencies/ ministries involved	Meetings minutes 2. Consultation Report	No involvement of agencies or ministries to the PACC program.	8 Ministries / agencies involved	Agency / Ministries involved: • Infrastructure Cook Is • Office of the Prime Minister • Ministry of Marine Resources • National Environment Service • Ministry of Internal Affairs • Te Ipukarea Society • Institution of Professional Engineers Cook Is • Cook Is Red Cross • Mangaia Island Government • National Council of Women	Climate Change Platform Meeting is a working group formed to provide an update and awareness for all CC & DRM projects in the Cook Is

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
	Gender integrated - Pacific Gender toolkit used	Communication Doc – with Internal Affairs RE: Gender Policy (anecdotal)	Gender toolkit and gender policy not used	Gender Policy Used	Cook Is Gender Policy was published in 2011, however was only known to the Project Coordinator in 2013, since then we have included INTAFF in all PACC discussion regarding gender. The Gender toolkit was developed late & there are only a few whom are well versed to use this tool kit.	
	Number of national women's ministries or departments, women's NGOS and CBOs, and gender focal involved	Communication Doc – with Internal Affairs RE: Gender Toolkit (anecdotal)	No women's organization involved.	1 women Ministry / Organization engaged	A representative of INTAFF Gender division was included in the planning and design of infrastructure projects	Prior 2012 ICI worked in isolation now have close links with key agency and NGO groups. Very useful at one meeting, the director of the gender division informed us that a new road project carried out in the Pa Enua[3] affected the livelihood of women collecting Maire a flower export to Hawaii. The inclusion of INTAFF in the planning and design gives additional value to the project.
Outcome 2: Increased access to Mangaia harbour in the Cook Island through measures to adapt to climate change impacts	Number of ships that berth and able to unload and load cargo during 15 knot winds	Communication Doc – with Harbour Master RE: Freight Service Records (anecdotal)	No ships berth during 15 knot winds . Harbour not operational during any small storm surge	All ships berth, unload & load cargo during 15 knot winds by April 2014	Prior to the Demonstration project, where wind conditions were in excess of 15 knot, ships would turn around, at that time there was only one main shipping company. Now since 2013 there is another shipping company operating in the Cook Is, as the harbour climate proof is completed no ships have turn around. Ships have berthed during windy conditions. This was observed during the construction works, the ship was delivering construction materials and equipment	

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
	Number of people and Time taken to launch and retrieve fishing boats safely by local fishermen in all weather conditions reduced by 50%.	Communication Doc – with Harbour Master & Fishing Club President (anecdotal)	Minimum of 5 people required to launch and retrieve fishing boat. Time taken to launch and retrieve fishing boats by local fishermen is on average 10 minutes at the old ramp.	The number of people and Time taken to launch/retrieve fishing boats by local fishermen reduced by 50% by April 2014, using the new ramp.	During the construction stage, we observed the usage of the old ramp and recorded number of people required and time taken to launch and retrieve fishing boats. The same was done for the new ramp.	The new ramp was position in a sheltered area, the ramp slope was reduce from 1 in 7 to 1 in 9 and widen to 10m. The Fishing Association were very appreciative to these changes, the ramp slope reduction helped fishermen with stable footing even when there was algae growth present. The widen ramp reduces the boat from hitting the sides, more space to manoeuvre safely.
	Number of days per year where there is safe access to the harbour	Communication Doc – with Harbour Master RE: Freight Service Records (anecdotal)	Unsafe access to harbour for 57 and 72 days per year on average	Number of days when there is unsafe access to harbour is reduced, December 2014		
	Number of accidents at harbour	Communication Doc – with Police Officer (anecdotal)	10 accidents whilst using the harbour(prior to harbour upgrade work)	No. of accidents reduced by 50% whilst using the harbour between May 2013 and December 2014		
	Total number of people and communities benefiting from project (gender disaggregated)	Cook Is PACC Community Impact Survey Report Communication Doc – with Mangaia Fishing Association (anecdotal)	Baseline from Consultation Report/Survey Report Obtain stats from 2011 Cook Is Census Report	Target from Consultation Report/Survey Report Mangaia Fishing Association has 60 members whom benefit directly from harbour use. There are 570 people whom benefit indirectly through increased access to goods and services from the cargo and also use of the site as picnic area.		

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
	% of target community households/ persons perceiving vulnerability reduction and benefits from demo project and coastal management work.	Cook Is PACC Community Impact Survey Report	Baseline from Consultation Report/Survey Report	Target from Consultation Report/Survey Report	Although the harbour is situated in the main village of Oneroa, it is also utilised by the other two villages of Tamarua and Ivirua. Key groups whom utilizes the harbour: Mangaia Island Government – freight service and upkeep Aronga Mana (Council of Chief) Mangaia Fishing Association Mangaia Schools – Picnics / receation	
	Community satisfaction with PACC project (gender disaggregated)	Cook Is PACC Community Impact Survey Report	Baseline from Consultation Report/Survey Report	Target from Consultation Report/Survey Report	The Community is very appreciative for the improvement work at the harbour, some of their support is shown by feeding the contractors every week while they were building the harbour.	
	Coastal calculator use. Number no. of times it is utilized to climate proof coastal infrastructure designs.	List of Projects (Detailed)	No Calculator used	Coastal calculator used six times to climate proof coastal infrastructure designs by December 2014	The Coastal Calculator used for: • x 4 harbours • x 2 EIA reports As per the CINIIP it is planned that all infrastructure development in the Cook Islands be climate proofed.	The Coastal Calculator is a very useful tool for planning and designing infrastructure along the coast line, very simple excell spreadsheet to use. The National Environment Services and Climate Change Division have shown interest to the utilization of this tool
	Cost of water demonstration component per household / per person	Finance data		No target set	Cost per person (USD) $1,608 Cost per household (USD) $ 5,412	

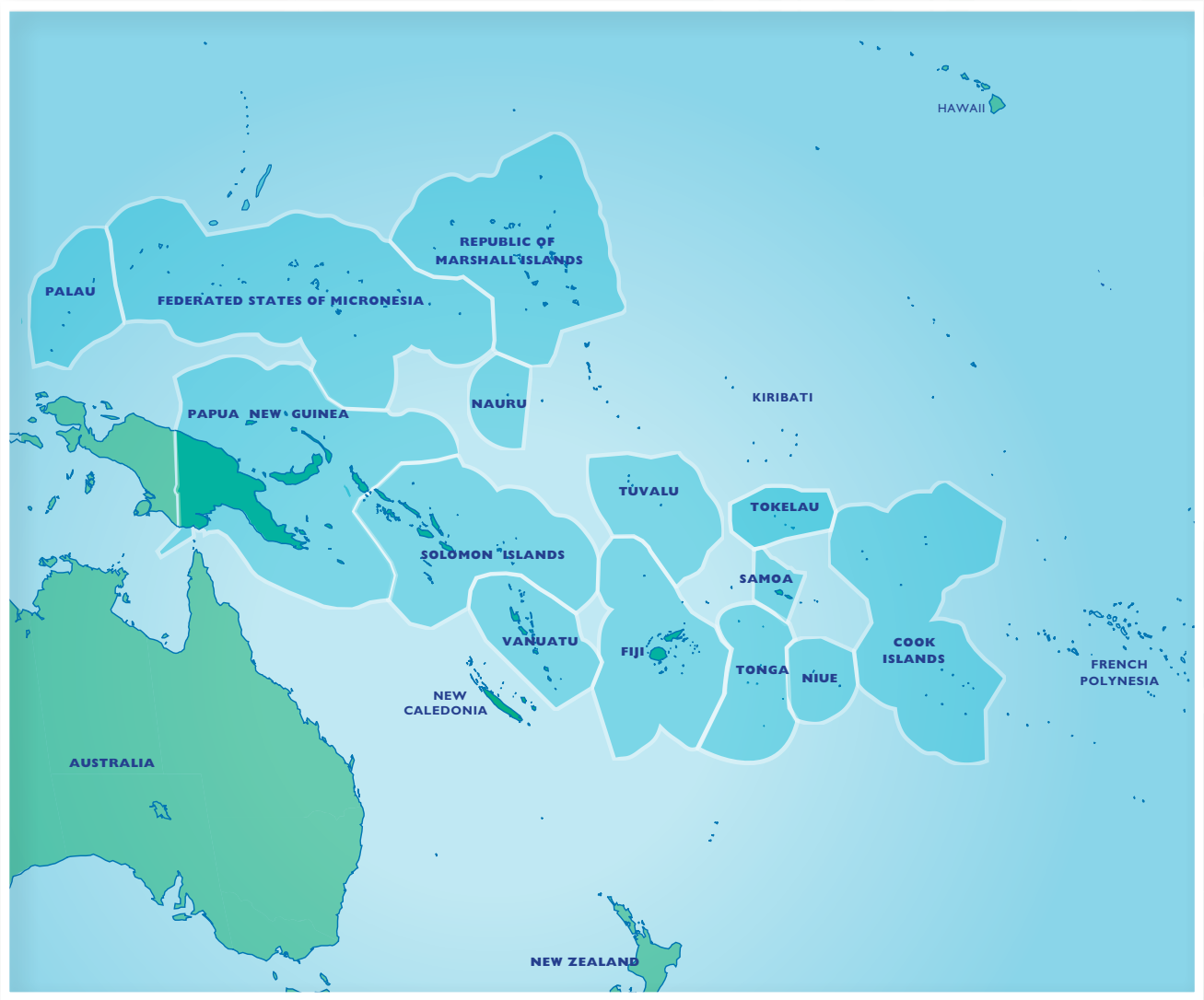
PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
Output 2.1 Demonstration project delivered to strengthen, operability and durability of the Mangaia harbour infrastructure to better withstand more intense cyclone events and general weather conditions (reflecting guidelines) .	New Harbour operational Climate change assessment tools used(Geospatial assessment / wave model)	Mangaia Harbour Completion Report, 2014 Mangaia Harbour Design Report	Harbour not climate proofed Climate assessment tools do not exist / not used	Climate proofed harbour operational Geospatial Assessment exists Wave model developed	New harbour officially opened in April 2014 The geospatial assessment is specific for Mangaia, it can be used by: MMR to aid with marine audit & mapping NES to aid with Environmental monitoring (biodiversity)	
Output 2.2: Cook Islands Coastal Calculator developed	Cook Islands Coastal Calculator developed and used to inform harbour design.	Cook Is Coastal Calculator (excel spreadsheet)	Limited computer software to model coastal impacts for volcanic and atoll island conditions. Software are intense and requires loading CD & license as oppose to something simple as Excel.	License free Calculator (Excel Spreadsheet) available by December 2012	Length process to develop the Coastal Calculator involving NIWA, SPC-SOPAC & SPREP, over 2 years. The Calculator is tailored specially for all the 15 islands in the Cook Islands.	Useful for all coastal projects in the Cook Islands: Harbours Roads Buildings Agriculture Farms Irrigation/Drains Just to name a few…
Output 2.2: Guidelines developed (technical synthesis)	(Gender-sensitive) technical guidelines developed	Technical Guideline Report	No Technical Guideline	Cook Island Technical Report developed	Gender Toolkit developed will be used by Internal Affairs in all Cook Islands	
	Usefulness / satisfaction of guideline	Project Coordinator (anecdotal)	No Technical Guideline	Cook Island Technical Report developed	Report developed late, will be used under other programs beyond this PACC project	Report still useful for other similar coastal projects.
Outcome 3: Increased understanding of CC impacts and awareness of how to adapt and build resilience (at community level)	Change in understanding of CC impacts	Cook Is PACC Community Impact Survey Report	Baseline from Consultation Report/Survey Report	Target from Consultation Report/Survey Report	The previous project coordinator held a workshop with the students of Mangaia College, Cook Is NEWS paper (Comms Plan)	Difficulty accessing reports / data from previous Project Coordinator
	Change in awareness/ resilience of how to adapt to CC	Cook Is PACC Community Impact Survey Report	Baseline from Consultation Report/Survey Report	Target from Consultation Report/Survey Report	The Climate Change Division from the Prime Ministers Office have undertaken several CC awareness programs in Mangaia, these are captured in CC Newsletters	To improve better coordination and working with all key stakeholders involved with Climate Change Projects – steering committee

PROJECT DESCRIPTION	INDICATOR	SOURCE / DATA COLLECTION METHOD	BASELINE	TARGET	WHAT HAPPENED Result and 'evaluation' (assessment)	WHAT DID WE LEARN Experience, lessons and recommendations
	Perception of resilience (means to adapt)	Cook Is PACC Community Impact Survey Report	Baseline from Consultation Report/Survey Report	Target from Consultation Report/Survey Report		
	Number of people/ percentage Gender disaggregated	Cook Is PACC Community Impact Survey Report	Baseline from Consultation Report/Survey Report	Target from Consultation Report/Survey Report		
	Number of actions taken up (gender disaggregated) from lessons etc	Observations Project Coordinator 'Contractors"	No change in peoples behaviour	At least one change noticed in the target community (Contractors)	Contractors whom carried out the Mangaia Harbour works are now well versed with Climate Proof designs and have applied these skills to other coastal projects 'Manihiki Harbour Upgrade'	Awareness programs should be promoted across all groups, especially those involved directly with the work, in this case the contractors.
Output 3.1 National PACC communications plan developed and implemented	National Plan exists	Cook Is National Communication Plan	National Plan for PACC project does exists	National Plan for PACC project exists by 2012	Communication plan developed	
	% of Comms plan implemented	Summary List of activities implemented as per the Comms Plan	PACC Comms plan not implemented.	100% of PACC Comms plan not implemented by 2014.	2011 developed: 100 t-shirts x4 banners (pull up) pamplets video documentary 2014 video documentary 2011 ICI Newsletter	During the transition, change over of project coordinators, the Communication Plan was not properly handed over. However once the Comms Plan was received much of the plan was already implemented.
	Number of community events incorporating climate change adaptation run	Summary List of all events PACC has attended	Limited Number of CC community awareness raising events run	3TARGET Number of CC community awareness raising events run	2014 Harbour Launch event, Mangaia 2013 Pacific Womens Conference, Rarotonga 2013 Pacific Water & Waste Conference, 2011 Geospatial Assessment & Coastal Calculator 2011 Mangaia School Workshop 2010 Community workshop & School Visit	The awareness carried out throughout the various years catered for different groups of people.

1 ICI - Infrastructure Cook Islands (Govt. Ministry)

2 MFEM - Ministry of Finance and Economic Management (Govt. Ministry)

3 Pa Enua - Islands outside of the main island Rarotonga



PACC – building adaptation capacity in 14 Pacific island countries and territories

PACIFIC ADAPTATION TO CLIMATE CHANGE (PACC) PROGRAMME

The PACC programme is the largest climate change adaptation initiative in the Pacific region, with activities in 14 countries and territories. PACC is building a coordinated and integrated approach to the climate change challenge through three main areas of activity: practical demonstrations of adaptation measures, driving the mainstreaming of climate risks into national development planning and activities, and sharing knowledge in order to build adaptive capacity. The goal of the programme is to reduce vulnerability and to increase adaptive capacity to the adverse effects of climate change in three key climate-sensitive development sectors: coastal zone management, food security and food production, and water resources management. PACC began in 2009 and is scheduled to end in December 2014.

The PACC programme is funded by the Global Environment Facility (GEF)'s Special Climate Change Fund (SCCF) and the Australian Government with support from the United Nations Institute for Training and Research (UNITAR) Climate Change Capacity Development (C3D+). The Secretariat of the Pacific Regional Environment Programme (SPREP) is the implementing agency, with technical and implementing support from the United Nations Development Programme (UNDP).

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The PACC Technical Report series is a collection of the technical knowledge generated by the various PACC activities at both national and regional level. The reports are aimed at climate change adaptation practitioners in the Pacific region and beyond, with the intention of sharing experiences and lessons learned from the diverse components of the PACC programme. The technical knowledge is also feeding into and informing policy processes within the region.

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ISSN 2312-8224